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EXPERT SPEAKERS

Prof. Yoshiharu Mutoh
Nagaoka University of Technology

EP-01

How should we understand the fretting fatigue phenomena for the purpose of life and strength assessment?

Basic phenomena and mechanisms of fretting fatigue are introduced from the viewpoint of fretting fatigue strength and life assessment. Based on these fretting fatigue phenomena and mechanisms, why the fracture mechanics approach is successful in fretting fatigue more than plain fatigue will be explained. Only three stress components (contact stress, tangential stress, applied cyclic stress) are existed on the fretting contact surface, where the fretting fatigue crack nucleates. Therefore, the critical condition for fretting crack nucleation can be estimated by combining these three stresses as the contact stress range-tangential stress range diagram. This diagram is useful in fretting fatigue design to determine fretting fatigue fracture condition not only for laboratory specimens but also for actual components.

Prof. Jung-il Song
Changwon National University

EP-02

Advancing Sustainable Materials: The Evolution of Natural Fiber Polymer Composites

Prabhakar M.N.[a], Dong Woo Lee[a], Jung-il Song[a*]

[a]Research Institute of Mechatronics, Department of Mechanical Engineering, Changwon National University, 20 Changwondaehak-ro, Uichang-gu, Changwon, Gyeongsangnam-do, 51140, Republic of Korea

*jisong@changwon.ac.kr

The integration of natural fibers into polymer composites has become a key development in the quest for sustainable materials, meeting the rising global demand for eco-friendly alternatives to synthetic composites. With advancements in polymer technology, natural fiber polymer composites (NFPs) are emerging as lightweight, renewable solutions for a wide range of industries, including automotive, construction, and packaging. Current research efforts focus on hybrid composites that combine both natural and synthetic fibers or different natural fibers, enabling precise control over properties such as tensile strength, flexibility, and weight reduction.

A recent breakthrough in the field involves the incorporation of bio-waste particles as a secondary reinforcement in NFPs. This approach enhances the mechanical performance and thermal stability of the composites while improving biodegradability, offering a dual solution to environmental sustainability and waste management. However, despite these advancements, flammability remains a significant hurdle. Researchers are exploring the addition of selective flame retardants to improve fire resistance without compromising the ecological benefits of NFPs.

The increasing adoption of NFPs in various sectors underscores their potential to replace conventional materials. However, challenges remain in scaling up production and achieving standardization for large-scale industrial applications. As NFP development continues to evolve, the scientific community plays a pivotal role in enhancing the performance, safety, and scalability of these composites. Advancements in this field are crucial for reducing the reliance on synthetic plastics, addressing pressing environmental concerns, and promoting sustainable material solutions for future generations.

Keywords: Natural Fiber Polymer Composites; Bio waste reinforcement; Lightweight; Mechanical properties; Flammability; Sustainability

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Prof. Kunio Hayakawa
Shizuoka University

EP-03

Numerical Simulations for Designing of Bulk Forming Processes

Kunio Hayakawa[a]*, Yoshihiro Kubota[a], Shinobu Narita[a]
[a]Department of Mechanical Engineering, Shizuoka University, Hamamatsu, Japan
*hayakawa.kunio@shizuoka.ac.jp

The use of numerical simulations for the design of manufacturing processes is a common practice in the field of metal forming. Typically, forging/forming simulations have been employed primarily for the purpose of designing the process for a given part, with a particular focus on the geometry of the part in question. However, it should be noted that the forging/forming process has an impact beyond mere shape; it also affects the mechanical and physical properties of the part. The present paper introduces some process simulations of bulk forming by the present authors.

One such analysis is an electro–thermo-mechanical analysis of the Spark Plasma Sintering (SPS) process, in which the deformation of the workpiece and tools is taken into account, as well as the compensation of tool geometry using the calculated result. The complex shape of electrically non-conductive ceramics powder, such as zirconia powder, presents a challenge in the design of graphite dies and tools and the mechanical properties of the resulting part. This is due to the lack of clarity surrounding the distribution of electrical current, temperature, relative density, and other pertinent factors throughout the process. In particular, the data regarding heat transmission from the die to the ceramic powder is of paramount importance, as electrically non-conductive ceramic powder is incapable of generating heat through resistive heating. The utilization of numerical analysis can facilitate the development of an optimal sintering process design for the net-shaped dense zirconia part with a complex geometry.

The second method is a multi-step cold forging process of stainless steel bolts, in which the impact of the manufacturing process on the product's strength is a key consideration. As the stainless steel bolt is not subjected to a heat treatment process, the strength is derived from the work hardening of the material during the manufacturing process. Moreover, if the loading direction is altered during the process, the bolt may lack sufficient strength due to the influence of the Bauschinger effect. It is therefore essential to employ numerical simulation, taking into account the Bauschinger effect, in order to achieve a more precise prediction of the strength and geometry of the non-heat-treated forged bolt. The numerical simulation of the manufacturing process and strength of the non-heat-treated stainless steel forged bolt was performed using a kinematic hardening model to investigate the usefulness and limitations. As a result, the influence of the Bauschinger effect on the strength can be calculated properly by considering the kinematic hardening behavior during the forging process by the kinematic hardening model.

Keywords: Bauschinger effect; finite element analysis; sintering; forging; stainless steel; zirconia.

Prof. Karunakaran
IIT Bombay

EP-04

Electron Beam Hybrid Manufacturing

Electron Beam Hybrid Manufacturing (EBHM) is extremely energy efficient (> 95%, hence sustainable), has phenomenally high scanning speeds and accelerations (v > 10,000 m/s, hence free from residual stresses and fast), operates in vacuum (hence high integrity), can handle almost all metals and has operational versatility (preheating, sintering/melting, post heating & in-situ microstructural analysis). Cost and time of vacuum is no longer major limitations. Hence, we foresee EBAM dominate metals while lasers will be restricted to polymers and ceramics. The challenges in EBHM arise from its 3V extremities, viz., vacuum, voltage & velocity. Two EBHM machines are being indigenously developed as part of a UAY project and a DST-AMT project, the former using powder stock and the latter using wire stock. Plasma Focused EB (PFEB) is their new approach to extract EB from plasma. Low [voltage, vacuum, cost] are its advantages. This talk will start with the definition of Hybrid Manufacturing (HM) and then explain the EBHM projects.

Prof. Somrerk Chandra-ambhorn
KMUTNB, Thailand

EP-05

Progress on Ferritic Stainless Steel Development for Solid Oxide Fuel Cell Interconnect Application

Somrerk Chandra-Ambhorn
Department of Materials and Production Technology Engineering,
Faculty of Engineering, King Mongkut's University of Technology North Bangkok,
Bangsue, Bangkok, Thailand
somrerk.c@eng.kmutnb.ac.th

A Solid Oxide Fuel Cell (SOFC) is one type of fuel cells that converts chemical to electrical energy at high temperatures [1]. At the working temperatures of or lower than 800 °C, ferritic stainless steels are promising for the application as an interconnect – a component used to separate fuel fed to an anode side of one cell from air fed to a cathode side of the adjacent cell [1,2]. However, when stainless steel is exposed to high temperatures, it can be oxidised giving thermal oxide scale which consists mainly of Cr-containing oxides [1]. With prolonged oxidation time period, the scale is grown resulting in metallic corrosion; the poorer scale adhesion can also be obtained and this could lead to the formation of air gap due to delamination of scale from steel substrate thus raising the electrical area specific resistance of the interconnect [3]. The formed Cr-containing oxides can also be volatilised at high temperatures contributing to degradation of SOFC components [2,4]. The present talk will review the oxidation, the scale adhesion and the volatilisation behaviours of ferritic stainless steels to be used as SOFC interconnect, emphasising on the experimental set-ups and the theoretical consideration to evaluate the scale adhesion [5,6] and the volatilisation effect [2,4,7]. Surface modification can be performed to help improve the oxidation resistance and reduce the volatilisation rate and the area specific resistance of stainless steel interconnect subjected to SOFC conditions [1]. Various surface modification methods e.g. the electrodeposition [8] and the slurry method [9] that lead to the Mn-Co spinel coating as well as the pre-oxidation technique [7] will be reviewed and presented in this talk. Keywords: Ferritic stainless steel; SOFC; Interconnect; High temperature corrosion; Surface modification.

Kazunari Shinagawa
Kyushu University

EP-07

Simulation of Liquid Phase Sintering by Combined MPFM/DEM Approach

Kazunari Shinagawa[a]*

[a]Department of Mechanical Engineering, Kyushu University, Fukuoka, Japan

*shina@mech.kyushu-u.ac.jp

Powder metallurgy has been widely used to fabricate structural parts as well as functional materials. To obtain a dense sintered body, the technique of liquid phase sintering (LPS) is useful especially for powders having a low sinterability. The metallurgical phenomena during LPS, however, is complicated and the way of controlling the process is often based on past experience. In this study, a method of theoretically simulating LPS process by a coupled multi-phase field method (MPFM) and discrete element method (DEM) is presented. In the first stage of LPS, the generation of the liquid film is computed in MPFM, and the rearrangement of powder particles can be simulated in DEM [1]. In the intermediate stage of LPS, to express the spreading of the liquid between two particles, the flux due to advection in MPFM is approximated by a simple function of the approaching velocity in sintering obtained from DEM. When the stage of LPS changes, the computation of the liquid formation by Allen-Cahn equation is switched into that by Cahn-Hilliard equation for a conserved order field. Simulation of a simple case is demonstrated to verify the proposed method.

[1] K. Shinagawa, Analysis of initial stage of liquid-phase sintering by combined multi-phase-field/discrete-element method, Ceramics International, 50 (2024) 37300-37307.

Keywords: multi-phase filed method; discrete element method; liquid phase sintering

Thermal Expansion and Microstructure of Aluminum Matrix Composites Prepared by Low-pressure Infiltration to AlN Porous Body

Gen Sasaki[a]*, Xiao Yan[a] , Yongbum Choi[a] , Kenjiro Sugio[a]

a Graduate School of Advanced Science and Engineering, Hiroshima University, Higashi-Hiroshima City, 739-0142

*gen@hiroshima-u.ac.jp

In recent years, the use of metal matrix composites as thermal management materials such as heat sinks has expanded. Therefore, there is a strong tendency to consider SiC, TiB2, AlN, and carbon materials, which have high thermal conductivity and low thermal expansion, as additives to metal matrices such as aluminum and copper in recent studies. The coefficient of interfacial heat transfer between ceramics and metals is generally low. For this reason, materials with low interface density are preferred. In this study, at first, an open-pore type AlN porous body was fabricated, and then molten aluminum alloy was impregnated at low pressure to obtain AlN/Al alloy composites. This composite is usually called an interpenetrating phase composite (IPC). In previous studies, the thermal conductivity and compression properties of the resulting composites were estimated. However, when using these composites as a thermal management material, it is necessary to evaluate the details of their thermal expansion behavior. Therefore, in this study, the change in thermal expansion behaviour for temperature was measured and was predicted using various thermoelastic models and finite element analysis, and was considered the differences between the measured and theoretical values. The following are the conclusions obtained in this study.

(1) The coefficient of thermal expansion (CTE) of Al/AlN IPCs decreased with decreasing perform porosity. The incorporation of AlN preforms effectively reduced the CTE and improved dimensional stability compared to the aluminum alloy matrix.

(2) The CTE of Al/AlN IPCs is lower than that reported in the literature for conventional particle-reinforced Al/AlN composites with the same AlN content, which is due to the unique interpenetrating structure that more effectively suppresses matrix expansion.

(3) The experimental values are consistent with the analytical boundaries, confirming the accuracy of the analytical model predictions.

(4) Finite element analysis of the 3D RVE verified mesh independence and revealed the complex distribution of thermal stresses within the IPCs. The FE model accurately predicts the experimental results when the preform porosity is high. However, as the preform porosity decreases, a large difference occurs between the calculated and actual values. This discrepancy is attributed to the omission of plastic deformation and residual thermal stresses in the FE simulation.

Keywords: Aluminum matrix composite; Porous AlN body; Thermal expansion; Microstructure; Simulation

Small crack propagation in a single crystal Ni-based superalloy under thermomechanical fatigue loading

Prof. Yasuhiro Yamazaki
Chiba University Japan

High-efficiency gas turbine combined cycle (GTCC) power generation has been used as the primary source of electricity. Single-crystal Ni-based superalloys have been used for turbine blades and vanes in GTCC power generation because of their excellent high-temperature strength due to their unique microstructure consisting of the γ matrix and γ′ precipitation, in which the γ′ phase has the inverse temperature dependence of yield strength. Gas turbine blades and vanes are subjected to thermomechanical fatigue (TMF) loading due to complex stress and temperature cycles. Such TMF cycles lead to the possibility of turbine blade failure.

Thermomechanical fatigue (TMF) tests on a single crystal Ni-based superalloy, CMSX-4, were conducted under in-phase and out-of-phase conditions to investigate the effect of the phase angle between temperature and mechanical loading on the crack propagation behavior. Experimental results show that the crack growth rate depends on the phase angle condition even if the crack closure is taken into consideration. To investigate the effect of the local plastic and creep deformations around the crack tip on the morphology of the crack tip opening displacement, finite-element analysis was also conducted. The experimental and analysis results reveal that the local plastic and creep deformations around the crack tip play essential roles in the fatigue crack propagation behavior in a single-crystal superalloy subjected to TMF loading.

Tomohiro Sato
Kansai University

EP-10

Reduction of Cu-Ni-Si Alloy Powders made by Water Atomization

Tomohiro Sato[a]*, Yasumasa Sawai[b], Ken-ichi Saitoh[a], Masanori Takuma[a], Yoshimasa Takahashi[a]

[a]Department of Mechanical Engineering, Kansai University, Suita, Osaka, Japan

[b]Fuji-Denshi Co. LTD., Yao, Osaka, Japan

tom_sato@kansai-u.ac.jp

Cu-Ni-Si alloys have good conductivity of heat and electricity and are used for electrical contacts. By using this alloy as a sliding member, a material with excellent high-temperature performance can be expected. Generally, this alloy is provided as a cast or expanded material, but considering its use as a bearing material, it is also desirable to use it as a sintered material by forming(atomizing) and sintering the powder. However, it has a possibility that an oxide film, which is difficult to reduce, may be formed when the Si-containing material is powdered as an atomized alloy powder. Therefore, this study focuses on the reduction method of alloy powders containing Si and its oxide films. As candidates for reducing agents, Ti, Al, and CaF2 were selected because they easily combine with oxygen in the sintering temperature range of this alloy powder. In addition, sulfide, a solid lubricant used as a material for sliding parts, was also generated as alloy powder during atomization, and its sintering state was also observed. As a result, the sintering state changed depending on the combination of the alloy powder composition and the mixture of Ti, Al, and CaF2. The changes in the sintering state were examined by comparison of the radial crushing strength and observation of the fracture surface. From evaluation of reducing agent by changing Cu-Ni-Si powder and additive reducing agent, the conclusion were clarified.

It was clarified the reduction performance of substances added as reducing agents during sintering of Cu-Ni-Si alloy powder. Ti reduces elements that are relatively easily reduced, such as iron oxide, well, but the reduction of Si is insufficient, and Ti itself remains in the test piece as an oxide. It was an impediment. Al showed high reduction performance and tended to have the highest strength as Si was completely reduced. Ti, CaF2 did not reduce Si sufficiently, but since CaF2 does not remain as an oxide, increasing the amount of CaF2 does not inhibit sintering. From the above, we believe that CaF2, which can reduce oxides, has the best performance as a reducing agent.

Keywords: sintering; reduction; fracture surface; Cu-Ni-Si

Damping Capacity of Short Alumina Fiber and VGCF Hybrid Reinforced Aluminum Alloy Composites

Kazunori Asano[a]*, Yuki Fujioka[a]

[a]Department of Mechanical Eingineering, Kindai University, Higashiosaka, Japan

*asano@mech.kindai.ac.jp

The hybrid aluminum alloy composites, in which alumina short fibers with superior high-temperature strength and VGCF with small diameter and high thermal conductivity as the reinforcements, were fabricated by squeeze casting. Volume fraction of the VGCF was 0, 3, 6, and 9 vol% and that of alumina fibers was 5,10 and 15 vol%. Microscopy of the composites showed that the VGCF was dispersed among the alumina fibers in the composite and the agglomeration of VGCF was clearly observed when the volume fraction of VGCF was great and that of alumina fiber was small. Electron microscopy revealed that the microporocity was observed near the agglomeration area. Damping capacity of the alloy was improved by the reinforcement at every temperature measured. It would be due to the energy loss by shear at the reinforcement-matrix interface. The damping capacity of the composite was the highest when the volume fraction of VGCF and alumina fiber was 9 and 15 vol%, respectively. In addition to the energy loss due to the shear as mentioned above, the energy loss due to friction would be caused by the movement of the exposed VGCF in the microporocity near the agglomeration area, leading to the improvement.

Keywords: alumina fiber, aluminum, damping capacity, squeeze casting, microstructure, VGCF

Yukio Miyashita
Nagaoka University of Technology

Fatigue strength of MIG and TIG welds in non-combustible magnesium alloy under plane bending load at negative stress ratios

Yukio Miyashita [a]*, Shao Xuanyi [b], Rafidah binti Ismail [c]

[a] Department of Mechanical Engineering, Nagaoka University of Technology, Nagaoka, Niigata, Japan
[b] Graduate School, Nagaoka University of Technology, Nagaoka, Niigata, Japan
[c] Under graduate School, Nagaoka University of Technology, Nagaoka, Niigata, Japan
*miyayuki@mech.nagaokaut.ac.jp

It has been known that magnesium alloy shows different proof stresses in tensile and compressive loading due to effect of its crystal structure. In this study, effect of stress ratio on fatigue strength of MIG and TIG welds in non-combustible magnesium alloy was studied for fatigue design of weld part in large transportation structure of highspeed rail.

Materials used were Mg-Al-Ca-Mn alloy and its MIG and TIG welds. Fatigue tests were conducted with plane bending fatigue test machine at stress ratio, R=-1, -0.5 and 0. Figure 1 shows results of the plane bending fatigue test. Fatigue strengths of MIG and TIG welds were lower than that of the base material. In case of the base material, fatigue strength at stress ratio, R=0 was lower within finite life region compared to R=-1 and 0.5. However, in case of MIG and TIG welds, effect of stress ratio at R=-1 was not clearly observed. Difference in stress ratio on fatigue strength at 10^7 cycle was also not significant as shown in Fig.1. Another non-combustible magnesium alloy which included slightly higher Al content compared to the present alloy also showed small effect of stress ratio on fatigue strength. It was indicated in the paper that effect of loading mode and distribution of precipitates could influence the fatigue strength and mechanism. Multiple cracking was observed in MIG weld but not in TIG weld on the fracture surface observations. Moreover, size of weld defect played as fatigue crack initiation point was lager in MIG weld compared to that in TIG weld. Fatigue crack initiation and propagation behaviors were studied by interlapped plane bending fatigue test at R=-1 in MIG and TIG welds. Fatigue crack initiated early time in both MIG and TIG welds, and it suggested that fatigue crack growth life was predominant on the total fatigue life. Difference in fatigue crack growth resistances among the base material, MIG and TIG welds were not significantly observed, however, fatigue crack growth resistances of the both welds were higher than that of the base material near the threshold region. Moreover, MIG weld showed higher fatigue crack growth resistance compare to TIG weld in this region. Larger weld defects and multiple cracking observed in MIG weld might induce the similar fatigue strength apparently even that the fatigue crack growth resistance was higher.

Keywords: Non-combustible magnesium alloy; MIG weld; TIG weld; Fatigue strength; Stress ratio;

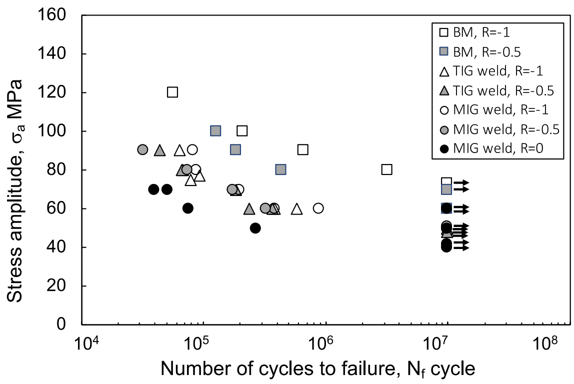


Fig.1 Effect of stress ratio on fatigue strength of the base material, MIG and TIG melds in non-combustible magnesium alloy.

Prof. Balasubramanian K
DIAT, India

EP-13

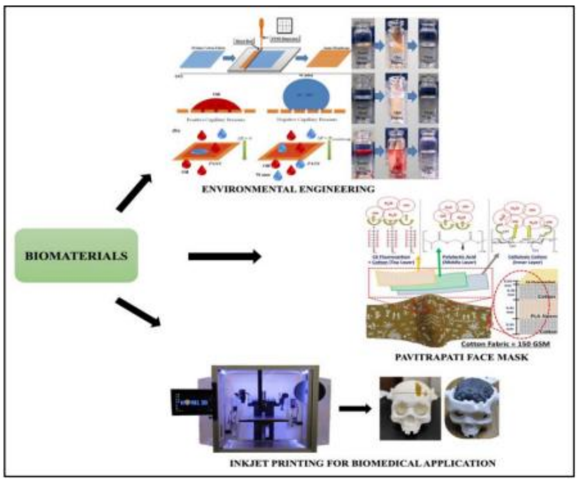
Biomaterials Breakthroughs: Expanding Applications in Science and Technology

Balasubramanian Kandasubramanian[a]*

[a],Department of Metallurgical and Materials Engineering, Defence Institute of Advanced Technology (DU), Pune-411025, India

*meetkbs@gmail.com

Over the last century, biomaterials have evolved from niche medical aids into a cornerstone of technological innovation, advancing through collaborative efforts in medicine, engineering, and molecular biology. Today, biomaterials span a wide array of materials, including polymers, metals, ceramics, and their composites, derived from both synthetic and natural sources, such as plants and animals. Our research comprehends this diversity by employing a multifaceted approach focusing on the synthesis, processing, and testing of biomaterials for applications in biomedical, additive manufacturing, and environmental engineering domains. In the biomedical field, biomaterials are now essential components in creating medical devices, implants, biosensors, tissue engineering scaffolds, antimicrobial coatings, and controlled drug delivery systems. Our group has pioneered several products in this domain, including the Pavitrapati face mask and Aushada Tara PPE suits, developed specifically to combat the COVID-19 pandemic. Other innovations include the Healthy Air room freshener and Brahma Graha: A Divine Essence of Dermal Health, each addressing unique health and wellness needs. Our research group further exploits advanced additive manufacturing techniques, such as direct ink writing, fused deposition modelling, and bioprinting, to develop biomaterials and biomimetic structures for medical and structural applications. Inspired by natural architectures, our group has replicated intricate architectures like the hierarchical layers of nacre, as well as honeycomb and lattice structures. These engineered biomaterials exhibit enhanced durability and fracture resistance, improving the mechanical performance of biomedical implants and protective equipment. Beyond these domains, biomaterials play a vital role in environmental engineering due to their cost-effectiveness, efficiency, and adaptability for bio-separation processes. Our group has developed and optimized materials, including 2D MXenes, graphene oxide, electrospun polymer nanofibers, silk fibroin, and biochar, to effectively remove pollutants such as heavy metals, dyes, and oils from wastewater. This environmentally focused research underscores the societal impact of biomaterials, highlighting their potential for addressing complex ecological challenges through sustainable innovation.



Prof. Noël Brunetière
Institut Prime, CNRS, Université de Poiters, ISAE ENSMA, France EP-14

Friction regimes of resin lubricated carbon fiber tows

Noël Brunetière[a]*, Olga Smerdova[a], AKiran Bhantrakuppe Narayanappa[a]
[a],Institut Pprime, CNRS, Université de Poitiers, ISAE ENSMA, Poitiers, France
noel.brunetiere@univ-poitiers.fr

During the forming of composite parts, the reinforcement tows are slid on the molding form and on the other tows to conform the mold and obtain the desired shape. The mechanical properties of the final composite structure are sensitive to the orientation of the tows that can be affected by the friction during the forming process.

In the present work, the friction of carbon fiber tows impregnated with liquid epoxy resin is analyzed. For that a tribometer composed of a rotating glass disk over which a cylindrical pin can be rubbed is used. A carbon tow is wrapped on the cylindrical pin that is oriented perpendicularly to the sliding velocity. The friction between the tows and disks is measured for different vertical loads and sliding speeds in the presence of a liquid epoxy resin layer applied on the disk. The experiments are compared to the results of a numerical model considering the lubricant flow, the resin rheology and the deformation of the tow. A good correlation is obtained. It is shown that different regimes from mixed to hydrodynamic lubrication regimes can be obtained. The transition between the regimes is discussed.

Keywords: Carbon fibers; Composite; Epoxy; Friction; Lubrication; Modelling.

Prof. Geetha Manikavasagam
VIT Vellore EP-16

3D Printing of orthopaedic metallic implants with high performance

Geetha Manikavasagam[a]
[a],Vellore Institute of Technology, Vellore, India

Hard tissue implantology is one of the most demanding areas in orthopedics, primarily due to its complex biomechanical requirements, the need for biocompatibility, and the challenges in achieving stable integration with surrounding bone tissue, which must endure significant physiological stresses. Each year, 2–4% of the global population receives some kind of orthopedic implant, mainly due to trauma, musculoskeletal disorders, or aging. While titanium implants are the premium choice in orthopedic implantology owing to their superior biocompatibility and corrosion resistance, cheaper alternatives like stainless steel and cobalt-chrome alloys are also used in implant manufacturing. Despite the stable clinical success of biomaterials in implantology, one major downside that motivates researchers to look beyond these metals is their excessive mechanical properties, which are several times higher than those of natural bone. This mismatch leads to a phenomenon known as stress shielding, caused by improper load distribution after implantation. When the metal implant bears most of the body weight, the adjacent bone begins to deteriorate, resulting in complications such as accelerated bone resorption, aseptic implant loosening, and eventual implant failure. Additionally, the inherently low bioactivity of these materials' surfaces can trigger adverse immune reactions, leading to conditions such as metallosis, fibrous tissue infections, and inflammation.

A promising solution for the above problems has arrived with the advent of advanced additive manufacturing (AM) techniques, and a new philosophy of biometal manufacturing known as 'biomimetic construction'. Through this approach, engineers can 3D print complex porous architectures that mimic natural human bone, thereby reducing the mechanical properties to levels closer to those of human bone. This advancement significantly lowers the chances of aseptic loosening of implants. While conventional production methods are well-established, mimicking the porosity of natural bone was previously unachievable due to its intricate architecture—until the advent of AM. AM offers the capability to produce biometallic implants with a high degree of customization, precisely tailored to meet the unique anatomical requirements of individual patients. This innovation addresses the long-standing challenge of mechanical mismatch between implants and surrounding biological structures. Furthermore, AM facilitates the creation of porous geometries that greatly enhance bioactivity, promoting natural bone growth and integration—advantages that are not easily achievable with traditional dense or solid implants. The personalized nature of these implants ensures an optimal fit, reducing complications associated with poor alignment and eliminating the need for bone removal to accommodate standard implant sizes.

This presentation is designed to introduce you to the evolving landscape of AM and its transformative impact on orthopedic implantology. Specifically, it highlights how AM has revolutionized the field by improving the longevity of orthopedic devices within the human body, enabling the fabrication of patient-specific implants with intricate geometries, optimized porosity for bone ingrowth, and reduced weight. The use of AM in our lab to enhance the functionality of implants in clinical applications is also emphasized, providing a comprehensive overview of our research approaches. This includes the integration of advanced techniques such as plasma spray coating and small-molecule technologies in pursuit of biomimetic solutions. These advancements are geared toward engineering next-generation implants with significant market potential.

Keywords: Additive Manufacturing (AM), Orthopedic Implants, Biomimetic Construction, Stress Shielding, Porous Architecture

Prof. Shanmugam Kumar
University of Glasgow, UK

EP-17

Sustainable Multifunctional Materials and Composites via Additive Manufacturing and Nanoengineering

S. Kumar
Professor of Composite Materials and Advanced Manufacturing,
Multifunctional Materials and Additive Manufacturing (M2AM) Laboratory
James Watt School of Engineering, University of Glasgow, UK

The emergence of micro-, nano-, and molecularly-tailored multimaterial systems, driven by advancements in additive manufacturing (AM), has revolutionized the design of novel functionalities. These technologies, especially in 3D and 4D printing, offer cost-effective automation and unparalleled flexibility in tailoring material architecture and properties locally. This presentation highlights our group's multidisciplinary research, covering: (i) compliance-, morphology-, and surface-tailored multilayers; (ii) nature-inspired materials such as nacreous and camouflage composites; (iii) nanocomposites and 4D printing, including piezoresistive self-sensing systems and morphing structures; (iv) multiscale fibre composites with hierarchical architectures and self-sensing capabilities; and (v) architected metamaterials, from 2D and 3D lattices for energy absorption to smart medical devices and EMI shielding. The ability to manipulate matter at micro- and nanoscales, in 3D and 4D, enables strain-, stress-, and functional-engineering, paving the way for enhanced performance and novel fabrication methods. The convergence of emerging AM techniques with precise control of geometry and structure promises new material classes with unprecedented properties.

Takahiro Ohashi
Kokushikan University

EP-18

Dissimilar Materials Joining of an SPCE Steel Sheet with a Prepared Stamping Hole with an Inside Chamfer to an A5083 Aluminum Alloy Sheet via Friction Stir Forming

Takahiro Ohashi[a]*, Shi Yingbing[a], Yukito Nakayama[a], Hamed Mofidi Tabatabaei[a], Tadashi Nishihara[a]
[a]Department of Mechanical Engineering, School of Science and Engineering, Kokushikan University, Setagaya, Tokyo, Japan
*tohashi@kokushikan.ac.jp

This paper reports the structural joining of steel to aluminum alloy plates via friction stir formation using a prepared hole with a chamfering punch. The joining process was performed using the following steps: First, a hole was pierced with a chamfering punch on the harder material being joined (i.e., the steel plate in the case of a steel–aluminum plate joint). Next, the harder material was turned over, and its chamfered side was placed against the backing plate, and the softer material (i.e., the aluminum plate in this case) was placed on top of it. Then, a rotary tool was inserted on top of the softer material to cause the softer material to flow into the hole in the harder material. The high fluidity of the material during friction stir forming allowed the softer material to fill the diagonal structure of the hole and form a mechanical interlock. Because this is not a metallurgical joining process, it is easy to join any combination of materials and conditions. In the experiment, a 0.8 mm-thick SPCE steel plate and a 3 mm-thick aluminum alloy plate were used as jointed materials. A chamfering punch with outer diameters of φ4.0 and φ6.0 and 10 dies with inner diameters of φ4.2 to φ6.0 were used to pierce the steel plates by varying the punch and die clearance. The chamfering punches had a 45-degree inclined step between their small- and large-diameter portions, and the shape of the step was transferred to the rim of the hole in the steel plate at the end of the piercing. In the friction stirring step, the tool rotation speed was 1167 rpm, and the tool plunge depth was 2.7 mm. No lubricant was used in the experiments. Cross-tensile strength (CTS) and tensile shear strength (TSS) test specimens were prepared, and strength tests were conducted using a Shimadzu Autograph AG-10TB/AG-X/R at a crosshead speed of 1 mm/min. Figure 1 shows the measured strengths of the joints. The TSS tends to increase slightly with increasing inner diameter of the die. The variation in the punch and die clearances is associated with the change in the depth of the rollover of the rim of the punched hole, and the CTS corresponds to this depth The highest CTS value was obtained when the clearance was 0.2 mm or less. This is believed to be because the material tends to escape into the space between the die and punch to reduce the rollover depth as the clearance widens.

Keywords: cross tensile strength (CTS); dissimilar materials joining; friction stir forming (FSF); friction stir processing (FSP), mechanical joining, tensile shear strength (TSS).

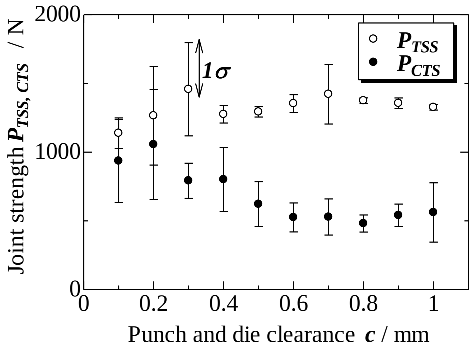


Fig.1 Strength of fabricated joints with different punch and die clearances (N = 6).

Clamp Force Reduction on Thin Plates Bolted Joint

Shinji Hashimura[a]*, Naoki Yamamoto[b], Takehiro Ohno[c]

a Mechanical Engineering Program, College of Engineering, Shibaura Institute of Technology, 3-7-5 Toyosu, Kotoku,Tokyo, 135-8548, Japan

b Graduate School of Engineering and Science Shibaura Institute of Technology

c Engineering Science and Mechanics, College of Engineering, Shibaura Institute of Technology

*hasimura@shibaura-it.ac.jp

Even though many studies on loosening of bolted joints have been conducted, accidents due to loosening still occur. This is because loosening occurrence conditions are different depending on the sizes and shapes of bolted joints. Although the loosening of thick plate bolted joints has been actively discussed in the literature so far, almost no research has been published on the loosening of thin plate bolted joints. In this study, a new type of bolt loosening, clamp force reduction of a bolted joint, was discovered when offset loads were repeatedly applied to both ends of a thin plate on a joint, tightened a block to the thin steel plate with a bolt and a nut. And we elucidated the mechanism of the loosening occurrence. In the experiments, effects of the offset distance on clamp force reduction was investigated when multiple applications of symmetric offset axial load to the bolted joint assembly. And elastic FE analysis was also conducted to elucidate the occurrence mechanism separating an effect of plastic deformations. The experimental results showed that even though the slight offset load was applied on the thin plate, the clamp force reduced from several percent. The reduction ratio of the clamp force depended on the offset distance, that is the bending moment applying on the thin plate. It was also found that the clamp force reduction depends not on the number of times the offset load is applied but on the magnitude of the offset load. The result indicates that if the offset load does not increase, the clamp force does not reduce. This loosening phenomenon is a new type of bolt loosening and its mechanism had not been also elucidated yet. The results of the FE analysis showed that the main factor causing the clamp force reduction was slippages between contacting surfaces on the thin plates and the bolted joint which was caused by offset load and the loosening was caused by the slippages did not return to the origin due to friction.

Keywords: Bolted joint; Loosening; Clamp force; Thin plate; Slippage.

Takenobu Sakai
Saitama University EP-20

Evaluation of Mechanical Properties on CFRP Adhesive Joints

Takenobu Sakai[a]*, Yudai Miyoshi[a]
[a]Graduate School of Science and Engineering, Saitama University, Saitama, Saitama, Japan
*sakai@mech.saitama-u.ac.jp

Mechanical joints using fasteners are used in the aerospace industry. To reduce weight, they need to be adhesively joined, but this has not been possible due to weak bond. In this study, the goal was to perform non-destructive testing of weak bonds and to understand the mechanical properties of weak bonds. Single-lap test specimens reproducing standard and weak bond adhesion conditions were prepared and tensile and dynamic mechanical analysis were carried out. As a result, it was revealed that weak bond reduces shear strength and shear modulus, and that dynamic mechanical analysis showed a decrease in the storage modulus. The above suggests that weak bonds can be detected by investigating the sound speed of the adhesive, which is related to the modulus of elasticity.

Keywords: CFRP, Viscoelasticity, Weak bond, Single-lap test, Epoxy adhesive

Poonam Kumari
Indian Institute of Technology Guwahati EP-21

Fabrication and Characterization of two-layered PZT-ZrO_2 discs through Cold Isostatic Pressing for Improved life

Saurabh Khare[a], Nandani Rai[a], Nikhil Dilip Kulkarni[a], Poonam Kumari[a*]
[a]Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Guwahati, Assam, India
*kpmech@iitg.ac.in

Pure and monolithic lead zirconate titanate (PZT) sensors break very easily and life is low. PZT disc and stacks are the main components for various applications like gas lighter, ammunition ignition, hydrogen gas ignitors and various sensors for ultrasonic applications. There is need to enhance fracture toughness of the PZT material for the longevity of the sensor components. CIP (cold isostatic pressing) is one the most economic and standard technique for fabrication of uniformly dense components/pellets. A two-layered disc (100% PZT (1.5 mm)/ 80%PZT-20%ZrO_2 (1.5 mm)) via cold isostatic pressing (CIP) is fabricated. Silver coating is done on the faces and after that electric poling is done at 100°C silicon oil. Sample X-ray diffraction (XRD), scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) have been done for the crystallographic, microstructural and compositional analysis. The sample is analysed under d33 meter and LCR meter for electrical properties. Uniform grain size of 1.9 ± 0.7 µm is observed and well-defined interface between the layers, indicating successful synthesis and uniform distribution of the constituents. The piezoelectric coefficient d33 and resonance frequency of the material is found to be 200 pC/N and 67 kHz, respectively. The work opens the field for developing functionally graded PZT material for enhancing the performance of piezoelectric devices to meet the requirement as sensors.

Keyword: Cold Isostatic Pressing; Composite; Piezoelectricity; PZT; Two-layered

Incremental Forming of PMMA Sheets by Oil Bath Heating

Masaaki Otsua*, Satoshi Komurab
aMechanical Engineering, Faculty of Engineering, University of Fukui, 3-9-1, Bunkyo, Fukui, 910-8507, Japan
bIndustrial Innovation Engineering, Graduate School of Engineering, University of Fukui, 3-9-1, Bunkyo, Fukui, 910-8507, Japan
*otsu@u-fukui.ac.jp

PMMA sheets are generally formed by thermoforming due to their difficulty in plastically deforming at room temperature. However, since thermoforming requires forming dies, it is not suitable for small-lot production. Incremental forming is one of the forming methods that does not require forming dies. In some papers reporting on the incremental forming of PMMA sheets, the sheets are heated by a resistance heater, friction heat, hot air blow, and so on to enable plastic deformation. However, these methods make it difficult to uniformly control the sheet temperature. In this study, an oil bath was employed to precisely maintain the sheet temperature uniformly during forming. Formable working conditions were investigated, and the formed shape and surface roughness were evaluated.

The forming system, including a die, sheets, and blank holder, was set into an oil bath, and the oil was heated by immersion heaters and stirred by a stirrer. A tool was driven by a 6-axis arm robot. After forming, the shape of the formed sheet was measured by a DIC system, and the surface roughness was measured by a contact roughness meter or a confocal laser scanning microscope. PMMA sheets with a size of 150 mm × 150 mm × 1 mm were used as specimens. JIS: A1050-H sheets with a size of 150 mm × 150 mm, and a thickness of 0.5 mm or 0.3 mm were used as a top dummy sheet. A PTFE or PMMA sheet of similar size was also used as an intermediate dummy sheet to protect the surface of the PMMA sheet. PMMA sheets were formed into a frustum of a conical shape with a height of 40 mm and an initial diameter of 100 mm. Experiments were conducted at various wall angles and temperatures.

As a result, the thinner the A1050-H sheets used as a top dummy sheet, the smaller the surface roughness obtained. The surface roughness of PMMA sheets with A1050-H and PMMA as dummy sheets was Ra = 0.02 µm, Rz = 0.13 µm at a temperature of 120°C and a wall angle of 40°. When the formed sheets were placed on a piece of paper with printed letters, the letters were clearly visible through the formed sheets.

Keywords: forming accuracy; incremental forming; oil bath; PMMA sheets; surface roughness

Zainuddin Sajuri
Universiti Kebangsaan Malaysia EP-23

Effect of Friction Stir Spot Welding Parameters on Lap Shear Strength of Similar and Dissimilar Aluminium Alloys

Zainuddin Sajuri[a,b]*, Ahmed Esmael Mohan[a,c], Amir Hossein Baghdadi[a], Nashrah Hani JamadonaAuthor[a,b]

[a]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

[b]Centre for Materials Engineering and Smart Manufacturing, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.

[c]Technical College of Al-Musaib, Al-Furat Al-Awsat Technical University, Kufa, Iraq

*zsajuri@ukm.edu.my

Friction stir spot welding (FSSW) is a solid-state single-point welding technique that uses a rotating tool consisting of a shoulder and a pin for joining nonferrous metals and alloys. FSSW produces a keyhole at the welding point, which decreases the mechanical strength of the joints. This study investigates the influences of tool rotational speed (1000, 1250, and 1500 rpm) and dwell time (5, 10, and 15 s) on the shear fracture load of the FSSW joints. A cylindrical M5 threaded pin of length 4 mm with a shoulder diameter of 15 mm was used as the welding tool. Two different grades of aluminium alloy plates, i.e., AA6061 and AA7075 were used to produce similar (7075-7075 and 6061-6061) and dissimilar (6061-7075) alloy joints. The plates with a thickness of 3 mm were folded above each other before a rotating tool pin was plunged through the thickness of the top plate to obtain an FSSW lap joint. It was found that tool rotational speed and dwell time induced a considerable impact on shear strength. The results showed that a tool rotational speed of 1250 rpm and dwell time of 10 s gave the highest shear fracture load for 7075-7075 similar and 6061-7075 dissimilar joints. However, for similar joints in 6061-6061, the highest mechanical strength was obtained at 1250 rpm and 10 s.

Keywords: Friction stir spot welding; Rotational speed; Dwell time; Fracture load; Aluminium alloys.

Dr. Dhanalakshmi
CVRDE, India

EP-24

Kalvam (Grinding in Traditional Medicine Manufacturing): Engineering Insight

A S Ganesh Kumar[a] and S Senthilvelan[a]

[a]Indian Institute of Technology Guwahati, Assam, India

The Siddha and Ayurveda are traditional medicine systems followed in India. Most traditional medicines require a grinding process, either wet or dry grinding. A mortar and pestle made of a specific material (Nannikal) is being used in grinding process, wherein the operator grinds the medicine using a pestle by applying force in forward and return stroke for a considerable time. The forces acting during the grinding in a stone mortar and pestle are impact force, which is applied by the pestle on a larger chunk of raw material in the initial phase; compressive force, which is applied by the pestle's self-weight and attrition arising from the particles scraping against one another which is due to shear force applied on the pestle. No work has been reported about the grinding force analysis of reciprocating mortar and pestle on a curved surface. The current work aims to study the grinding forces in a stone mortar and pestle, develop a test rig to measure the forces and calculate the work done per cycle and the power required.

Current work also evaluated physical, thermal and mechanical properties of this Nannikal along with tribological performance. The bulk density of the Nannikal was found using Archimedes's principle. The apparent porosity was found using a Helium pycnometer. The hardness of the Nannikal was found using Mohs hardness testing tips. The compressive strength and Young's modulus of the Nannikal were found using the uniaxial compression test. The thermal properties were found using the transient plane heat source method. Petrographic and XRD and XRF analysis of the Nannikal was carried out . Friction and wear properties of Nannikal was carried out using pin-on-disc configuration. Three kinds of pins (Nannikal, black stone, and stainless steel), and the disc material was of Nannikal was utilized for all the tests. The frictional force coefficient, wear, and temperature developed during the test were measured to understand its performance.

Dr. Dhanalakshmi
CVRDE, India

EP-25

Secondary Processing of Aluminium Matrix Components – Challenges & Applications

Dhanalakshmi[a]

[a]Combat Vehicle Research and Development Establishment, Chennai, India

Light Metal Technology is very much in need for the Automotive, Aerospace and Defence Sectors owing to the continuous performance improvement demanded by these sectors. The Metal Matrix Composites, particularly, the Aluminium Matrix Composites (AMC) falls under one of the advanced light weight high performance materials. Composites made using AI-2XXX Series Aluminium alloys as matrix materials find wide range of application. The Secondary Processing of these composites results in high specific strength, high specific stiffness coupled with high fatigue and wear properties. In 2XXX Series alloys, the AI 2014 Alloy designated as Al-4.4Cu-Mg alloy, is presently used in heavy-duty diesel engine piston and floating piston of hydro-gas suspension of the Armoured Fighting Vehicles (AFVs). In this paper, the secondary processing for Al 2014 based composites with respect to the challenges faced during extrusion, the metallographic and mechanical property are dealt in detail. And as a case study, application of extruded aluminium matrix composites for AFV application is also presented.

Dr. M. Vasudevan
IGCAR Kalpakkam, India

EP-26

Development of Structural Materials and the Associated Processing of Welding Technologies for Fast Breeder Reactors

M. Vasudevan[a]

[a] Materials Development and Technology Group - Metallurgy and Materials Group, Indira Gandhi Centre for Atomic Research, Kalpakkam, India

Structural materials and their availability are the key factors influencing the growth of nuclear energy. Advances in structural materials and their associated technologies make a wide range of nuclear reactors possible today. To enhance the target burnup and service life of FBRs, development of high performance materials and innovative processing and welding technologies are very much important. Compositional modifications, optimization of the thermo-mechanical treatments for modifying the initial microstructure have been carried out for enhancing the high temperature performance of the selected core and structural materials of fast breeder reactors (FBRs). Innovative processing and welding technologies have been developed for the structural materials with significant improvement in high temperature mechanical properties. Compositional modifications and optimization of thermo-mechanical treatment have been carried out for alloy D9 to enhance the high temperature microstructure stability and mechanical properties. Optimum nitrogen content in 316LN stainless steel and its weld metal has been determined for enhancing the high temperature mechanical properties and improving the weldability (resistance to hot cracking) of structural components of FBRs. Optimum boron and nitrogen content and TMT have been optimized to enhance the resistance to type IV cracking in Grade 91 steel. Advanced welding technologies have been developed for similar and dissimilar welding of structural materials with significant enhancement in creep rupture life. Finite Element Modeling (FEM) and Computational Fluid Dynamics (CFD) simulations have been carried out using hybrid heat sources for modeling of the welding processes in order to improve the performance of the processes to produce quality weld joints. Deep learning approach has been developed for real time monitoring and prediction of depth of penetration during autogenous TIG welding of 10 mm thick 316LN stainless steel. The above developments in structural materials and their associated technologies would enhance the design flexibility, safety margins and extend the service life of FBRs.

Hiroki Akasaka
Institute of Science Tokyo, Japan

EP-27

Shape and structure changes of diamond-like carbon films by defocused laser irradiation

Dai Harada[a], Yuko Aono[a], Karyu Hase[a], Yuki Hirata[a], Naoto Ohtake[a], Hiroki Akasaka[a]*

[a]1 Dept. of Mechanical Eng., Inst. of Science Tokyo (formerly Tokyo Inst.of Tech.), Tokyo, Japan

*akasaka.h.ac@m.titech.ac.jp

Diamond-like carbon (DLC) films are consisted of sp^2 and sp^3 bonded carbon networks and hydrogen atoms as carbon network terminations, and have low frictional coefficient and high hardness. Due to these fine tribological properties, DLC films have been applied to sliding parts surface as solid lubricant. In this study, the laser with 1064 nm irradiated under defocusing condition the surface of DLC film surface and subsequently evaluated the resultant changes in the carbon bonding distribution in the irradiated area and the change in the surface topography. DLC films with smooth and flat surface were deposited on Si(100) from C_2H_2 using pulsed plasma chemical vapor deposition method. These DLC films coated Si(100) were placed 1-10 mm below the focal point of the laser, and a pulsed laser beam with a wavelength of 1064 nm was irradiated in a grid pattern with 200 mm intervals. At a defocus of 3 mm, ablation occurred and DLC film were partially damaged and peeled off. While at 5 mm, a semicircular protrusion was observed, as shown in the figure. No change due to irradiation was observed beyond 8 mm. When the $sp^2/(sp^3+sp^2)$ hybridized carbon bonding ratio in the raised part of the 5 mm film was evaluated, an increase in $sp^2/(sp^3+sp^2)$ ratio was observed in the center of dimple. From the cross-sectional SEM observation, the laser irradiated center of the surface showed a melting mark. The photon distribution of the used laser is Gaussian distribution, and the dimple shape also followed a Gaussian distribution, suggested that the shape and structural changes depend on the irradiated photons. Furthermore, based on the melting mark at the center of laser irradiation are, we realized that it may be possible to bond DLC films together. Thus, we tried to join DLC films by contacting a DLC film formed on glass with a DLC film formed on Si and irradiating a laser under defocusing condition from the glass side. As a result, the two DLC films were bonded.

Keywords: Diamond-like carbon film; laser irradiation; Defocus; Structural change; NEXAFS.

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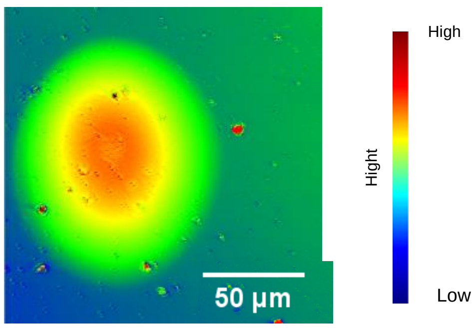

Figure. Hight mapping around laser irradiation area observed by laser microscope.

Tsunehisa Suzuki
Akita Prefectural University

Effects of ion beam irradiation on the crystal growth of TiN thin filmsand the interface between the films and cemented carbide substrates

Tsunehisa Suzuki[a]*, Soya Sato[a], Tatsuya Fujii[a] Mitsuyoshi Nomura[a], Takashi Sekine[b], Yasushi Sugawara[b], Shigeaki Sugiyama[b]

[a]Department of Mechanical Engineering, Akita Prefectural University, Yuri-honjo, Akita, Japan

[b]Akita Industrial Technology Center, Akita, Akita, Japan

For the base metal of cutting tools, ultra-fine cemented carbides made of tungsten carbide (WC) powder with a grain size of 1 μm or less and sintered with a binder such as cobalt (Co) are used to improve hardness and durability. Titanium-based ceramic coatings such as TiN and TiAlN are depositedon the surface of the base metal to improve wear resistance, lubricity, and heat resistance, and are nowin practical use. The challenges of these coatings for cutting tools are to ensure adhesion to the substrate, ultrafine-grained cemented carbide, and to establish a deposition method that can freely control the crystal structure and composition ratio. In particular, it is important to suppress the reaction between the binder metal and the coating film to ensure adhesion.

In this study, TiN thin films were deposited on ultrafine-grained cemented carbide substrates by ion beam assisted deposition (IBAD), and cross-sectional TEM observation, EDS analysis, and XPS analysis were performed to clarify the effect of ion beams on the crystal structure of the TiN thin filmsand the interface with the cemented carbide substrate.

An IBAD system equipped with an electron beam (EB) evaporation source and an ECR ion sourcewas used for TiN deposition. Ultrafine-grained cemented carbide with Co as the binder was used as thesubstrate. For TiN deposition, N_2 gas (20 sccm) was introduced in the vicinity of the substrate and the TiN film was deposited on the surface of the substrate using an Ar ion beam generated by applying 1 kV to the ECR ion source and -2 kV to the acceleration grid for 360 s. N2 gas (20 sccm) was introducednear the substrate, and high-purity Ti (99.8%) was evaporated by EB at a deposition rate of approximately 0.4 nm/s. During deposition, the substrate was irradiated with an ion beam generated under the same conditions as during cleaning using an ECR ion source with Ar gas (3 sccm) introduced,and the sample deposited while ion mixing was performed was designated as IBAD.

The chemical bonding state of the thin films was determined by X-ray photoelectron spectroscopy(XPS: PHI5000 from ULVAC Phi). To investigate the interface between the thin film and the substrate,a cross-sectional sample of the thin film was prepared by focused ion beam, and high-resolution STEM images and EDS analysis were performed using a transmission electron microscope (JEOL JEM- ARM200F).

In this study, the effects of ion beam irradiation on the crystal growth of TiN thin films and the interface with cemented carbide substrates were investigated, and the following were found. (1) Ar ionbeam irradiation ionizes N2 gas in the vicinity of the substrate, accelerating the reaction between Ti andN and increasing the TiN ratio. (2) A mixing layer of about 2 nm is formed at the interface between theTiN film and the WC particles that constitute the cemented carbide. (3) Diffusion of Co into TiN is suppressed at the interface between the TiN film and Co in the cemented carbide.(4) The growth of crystal grains is suppressed and a dense TiN film with fine crystal grains is formed.

Keywords: Adhesion, Cemented carbide, Crystal structure, Ion beam assisted deposition, Titanium nitride

Development of High temperature Ti alloys with improved properties

Jayaprakash Murugesan[a]*

[a]Department of Metallurgical Engineering and Materials Science, IIT Indore, Indore, Madhya Pradesh, India
*jayaprakash@iiti.ac.in

Titanium alloys used for high temperature applications in jet engine components are Ti-Al-Zr-Sn-Mo-Si based near alpha Ti alloys. The maximum temperature range that near alpha Ti alloys can be used currently is up to 600°C. At above 600°C, its strength decreases drastically due to the microstructure instability. In the regions temperature over 600°C, Nickel based superalloys are being used, which are two times heavier than that of Ti alloys.

If a new high temperature Ti alloy with improved properties to use in the temperature range 600- 700 C has been identified, it would be possible to save weight and increase heat efficiency and thereby reducing the fuel cost.

One of the effective techniques to enhance the mechanical properties is by alloying additions. In the present study, the effect of nitride additions on Ti-Al-Zr-Sn-Mo-Si based near alpha Ti alloys on mechanical properties and microstructure features at room temperature and high temperature has been investigated.

The results revealed that the mechanical properties have significantly enhanced with nitride addition at both room temperature and high temperature.

The results were discussed based on the microstructure characterization using optical microscope, SEM, TEM., mechanical properties characterization using micro hardness test, compassion test at room temperature and at 650°C.

ORAL PARTICIPANTS

Kenjiro Sugio
Hiroshima University

Automatic particle detection of Al-SiC particle dispersed composites by machine learning

Kenjiro Sugio[a]*, Kyoichiro Ogawa[a], Gen Sasaki[a]
[a]Graduate School of Advanced Science and Engineering, Hiroshima University, Higashi-Hiroshima, Hiroshima, Japan
*ksugio@hiroshima-u.ac.jp

Three methods were used to automatically detect SiC particles in Al-SiC particle-dispersed composites. The detection accuracy was compared using the traditional image processing, which consists of smoothing and thresholding, and the neural network algorithms SSD (Single Shot Multibox Detector) and Mask R-CNN (Mask Region-based Convolutional Neural Network).

For object detection using SSD, a rectangle was drawn over the particles using the VoTT annotation tool to create a model, and the four corner points of the rectangle and the object class information were used as training data. Since Mask R-CNN can detect the region of an object, it is necessary to input the region information of the object for the training data used to create the detection model. The annotation tool labelme can represent object regions as a sequence of points, and this tool was used to extract the coordinates of the point sequence and object class information.

The detection accuracy of the above three detection methods were compared. The five SEM images and the correct particle solution for each image were prepared. The five images are detected by each detection method and compared with the correct answers to calculate the undetected rate U and the false positive rate F. They are calculated as follows.

$$U = N_U/N, \qquad F = N_F/N$$

where N is the number of all correctly detected particles, N_U is the number of undetected particles, and N_F is the number of false positives. Undetected refers to the case where a previously prepared correct answer particle has not been detected. False positives are cases where multiple particles are detected as a single particle or where a region is detected that is not a correct particle. Only those particles that are all shown in the image are selected as the correct particles, and those that are out of the image are not considered to be particles. The undetected rate and false positives are shown in Table 1.

Table 1 Comparison of particle detection accuracy.

Method	Undetection, U [%]	False detection, F [%]
Traditional	0	114.82
SSD	54.17	6.39
Mask R-CNN	9.82	0.30

Keywords: automatic particle detection; metal matrix composites; convolutional neural network; image processing.

Banamali Sahu
Department of Applied Mechanics, IIT Madras

Patch size study on GFRP laminate under flexural loading

Arockiarajan A, Banamali Sahu*
Department of Applied Mechanics, IIT Madras, Chennai, Tamil Nadu, India
banamali095@gmail.com

The objective of this study is to determine the effect of patch size and optimal patch dimension for a glass fiber reinforced polymer composite plate with a central hole under a four-point bending load. The plate consists of a symmetric 16-layer structure with dimensions of 125 mm x 15 mm x 2.8 mm and a 5 mm diameter hole in the center. Patch repairs are employed to enhance the bending strength of the specimen by varying patch length and thickness. The four-point bending test setup includes two inner and two outer loading points. For the optimization process, different patch sizes are simulated using Abaqus to assess their effect on stress distribution, stiffness, and strength of the plate. To find the optimal patch configuration, topology optimization technique is applied, which aims to minimize the strain energy in the specimen by adjusting the geometry and material distribution of the patch. This optimization focuses on reducing weight while maintaining or improving the load-bearing capacity of the structure. The primary challenge involves determining the ideal patch dimensions and placement that result in improved performance without compromising structural integrity. The Abaqus-based simulation, along with topology optimization, helps in finding the most efficient patch design in terms of dimensions, ultimately contributing to the development of repair strategies for composite materials in practical applications. The results of this study will inform guidelines for patch repair in composite structures subjected to flexural loads, ensuring an optimized balance between structural reinforcement and material efficiency.

Keywords: Glass Fibre; Patch Repair; ABAQUS; Optimization; Flexural; Topology.

Pramod Kumar Parida
IIT Bhubaneswar

Influence of fumed silica nanofiller and stacking sequence on solid particle erosion response of bidirectional jute-kevlar hybrid composites

Pramod Kumar Parida, Mihir Kumar Pandit, Arun Kumar Pradhan
School of Mechanical Sciences, Indian Institute of Technology Bhubaneswar, Jatani, Odisha, India
pkp13@iitbbs.ac.in

This study investigates the impact of nanofiller content and stacking sequence on the erosion wear properties of Jute (J) –Kevlar (K) fabrics hybrid composites, using scanning electron microscopy. The research focuses on four-layer fabric composites with stacking sequences JJJJ (Jute-Jute-Jute-Jute), JKKJ (Jute-Kevlar-Kevlar-Jute), and KJJK (Kevlar-Jute-Jute-Kevlar), each containing varying nanofiller weight fractions (0%, 1.5%, 3%, and 4.5%), alongside a KKKK (Kevlar-Kevlar-Kevlar-Kevlar) fiber-reinforced composite without nanofiller (KKKK-0) fabricated as a reference for comparison. The effect of the cumulative weight of impinging Al2O3 erodent particles ranging from 5–30 g on these composites is examined at different impingement angles (30°, 45°, 60°, and 90°) with a constant particle velocity of 62 m/s. The findings reveal that at lower impingement angles, the erosion rate shows a sharp decreasing trend and then it is decreasing with a much slower rate as the cumulative weight of impinging particles increases, while at a higher impingement angle (90°), an opposite trend is observed.

Keywords: Erosion wear; Fumed silica; Hybrid composite; Jute; Kevlar; Nanofiller; Scanning electron microscopy

Keerthika. N. B
IIT Madras

Tensile Characteristics of 3D Printed Flexible Polybutylene Succinate (PBS) / Coir Composite

Keerthika. N. B*, R. Gnanamoorthy

Architected and Sustainable Materials Design Research Centre
Indian Institute of Technology Madras, Chennai 600036, India
* *Corresponding author e-mail*: keertej@gmail.com

With an increase in awareness about environmental issues, the trend in the automobile industry is to use "Recycled" or "Sustainable" or "Biodegradable" materials in large quantities. Lightweighting requirements in modern mobility forced the extensive use of synthetic polymer and its composites raising concern over the threat to the environment post usage. Various alternatives to synthetic materials are emerging provided their suitability is assessed for specific functional demands for specific applications such as headliner, door pad, carpets, insulation, etc in a vehicle. In recent years, there has been a growing interest in the use of technical textiles in automotive applications due to their lightweight, high performance, and versatility. Car headliners, in particular, play a crucial role in enhancing the overall aesthetics and comfort of the vehicle interior. Natural material reinforced polymer composites can offer potential advantages such as being lightweight and improving the overall green rating of the vehicle. Coir pith-reinforced Polybutylene Succinate (PBS) is considered for the development of highly flexible parts using additive manufacturing. The Fused Filament Fabrication (FFF) based 3D printing is preferred and the source material, in the form of a filament, is developed in the laboratory. This paper describes the development of PBS/Coir filament for FFF process using melt compounding with 10% of the coir. Thin samples were fabricated with different infill porosity to achieve the high degree of flexibility needed. Tensile behaviour of 3D printed PBS and coir pith reinforced PBS are reported. The failure of micro-mechanisms under tensile loads is discussed.

Keywords: *Agrowaste, Sustainable Composites, PBS, Coir, Flexible Sheets, Tensile Characteristics*

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Marco A. García-Revilla
University of Guanajuato, Guanajuato, Guanajuato, Mexico.

Modeling adsorption and optical properties for the design of CO_2 photocatalytic Metal Organic Framework

Marco A. García-Revilla[a]*, Priscila Chacón[a], Joseelyn Hernández-Lima[a], Adán Bazán-Jiménez[a]

[a]Department of Chemistry, University of Guanajuato, Guanajuato, Guanajuato, Mexico

magarcia@ugto.mx

Abstract

We have modelled four MOFs (IRMOF-C-BF2, IRMOF-C-(2)-BF2, IRMOF-C’-BF2, and IRMOF-C-CH2BF2) based on IRMOF-1, using a linker based on Frustrated Lewis Pairs (FLP) and coumarin fragments to confer photo-catalytic properties to the designed MOFs. The four different linkers used were: a) a BF2 group attached to a coumarin moiety at position 3, b) two BF2 fragments attached to a coumarin moiety in positions 3 and 7, c) a BF2 group attached in the coumarin moiety in position 7, and d) a CH2BF2 moiety attached at 3 position. Adsorption properties of molecules: H2, CO2 and H2O, and the possible CO2 photo-catalytic capabilities of resulting MOFs, were analyzed by computational modelling using Density Functional Theory (DFT) and Time Dependent Density Functional Theory (TD-DFT) using a quantum chemical periodic wave function approach. Results show that the new linkers are improve the adsorption, bulk properties, and optical properties of IRMOF-1 for CO2 adsorption and photo-catalysis.[1]

Keywords: MOF; CO2; Environmental remediation.

[1] Chacón, P.; Hernández-Lima, J.G.; Bazán-Jiménez, A.; García-Revilla, M.A. Modeling Adsorption and Optical Properties for the Design of CO2 Photocatalytic Metal-Organic Frameworks. Molecules 2021, 26, 3060.
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G V Balakrishna
IIT Madras

Identification of grease formulation using Fourier Transform Infrared Spectroscopy: Application of Artificial Intelligence

G V Balakrishna[a]*, R Gnanamoorthy[a]
[a]Architected and Sustainable Materials Design Research Centre, IIT Madras, Chennai, Tamil Nadu, India - 600036
me19d403@smail.iitm.ac.in

ABSTRACT

Lubrication failures constitute nearly 60-70 % of failures in bearings. Grease lubricants formulated using different types of base oils and thickeners are used to lubricate bearings used in motors and generators. Some causes of lubrication failure include improper grease application, lubricant contamination, and lubricant degradation. Fourier transform infrared spectroscopy (FTIR) is used to characterize the chemical footprint of the molecules present in a material. Identifying the base oil and thickener can give basic information on the type of grease present and can help in judging if an appropriate lubricant is used for the application. Lubricant degradation is usually caused due to exposure to excessive temperatures. Excessive temperature induces chemical changes with the appearance of ketone and aldehyde groups in the FTIR spectrum. In this work, greases with combination of thickeners: lithium and polyurea with base oils: PAO oil, ester oil and mineral oil are considered. The greases are subjected to high temperatures of 220 °C by heating in a crucible for 6 hours. A neural network-based classifier is developed to identify the grease formulation both in fresh and thermally aged condition from IR spectra. A front-end interface is developed in Python where uploading a grease spectra can predict the type and damages in the field visit when coupled with a handheld FTIR spectrometer.

Keywords: *Bearings, Lubrication, Greases, AI/ML, classifiers*.

Shun TAKAMURA
Waseda University, Japan

Investigation of Densification treatment method for CNT yarns using Molecular Calculations

Shun TAKAMURAa*, Yoshimasa KUZUNOa, Takumi ITOa,
Akira KUNITOMOb, Atsushi HOSOIac and Hiroyuki KAWADAac
aDepartment of Applied Mechanics and Aerospace Engineering, Waseda University 3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555, Japan
bTOYOTA MOTOR CORPORATION, 1, Toyota-cho, Toyota, Aichi, 471-8572, Japan
cKagami Memorial Laboratory for Materials Science and Technology, Waseda University 2-8-26 Nishiwaseda, Shinjuku-ku, Tokyo 169-0051, Japan
*[*shundy.t@akane.waseda.jp*](mailto:shundy.t@akane.waseda.jp)*

Abstract

Over the past few decades, aerospace applications require lightweight materials with high strength. The fiber-reinforced plastics (FRP) industry is developing by the demand. Carbon nanotube (CNT) yarns, which are fabricated by bunding CNTs together, are expected to be the next generation reinforcements fiber of FRPs because of their high specific strength and stiffness. However, the strength of CNT yarns is much smaller than the strength of individual CNTs due to the weakness of the interaction between individual CNTs. Therefore, it is demanded to strengthen the interaction between individual CNTs of CNT yarns. As one of the methods to enhance the interaction between individual CNTs, densification treatment using polymer solution is effective. Densification treatment using polymer solution is effective to strengthen interaction between individual CNTs because the distance between individual CNTs is reduced by capillary force during the solvent evaporation, and the cross-linked structure is built by hydrogen bonding. Although conditions of densification treatment are being optimized, the strength of CNT yarns is less than that of carbon fibers. It is required to improve conditions of densification treatment. As the conditions of densification treatment, the effects of the hydrogen bonds formed between CNTs, the distance between individual CNTs, and resin content have been fully considered.

In this study, we used polyacrylic acid (PAA) as the polymer to strengthen CNT yarns. As a result, we obtained CNT yarns that have high strength with 3.28 GPa. In addition, it was suggested that the interaction between CNTs changed by the resin content in CNT yarns. We have evaluated the CNT/resin interaction by creating a CNT bundle model using molecular dynamics calculations and performing CNT pull-out analysis. The effect of the distance between individual CNTs and the content of resin were evaluated as a parameter. As the distance between individual CNTs decreased, the maximum pull-out force improved. On the other hand, as the resin content increased, the maximum pull-out force improved. Comparing the effects by the distance between individual CNTs and the resin content, maximum pull-out force was changed more significantly by the distance between individual CNTs. Therefore, it was suggested that the distance between individual CNTs was more effective than the resin content to the strength of CNT yarns.

Keywords: Advanced materials; CNT yarn; densification treatment; interaction between CNT; molecular calculations

Soma Maji
IIT Madras

Simulation of Heat Transfer and Microstructural Evolution during AdditiveManufacturing of Inconel 625

Soma Maji[a]*, Murugaiyan Amirthalingam[a]
[a]Department of Metallurgical and Materials Engineering, IIT Madras, India
*mm18d014@smail.iitm.ac.in

Inconel 625 (IN625) alloy is known for its high-temperature mechanical properties and corrosion resistance, making it essential in aerospace, solar, and marine applications. However, manufacturing complex geometries using conventional manufacturing processes is challenging. Laser Powder Bed Fusion (LPBF) offers a promising solution, but its rapid, non-uniform thermal profiles result in heterogeneous microstructures, necessitating careful parameter selection to avoid undesirable phases.

A simplified three-dimensional heat source model was developed using the finite element method (FEM) to analyze thermal cycles during the additive manufacturing of Inconel IN625. The model assumes that all elements within a layer melt simultaneously, reducing computational time. A multi-phase field modeling (MPFM) was employed to simulate microstructural evolution and predict the elemental segregation of alloying elements based on the thermal boundary conditions from the FEM analysis. The effects of thermal gradients and cooling rates on the morphology and elemental segregation in the microstructure were examined. Both experimental techniques and modeling analyzed the primary dendritic arm spacing (PDAS) and elemental segregation behavior, showing a strong correlation with experimental results. A thorough comparative analysis established optimal LPBF parameters for fabricating IN625 components, achieving minimal defects and avoiding undesirable microstructural features.

Keywords: Inconel 625, Finite Element Method (FEM), Microstructural Evolution, Multi-Phase Field Modeling (MPFM), Primary Dendritic Arm Spacing (PDAS).

Taiki Yamamoto
Ritsumeikan University

Development of New Techniques for High-Temperature Fatigue Testing Machine Using Miniature Specimens

Taiki Yamamoto [a], Lei He [*b], Takamoto Itoh [*b]

[a] Graduate School of Science and Engineering, Ritsumeikan University, Kusatsu, Siga, Japan
[b] Department of Mechanical Engineering, Ritsumeikan University, Kusatsu, Shiga, Japan.
*lei-he@fc.ritsumei.ac.jp, *itohtaka@fc.ritsumei.ac.jp

In recent years, the importance of material testing under high-temperature conditions has increased in the industrial field. Specifically, there is a growing demand for the use of miniature specimens, which are smaller than conventional ones. Miniature specimens play a crucial role in various applications, such as the material tests in local area of weldment zones, radiation damaged materials, and new materials where standard specimen cannot be manufactured due to small sample sizes. Size effect on fatigue properties or fatigue life have been observed in high cycle fatigue region at room temperature. However, it is a few publications focus on investigating size effect at high temperature in high cycle fatigue region. The research topic remains an open issue.

This study aims to optimize the use of miniature specimens under high-temperature conditions and to establish reliable testing techniques. In this study, a self-developed fatigue testing machine with a maximum capacity of 1 kN for utilizing miniature specimen was employed. The shape and dimensions of the proposed specimens are diameter of 1.6 mm and gauge length of 4 mm. To investigate the size effect on fatigue life, validating tests were conducted at room temperature using miniature specimens and bulk specimens machined from the identical bar of AISI 304 stainless steel. Based on the results obtained, fatigue life distribution behaviors between miniature and bulk specimens were discussed. Additionally, the testing machine is equipped with a heating system that enables fatigue testing at temperatures up to 800°C by the which high-temperature tests will be conducted, and the validation test results will be discussed. Furthermore, the impact of oxidation in high-temperature environments on miniature specimens will be examined through cross-sectional observations. Improvement will be conducted to the testing machine to enhance testing techniques. Additionally, tests will be conducted using various materials to evaluate fatigue properties.

Keywords: Fatigue life; Fatigue test machine; High temperature; Miniature specimen

Nan Zhang
Nagaoka University of Technology

ASMP-07

Fatigue Strength and Corrosion Behavior under Humidity in Self-Pierce Riveting Joint of Non-Combustible Mg-4%Al-1%Ca-0.2%Mn Alloy

Nan Zhang[a]*, Yukio Miyashita[a], Xuanyi Shao[a], Koji Miyake[a]

[a]Mechanical Engineering department, Nagaoka University of Technology, Nagaoka, Niigata, Japan

nanzhang@vos.nagaokaut.ac.jp

Non-combustible magnesium alloys, such as AX41 (Mg-4%Al-1%Ca-0.2%Mn), have garnered attention for their potential in lightweight automotive structures. However, reports on the fatigue performance of self-pierce riveting (SPR) joints using these alloys are limited, hindering their practical application. To investigate the factors influencing the fatigue strength of AX41/AX41 similar and AX41/AA6061 dissimilar material joints through failure mechanism analysis, the fatigue test was conducted in this study. The stress ratio was 0.1 and the frequency was 10 Hz. The materials used in this study were extruded AX41 magnesium alloy and a rolled AA6061 aluminum alloy.Firstly, the fatigue test of similar materials (AX41/AX41) and dissimilar materials (AX41/AA6061) was conducted under relatively low humidity (55%). The primary factor influencing fatigue strength and failure modes in these joints was the bending stiffness of the sheets. Fatigue life improved significantly by increasing the bending stiffness of either the upper or lower sheet. The ratio of bending stiffness between the upper and lower sheets directly affected the failure mode of SPR joints. In AX41/AX41 similar material joints, cracks initiated near the rivet foot as shown in Fig. 1, and processing cracks near the rivet foot may facilitate rivet rotation, causing bending in the lower sheet and leading to reduced fatigue life. However, AX41/AA6061 dissimilar material joints exhibited longer fatigue life compared to AX41/AX41 similar material joints. The AX41/AX41 joints exhibited shorter fatigue life, likely due to the processing cracks that promoted rivet rotation, which induced bending in the lower sheet.

Additionally, it has been reported that the high humidity environment reduced the fatigue strength of SPR. Thus, the fatigue tests for dissimilar materials (AX41/AA6061) were conducted under high humidity conditions (85%). As shown in Fig. 2, corrosion pitting was observed on the fracture surfaces under high humidity, whereas no corrosion pitting was observed at 55% humidity. However, despite the presence of pitting under high humidity, there was no significant reduction in fatigue strength compared to the relatively low humidity conditions.

In conclusion, the bending stiffness ratio between the upper and lower sheets was the primary factor influencing fatigue strength and failure processes in AX41 similar and dissimilar material SPR joints. While pitting corrosion was observed under high humidity, it did not significantly impact the fatigue strength of AX41/AA6061 joints.

Keywords: Self-Piercing Rivet (SPR); Dissimilar materials; Fatigue strength; High humidity environment; Galvanic corrosion

Fig.1 Schematic illustration of

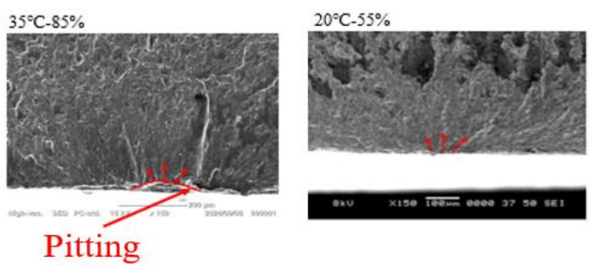


Fig.2 Fracture surface

Praveen Kumara,
IIT Bombay

Analysis of flow and fracture behavior of copper as a function of temperature and strain rate before and after gaseous hydrogen charging

Praveen Kumara*, Bhagwati Prasad Kashyapb

a*Department of Metallurgical Engineering and Materials Science, IIT Bombay, Mumbai, Maharashtra, India
bDepartment of Metallurgical and Materials Engineering, IIT Jodhpur, Jodhpur, Rajasthan, India
*a*22d0984@iitb.ac.in, bbpk@iitj.ac.in*

Abstract

In this research work copper with 3.50 wt. % zinc was used for gaseous charging hydrogen from 9 ppm to 17 ppm in Sievert's apparatus at 800°C with varying pressure from 680 to 830 torr. Hydrogen content has been measured in ppm by hydrogen analyzer system after gaseous hydrogen charging. Mechanical properties such as yield strength, ultimate tensile strength and ductility have been calculated after tensile test. Tensile test samples in hydrogen charged condition were deformed at room temperature and strain rate 10-3 s-1 for each hydrogen contents. Ultimate tensile strength was found to vary from 383 MPa to 361 MPa and ductility from 0.47 to 0.42 for 0 ppm to 17 ppm hydrogen levels. Thus, gaseous hydrogen charging resulted in decrease in strength and ductility at room temperature with an increase in hydrogen content. Ductile to brittle fracture were observed during scanning electron microscopic analysis. It has been also observed that during microstructure analysis of gauge portion of tensile test samples, grain size varies from 117 µm to 84 µm with an increase in hydrogen content.

Keywords: Gaseous Hydrogen charging, Sievert's apparatus, hydrogen contents, room temperature, strain rate, mechanical properties

Katsunari Takeuchi,
Nagaoka University of Technology, Japan

Factors affecting fatigue strength characteristic in friction stir welded aluminum alloy lap joints

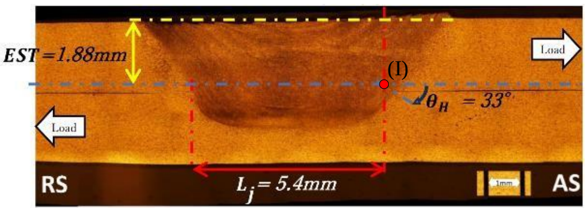
Katsunari Takeuchi[a]*, Yukio Miyashita[a], Nan Zhang[a], Nobushiro Seo[b]
[a]Mechanical Engineering department, Nagaoka University of Technology, Nagaoka, Niigata, Japan
[b]Nikkei Research & Development Center, Shizuoka, Shizuoka, Japan
*s223041@stn.nagaokau. ac.jp

Friction Stir Welding (FSW) is a solid-state joining method that utilizes tool stirring to achieve plastic flow for bonding. The strength properties of the FSW joints are different from those of the base material because the microstructures, defects, and burrs state vary depending on the process conditions. Additionally, the stress state of lap joints is complexly changed by the offset of the load axis. To investigate the major factors influencing the fatigue strength of FSW lap joints, specimens joined under different process conditions were compared.

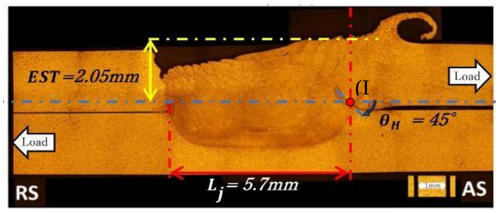
Fatigue tests were conducted under tensile shear load with the load ratio of 0.1 in A6061-T6 FSW lap joints joined with 4 types of tools with different shapes and geometry. Fig.1(a)~(d) shows joints welded with these tools. The results showed that the fatigue life of each specimen was varied, and the specimens were broken near the joint part on the Advancing Side (AS) of the upper plate. Fracture surface observation indicated that the crack initiated on the overlapping surface side of the upper plate as shown in point (I) in Fig.1 and propagated toward the tool entry side. The crack initiation point was attributed to the bending moment which was caused by the offset of the load axis in the lap joint, and the presence of hook-shaped defects on the AS side. The effect of effective plate thickness (EST) which was considered a hook-shaped defect and reduction in thickness by the joint processing, joint width (Lj), angle of hook-shaped defects (θH), and hardness near the fracture on fatigue life was investigated. As

a result, θH had the highest correlation with fatigue life. Since the direction of crack propagation was perpendicular to the loading direction, hook-shaped defects played as starter cracks. Therefore, fatigue strength decreased as the θH became more perpendicular to the load direction.

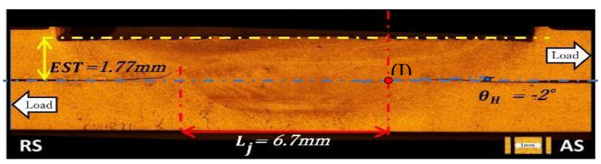
Keywords: Friction Stir Welding; Lap joint; Fatigue strength; Hook-shaped defect; A6061 aluminum alloy;



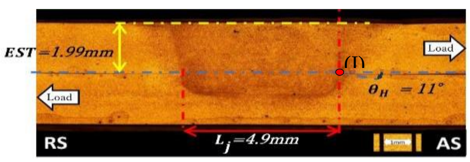
(a) Tool 1



(b) Tool 2



(c) Tool 3



(d) Tool 4

1mm 1mm

Fig.1 Cross section of joint part in joints welded with 4 types of tools with different shapes and geometry

Darshan Dange
Indian Institute of Technology Madras, Chennai

Scratch resistance behaviour of the coir-pith PLA composite for automotive interior applications

Darshan Dange*, Pream Kumar AL, R. Gnanamoorthy
Architected and Sustainable Materials Design Research Centre
Indian Institute of Technology Madras, Chennai, 600036, India
**dangedarshan@gmail.com*

ABSTRACT

Developing the natural fibre reinforce polymer composite materials for the automotive interiors is the demand of the current age for sustainable development. Additionally, the extrusion based additive manufacturing (AM) technique leverages us to develop the complex and intricate parts with desired surface architecture using thermoplastic polymers. To ensure the functionality and aesthetics of the composite surface over its service life in automotive interiors, it needs to be analysed the surface performance and scratch resistance. In the current work, the coir pith particles having the particle size 200-350 µm are blended with the PLA (polylactic acid) in 12.5% and 25% by volume using the twin screw extruder. The coir-pith PLA composite filament of nearly 1.75 mm diameter has been extruded and further used in fused filament fabrication (FFF) based AM technique for the part fabrication. The inbuilt ironing feather is implemented to modified surface texture of AM part. The scratch test has been performed on as-manufactured and ironed textured surface using the inhouse developed scratch test setup for the static loading condition at 30 N and dynamic loading condition ranging from 2-50 N and the displacement speed of 2 mm/sec for 50 mm stroke length. The scratch resistance of all manufactured specimen with different pith-reinforcement % and differently surface texture conditions are compared. The deformed surface is analysed under the optical microscope to analysed the damage characteristics. The ironed surface exhibits enhanced scratch resistance and less coefficient of friction for scratch in comparison to the as-printed specimens.

Keywords: Additive Manufacturing, Coir Fiber, Cor-Pith/PLA Composite, Scratch Test**.**

Ketan Patil
Nagaoka University of Technology , Japan

Rolling Contact Fatigue Mechanism in Additive-Manufactured Maraging Steel

Ketan Patil[a]*, Y.Miyashita[a], N.Zhang[a]

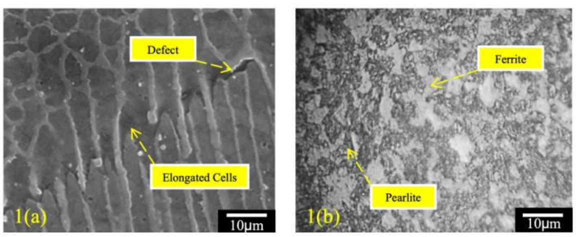
[a] Mechanical Engineering, Nagaoka University of Technology, Nagaoka, Japan

*s235016@stn.nagaokaut.ac.jp

Abstract

Recent advancements in metal 3D printing are expected to produce critical components such as gears, bearings and valves where rolling contact fatigue (RCF) presents significant challenges. Ensuring the reliability and longevity of 3D printed parts requires a deep understanding of RCF behavior. This study investigated the RCF properties and failure modes of materials produced via laser beam powder bed fusion (PBF-LB), focusing on defects and performance under high stress. Maraging steel manufactured through PBF-LB, and S45C produced by conventional rolling process were examined to compare these RCF behaviors. PBF-LB printed maraging steel and rolled S45C steel were tested under severe loading conditions to study the initiation and propagation of fatigue cracks at the surface and subsurface. Testing was performed using a custom-built twin-disc rolling contact fatigue tester for both materials, operating at 1000 r.p.m with a maximum Hertzian pressure of 3.25 GPa. The contact part was lubricated with VG100 oil at 6 drops per minute. The experiment was automatically terminated when vibration reached three times the initial value. Most tests ended due to pit formation on the contacting surface.The microstructure of maraging steel printed via PBF-LB shows equiaxed and elongated grains, while rolled S45C steel has a mix of ferrite and pearlite with refined and elongated grains as shown in Fig.1 (a) and (b). Moreover, the PBF-LB printed maraging steel exhibits defects such as pores, lack of fusion, and unmelted powder as shown in Fig.1(a). The average hardness of the 3D printed maraging steel, measured along the printing direction, was 31.3 HRC, compared to 24.5 HRC for S45C. Damage was detected after 318,000 cycles in 3D-printed maraging steel and 516,000 cycles in rolled S45C, based on the defined failure criteria. The results showed that maraging steel specimens often experience significant pitting and subsurface cracking. The 3D printed maraging steel showed pitting with depths around 100- 200 μm and surface-peeling cracks at 1°-2° angles. When lack of fusion type defects in subsurface were present, cracks were initiated at these points and propagated. Without such defects, surface failures and pitting were more common. Defects tend to coalesce, causing subsurface crack propagation and material removal from the surface as shown in Fig 2(a). Rolled S45C showed delamination, surface cracking, and pitting (330–400 μm deep), as shown in Fig. 2(b). Despite its higher hardness, PBF-LB printed maraging steel had more wear and deformation, indicating lower wear resistance, with defects dominating its fatigue performance and reducing durability.

Keywords: Additive Manufacturing ; Rolling Contact Fatigue; Laser beam powder bed fusion ; Maraging Steel.



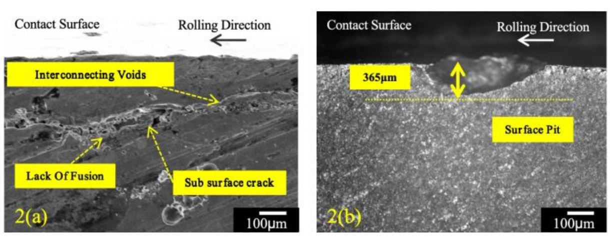


Fig. 1 Observations of microstructure in (a) maraging steel produced by PBF-LB and (b) Rolled S45C

Fig. 2 Cross section observations of damages introduced by rolling fatigue in (a) maraging steel produced by PBF-LB and (b) rolled S45C steel.

Sumanta Prasad Dewri
Indian Institute of Technology Madras

Sliding Friction of Coir Fiber in Dry and Wet Conditions

Sumanta Prasad Dewri*, R Gnanamoorthy
Architected and Sustainable Materials Design Research Centre,
Department of Mechanical Engineering,
Indian Institute of Technology Madras, Chennai 600036, India
**me21d405@smail.iitm.ac.in*

ABSTRACT
Developing sustainable technical textiles is important for achieving the United Nations Sustainable Development Goals. Natural fibres produced from agricultural waste are considered to produce sustainable technical textiles and contribute to environmental conservation and a circular economy. Unlike synthetic fibers, natural fibers are biodegradable and less toxic to the environment. Both during processing and during service, the fibers in textiles contact and experience relative motion with other parts. The relative motion between the fibers and other bodies generates friction, which plays a crucial role in the performance of textiles. Natural fibers are hygroscopic and absorb moisture from the surrounding environment which affects their properties including frictional properties. The natural fiber extracted from coconut husks, known as coir, is considered for this investigation. This study is focused towards understanding the friction behavior of single coir fiber against a cylindrical polymer body in dry and wet conditions. Both untreated and alkali-treated coir fibers, in dry and water-soaked states, are slide against a polyamide cylinder in an in-house developed capstan-based tribometer. The results show that water-soaked coir fibers have a higher friction coefficient compared to dry fibers. The water absorption of the fibers contributes to the increase in real contact area between the fiber and counter body which increases the friction. Alkali treatment increased the water absorption capacity of coir fibers and hence alkali-treated coir fibers exhibit a higher friction coefficient in wet conditions.

Keywords: *natural fibers; coir; water absorption, alkali treatment, fiber friction; mechanism;*

Chandramouli T V
N.I.T.K, Surathkal

Tribological Performance of Fe-Based Composite Coatings under Elevated Temperature Conditions

Chandramouli T V a*, Sharnappa Joladarashi a, Ramesh M Ra

aDepartment of Mechanical Engineering, National Institute of Technology Karnataka, Surathkal, Mangaluru – 575025, India.

Abstract

The present study investigated the tribological performance of Fe-based coatings reinforced with carbides onto a maraging steel substrate using the HVOF spray technique. These materials are widely used in the manufacturing of various components in the aerospace and energy sectors. Commercially available SS316L and 17-4PH are reinforced with WC-Co feedstock powders to deposit these composite coatings on maraging steel substrate. The dry sliding wear tests were conducted using the ball-on-disc tribometer at varying temperatures (25 and 300 °C) with 10N normal load using an alumina ball (Al2O3) as the counter body. The study includes micro-hardness, porosity, density, bond strength, and surface roughness of the coatings. The samples subjected to wear testing are analyzed using SEM/EDS and XRD techniques, and the wear scar volume was measured using a 3D profilometer to calculate the volume metric loss. The wear rate of SS316L30%WC-Co is 64.46% lower than that of 17-4PH30%WC-Co at room temperature and 67.33% lower at 300 °C under a load of 10 N. At room temperature, the worn surface exhibited abrasive wear, while at 300 °C, adhesive wear and oxidative wear were observed owing to the formation of protective layers. Therefore, SS316L-30%WC-Co demonstrates superior wear resistance compared to 17-4PH-30%WC-Co and offers enhanced mechanical strength, particularly in challenging environments. The deposition of these coatings effectively protects the maraging steel substrate.

Keywords: HVOF; Iron-based coatings; carbides; Tribology.

Rattana Borrisutthekul
Suranaree University of Technology

Dissimilar welding of Low-Carbon Steel and Magnesium Alloy

Rattana Borrisutthekul*[a], Pusit Mitsomwang [a] , Usanee Kitkamthorn [a], Chutimon Makee [a]

[a]Institute of Engineering, Suranaree University of Technology, Muang, Nakhon-Ratchasima, Thailand.

rattana@g.sut.ac.th

According to the differences in physical properties and the poor metallurgical compatibility of steels and magnesium alloys, the integrity of the steel/magnesium alloy dissimilar metal weld is highly difficult to obtain. In this research work, the application of an aluminum (Al) interlayer to promote the steel/magnesium alloy welding was investigated. Results showed that the application of the Al interlayer can extend the welding process window, increase of the welding layer area and the failure load resistance of the dissimilar metal joint. Therefore, aluminum alloy is an excellent material used as the interlayer material for promoting steel/magnesium alloy welding.

***Keyword*: Magnesium alloy, Dissimilar metal joining, TIG welding, Brazing, Interlayer

Yoshiki Watanabe
Osaka Institute of Technology

Effects of Al Welds Characteristics on Joint Strength in Cu/Al Dissimilar Materials Resistance Spot Welding

Yoshiki Watanabe[a]*, Muneyoshi Iyota[b]

[a]Major in Electrical, Electronic and Mechanical Engineering, Graduate school of Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan

[b]Faculty of Mechanical Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan

*m1m23453@oit.ac.jp

Recently, the use of aluminum (Al) in electrical components such as wire harnesses and bus bars has been increasing to reduce the weight of automobiles, and demand for dissimilar materials joining such as copper (Cu) and Al has been increasing. Resistance spot welding (RSW) is being considered as one of the joining methods. In joining Fe using RSW, it is known that the larger the nugget diameter formed at the joining interface, the higher the joint strength. In the joining of Fe/Al dissimilar materials, it is known that an intermetallic compound (IMC) is formed at the joining interface and that joining is achieved through this IMC, and that the thickness and composition of the IMC affect joint strength. In contrast, the mechanism of joining formation and the joint strength of Cu/Al joining have not been investigated in many cases, and the dominant factors in joint strength are not clear.

In this study, the mechanism of joining formation of Cu/Al dissimilar materials RSW was investigated and the relationship with joint strength was clarified. First, the mechanism of joining formation was investigated from the viewpoint of heat generation patterns by using experiments and numerical simulations. As a result, it was found that the heat generated by the contact resistance between the cathode electrode and Cu in the initial stage of current time is transferred to the joining interface, resulting in the formation of Al welds. It was also found that the joining was achieved by the formation of IMC due to the diffusion of Cu in the Al welds. Subsequently, it was found that the diameter of the Al welds and the formation area of IMC expanded as the contact area between the electrode and Cu increased with an increase in the current time. In addition, the composition within the Al welds was found to change as the amount of Cu diffusion within the Al welds increased.

Furthermore, in order to clarify the effects of the diameter of the Al welds and the composition within the Al welds on the joint strength, tensile tests were conducted under the conditions of varying the current time. The results showed that the increase in the diameter of the Al welds and the change in composition within the Al welds due to the increase in the current time affected the joint strength by changing the crack propagation behavior within the Al welds.

Keywords: Resistance spot welding; Dissimilar materials joining; Mechanism of joining formation; Joint strength; Copper; Aluminum

Ramesh Babu Arigela
BHEL, Tiruchirappalli

Feasibility study of Activated GTAW in STBW machine for welding of SA210-Gr.C tubes

Ramesh Babu Arigela[a]*, Dr. S Jerome[b], Dilip Kumar Singh[c], Dr. N Durairaaj[d].

[a]NDTL & MME Dept., BHEL & NITT, Tiruchirappalli, Tamilnadu, India

[b]MME Department, National Institute of Technology, Tiruchirappalli, Tamilnadu, India

[c]NDTL, BHEL, Tiruchirappalli, Tamilnadu, India

[d]Quality, BHEL, Tiruchirappalli, Tamilnadu, India

*rameshbabuarigela@bhel.in

Abstract

In the fabrication of sub-critical to Advanced Ultra Super Critical boilers, riser tubes and heat exchanger coils are made from seamless steel tubes of low-carbon steel to high-strength alloys. The thickness of the tubes varies from 4 mm to 12.7 mm, and they are obtained in standard sizes from tube manufacturers. In order to meet the design requirements of components, cutting and tube-to-tube butt welding are necessary. This involves machining the tube edges to the required bevel angle using automated machines. The welding process involves Gas Tungsten Metal Arc Welding (GTAW) and Shielded Metal Arc Welding (SMAW), which can be done manually or using automatic and semi-automatic machines. The Straight-Tube-Butt-Welding (STBW) machine is a semi-automatic, DCEP machine equipped with MIG and TIG weld heads. During the welding process, the tubes are held in a rotating chuck mechanism against a stationary weld head.

The purpose of this study is to replace the traditional GTAW method in STBW machine with "Activated-GTAW" method. This technique enhances the depth of penetration by adding specific oxides and salts to the weld, which creates a positive surface tension to temperature gradient in the weld pool, known as the reverse Marangoni effect. This effect along with the Lorentz forces, dominates the effects caused by buoyancy force and shear stress from the arc plasma. As a result, the fluid flow is reversed from the fusion boundary to the weld centre line, leading to reduced weld bead width and increased depth of penetration.

In this study, Titanium Dioxide (TiO_2) was used as an activated flux to weld SA210-GrC low carbon steel tubes with a 44.45mm outer diameter and 6.2mm weld thickness using an STBW machine with a TIG head. The welding process was carried out with square edges and no filler material was used. A successful weld joint with complete root penetration was achieved in a single pass. Microstructure study reveals coarse grains of pearlite and Widsmantattein network of ferrite observed in weld zone and mixture of fine and coarse grains of bainite observed in HAZ zone.

Keywords: Activated-GTAW; SA210-Gr-C; STBW; Titanium dioxide; Tube-to-tube butt-welding;

Arata Ishikawa
Osaka Institute of Technology

Effects of External Magnetic Field on Nugget Formation and Electrode Wear of Resistance Spot Welding for Aluminum Alloy

Arata Ishikawa[a]*, Muneyoshi Iyota[b]
[a]Major in Electrical, Electronic and Mechanical Engineering, Graduate school of Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan
[b]Faculty of Mechanical Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan
*m1m24401@oit.ac.jp

In resistance spot welding of aluminum alloys, it is known that the surface condition of the electrode deteriorates , which calls “electrode wear” due to an increase in the number of welding points, resulting in unstable contact conditions and the inability to form stable nuggets. Therefore, there is a need to suppress electrode wear during consecutive spot welding. One of the causes of electrode wear is the occurrence of pitting. It is known that pitting is formed when an Al/Cu alloy layer is generated on the electrode surface due to the increase in temperature between the aluminum alloy sheet and electrode during welding, and then the Al/Cu alloy layer is detached. In other words, a decrease in the temperature between the aluminum alloy sheet and electrode is expected to be effective in suppressing pitting. On the other hand, in previous studies on resistance spot welding of Fe/Al dissimilar materials, it has been shown that the temperature field inside the joint can be controlled by changing the convection behavior in the aluminum alloy melt by applying an external magnetic field. It has been confirmed that the state of nugget formation and electrode wear change when an external magnetic field is applied to generate circumferential convection in the melt zone in a continuous welding test using aluminum alloy resistance spot welding. However, the effects of changes in magnetic field conditions, such as magnet arrangement and distance between magnets, on nugget formation and electrode wear have not been fully investigated. In this study, changes in nugget formation state and electrode wear were investigated by consecutive spot welding of aluminum alloys under different magnetic field conditions. As a result, it was found that as the distance between the magnets was increased, the nugget became thinner, and the change in electrode wear became smaller. This is because a change in the temperature distribution inside the joint caused by a change in the convection behavior in the melt zone due to the distance between the magnets. When the magnet arrangement was changed to one that generates convection in one direction in the melt zone, the nugget became thinner, and the change in electrode wear was smaller. This is because a change in the temperature distribution inside the joint caused by a change in the convection behavior in the melt zone due to the magnet arrangement.

Keywords: Aluminum alloy; Consecutive spot welding; Electrode pitting; External magnetic field; Nugget; Resistance spot welding

Nitin Kumar
Indian Institute of Technology Madras, India

Influence of pre-weld solution treatment on HAZ liquation in additively manufactured Inconel 718

Nitin Kumar [a]*, S.G.K. Manikandan [b], M. Kamaraj [a]
[a]MME, Indian Institute of Technology Madras, India
[b] Indian Space Research Organization, India
*mm20d024@smail.iitm.ac.in

Electron beam welding generates precise welds with narrow heat-affected zones (HAZ). In this study, the effect of 1180°C and 1065°C pre-weld solution treatment on additively manufactured plates, along with the influence of alloy chemistry on HAZ liquation cracking, is investigated. Laser Powder bed fusion (LPBF) of Inconel 718 generates complex microstructure with Laves phase and inter-dendritic segregation. The pre-weld solution treatment at 1180 °C/1h efficiently dissolves the Laves phase and reduces niobium segregation along with recrystallization and grain growth. The pre-weld solution treatment at 1065°C/1h is not sufficient for recrystallization, leaving columnar grains with incomplete dissolution of Laves phase, leaving 0.92±0.02% by volume.

Microstructure obtained after electron beam welding in HAZ shows the appearance of grain boundary wetting by liquid-like film surrounding liquating particle for 1180 °C/1h pre-weld case having coarse grain (ASTM grain size 3) with less grain boundary area receiving increased solute and impurity segregation due to formation of grain boundary diffusion pipeline from fusion zone to HAZ. For the HAZ region in the 1065°C/1h case, few liquating particles are present at discreate locations without any diffusion from fusion zone to HAZ region. The presence of trace elements (S, P, and B) at the grain boundary and their role in lowering the melting temperature of grain boundaries is also examined.

Keywords: Electron Beam Welding (EBW); Heat Affected Zone (HAZ); Laser Powder Bed Fusion (LPBF); Liquation

Arvind Kumar,
Indian Institute of Technology Jammu

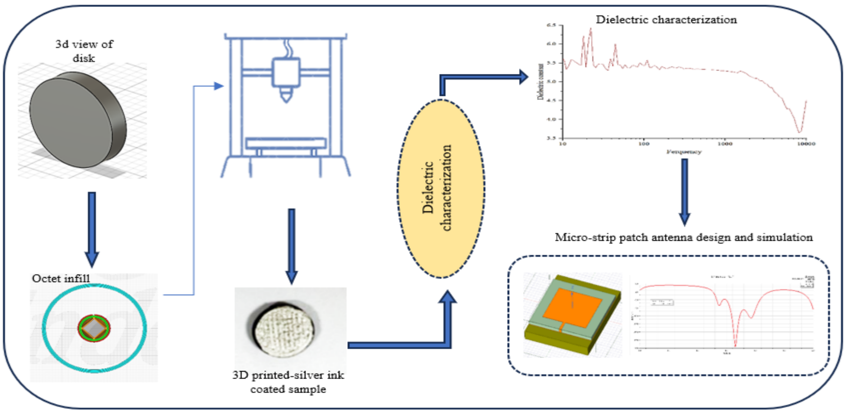
Innovative Additive Manufactured Pressure Sensors: Design and Simulation for IoT Health Applications

Arvind Kumar[a], Anand kumar S[a*], Rajkumar V[a], Rahul Gorka[b]

[a]Additive Manufacturing Research Laboratory, Department of Mechanical Engineering, Indian Institute of Technology Jammu, Jammu, India

[a]Department of Burn and plastic surgery, AIIMS, Vijapur, Jammu, India
*anand.subramaniyan@iitjammu.ac.in

In recent years, significant progress has been made in additive manufacturing (AM) of pressure sensor-based microstrip patch antennas (MPAs); however, limited research exists on their application as an Internet of Things (IoT) solution for online health monitoring. This study explores the additive manufacturing of MPA-based pressure sensors as an innovative approach, leveraging AM technology to fabricate the sensors. Before the design and simulation, dielectric characterization of the additively manufactured PLA material was performed. As a result of this characterization, a dielectric constant of 5.9 and a loss tangent of 0.12 were observed. The MPA-based pressure sensor was designed and simulated using HFSS Ansys Student version software based on these values. The sensor's substrate was fabricated using a fused deposition modeling (FDM) printer. A vector network analyzer (VNA) was subsequently used to assess the pressure sensor's radiofrequency (Rf) performance and S11 parameters. The results indicate that the proposed solution achieves an acceptable specific absorption rate (SAR) of 1.470 W/kg. Moreover, the resonance frequency was recorded at 3.650 GHz with an insertion loss (S11) of -19.6817 dB during simulation. This study demonstrates the feasibility of utilizing AM to develop pressure sensors for IoT-based health monitoring systems.



Keywords: Micro-strip patch antenna based Pressure sensor, Additive manufacturing, Dielectric characterization, Specific absorption rate, IoT-Based health monitoring

Shinobu Narita
Shizuoka University

Evaluation of effect of forming condition on strength of formed part by Powder Bed Fusion type additive manufacturing

Shinobu Narita[a], Toshiaki Uematsu[b], Hirofumi Oosawa[b] and Kunio Hayakawa[a]*

[a] Department of Mechanical Engineering, Shizuoka University, Hamamatsu, Shizuoka, Japan

[b] Industrial research institute of Shizuoka prefecture, Hamamatsu, Shizuoka, Japan

**hayakawa.kunio@shizuoka.ac.jp*

Abstract

It is well known that in the metal powder bed fusion (PBF) type additive manufacturing (AM) process, the geometry of formed part depends on the forming condition, i.e., arrangement, inclination angle, use of supports, and so on. Furthermor e, the strength is also affected by forming condition. It is worthwhile to prediction of the strength of AMed part by numerical simulation, ex. for the design of structures where the AMed parts are used. In this study, FEM simulation was carried out for the sequential process from AM process to tensile test, to predict the strength of parts with same geometry but different forming condition as shown in Figure 1. Three round bar tensile test specimens of aluminum alloy AlSi10Mg with different inclination angle to the base plate, where the angle between longitudinal axis and the baseplate were 0°, 45° and 90°, were formed by PBF type AM process. The subsequent tensile tests by AMed specimens revealed that the tensile strength varied depending on inclination angle; the 90º specimen had higher strength than other specimens. In the simulation of the tensile test of AMed specimens taking the history of the preceding AM process into account, the difference in tensile strength due to the inclination angle did not predict with von Mises type isotropic yield function. On the other hand, the difference in the tensile strength of the specimens with different inclination angle successfully predicted using the anisotropic yield function model, by assuming that the difference in tensile strength results from anisotropic nature induced during fabrication.

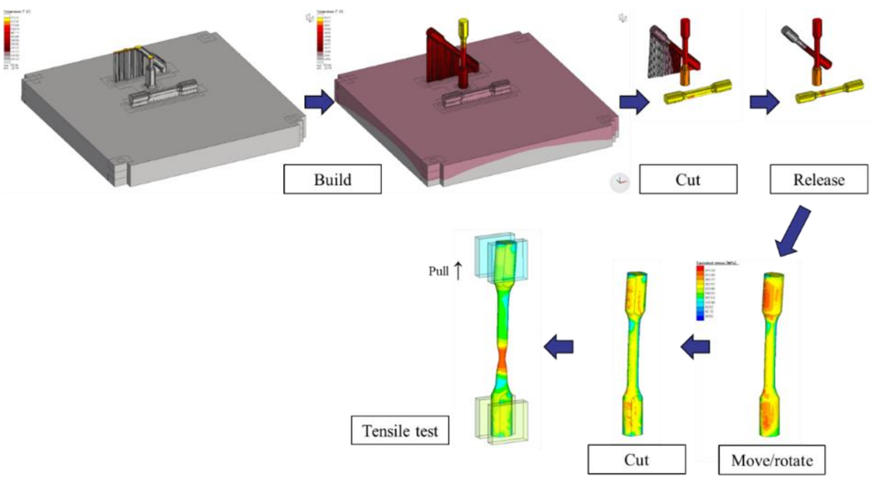


Figure 1 Numerical simulation process of tensile test of additive manufactured specimens with different inclination angles.

Keywords: additive manufacturing; aluminum; tensile strength; FEM simulation; anisotropic

Avinash Mohan
IIT Madras

Microstructural Characteristics of additively manufactured ALF357 alloy: Effect of Tensile Loading and Build Orientations

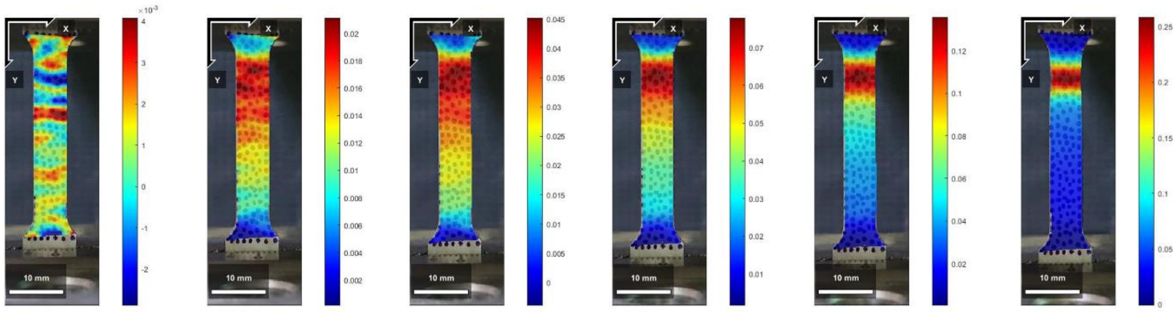
Avinash Mohan[a]*, Jayaganthan Rengaswamy[a]

[a] Department of Engineering Design, Additive Manufacturing Group, & Center of Excellence for Materials and Manufacturing for Futuristic Mobility, Indian Institute of Technology Madras, Chennai, 600036, Tamil Nadu, India

*[*ed21d002@smail.iitm.ac.in*](mailto:ed21d002@smail.iitm.ac.in)*

Aluminium alloys have high specific stiffness, specific strength, corrosion resistance, and machinability, making them highly desirable for lightweight applications in the automotive and aerospace industries. Additive manufacturing (AM) has recently expanded the potential for using aluminium alloys in safety-critical applications. However, AM introduces uncertainties that may impact mechanical properties, especially fracture behaviour. In this study, AlF357 was fabricated using Laser Beam Powder Bed Fusion (LPBF) in vertical and horizontal printing directions to assess their quasi-static and fracture responses. Digital Image Correlation (DIC) is employed to estimate fracture parameters directly by measuring in-plane surface displacements near cracks. The fracture behaviour was further characterized using optical and scanning electron microscopy. It is observed that the ALF357 exhibits superior tensile properties as compared to AlSi10Mg.

Keywords: DIC; ALF357; Microstructure; LPBF



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Chithambaram Karunanithi
Indian Institute of Technology Madras

Scratch resistance of polylactic acid (PLA) based biodegradable polymer reinforced with pineapple leaf fiber

Chithambaram Karunanithi*, Ali Akbar, Pream Kumar AL, Gnanamoorthy R
Architected and Sustainable Materials Research Centre
Department of Mechanical Engineering
Indian Institute of Technology Madras, Chennai, India
**chithambaram97@gmail.com*

ABSTRACT

Sustainable composite materials from agricultural waste are considered as the next-generation materials in the move towards creating a sustainable world. In many applications, the surface of parts experiences frequent interaction with various countertops and the durability of the surface is important. Scratch testing of polymers assesses the material's resistance to scratches, a critical factor for applications requiring surface durability. In this project, the resistance to scratch of the bio composites is assessed using standard test procedure. Injection molded PLA polymers with reinforcement of pine apple leaf natural fiber with and without 5% NaOH solution treatment are considered in this project. Samples were produced using 80 wt.% PLA biodegradable polymer and 20 wt.% natural PALF fibers, using injection molding. Three samples of each form were subjected to scratch testing over a stroke length of 100 mm with static load of 30 N, and velocity of 100 mm/min. Scratch friction coefficient and scratch damage were assessed to assess the failure mechanism. Optical microscopy showed a different failure indicator like fiber removal, breakage and mild abrasion on the scratch path. The preliminary studies indicated the improved scratch resistance due to addition of natural fibers into PLA matrix. The addition of pineapple leaf fiber enhances the mechanical properties of the composite, and the NaOH treatment improves the bonding between the fibers and the PLA matrix, resulting in a tougher and more scratch-resistant material. The result of the study indicates that the scratch resistance of biodegradable polymer reinforced with the pineapple leaf natural fiber helps in protecting against mechanical damages, especially against scratches.

Keywords: *Sustainable Composites, Pineapple leaf fiber; Polylactic acid; Injection Molding, Scratch resistance*

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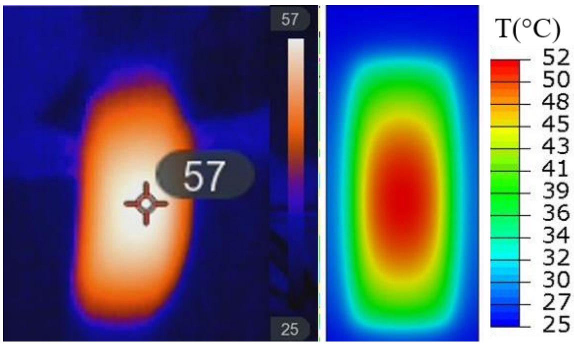
Neeraj C S,
IIT MADRAS

Dual Dye Based Light And Thermal Responsive Liquid Crystal Polymer Films

Neeraj C S[a], Akhil Reddy Peeketi[a], Divya Jayoti[a], Ratna Kumar Annabattula[a]*
[a] Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai, Tamil Nadu - 600036, India
ratna@iitm.ac.in

Liquid crystal polymers (LCPs) are highly opted for stimuli-responsive material owing amalgamation of properties arising from liquid crystals (LCs) as well as polymers. The thermotropic liquid crystals have temperature-dependent phases and undergo phase transition when subjected to temperature change. These polymers are prepared by photopolymerization of monomers (reactive mesogens) having liquid crystal properties. The director is the average direction of the long axis of rod-like molecules (mesogens). The director orientation of LC molecules is locked by polymerizing it and when subjected to thermal stimuli, they undergo phase transition. This produces contraction parallel to the director and expansion perpendicular to it which produces a through-thickness strain gradient. To make them responsive to light stimuli photo-responsive dyes are added. Azo-dyes are commonly used due to their easy integration with polymer networks. In this work, we will be discussing the influence of multiple azo dyes in the same polymer network. The azo-chromophores used are A3MA (λmax = 365 nm) and DR1A (λmax = 483 nm) where the wavelength corresponding to peak absorbance is shown in brackets. Densely crosslinked liquid crystal networks (LCNs) thin films with twisted nematic alignment and thickness of 23 µm is prepared. The absorbance spectra of dual-dye thin films showed multiple wavelength peaks corresponding to the individual dye contributions. The glass transition was observed nearly equal to 49 °C. The photo-response is determined under illumination with LED lights of wavelengths 365, 455 and 395 nm. The isomerization parameters for the films were determined from experimental data. These were used as input to combined photo-chemo and photo-thermo-mechanical model. The computational model is implemented through finite element



simulations and demonstratesgood quantitative agreement with experimental observations.

Figure 1: The temperature profile on the illuminated area of the thin film obtained from the IR camerais shown on the left and the right image shows the same from the simulation. The experimental profile has maximum temperature at centre of illumination spot followed by reducing values towards edges. Asimilar profile is obtained in simulation by distributing the light intensity in a Gaussian distribution.

Keywords: liquid crystal polymers; stimuli-responsive materials; soft robotics

Tejasva Vashistha
Indian Institute of Technology Gandhinagar

Unveiling Structure-Property Links in SiO2-Cr-Au Thin Films via Molecular Dynamics

Tejasva Vashistha*,Raghavan Ranganathan
[a]Materials Engineering, Indian Institute of Technology Gandhinagar, Gandhinagar, Gujarat, India
*tejasva.vashistha@iitgn.ac.in

Ultra-thin layers of material, called thin films, are deposited onto a substrate and typically have a thickness of a few nanometres to several micrometres. They are essential to many technical applications, such as coatings, sensors, semiconductors, and optics. Thin films are important because they can change surface characteristics like electrical conductivity, optical transparency, and chemical reactivity. This makes it possible to create new materials and devices with specific functions. Since the microstructure of thin films is shaped by the processing circumstances, it is imperative to comprehend the relationship between processing, structure, and attributes of thin films. Different microstructures, such as grain size, crystallinity, and defect density, can result from variations in deposition methods, temperature, pressure, and other factors. These variations can then have an impact on the mechanical, electrical, and physical properties of the film. Understanding this relationship will enable scientists and engineers to accurately manipulate thin-film properties to maximise performance for particular applications, resulting in advancements in material science and technology. The purpose of this work is to investigate the connection between thin film processing parameters, microstructural features, and final physical attributes using molecular dynamics simulations. Molecular Dynamics is used to deposit thin film of Cr and Au on Silica mimicking the sputtering phenomenon over a range of deposition energies, followed by characterisation of thin films using RDF and stress analysis within thin films. Following this, the study discusses mechanical and thermal properties of thin films namely tension, compression, hardness, coefficient of thermal expansion.

Keywords: Molecular Dynamics; Processing-Structure-Property Correlation; Thin films

S. Manova Raja Singh
Hiroshima University, Japan

Controlling the wettability behavior of Zn alloy on SUS310S steel by application of ultrasound

Selvaraj Manova Raja Singha, Yong bum Choi a*, Takuya Koshibaa, Katsuya Hoshinob, Mai Miayatab, Yusuke Okumurab

aGraduate School of Advanced Science and Engineering, Hiroshima University, Higashi-Hiroshima, Hiroshima, Japan

bSteel Research Lab, JFE Steel Corporation, Fukuyama, Hiroshima, Japan

ybchoi@hiroshima-u.ac.jp

Abstract

The effect of ultrasound vibration on influencing molten Zn-Al alloy spreading rate and wettability properties on the silicon content of steel substrates was investigated. In general, hot-dip galvanizing the oxidized surface of annealed steel generates non-wetting behavior between the solid and liquid contact, which may cause bare spots and reduce the anti-corrosion properties. However, many steel industries are focusing on improving the wettability of molten Zn alloys through forced wetting. The main goal with this study is to figure out how the cavitation effect of ultrasound vibration forces affects the wetting process between SUS310S and a droplet of molten Zn-Al alloy. This research primarily aims to explore the initial mechanism of ultrasound vibration that directly impacts the steel plate. The amplitude wave propagates horizontally, following the displacement of a molten Zn alloy droplet on the steel surface. The second mechanism directly applies ultrasound vibration to the molten Zn alloy droplet. The amplitude wave is proportional to the molten Zn alloy droplet's displacement on the steel surface. The molten droplet's shape and direction of oscillation (horizontal or vertical) are important parts of manipulating the interface region. The contact angle hysteresis method (CAH) showed that the ultrasound vibration made the metal-to-metal contact more wettable and sped up the spreading rate. The investigation revealed that the ultrasound vibration created a hysteresis effect, leading to a reduction in the advancing and receding contact line of the molten Zn alloy on the steel plate. Subsequently, these hysteresis effects simulated the Al concentration to increase the flowing fluidity of Zn melts close to the interface. It significantly improved the Fe-Zn alloy reaction layer at the Al-Fe interface.

Keywords: High-strength steel; Ultrasound (US); Wettability; Contact angle hysteresis effect (CAH); Cavitation effect

Pream Kumar AL
Indian Institute of Technology Madras

Coir Yarn Friction in Technical Textiles – A New Methodology for Assessment

[a]**Pream Kumar AL,** [a]**Samiksha Moharana,** [a]**R Gnanamoorthy,** [b]**Gurunathan C**

[a]Architected and Sustainable Materials Design Research Centre
Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai 600036
[b] Department of Mechanical Engineering, IIITDM Kancheepuram, Chennai
Corresponding email id: me23s033@smail.iitm.ac.in

Abstract

The use of technical textiles in erosion control measures to protect the environment has increased significantly**.** Preventing soil erosion due to our activities and or climate changes will contribute to better life-on-land and zero hunger while marine erosion control will assist in preserving the coastal ecosystem. Large quantities of synthetic polymers are used for making different types of technical textiles due to their longevity. However, the gradual degradation and pollution of the environment is a concern and textiles made of biodegradable material are preferred. One of the causes of the failure of the technical textiles used in environmental protection is due to the damage caused by the interacting yarns. The low amplitude sliding between contacting yarns degrades the yarns gradually. A new methodology is proposed to study the friction and wear characteristics of interacting yarns. An in-house developed micro motion test rig which can replicate real life load and contact conditions is modified for yarn-yarn interaction assessment. Preliminary studies are carried out using coir yarns, widely preferred as a sustainable alternative to synthetic yarns. Two-ply coir yarn interacting with each other mimicking the geotextile local contact is considered. Tests are conducted at different normal loads and relative displacements and its effect on coefficient of friction are reported. Friction assessment between the interacting yarn will assist in development of surface modification techniques for yarn materials for improved life.

Keywords: Technical textiles; erosion control, yarn-yarn interaction; coir, coefficient of friction

Yuya Omiya
Kagawa University

Contact Behavior of Friction Joint Using Wedge Structure

Yuya Omiya[a]*, Tatsuto Kuzuma[b], Tadashi Shiota[c], Masahiro Fujii[c]

[a] Faculty of Engineering and Design, Kagawa University, Takamatsu, Kagawa, Japan

[b] Showapulley, Ibara Okayama, Japan

[c] Graduate School of Natural Science and Technology, Okayama University, Okayama, Japan

*omiya.yuya@kagawa-u.ac.jp

There is a joining method that utilizes frictional forces to connect components, such as in the joints of buildings. In the mechanical field, wedge structures are also used for joining. This study specifically focuses on friction joints used to connect shafts and pulleys. Such friction joints do not require complex machining compared to traditional methods using keys or splines, making alignment easier and allowing for simplification of machinery. Therefore, this friction joint is expected to be widely used in the future. However, the contact stress state, torque transmission, and slip behavior of these friction joints have not been thoroughly examined, resulting in a lack of rational design guidelines. Consequently, it remains unclear whether the performance of components, such as the maximum and allowable values of transmitted torque, are being adequately realized, leading to significant challenges regarding weight reduction. Therefore, in this research, we investigated the contact stress state at the joint surface between the shaft and pulley, the changes in contact stress state under torque loading, and the occurrence of slip at the joint surface using finite element analysis. Additionally, the influence of variations in the dimensions of the wedge on the transmitted torque was examined. The results revealed that high contact stress occurs at the tip of the wedge in the joint surface between the shaft and pulley. It was also found that with torque loading, there is a slight slip at the joint surface, which causes a change in the distribution of contact stress. It was found that changing the dimensions of the wedge structure affects the transmitted torque.

Keywords: contact stress; finite element analysis; friction joint; optical design.

Taisho Fukui
Nagoya University

High-Throughput Measurement of Transition Temperatures of Thermoresponsive Polymers

Taisho Fukuia*, Junpei Sakuraia, Seiichi Hataa, Chiemi Okaa
aDepartment of Micro-Nano Mechanical Science and Engineering, Nagoya University, Nagoya, Aichi, Japan
*[*fukui.taisho.j2@s.mail.nagoya-u.ac.jp*](mailto:fukui.taisho.j2@s.mail.nagoya-u.ac.jp)*

Abstract

Thermoresponsive polymers are materials that possess a transition between a water-soluble (hydrophilic) state and a water-insoluble (hydrophobic) state around their transition temperatures. The transition property is useful in various applications, including drug delivery, sensors, and actuators. To meet specific application requirements, transition temperatures need to be finely tuned, often necessitating repeated preparation and evaluation of polymer materials. However, conventional methods for measurement of transition temperatures, such as ultraviolet-visible (UV-Vis) spectroscopy and differential scanning calorimetry (DSC), are time-consuming because of one-by-one measurements. Therefore, we propose a high-throughput method, which evaluates the transition temperatures of multiple samples at once, utilizing color change of thermoresponsive polymers around transition temperatures and video analysis. The purpose of this study is to manufacture an apparatus evaluating multiple thermoresponsive polymer solutions in a 96-well plate simultaneously. The apparatus mainly consists of a heater, an aluminum block, a 96-well plate, thermocouples, a camera, and a thermography camera. Poly(N-isopropylacrylamide (NIPA)-co-acrylamide (AAm)), which is a thermoresponsive polymer having lower critical solution temperature (LCST), was selected and the polymer aqueous solutions were prepared in various monomer compositions. P(NIPA-co-AAm) solutions change from colorless and transparent (corresponding to a hydrophilic state) to white and turbid (corresponding to a hydrophobic state) around their transition temperatures with temperature rising. Since the transition temperatures can be measured from the color change, we manufactured an apparatus heating P(NIPA-co-AAm) solutions in a 96-well plate and monitoring their colors. In addition, we created a video analysis program to detect the color change. By detecting the time of the color change and referring to the temperature measured by thermocouples at the time, the transition temperatures can be determined. To evaluate the validity of the system, we first identified a region in the 96-well plate that heated uniformly, as achieving uniform heating across the entire plate was challenging. Then, the simultaneous measurement in the region was conducted using P(NIPA-co-AAm) solutions, whose transition temperatures, or LCST, were from about 32°C to above 60°C. The polymer solutions in each well became turbid with the temperature increase, starting with the polymer solutions that have a low transition temperature. Furthermore, their transition temperature could be determined via video analysis. The determined temperatures were almost the same as the temperatures measured by DSC. Therefore, though the expansion of a uniform heating area is required, our developed system is applicable to the high-throughput measurement of transition temperatures of thermoresponsive polymer solutions.

Keywords: Lower critical solution temperature; Thermoresponsive polymers; Transition temperature; Video analysis

Pramod Kumar Parida
IIT Bhubaneswar

Influence of fumed silica nanofiller and stacking sequence on solid particle erosion response of bidirectional jute-kevlar hybrid composites

Pramod Kumar Parida, Mihir Kumar Pandit, Arun Kumar Pradhan
School of Mechanical Sciences, Indian Institute of Technology Bhubaneswar, Jatani, Odisha, India
**pkp13@iitbbs.ac.in*

Abstract
This study investigates the impact of nanofiller content and stacking sequence on the erosion wear properties of Jute (J) –Kevlar (K) fabrics hybrid composites, using scanning electron microscopy. The research focuses on four-layer fabric composites with stacking sequences JJJJ (Jute-Jute-Jute-Jute), JKKJ (Jute-Kevlar-Kevlar-Jute), and KJJK (Kevlar-Jute-Jute-Kevlar), each containing varying nanofiller weight fractions (0%, 1.5%, 3%, and 4.5%), alongside a KKKK (Kevlar-Kevlar-Kevlar-Kevlar) fiber-reinforced composite without nanofiller (KKKK-0) fabricated as a reference for comparison. The effect of the cumulative weight of impinging Al_2O_3 erodent particles ranging from 5–30 g on these composites is examined at different impingement angles (30°, 45°, 60°, and 90°) with a constant particle velocity of 62 m/s. The findings reveal that at lower impingement angles, the erosion rate shows a sharp decreasing trend and then it is decreasing with a much slower rate as the cumulative weight of impinging particles increases, while at a higher impingement angle (90°), an opposite trend is observed.
Keywords: Erosion wear; Fumed silica; Hybrid composite; Jute; Kevlar; Nanofiller; Scanning electron microscopy

Kazuhito Asai,
National Institute of Technology, Toyota College

Forming of Plate with Pin by Plane Strain Compression

Kazuhito Asai[a]*, Kazuhiko Kitamura[b]

[a] Department of Mechanical Engineering, National Institute of Technology, Toyota College, 2-1 Eisei-cho, Toyota, Aichi, 471-8525, Japan

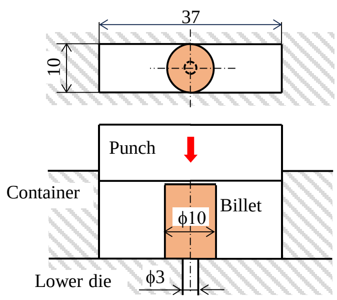
[b] Department of Electrical and Mechanical Engineering, Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya, Aichi, 466-8555, Japan

* kazuhito@toyota-ct.ac.jp

Lightweight in an automobile has been required with growing electric automobile industry. Light metal including aluminum alloy and magnesium alloy, carbon composite material, and plastic, etc. are used for the alternate material of the automobile parts. While the more suitable material must be selected to achieve the required mechanical properties. In an example of a housing body with a pin to fix a rotating plastic pulley, metal is more suitable for the pin than plastic to achieve the necessary strength. The pin has been fixed to the body by welding formerly. If the pin and the housing body can be formed in one-piece, the strength and the reliability of the product is improved much better than welding. Extrusion is often used to form the body with the pin. However, the forming pressure is too high to extrude a pin when the extrusion ratio is high, because the pressure is comparable to the fracture pressure of the die material.

This study focuses on a process to form a rectangular plate with a pin by semi-open upsetting. **Fig. 1** shows the outline of the semi-open upsetting. The lower die has a small hole, and the semi-open container are used. The billet is made of pure copper which has an initial diameter of 10 mm. The initial billets are 7.5 and 15 mm in height. The container has a rectangular hole 10 mm by 37 mm. The lower die has a hole of 3.0 mm in diameter. The billet is compressed by a hydraulic press using the flat and rectangular punch. **Fig. 2** shows a formed sample after this trial under an unlubricated condition. This is a pin with a length of 9 mm on a rectangular plate having a 1.9-mm thickness, 10-mm breadth, and 28-mm length. It has a little dent of 8 μm near the center on the side of the plate without the pin. According to FEM analysis, the billet keeps a small dead metal near the lower die and the punch under high friction between the tools and the billet. A high shear zone near the dead metal must promote forming of the long pin as the upsetting proceeds without overload.

Keywords: One-piece forming; Upsetting; Plane strain; Friction



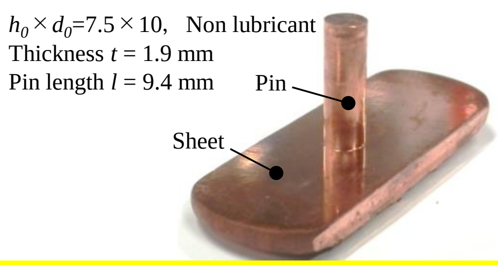


Fig. 1. Outline of semi-open upsetting **Fig. 2**. Formed sample after semi-open upsetting to form rectangular plate with pin

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Shakti Swaroop Choudhury
IIT Madras

Methodology for Manufacturing Functionally Graded Materials with DEM-Assisted simulation of Powder Spreading in LPBF

Shakti Swaroop Choudhury[a], Jaggannagari Sujith Reddy[a], Murugaiyan Amirthalingam[b], Ratna Kumar Annabattula[a*]

[a]Department of Mechanical Engineering, IIT Madras, Chennai, India
[b]Department of Metallurgical and Materials Engineering, IIT Madras, Chennai, India
*Ratna@iitm.ac.in

Functionally graded materials (FGMs) are advanced engineered materials that exhibit a gradual variation in composition, microstructure, or properties throughout their volume in a desired direction. This intentional design allows FGMs to achieve unique combinations of characteristics that single-material components cannot offer. By adjusting the composition or microstructure, FGMs can deliver various properties, such as mechanical strength, thermal and electrical conductivity, and wear resistance. Conventional techniques for producing FGM components include powder compaction, electrodeposition, thermal spraying, plasma spraying, and vapor deposition methods like chemical vapor deposition (CVD), infiltration (CVI), and synthesis (CVS). However, these methods are often costly, part-specific, and limited by the need for specialized tooling and component dimensions.

Additive manufacturing, especially the powder bed fusion technique, Additive manufacturing, particularly powder bed fusion, offers a precise and cost-efficient way to create functionally graded products without specialized tooling, providing better control over gradation rates than traditional methods. However, producing FGMs in the spreading plane remains challenging due to the complexities of controlling multi-material spreading.

This study employs the Discrete Element Method (DEM) to develop an effective approach for spreading functionally graded, polydispersed metal powders on the build platform, addressing the complexities of powder behaviour and interaction. A partitioned dispenser chamber is used in the Laser Powder Bed Fusion (LPBF) process to enhance control and precision in the powder spreading.

After defining the FGM spreading framework, two industrially significant materials, Inconel 718 and 17-4 PH stainless steel, were used to spread across the build platform. These materials were selected for their suitability for aerospace and power plant applications. The resulting FGM components underwent examination for microstructural evolution and compositional variation using a scanning electron microscope. Additionally, mechanical properties were analyzed and compared at different gradation levels within the FGMs.

Keywords: Functionally graded material(FGM), Discrete element method(DEM), IN-718, 17-4-PH, Laser powder bed fusion.

Parameswaran P
Indian Institute of Technology Madras.

A Study on Failure Mechanisms in Additively Manufactured Dumbbell Lattice Structures of Ti6Al4V

P. Parameswaran a,* , D. Kesavan b , R. Jayaganthan a
a Department of Engineering Design, Indian Institute of Technology Madras, Chennai, Tamil Nādu, India
b Department of Mechanical Engineering, Indian Institute of Technology Palakkad, Kerala, India
** ed22d008@smail.iitm.ac.in*

Lattice structures have emerged as a groundbreaking solution in biomedical engineering, particularly in the development of orthopedic implants, scaffolds for tissue engineering, and drug delivery systems. These structures are characterized by their lightweight nature, customizable geometries, and the ability to mimic the mechanical properties of natural bone, making them ideal for applications where weight reduction and biocompatibility are critical. In orthopedic implants, lattice structures can significantly enhance osseointegration, allowing for better load transfer and reduced stress shielding. In this article, the newly designed lattice structure constituting Ti6Al4V alloy inspired from the dumbbell was made with LPBF (Laser Powder Bed Fusion). The compression tests were conducted to evaluate how the lattice architecture influences the load-bearing performance and deformation characteristics during compression. Results indicate that the dumbbell lattice structures exhibit a nonlinear stress-strain behavior with layer-by-layer failure of the rows. FEA (Finite Element Analysis) was performed to compare the results of the experimental work for validation. Johnson Cook damage material model was used to capture the stress-strain behavior of the lattice structure. Fracture morphology analysis revealed distinct failure patterns, including ductile tearing and brittle fracture, which correlated with the lattice design and material properties.

Keywords: Additive manufacturing; Dumbbell lattice structure; FEA; Fracture morphology; Meta-materials.

Dr. Arul Mozhi Selvan
NIT Trichy,

Integration of Nanomaterials in 3D Printing Processfor Enhanced Mechanical and Functional Properties

Dr. Arul Mozhi Selvan[a]*, Arunangshu Das[b], Dilip Khanal[a]
[a]Department of Mechanical Engineering, NIT Trichy, Tiruchirappalli-620015, Tamil Nadu, India
**arulmozhi@nitt.edu*

Additive Manufacturing (AM), or 3D printing, is a process that involves the transformation of modern manufacturing processes by enabling the production and manufacturing of complex structures with a high degree of precision. In the present-day scenario, the recent problems revolving around 3D printing methods highlight the numerous mechanical, thermal, and functional limitations of traditional 3D printing materials, which restrict their wider adoption in sectors requiring high-end performance like aerospace, automotive, and medical domains. This research project proposes the integration of advanced nanomaterials (including carbon nanotubes (CNTs), graphene, and metal nanoparticles) into 3D printing materials to enhance their properties significantly. By developing methods for uniform dispersion of nanomaterials, optimizing the 3D printing parameters, and tailoring the material-processing interactions, the study is conducted to achieve superior mechanical strength, thermal stability, and electrical conductivity in printed components. The project will involve comprehensive testing and analysis to evaluate the improvements in material performance, with a special emphasis on lightweight aerospace components, biocompatible medical implants, and conductive electronic devices. This research is expected to serve as a stepping stone towards the creation of new capabilities for 3D printing technologies, thus rendering multi-functional, nanocomposite-based materials suitable for next-generation industrial applications.

Dinesh kumar A,
IIT Madras.

Influence of Build Orientation on Additively Manufactured Polyvinylidene Fluoride with Electrical Poling for Strain Sensing and Energy Harvesting Applications

A Dinesh kumar[a], N Arunachalam[b], R Jayaganthan[a]*,

a Department of Engineering Design, b Department of Mechanical Engineering,
Indian Institute of Technology, Madras, Chennai-600036, INDIA

Additive manufacturing (AM) of sensors has become a potential manufacturing route worldwide due to its flexibility of incorporating geometrical complexity and micro-structural engineering of materials constituting the sensors. The strain sensors fabricated using this route with flexibility and sensitivity for the precise measurement of strain with a wide range of values. In this work, the polyvinylidene fluoride (PVDF) piezoelectric material-based strain sensor was fabricated using the material extrusion process (ME). The sensing material PVDF, was extruded with three different printing flat orientations such as 0°, 45°, and 90° to understand the effect it has on strain sensing characteristics studies. The fabricated PVDF material was poled by two poling methods contact poling and corona poling process for enhancements of the β-phase in the microstructure and to get better piezoelectric properties. The mechanical test results have shown that the maximum values of Young's Modulus (131.17 ± 2.25 MPa) and Ultimate tensile strength (23.57 ± 0.76 MPa) were observed for the material fabricated with the printing orientation of 45°. The studies on strain sensing characteristics were made for all the samples and found that the sample printed in 0° orientation and poled with the corona poling process has shown the maximum output voltage, short circuit current and power output of 11 V, 0.9 μA and 5.5 μW under the stain condition of 20%. During mechanical testing, the sample printed with a 0° orientation yields more strain as well as the strain sensing results show that effective deformation on the 0° orientation sample leads to providing excellent piezoelectric output. Under different stretching and bending conditions, the fabricated device could serve as both a strain sensor and a piezoelectric energy harvester as observed from the present work.

Keywords: Material Extrusion; Polyvinylidene fluoride; Poling; High voltage Direct Current; d31 Piezoelectric Coefficient; Sensing Application.

Vijeesh Vijayan,
NMAM Institute of Technology (NMAMIT)

Fabrication of martensitic stainless steel using twin wire arc additive manufacturing

Vikas Marakini[a], Vijeesh Vijayan[a]*

[a] Department of Mechanical Engineering, Nitte (Deemed to be University), NMAM Institute of Technology (NMAMIT), Nitte - 574110, India

* vijeeshv@nitte.edu.in

Abstract

Conventional methods often lack the ability to tailor the composition of alloys with accuracy, which limits their capability to meet specific performance requirements in various industries. Additive manufacturing is a relatively new manufacturing method, which is under consideration in various industries. Amongst, Wire Arc Additive Manufacturing (WAAM) is flexible and can use multiple materials during the manufacturing of product. Martensitic stainless steel (MSS) is widely used in steam generators and food industries due to its high mechanical properties and good corrosion resistance. However, the fabrication of MSS using WAAM presents both challenges and advantages, impacting the microstructure and mechanical properties of the resulting steel. The proposed method addresses the challenge of achieving precise control over the composition of alloys during WAAM processes. The method utilizes two gas metal arc welding machines and a specially designed holder to solve this problem and enable controlled deposition of two different wires (alloying elements) onto a substrate, facilitating the production of alloys with highly customized compositions. In this study, an attempt was made to deposit a new alloy with targeted composition of 50% low carbon steel ER70S grade and 50% stainless steel 308L grade. Desired material composition is achieved by predicting the current and feed rate of individual wires. Results of elemental composition, microstructure and hardness in the fabricated new alloy are presented. Elemental analysis showed the presence of Cr and Ni contents, almost half of the parent material. Microstructure analysis of the new alloy showed the presence of martensitic, and δ ferrite structures. Also, the desired hardness is achieved.

Keywords: Deposition; Mechanical properties; Metals and alloys; Microstructure; WAAM.

Fretting Characteristics of 3D Printed Polyphenylene Sulfide (PPS) Insulation Shields – Layer Orientation

Muluken Yehualaw[a]*, R. Gnanamoorthy
[a]Architected and Sustainable Materials Design Research Centre,
Department of Mechanical Engineering,
Indian Institute of Technology Madras, Chennai, India - 600036

**me22d200@smail.iitm.ac.in*

ABSTRACT

Among different types of polymer additive manufacturing techniques, fused filament fabrication is the cheapest method of 3D printing to fabricate parts from high-performance thermoplastic materials like polyphenylene sulfide (PPS), which has exceptional mechanical properties, thermal resistance, and chemical resistance. Polyphenylene sulfide (PPS) is promising for electrical insulation applications and is considered for development as a shielding material in electric vehicle traction motor bearings. The shield of the bearing used on the outer race experiences fretting due to contact between the motor casing materials. This project is focused on the development of shielding using additive manufacturing, as the different surface and interior designs are feasible in the fused filament fabrication process. The damage due to fretting decides the insulation capabilities of the shield and is investigated. This paper explores the impact of 3D printing layer orientation on the fretting wear behavior of polyphenylene sulfide. Fretting tests were conducted using different normal loads with a constant slip amplitude in laboratory test conditions. The PPS samples were 3D printed with different layer orientations and preconditioned before testing. The results revealed that the impact of layer orientation on fretting wear is load-dependent. The wear characteristics including fretting friction coefficient, fretting loop, and surface morphology are reported.

Keywords: Bearing Electrical Insulation Shield, PPS, 3D printing; Fretting; layer orientation;

Yae Hasegawa,
Shibaura Institute of Technology

Effect of cylindrical tube geometry on the corrosion behavior of ZM21 magnesium alloy in flow field

Yae HASEGAWA*, Shoichiro YOSHIHARA*

Mechanical Engineering, Shibaura Institute of Technology,3-7-5 Toyosu, Koto-ku, Tokyo 135-8548 Japan.
*md23102@shibaura-it.ac.jp

Abstract

Magnesium alloys, owing to their exceptional mechanical properties and biocompatibility, stand as promising contenders for the future of coronary stents. However, their rapid corrosion in the body presents significant obstacles that need to be effectively controlled. While much research has focused on internal factors such as grain size in understanding magnesium's corrosion behavior, external factors such as blood flow and heartbeat remain less explored. This study aims to determine the hydrodynamic effects on the corrosion behavior of magnesium alloys, which will contribute to improved stent design in the future. Corrosion behavior was examined through flow corrosion experiments and Computational Fluid Dynamics (CFD) analysis. This approach sought to clarify initial corrosion progression and provide insights into optimizing stent geometry.

In the experiments, five different circular tube materials (Outer diameter: 4.8mm, Inner diameter: 2, 2.5, 3, 3.5, and 4 mm) made of ZM21 magnesium alloy were immersed in a 0.9 mass% NaCl solution at flow rates of 0.5, 0.7, 0.9, 1.1, and 1.3 m/s for 3 hours. The results showed that mass loss increased with higher flow velocity, particularly in specimens with smaller inner diameters. A 3D stent was modeled to observe the shear stress distribution using CFD analysis. Shear stress distribution inside the specimen was investigated to determine its role in corrosion progression, revealing that high shear stress at the inflow zone accelerates corrosion. Based on the experience from the tubing study, two different stent models were designed. One is a mesh model with rhombic cells in a row and the other with fewer rhombic cells, which are connected by links. The mass loss of the two models was tested at a flow velocity of 1.3 m/s, which reflects typical human blood flow conditions, and a comparison of the mass loss of the two models indicated that the mesh model was highly resistant to corrosion; CFD analysis results demonstrated that the shear stress in the mesh model was spread over the entire strut. On the other hand, in the model with the reduced number of cells, the highest shear stresses were concentrated at the entrance, although the average stresses were relieved. These results indicate that local shear stress concentrations have a significant influence on corrosion behavior, suggesting the importance of optimizing the shear stress distribution in stent design.

Keywords: Corrosion behavior; Magnesium alloy; Stent; Flow velocity; Shear stress

Ryo Matsumoto
Osaka University, Japan

Reduction in Barreling of Hollow Cylinder by Ram Pulsation in Upsetting

Ryo Matsumotoa*, Yuya Mondaa, Hiroshi Utsunomiyaa
aDivision of Materials and Manufacturing Science, Osaka University, Suita, Osaka, Japan
ryo@mat.eng.osaka-u.ac.jp

Abstract

Relationship between ram pulsation of press and barreling of hollow cylinder in cold upsetting was investigated with experiment and finite element analysis. In experiment of upsetting of hollow cylinder with 18Cr-12Ni-2.5Mo stainless steel (JIS: SUS316), barreling of the hollow cylinder was reduced by ram pulsation with complete unloading, especially by multiple pulsations with short forming stroke. On the other hand, barreling of the hollow cylinder was not reduced by ram pulsation with partial unloading. In case of hollow cylinder with pure aluminum (JIS: A1070), barreling of the hollow cylinder was not reduced by ram pulsations with both complete and partial unloadings.

The mechanism of reduction in barreling of the hollow cylinder was discussed from the viewpoints of (a) friction at the die–workpiece contact interface, (b) plastic heat generation, and (c) elastic and plastic deformations. No seizure and adhesion of the workpiece occurred on the die surface after upsetting with/without ram pulsation. Therefore, the friction was not affected by the ram pulsation. The temperature rise due to plastic heat generation was approximately maximum 30 K in the workpiece in the elastic-plastic finite element analysis with heat conduction. Therefore, the influence of the temperature change on the plastic deformation was considerably small. In the elastic-plastic finite element analysis, the stress distribution in the workpiece before unloading and before reloading at the same forming stroke was considerably different in upsetting with ram pulsation with complete unloading. Therefore, the reduction in barreling in upsetting with ram pulsation was concluded to be mainly due to the elastic and plastic deformations characteristics of the workpiece.

Keywords: upsetting; pipe; deformation; ram motion; oscillation.

Dinesh Kumar S
Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram

Fast fabrication of titanium self-cleaning surfaces using laser surface texturing for surgical tools

Dinesh Kumar S[a], Kishor Kumar Gajrani[a]*

[a]Department of Mechanical Engineering, Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram, Tamil Nadu, India

*g.kishor@iiitdm.ac.in

The chemical etching method is widely used to fabricate self-cleaning surfaces. However, the process is slow as well as the life of the surface is limited. To overcome these limitations, laser surface texturing can be used to fabricate the self-cleaning surfaces in less time. The present work demonstrates the application of laser surface texturing to enhance the hydrophobicity of Ti6Al4V alloy surfaces. Several micro-textures, namely hatched (45°), window pane (0°/90°), cross-hatched (45°/-45°), dash-hatched (45°), and striped (90°) were fabricated with varying offset (*d*) distances. The textures were fabricated using a fiber laser at varying scanning speed, frequency and power. The surface characteristics of the fabricated textures were analyzed using an optical microscope, scanning electron microscope, and a non-contact surface profilometer. Further, the wettability of the fabricated surfaces with water droplets were tested using a contact angle goniometer. It was observed that the window pane textures having offset distance of 0.25 mm and fabricated at scanning speed of 2000 mm/s, frequency of 10 KHz, and power of 16 W have shown the highest water contact angle (153°) among all textures after low temperature heat treatment. These textures exhibit super hydrophobic behaviour, which was significantly higher than the contact angle (74.6°) of an as-received Ti6Al4V surface. Figure 1 shows the surface morphology, 3D surface profiles and measured water contact angle for fabricated windowpane and cross-hatched micro textured self-cleaning Ti6Al4V surfaces. Further, the effect of surface roughness (S_a) on the water contact angle is also analyzed. Results shows a 105 % enhancement in water contact angle on fabricated windowpane microtextures after sequential low temperature heat treatment, due to which the fabricated surface shows self-cleaning characteristics.

Keywords: Contact angle; offset distance; self-cleaning surfaces; super hydrophobic; textures; wettability.

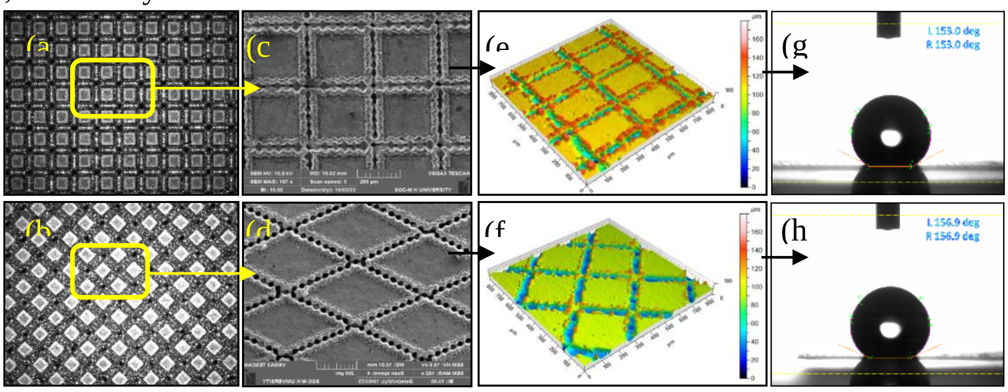


Fig. 1: Laser textured window pane and cross hatched surfaces: (a-b) morphology, (c-d) SEM images showing dimension, (e-f) 3D surface profile, and (g-h) water deoplet contact angle on the fabricated surface

Shubhang Srivastava
Indian Institute of Technology Madras

Analysis of Tribological Data of Lubricants using Advanced Statistical Methods

Shubhang Srivastava [a, b], Muthusamy Kamaraj [b, *], Sundara Ramaprabhu [a, *]

a Alternative Energy and Nanotechnology Laboratory (AENL), Department of Physics, Indian Institute of Technology Madras, Chennai 600036, India.

b Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai 600036, India

* ramp@iitm.ac.in, kamaraj@iitm.ac.in

Sustainable lubricant formulation is one of the key areas in the context of energy conservation scenario. Efficient design and development of lubricants is necessary to achieve notable friction and wear performance. Systematic tribological investigation of different industrial lubricants is carried out in this work by varying the test conditions like rotational speeds and temperatures to understand the influence of these parameters on friction and wear behavior. The friction tests are carried out in our lab using the four ball tester instrument. Coefficient of friction (COF) and wear scar diameter (WSD) values have been recorded for the given test parameters. Observed results have helped to estimate the best oils and best test conditions based on the lowest COF and WSD values. Lubricants form a protective tribo-film on the contact interface leading to changes in these measured values. Recently, developed advanced statistical methods based on ANOVA models have been applied on the data set generated from our experiments. These novel test procedures have been used to detect trends in effect values. Optimal oil and optimal test conditions have been determined based on the ordering of best oils and best parameters. Statistical computations show highly consistent results compared to experimental values. This methodology is applied for the first time simultaneously on both friction and wear data. This latest design of experiments approach holds potential in energy saving applications like automobiles, industrial machinery and can also be extended to other allied areas.

Keywords: Advanced statistical procedures, Energy conservation, Friction, Sustainable lubricants, Tribology, Wear.

Taichi Hino
Nagoya University

Evaluation of Irradiation Characteristics of FAB Source with Potential Distribution Control Electrode

Taichi Hino[a]*, Chiemi Oka[a], Junpei Sakurai[a], and Seiichi Hata[a]*

[a]Micro-Nano Mechanical Science and Engineering, Nagoya University, Chikusa-ku Furo-cho, Nagoya, Japan

hino.taichi.v6@s.mail.nagoya-u.ac.jp

Abstract

Surface activated bonding is a technique that enables the direct bonding of different materials at room temperature. In this process, a fast atom beam (FAB), such as a fast argon beam, is irradiated in a vacuum. This irradiation removes oxide films and contaminants from the surfaces, creating an amorphous layer with dangling bonds. When two surfaces activated by the FAB are pressed together under low pressure, covalent bonds form between them, allowing for direct bonding. Since this method is performed at room temperature and does not require heating, there is no distortion due to thermal deformation or differences in the coefficients of linear expansion. As a result, surface activated bonding can directly bond materials with different coefficients of linear expansion, making it useful in the production of heterogeneous wafers, such as surface acoustic wave filters, and in potential applications for 3D semiconductor integration.The FAB source is a critical component in the surface activated bonding process. Argon gas is introduced into the FAB source under vacuum conditions, and a high DC voltage is applied to ionize the argon into plasma. The argon ions in the plasma are accelerated toward the cathode due to the potential distribution within the FAB source. These ions are then ejected as a beam through an aperture. Inside the aperture, the accelerated argon ions are neutralized to form a fast neutral atom beam. This neutralization occurs through surface recombination reactions, where argon ions gain electrons on the cathode surface, and through charge exchange reactions, where argon ions exchange electrons by colliding with neutral argon atoms in the gas phase.In recent years, there has been a growing demand for FAB sources that provide a larger irradiation area and more uniform irradiation across the entire wafer to accommodate larger wafer diameters. In this study, we aimed to expand the irradiation area and achieve more uniform irradiation over the entire wafer by designing an FAB source with a modified potential distribution compared to conventional FAB sources. We also controlled the acceleration direction of the argon ions. To evaluate the performance of the irradiation, we conducted an oxide film removal test and compared the results with those obtained using a conventional FAB source. Our findings demonstrated that the irradiation characteristics were superior to those of the conventional FAB source. Additionally, since the fast atom beam is irradiated at an oblique angle during the bonding process, we modified the aperture shape to achieve uniform irradiation under oblique conditions and evaluated its effectiveness.

Keywords: fast atom beam source; potential distribution; surface activated bonding,

Bindu Pal
IIT Madras

Effect of double pulsing on the fatigue behaviour of resistance spot welded Boron steel

Bindu Pal[a*], Murugaiyan Amirthalingam[b] and S. Ganesh Sundara Raman[c]
Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai, India.
amm18d020@smail.iitm.ac.in, bmurugaiyan@iitm.ac.in and cganesh@iitm.ac.in

Advanced high strength steel (AHSS) is the first choice for an automotive maker to ensure light weight, manufacturing efficiency, passenger safety and durability of automotive vehicles. Around 55 % of total material used in any car body is AHSS using which different components like B-pillar, A-pillar, door impact beam, roof rail etc. are manufactured. Boron alloyed steel, an AHSS, provides increased hardenability at very minimum concentration of boron ~ 10-20 of weight parts per million. Hot stamping is one of the manufacturing processes in which a blank of boron alloyed steel is heated for the full austenization in a furnace then moved to a press, where it is formed and quenched in a closed die, which reduces spring back and enhances hardenability.

Having advantages of high dimensional accuracy, excellent fit up and no extra weight addition, resistance spot welding (RSW) has become one of the prominent joining techniques to assemble automotive components. However, brittle weld zone is found to be detrimental for the mechanical performance of welds. Among many advancements of conventional RSW process, double pulsed RSW has been proved as one of the effective ways to tailor microstructure of heat affected zone (HAZ) and fusion zone and to improve weld strength.

In the current study, boron steel (ferrite + pearlite) was heated in a furnace and taken out for compressed air quenching to achieve a microstructure (martensitic) and properties of material similar to those of hot stamped parts. Heat-treated boron steel sheet was used for further studies. Welds were prepared with and without double pulsing. Double pulsing was introduced to the welding schedule to improve mechanical performance of welded joints by tempering of HAZ and fusion zone. Optimization of RSW parameters was carried out to ensure industrially accepted failure mode and fusion zone size. Microstructural investigation and evaluation of mechanical performance under tensile-shear and fatigue loading were done. Welds were tested in lap-shear mode. The influence of double pulsing on fatigue life and failure modes was studied.

Keywords: Double pulsed resistance spot welding, weld strength, fatigue behaviour of welded joints, boron steel.

Muneyoshi Iyota
Osaka Institute of Technology

Improvement on Joint Strength of Fe/Al Dissimilar Materials Resistance Spot Welded Joints by using External Magnetic Field

Muneyoshi Iyota[a]*, Yuta Funabiki[b], Takahisa Shobu[c], Tomoki Matsuda[d], Yujiro Hayashi[e] and Tomokazu Sano[d]

[a]Faculty of Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan
[b]Graduate school of Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan
[c]Japan Synchrotron Radiation Research Institute, Sayo-gun, Hyogo, Japan
[d]Graduate school of Engineering, Osaka University, Suita, Osaka, Japan
[e] RIKEN SPring-8 Center, Sayo-gun, Hyogo, Japan
*muneyoshi.iyota@oit.ac.jp

In resistance spot welding (RSW) of Fe and Al alloy, an intermetallic compound (IMC) is formed at the joining interface, and it is known that the strength of the joint decreases as the IMC becomes thicker. One of the factors that determines the thickness of the IMC is the temperature field during welding, which is considered to vary greatly depending on convection within the Al alloy melting zone. Therefore, changes in convection are considered to possibly affect the state of IMC formation, but there have been few detailed studies of this phenomenon. In this study, convection in the Al alloy melting zone of an Fe-Al alloy RSW was varied and the effect on the joint characteristics was investigated. For this study, to focus on the electromagnetic force generated in the Al alloy melting zone, convection in the Al alloy melting zone was changed by applying a magnetic field using neodymium magnets. In-situ evaluation of the convection using synchrotron radiation and cross-sectional images of the joint revealed that the presence of a magnetic field during welding causes a non-axisymmetric change in convection in the Al alloy melting zone, which deflects this zone. The magnetic field increases the driving force for convection and homogenizes the temperature field at the joining interface, leading to the formation of a thin uniform IMC near the joint center. Furthermore, from a cross tension test and observation of the fracture surface of the joint after the test, it was clarified that the cross tension strength of the joint welded under a magnetic field was improved by the propagation of cracks into the Al alloy melting zone during the test.

Keywords: Dissimilar materials joining; Resistance spot welding; Joint strength; External Magnetic Field; Convection; Intermetallic compound

Mr. Rahul Srivastava
Indian Institute of Technology Madras, Chennai

Insights into the bonding characteristics and bendability of Al/Mg/Al tri-layered multi-metallic clad sheets

Rahul Srivastava*, Sushanta Kumar Panigrahi

Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai, Tamil-Nadu, India

*rahulme0110@gmail.com , *skpanigrahi@iitm.ac.in*

Abstract

Magnesium (Mg) is the lightest commercially available structural metal and is extensively utilized in the automotive and aviation sectors to decrease vehicle weight, thereby improving fuel efficiency and reducing emissions. Moreover, Mg possesses excellent damping properties, a long fatigue life, good fracture resistance, and a high strength-to-weight ratio. However, it tends to have poor corrosion resistance, lower ductility/formability, and bendability. It is expected that Al and Mg composite developed by cladding Mg alloys with Al alloys can limit the corrosion of Mg alloys and enhance the corrosion resistance and formability of Al/Mg/Al clad sheets, keeping a high strength-to-weight ratio. This sheet has wide applications as a structural material in the aerospace and automotive industries due to its lightweight characteristics. The performance of the sheets is primarily determined by the formation of mechanical and metallurgical bonding at the adjoining Al-Mg and Mg-Al interfaces. The primary challenge in developing Al/Mg/Al clad sheets is achieving proper bonding at the interfaces while preventing the evolution of undesirable phases, such as intermetallic compounds like Al3Mg2 and Al12Mg17. The present study focused on achieving high-quality bonding and bending characteristics by engineering the microstructure of substrate and interface structure in the Al/Mg/Al clad sheets during the hot roll bonding process by reducing the formation of intermetallic compounds. Microstructural investigations in the Al/Mg/Al clad sheets, such as grain morphology of the core, clad, and interface structures, were perceived using electron backscatter diffraction (EBSD), and interfacial phase evolution was analyzed using an X-ray diffractometer (XRD). Energy dispersive X-ray spectroscopy (EDS) was performed to determine the elemental diffusion of Al and Mg atoms at the interfaces. Mechanical testing, including peel, tensile, and three-point bend tests, was carried out to assess the bonding strength, mechanical properties, and bending characteristics of the Al/Mg/Al clad sheets. The bent samples were examined using a scanning electron microscope (SEM) to visualize the zones prone to crack initiation and its propagation in the clad sheets, and fractography analysis of tensile-fractured samples was completed. The Al clad material significantly improved the corrosion resistance and enhanced the formability and bendability of the Al/Mg/Al clad sheets while maintaining the synergy between the strength-to-ductility. The underlying mechanism for achieving extraordinary bond strength and bendability in the Al/Mg/Al clad sheets was identified, and the correlation between the bonding temperature, critical percentage reduction, resulting interfacial and substrate microstructures, bonding strength, and mechanical properties was established.

Keywords: Al/Mg/Al clad sheet; Bending; Hot roll bonding; Mechanical properties; Microstructure; Thermo-mechanical processing

Saravana Bavan
Dayananda Sagar University, Bengaluru, India

Tensile and hardness behaviour of friction stir cast welds for automotive application

B. S. Bindhushree,[a,b] S. P. Shanmuganatan,[b] M. Madhusudan[b], Saravana Bavan*,[a]

[a] Department of Mechanical Engineering, Dayananda Sagar University, Bengaluru

[b]Department of Mechanical Engineering, Dayananda Sagar College of Engineering, Bengaluru

*saranbav@gmail.com

Abstract

Stir cast alloys are beneficial in the aerospace industry by virtue of their low porosity, high specific strength, corrosion resistance, and weldability. Friction stir welding (FSW) is an advanced technique for joining materials continuously. The present investigation enfolds solid state joining of cast A356 and AA 2014 alloys by varying process parameters such as tool pin shape (cylinder, threaded cylinder, square, and conical), tool rotation speed (1800–2100 rpm), and welding speed (10–25 mm/min). Experiments were conducted to evaluate the influence of process parameters on the tensile and hardness behaviour of the welded specimens. Mechanical test results were assessed and compared with fuzzy logic approach. Optical microstructural characteristics of the friction stir cast welds were analysed with energy dispersion spectroscopy. The results revealed complete fusion in the cast welds with no porosities or segregations, and finer grains resulting from recrystallization. The threaded cylinder and square-shaped tools achieved the highest tensile strength and micro hardness of 136.6 MPa and 109.4 Hv respectively

Keywords: Dissimilar T6 alloys; Stir casting; Friction stir welding; Mechanical properties; Fuzzy Logic approach

Dr. Abir Saha
IIT Guwahati

Development of Bamboo Micro Particle- Long Fiber Reinforced Hybrid Green Composites for Automobile Interior Applications

Dr. Abir Saha[a]*, Dr. Nikhil Dilip Kulkarni[a], Prof. Poonam Kumari[a]

[a]Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Guwahati, Assam, India-781039

*abir2016saha@gmail.com

Abstract

Researchers are increasingly exploring natural alternatives to synthetic materials due to growing concerns about global warming and the need for sustainable solutions. Natural fiber-reinforced polymer composites (NFRPCs) have gained significant attention because of their low cost, biodegradability, lightweight properties, and excellent lifecycle performance. These composites are widely used in industries ranging from automotive manufacturing to civil engineering. The present study focuses on creating a hybrid composite by reinforcing it with Bambusa tulda fiber and bamboo-based microparticles. The bamboo biomass, sourced as waste from local industries, was chemically treated to produce valuable micro-particles. Hybrid composites were developed with a constant bamboo fiber content of 30%, while the weight percentage of bamboo microparticles varied between 0% and 10%, in intervals of 2.5%. Experimental findings showed that adding bamboo microparticles enhanced the tensile strength by up to 12.72% and the flexural strength by up to 19.79%. However, when the microparticle content exceeded 5%, agglomeration occurred, leading to a decline in performance. Based on these observations, the developed composite demonstrates strong potential for applications in the automobile sectors, particularly the parts which are made of Polypropylene (20-40 MPa), ABS (30-50MPa), Polycarbonate (55-75 MPa), Nylon (60-80 MPa), and PET (50-100 MPa). This study highlights the viability of utilizing bamboo waste to create eco-friendly and high-performance materials.

Keywords: Green Composite; Sustainable Materials; Natural Fiber; Automobile Applications, Hybrid Polymer Composites.

Shruti Gupta
Defence Institute of Advanced Technology (DU)

Recycling Carbon Fiber via Additive Manufacturing for Superior Mechanical Properties

Sanket Dilip Meshram[a], Shruti Gupta[b], Jigar Patadiya[b], Balasubramanian Kandasubramanian[b*]

[a] COEP Technological University, Pune - 411005, Maharashtra, India

[b] Additive Manufacturing Laboratory, Department of Metallurgical and Materials Engineering, Defence Institute of Advanced Technology (DU), Ministry of Defence, Girinagar, Pune 411025, Maharashtra, India.

[* meetkbs@googlemail.com](mailto:meetkbs@googlemail.com)

Abstract

Carbon fiber reinforced composites (CFRPs) are gaining prominence in the automobile and aeronautical sectors, attributable to their exceptional strength–to–weight ratio, lightweight nature, and durability. Howbeit, the escalating adoption of CFRPs has concurrently led to a substantial increase in waste derived from obsolete pre-pregs, manufacturing offcuts, test materials, end-of-life components, and production tooling. This surge in waste generation presents significant environmental challenges, underscoring the imperative for advanced recycling methodologies to sustain environmental stewardship and foster a circular economy. In this context, the present research investigates the potential of 3D printing as a sustainable and economically viable approach for reusing waste carbon fiber (CF) fabric into high-value products. This study leverages the synergistic integration of two distinct additive manufacturing techniques, DIW (Direct Ink Writing) and FDM (Fused Deposition Modelling), to fabricate sandwich structures combining Nylon and waste carbon fiber as core. The research highlights the mechanical performance of the fabricated composites, demonstrating significant enhancements in key properties compared to pristine Nylon. The Comprehensive mechanical testing revealed that the tensile strength of the Nylon carbon fiber reinforced composite exhibited a notable increase, reaching 86.36 MPa, a substantial improvement from the 54.7 MPa observed in unreinforced Nylon. Furthermore, the impact strength of the composite experienced a dramatic surge, escalating from 56.8 J/m² to 420.565 J/m². These findings underscore the potential of this recycling approach not only to transform industrial waste into valuable resources and mitigate the environmental impact of CFRP waste but also to produce high-performance composites suitable for demanding applications in the automobile and aeronautical sectors.

Keywords: CFRP, DIW, FDM, Mechanical properties, Waste Carbon fiber

Kazutoshi Tachibana
Macoho Co., Ltd.

Trial of Replacement from Conventional Pickling to Wet Shot Blasting Prior to Zinc-phosphate Lubrication for Cold Forming

Kazutoshi Tachibana[a]*, Kazuhiko Kitamura[b], Takeru Imoto[b]
[a]Macoho Co., Ltd, Nagaoka, Niigata, Japan
[b]Department of Electrical and Mechanical Engineering, Nagoya Institute of Technology, Nagoya, Aichi, Japan
k_tachibana@macoho.co.jp

Replacing conventional pickling prior to a lubrication process of a soap and zinc-phosphate coating for cold forming by an epoch-making wet shot blasting was investigated to reduce chemical emission from the chemical pickling. This lubrication process is most valuable and widely used for cold forming such as forging and drawing. It includes, however, a step of cleaning surface of workpieces in preparation for the zinc-phosphating, which fundamentally accompanies a large amount of chemical emission harmful to environment. In this study, an influence of the pickling or wet blasting prior to the soap and zinc-phosphate on the lubrication performance is estimated using a ball penetration test. The wet blasting is a mechanically-cleaning pretreatment of a workpiece surface without chemical emission. After the tests, intense galling was observed insides of tube-like specimens in a severe condition, but starting depth of the galling was larger on the specimens pretreated by wet shot blasting. This meant the wet shot blasting improved the anti-galling performance than pickling. Therefore, it suggested that the replacement of pickling by wet shot blasting could be possible. Before soap lubrication, the typical crystal of capillary hopeite was observed on only wet shot blasting specimens although under the same condition of conversion coating.

Keywords: chemical conversion; cold extrusion; lubrication; pickling; seizure; surface treatment

Jinrong Liu
Kindai University

Machinability of Carbon Fiber Reinforced Aluminum Alloy Composites

Jinrong Liu [a]*, Kazunori Asano [a]*, Mutsuo Hayashi[b]*, Shuhei Katsumata[b]*and Shogo Ochiai[b]*

[a] Kindai University, Higashi-osaka, Osaka, 577-8502, Japan

[b]Advanced Composite Corporation, Fuji City, Shizuoka, 417-0801, Japan

**2333330366d@kindai.ac.jp _asano@mech.kindai.ac.jp*

m.hayashi@advance-composite.co.jp katsumata@advance-composite.co.jp

ochiai@advance-composite.co.jp

The machinability of fiber-reinforced and particle-dispersed aluminum alloy composites was evaluated using PAN-based carbon fibers (CF) and silicon carbide particles (SiC_p) as reinforcing materials. The composites were fabricated by squeeze casting, with optical microscopy revealing a random distribution of CF and SiC_p within the alloy matrix. During machining, CF-reinforced composites exhibited larger fluctuations in cutting resistance compared to SiC_p-dispersed composites and the unreinforced alloy. Increasing the volume fraction of SiC_p led to higher average cutting resistance, while CF-reinforced composites showed lower cutting resistance than the unreinforced alloy. The surface roughness of the machined composites generally decreased due to the reinforcement, especially with fine SiC_p particles contributing to a smoother surface. Reinforcement also suppressed the formation of the built-up edge, enhancing surface smoothness. For SiC_p composites, A higher particle volume fraction resulted in a slight increase in tool wear, while larger particle sizes caused a significant, doubling effect on wear.

Keywords: *aluminum, composites, carbon fiber, SiC particle, machinability*

Junpei Sakurai
Nagoya University

Combinatorial searching for High Heat-Resistant Thin Film Amorphous Alloys for MEMS Ultrasonic Devices

Junpei Sakurai*, Akira Ito, Chiemi Oka and Seiichi Hata
Department of Micro-Nano Mechanical Science and Engineering, Nagoya University, Nagoya, Aichi, Japan
*junpei.sakurai@mar.nagoya-u.ac.jp

MEMS ultrasonic sensors are a non-contact distance sensor that detects objects by transmitting and receiving ultrasonic waves through the vibration of a diaphragm. It is commonly used in vehicle parking assistance and automated parking systems. In response to increasing demands in recent years, there is a need to extend the detection range and improve accuracy. It is anticipated that increasing the diaphragm displacement will enhance the transmission sound pressure, thus extending the detection range. We have been studying thin-film amorphous alloys with low Young's modulus and a large elastic range as potential candidates for novel diaphragm materials. Among these, the Ni-Nb-Zr thin-film amorphous alloy (1) has demonstrated superior material properties compared to the conventional diaphragm material, Si, and is expected to be applied in sensors. However, it cannot withstand the process temperature (773 K) required during PZT deposition, a piezoelectric film, and crystallizes as a result. In this study, we combinatorial searched Ni-Nb-Hf thin-film amorphous alloys (TFAAs) to increase the crystallization temperature. The third element Zr in Ni-Nb-Zr alloy was replaced with Hf, because these alloys are expected to have a higher melting point.

We searched for Ni-Nb-Hf TFAAs having high crystallization temperature of over 823 K, to prevent amorphous diaphragm from crystallization during fabrication process of piezoelectric film. Thus, we succeeded to search for new Ni-Nb-Hf TFAAs with the target heat resistance.

Keywords: thin film amorphous alloy; high thermal resistance; MEMS; Diaphragm; crystallization; ultrasonic sensor; combinatorial methods.

Yuya Takamatsu
Nagoya University

Three-Dimensional Estimation of Oxide Film Removal in Surface Activated Bonding using a Fast Atom Beam

Yuya Takamatsu[a]*, Kyosuke Oshima[a], Chiemi Oka[a] , Jumpei Sakurai[a] , Seiichi Hata[a] ,
[a]Department of 1st Author, Nagoya University, Nagoya, Aichi, Japan
*Seiichi.hata@mae.nagoya-u.ac.jp

Abstract

Direct bonding of silicon wafers is a critical step in the fabrication of three-dimensional integrated circuits and MEMS (Micro Electro Mechanical Systems). Several techniques exist for direct silicon wafer bonding, including hydrophilic bonding and plasma activation bonding. However, these methods typically require high-temperature processing and carry the risks of impurity diffusion, void formation, and t are unsuitable for bonding materials with different coefficients of thermal expansion. To address these challenges, surface activation bonding (SAB) has garnered attention, as it enables bonding at room temperature. SAB is a technique that achieves direct bonding at room temperature and low pressure (on the order of a few MPa) by using a fast atom beam (FAB) of inert gases like argon under vacuum to remove stable oxide layers and absorbed films, transforming the surface into an amorphous layer. The activated surfaces are then pressed together to form a bond.

In this study, we focused on the FAB source. As the diameter of silicon wafers has increased in recent years, there is a growing demand for FAB sources capable of uniformly irradiating large areas. Traditionally, optimizing the irradiation characteristics of the FAB source required repeated experiments and validations, which is time-consuming and inefficient. Therefore, we aimed to enhance the efficiency of this process by employing two-dimensional plasma simulation to enable performance evaluation of the FAB source without the need for extensive experimentation. In prior research, we developed a model to predict the amount of oxide removal along the y-axis of the wafer when FAB is irradiated perpendicularly. However, in practical SAB processes, FAB is irradiated at an angle to the wafer, as this increases the sputtering rate compared to perpendicular irradiation and is compatible with the bonding equipment configuration.

In this study, we investigated the effect of angled FAB irradiation on the model for predicting oxide removal along the y-axis of the wafer. Additionally, we predicted the oxide removal distribution along the x-axis and proposed the development of a three-dimensional predictive model that combines the predictions for both the y- and x-axes to estimate the oxide removal distribution across the entire wafer.

Keywords: Direct bonding; Surface activation bonding; Fast atom beam; Plasma simulation

Tetsuro Yanaseko
Kogakuin University

Evaluation of Healing State of Self-Healing Ceramics by Acoustic Emission

Tetsuro Yanaseko[a]*, Ryohei Ohashi[b], Masaki Hiratsuka[a], Koji Hasegawa[a]

[a]Department of Mechanical Engineering, Kogakuin University, Hachioji-shi, Tokyo, Japan

[b] Graduate School of Engineering, Kogakuin University, Hachioji-shi, Tokyo, Japan

yanaseko@cc.kogakuin.ac.jp

Self-healing ceramics are expected to be novel heat-resistant materials for use in jet engines and other machines that operate at high temperatures. The self-healing mechanism in self-healing ceramics is crack filling and bonding by oxides produced by oxidation of self-healing agents embedded in the matrix ceramics. Therefore, the suitable selection of a self-healing agent requires evaluations of the volume expansion rate due to oxide, the oxidation rate, and the bonding strength between oxide and matrix. In this study, feasibility of using acoustic emissions (AE) to evaluate the bonding strength between the generated oxide and the matrix was investigated. As a first step to evaluate the bonding strength, SiC/Al_2O_3 composite was used as typical self-healing ceramics and healed varied conditions to realize several healed states and evaluated the correlation between the acoustic emissions generated during strength tests and the healing state in each healing conditions. The results suggest that it was possible to distinguish between incomplete and complete healing based on the cumulative AE energy. Moreover, the evaluation of the frequency of the earliest AE that occurred in the specimen using time-frequency analysis could be used to distinguish the healing state. These results suggest that it is possible to investigate the bonding strength between the oxide of self-healing agents and the matrix ceramics.

Keywords: Acoustic Emissions; Ceramics Matrix Composites; Oxidation; Self-Healing Ceramics; Strength

Taro KANEHIRA
Kindai University

Effects of phosphorus and calcium on the refinement of Mg2Si crystallized in Mg alloy

Taro KANEHIRA*, Hirofumi TOMII[a], Kazunori ASANO[a]

[a] Graduate School of Science and Engineering, Faculty of Science and Engineering,
Kindai University, Higashiosaka, Japan
**2433330312v@kindai.ac.jp*

Abstract

The effects of phosphorus and calcium on the growth pattern of Mg_2Si crystals in the magnesium alloy melt were investigated by observation of the microstructure and analysis of the elemental distribution of the specimens. The morphology of primary Mg_2Si particles changed from dendritic and isotropic to polygonal with the addition of 0.5mass% phosphorus and 1.0mass% calcium, and the average diameter of Mg_2Si particles decreased from about 37μm to about 26μm inMg-3Si alloy with phosphorus and about 24μm in Mg-9Al-1Zn-3Si alloy with phosphorus and calcium. EPMA confirmed the formation of a CaMgSi as a heterogeneous nucleation substrate from the center of the Mg_2Si particles and the distribution of phosphorus within the particles. It was thus recognized that calcium contributed to the refinement of Mg_2Si particles by heterogeneous nucleation, while phosphorus contributed to the refinement of Mg_2Si particles by inhibiting crystal growth through the poisoning effect.

Keywords: calcium; magnesium; Mg_2Si; microstructure; modification; phosphorous;

Nodoka Inui
Nagoya University

Novel Design and Fabrication of Tactile Pin Actuator for Tactile Displays Utilizing Kirigami Structure

Nodoka Inui[a]*, Chiemi Oka[a], Seiichi Hata[a] , Junpei Sakurai[a]

[a]Department of Micro-Nano Mechanical Science and Engineering, Nagoya University, Nagoya, Aichi, Japan
*inui.nodoka.h2@s.mail.nagoya-u.ac.jp

We proposed a new concept of tactile pin actuator for tactile displays using Ti-Ni-Cu shape memory alloys (SMAs). We had been fabricating a variable reaction force tactile display which reproduces skin deformation upon object contact by utilizing the reaction force when the pins are pressed in with a finger. It has multiple tactile pins integrated on the substrate. SMAs were used as the material for these actuators, which have advantages of large deformation and low voltage drive. In addition, using the superelastic effect of SMAs as the driving principle, the reaction force can be adjusted according to the temperature of the actuator. This driving principle makes it possible to express the hardness and softness of an object, which could not be expressed by conventional types.

In previous research, miniaturization was achieved by pin actuators with convex structure integrated the driving part and the tactile part into an actuator using high formable SMAs (HFSMAs). However, these actuators had the issues of ensuring thermal and electrical insulation of tactile part. This was because actuator was heated by current flow, though tactile pin actuator was touched directly.

In this study, Therefore, we devised a new tactile pin actuator's structure with flat structure that is pushed out vertically from a flat surface. To ensure the large deformation when the actuator was pushed, we adopted "Kirigami" structure. Moreover, to ensure the thermal and electrical insulation of tactile part, the flat tactile part covered with a film resist.

We designed the actuator based on the results of finite element simulation. The simulation evaluated the volume of the martensitic transformation, the reaction force value, and the absence of plastic deformation during indentation. Then, we fabricated the actuators by MEMS processes such as lithography, sputter deposition, RIE, and annealing, and the driving characteristics were evaluated by indentation tests.

In the indention tests, the pin actuators were indented with a needle and the reaction force at various temperatures. We clarified the relationship between temperature and reaction force from the actuator. From the results, new pin actuators exhibited the superelastic effect during indention tests and the reaction force ranged from 30 to 50 mN at an indentation depth of 300 μm.

These results indicated that new actuators can be used as a tactile display that express desired hardness or softness by temperature control.

Keywords: Tactile display; Shape memory alloys; Kirigami (structure); Microactuators

Kohei Nobata
University of Fukui

Toolpath Generation from Product Depth Map in Incremental Forming by Convolutional Neural Network

Kohei Nobataa*, Masaaki Otsub

aIndustrial Innovation Engineering, Graduate School of Engineering, University of Fukui, 3-9-1, Bunkyo, Fukui, 910-8507, Japan

bMechanical Engineering, Faculty of Engineering, University of Fukui, 3-9-1, Bunkyo, Fukui, 910-8507, Japan

mi230837@g.u-fukui.ac.jp

Abstract

In the incremental sheet forming process, it is difficult to obtain a toolpath to form the objective shape precisely due to springback. To solve this problem, a method to generate a toolpath from a product depth map was developed based on convolutional neural network (CNN) algorithm. In the proposed approach, the product depth map was defined as an image that contains z-axis height information of the product and was used as input data. The toolpath was defined as 81 two-dimensional coordinate points where a tool tip passes through during the forming process and was used as output data. The CNN model was trained using a data set consisting of 68 product shapes of truncated cones with varying wall angles, forming heights and initial diameters. All specimens were made of JIS: SUS304 sheets with a thickness of 0.3 mm and a size of 150 mm × 150 mm, and formed with a hemispherical tool with a diameter of 6 mm. To verify the effect of image resolution of the input data, three different CNN models using different input image sizes were constructed. These sizes were 50 pixels × 50 pixels, 100 pixels × 100 pixels and 200 pixels × 200 pixels, respectively.

The trained models were evaluated based on two abilities: reproducibility and generalizability. The former was evaluated by the error between the predicted toolpath from the depth map used in the model training and ground truth (the correct toolpath data corresponds to the inputted depth map). The latter was evaluated by the error between the product shape formed by the predicted toolpath from the depth map not used in the model training and the objective product shape. To compare the formed and objective product shapes, a gap volume was used.

The results showed that a usable toolpath was generated in each model. In generalizability validation, a forming accuracy of the product formed by the predicted toolpath was improved than that by the conventional one. Especially, the forming height was improved more than 30%. This indicates that the proposed CNN model successfully learned the effects of springback and generated an improved toolpath. Among the three CNN models, calculation time and GPU memory usage increased as the input image size became larger, but no significant differences were observed in the forming accuracy.

Keywords: Convolutional neural network; Depth map; Forming accuracy; Incremental forming; Springback; Toolpath generation

Yuto Koga
Osaka Institute of Technology

A Study on Suppression of Electrode Deformation in Fe/Al Resistance Heating Clinching by using W Punch-Shaped Electrode

Yuto Koga*, Eiji Shimokawa[b], Muneyoshi Iyota[b]

[a]Major in Electrical, Electronic and Mechanical Engineering, Graduate school of Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan

[b]Faculty of Mechanical Engineering, Osaka Institute of Technology, Osaka, Osaka, Japan

*m1m23417@oit.ac.jp

Abstract

Recently, resistance spot welding has been proposed for joining steel and aluminum alloys to reduce the weight of automobile bodies. However, in resistance spot welding of dissimilar materials joining, it is known that thick growth of intermetallic compound (IMC) formed at the joining interface significantly reduces joining strength. In addition, the thickness of IMC is unstable, which may lead to instability in joining strength. On the other hand, mechanical clinching provides stable joining strength by forming interlock, however, it has lower joining strength than other mechanical joining techniques. To stabilize joining strength by forming interlock, resistance heating clinching, in which the electrode of resistance spot welding is replaced by a punch/die-shaped, has been developed. The important factors for the interlock formation in this technique are temperature and push-in amount of punch-shaped electrode. However, it is known that the use of copper electrodes causes electrode deformation due to thermal factors, resulting in a decrease push-in amount of electrode. Therefore, tungsten (W), which has high hardness at high temperatures, was used for punch-shaped electrode to suppress electrode deformation and secure push-in amount of electrode. However, there are no examples of studies on the use of W punch-shaped electrodes in this technique, and whether electrode deformation can be suppressed or not.

In this research, joining characteristics including electrode deformation and joint deformation in resistance heating clinching by using W punch-shaped electrode were investigated. First, numerical simulation was performed to determine the temperatures of the electrodes and joints. The results showed that W punch-shaped electrode was able to form an interlock while suppressing electrode deformation. This is because the temperature of punch-shaped electrode increased due to the higher electrical resistance of W compared to copper, and the temperature of the joint increased due to the transmission and conduction of the temperature to the joint. Therefore, it is assumed that the promoted softening of the joints increased amount of electrode push-in to form an interlock. On the other hand, the use of W electrode suppressed electrode deformation despite the increase in electrode temperature. This is because the higher hardness of W at high temperatures compared to copper, which suppressed electrode deformation. This result suggests that one of the reasons for the interlock formation using W electrode is that the joint can be pressed in while maintaining the stiffness of electrode.

Further, experimental investigations revealed that push-in amount of electrode increased while electrode deformation was suppressed.

Keywords: Resistance heating clinching; W punch-shaped electrode; Electrode deformation; Push-in amount of electrode; Interlock formation; Temperature

Sujith Reddy Jaggannagari
Indian Institute of Technology Madras

Analysis of powder bed homogeneity in additive manufacturing through multi-layer spreading simulations

Sujith Reddy Jaggannagari[a]*, Ratna Kumar Annabattula[a], Yixiang Gan[b]

[a] Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai-600036, India.

[b] School of Civil Engineering, The University of Sydney, NSW 2006, Australia.

*Sujithreddyiitm@gmail.com

Laser Powder Bed Fusion (LPBF) is an additive manufacturing process that utilises metallic powders to produce components with high dimensional accuracy. In LPBF, powders are spread and selectively fused by a laser in a layer-by-layer manner. Powder spreading is a crucial aspect of powder bed fusion, as achieving a uniform and homogeneous powder bed under varying process conditions is critical to ensure the quality of the final components. A key challenge in LPBF is the presence of segregation phenomena and non-uniformities in the powder bed. Experimental studies have shown significant variation in particle size distribution, especially at the extreme zones of the spreading platform, indicating powder segregation. Such variations can lead to inconsistencies in laser absorption and material properties, ultimately affecting component quality. Therefore, a thorough understanding of the factors influencing powder bed uniformity is essential for optimising LPBF processes. To investigate these phenomena, scaled Discrete Element Method (DEM) simulations were conducted to model the multi-layer spreading process. The simulation results showed that the packing density of the spread layer initially increases during the spreading process and then reaches a constant value of approximately 56%, aligning well with the experimental findings. Further, the simulations highlighted spatial variations in packing density and particle size distribution in different zones of the spreading platform. This study provides detailed insights into the impact of process parameters, such as dosing factor, first layer thickness, and recoater velocity, on powder bed homogeneity. Furthermore, the effect of recoater geometry on the quality of the powder bed was investigated. These findings contribute to a deeper understanding of the powder spreading mechanism in LPBF and provide insights to enhance overall powder bed quality.

Keywords: Discrete Element Method (DEM); Dosing factor; Laser powder bed fusion (LPBF); Multi-layer powder spreading; Powder bed homogeneity; Recoater velocity

Amiya Prakash Das,
IIT Madras, Chennai

Mechanical Characterization of Manganese Rich Polymetallic Nodules

Amiya Prakash Das[a], Shakti Swaroop Choudhury[a], Amudha Krishnan[b], Ratna Kumar Annabattula[a]*
[a]Department of Mechanical Engineering, IIT Madras, Chennai, India
[b]Deep-sea Mining Research Group, NIOT, Chennai, India
*ratna@iitm.ac.in

Polymetallic nodules are mineral concretions composed of manganese, nickel, and rare earth elements, and are viewed as a key resource for green technology. Polymetallic nodules are typically mined from the seabed at exceeding depths of nearly 5-6 km. The extraction process requires crushing these nodules to facilitate transport and further processing, raising concerns about the materials' behavior under mechanical stress. A detailed understanding of their mechanical properties is essential to optimize crushing and wearing processes. This study combines compression testing, macro-indentation hardness measurements, and X-ray computed tomography (CT) to comprehensively characterize the mechanical behavior and internal structure of polymetallic nodules. The CT images offer a high-fidelity reconstruction of the nodules' internal structure and surface profiles, while the mechanical tests provide critical data on strength and hardness. This multi-faceted approach enables us to generate relevant data for finite element and discrete element simulations, for modeling the breakage and wearing behavior during mining and transport. The intended outcome will improve the design and efficiency of crushing and transport processes.

Keywords: Polymetallic nodules, particle breakage, discrete element method, deep-sea mining

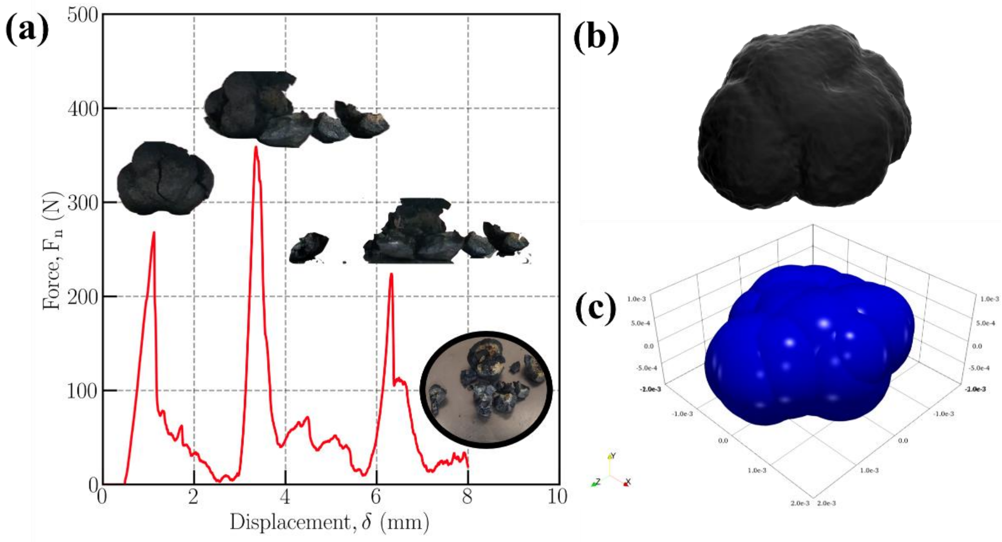


Figure 1: (a) Force-displacement curve obtained from the compression test of a polymetallic nodule, illustrating three distinct peaks corresponding to the major cracking and fragmentation events. Each peak is accompanied by an image showing the physical state of the nodule at that different phase of the compression. (b) CT scan of a pristine polymetallic nodule, for particle breakage simulations in finite element. (c) A multi-sphere approximation based on CT images, developed for discrete element simulations.

Sahil Kumar Yadav
IIT Delhi

Process parameters optimization for patterned vertical aligned carbon nano tubes growth

Sahil Kumar Yadav, Sivanandam Aravindan, P. V. Rao
Department of Mechanical Engineering, IIT Delhi India, 110016
**aravindan@mech.iitd.ac.in ,*

Carbon nano tubes (CNTs) forest was grown over silicon substrate by depositing a thin iron catalyst layer in thermal chemical vapor deposition system. Growth parameters such as growth temperature, sample positioning in quartz tube, growth time were investigated to synthesize dense vertically aligned carbon nano tubes forest. Moreover, the influence of iron catalyst thickness which gets converted into small solid nano particles during thermal annealing are studied and optimized for thin and longer CNTs. During downstream sample positioning gives the thinner and aligned tubes as compared to other locations. Optimized parameters were used to grow patterned CNTs which were made by using UV-lithography process. 20-micron and 80-micron diameter circle was fabricated with the same gap between two circles. Mix carrier gas of N2+H2 (70:30) with ethylene gas of 100 SCCM, one minutes of catalyst deposition, sample location is 100 mm away from furnace center and 850˚C growth temperature were finalized for patterned CNTs growth.

Key words- Carbon nano tube; growth temperature; iron catalyst ; UV- l lithography

Anurag Dubey

A method to identify and characterize damage in mechanical structures using dynamic parameters changes

Anurag Dubey[1,2]

(1) Post Doctoral researcher, IMT Nord Europe, 764 Bd Lahure, 59500 Douai (2) PhD, INSA Centre Val de Loire, Laboratoire de M´ecanique Gabriel Lam´e - EA 7494, 3 rue de la Chocolaterie, Blois, France

email: anurag.dubey@insa-cvl.fr

Different damage identification methods have been used to deal with structural integrity using vibration measurements. They are based on changes in dynamic characteristics such as natural frequencies, and mode shapes of the structure. The work includes the development of an algorithm based on changes in natural frequencies using finite element models of the beam structure. The algorithm employs a statistical error function using frequency shift, and the comparison between intact and damaged structures is investigated. The strategy is developed for localization and estimation of damages by only changes in natural frequencies. Damage cases are studied in different parts along the beam, with changes in the positions and sizes of damages. These normalized ratios are used to locate and estimate the extent of defects. In addition, different damage cases are investigated using the normalized ratio of natural frequencies. The results of the proposed algorithm and their performance to localize and estimate damages are analyzed. The damages are characterized by location, size, severity, and geometry type. The algorithm offers practical attention by requiring a short amount of computational time. Finally, the conclusion of the analyses indicates that the method using the FE models correctly identifies the damage.

Usha Rani S
Indian Institute of Technology Madras

A study on influence of annealing on mechanical, corrosion and wear behaviour LPBF processed Ti-6Al-4V alloy

Usha Rani S[a]*, Kesavan[b], Kamaraj[a]

[a]Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai, Tamil Nadu, India

[b]Department of Mechanical Engineering, Indian Institute of Technology Palakkad, Kanjikode, India

*usharani1011gmail.com

The Ti-6Al-4V, a dual phase alloy, owing to its outstanding properties such as low density, biocompatible and corrosion resistance, widely used for biomedical implants. Laser based powder-bed fusion (LPBF) is one among the additive manufacturing technologies, gaining its importance in the medical field by producing customized and complex geometry implants. However, the high energy laser and layer wise fusion introduces rapid thermal cycles involving steep heating and cooling rates, which results in a metastable α′ microstructure. The as-built Ti-6Al-4V consists of brittle α′ microstructure which requires post heat treatment to improve its ductility. The present study aims at analyzing the effect of annealing on evolution of microstructure, mechanical, wear and corrosion properties of LPBF Ti-6Al-4V alloy annealed at 850°C. The phase transformation of α' occurs via decomposition into stable α- and β- phases upon annealing and has a significant impact on various properties. The annealed samples showed improved in ductility of >50% with increase in β-fraction. The corrosion resistance was improved more than 50% after annealing. The wear rate after annealing decreased up to ~10%.

Keywords: Ti-6Al-4V, Annealing, Microstructure, Tensile properties, corrosion, fretting wear.

Yuki Hirata
Institute of Science Tokyo

Synthesis of 2D Nanomaterials and exploration of Van Der Waals Heterostructures Using SAHP method

Yuki Hirata[a]*, Yuya Tamura[b], Nobuharu Kajiyama[b] , Hiroki Akasaka[b] , Naoto Ohtake[b]

[a] Institute of Integrated Research (IIR), Institute of Science Tokyo, Yokohama, Kanagawa, Japan

[b] Department of Mechanical Engineering, Institute of Science Tokyo, Meguro-ku, Tokyo, Japan

*[*hirata.y.0575@m.isct.ac.jp](mailto:hirata.y.0575@m.isct.ac.jp)*

Two-dimensional functional atomic thin films (hereinafter referred to as 2D materials) are layered atomic thin films consisting of a single layer or multiple layers. Compared to bulk materials, they are extremely thin, have a large surface area, and exhibit unique electrical, optical, and mechanical properties, which are expected to bring innovative advances in fields such as next-generation electronic devices, electronics, energy conversion, and biosensing. In particular, graphene, the most famous among 2D materials discovered for the first time, has led to innovative technologies and applications due to its remarkable physical properties. Subsequent research on 2D materials other than graphene has led to the study of van der Waals heterostructures (vdWH), where these materials are combined with each other to create more functional materials. While 2D materials themselves have interesting properties, combining multiple 2D materials with various compositions, overlaps, twists, interlayer spaces, and fusions with other-dimensional materials can create a significantly broader range of possibilities. However, practical applications still face challenges such as improving material stability and reliability, establishing mass production techniques, and further research and development are expected in the future. This study aims to address these challenges by using the innovative 2D nano-material synthesis method developed by our group in recent years, the Sputter-Anneal Hybrid Process (SAHP), to realize the synthesis of unexplored nanomaterials through vdWH using graphene, hexagonal boron nitride (hBN), and other various 2D nanomaterials as building blocks, and to solve the technical challenges faced through device development.

Keywords: Hexagonal boron nitride, Graphene, van der Waals Heterostructure, SAHP

Bhartendu Mani Tripathi
Indian Institute of Technology (BHU), Varanasi, India 221005

Synthesis and Characterization of Beeswax-Lauric Acid-Graphite/Zeolite Form-Stable Composite Phase Change Material for Building Applications

Bhartendu Mani Tripathi [a*], Shailendra Kumar Shukla [b]

[a,b] Department of Mechanical Engineering Indian Institute of Technology (BHU), Varanasi, India 221005

bhartendumanitripathi.rs.mec22@itbhu.ac.in

In this study, a composite of beeswax-lauric acid and zeolite, enhanced with graphite nanoparticles (BW-LA-GNP/Z), was developed as a shape-stabilized composite phase change material (SSCPCM) using the vacuum impregnation method for application in energy-efficient building envelopes. The research aimed to explore the chemical compatibility, microstructure, and thermal properties of the SSCPCMs. The results demonstrated that no chemical reactions occurred between the raw materials, indicating a purely physical combination. Furthermore, BW-LA-GNP was successfully absorbed into the porous structure of the zeolite (Z), with no leakage observed even when the material was in its molten state. This confirmed the stability and effective containment of the components, which is crucial for thermal energy storage applications. Differential scanning calorimetry (DSC) analysis revealed that the BW-LA-GNP/Z composite has a melting point of 30.86°C and a significant enthalpy value of 210.7 kJ/kg, highlighting its potential for efficient thermal energy storage systems.

Furthermore, thermal cycling measurements demonstrated that this shape-stabilized composite PCM maintains adequate stability after undergoing 200 melting/freezing cycles. Adding GNP (carbon fiber) to the BW-LA/Z composite enhanced thermal conductivity, increasing it from 0.266 Wm^{-1} K^{-1} to 1.15 Wm^{-1} K^{-1}. This improvement in thermal conductivity contributes to the shape of stabilized composite PCMs having more suitable thermal properties and enhanced thermal stability, which is particularly beneficial for applications in energy-efficient buildings.

Keywords: Buildings; Phase Change Material; Shape stabilized; Thermal Energy Storage; Thermal characterization.

Dr. Sumangala T. P.
Vellore Institute of Technology, Vellore, Tamil Nadu, India

Effect of cobalt ferrite concentration on the EMI shielding effectiveness of cobalt ferrite/graphene-based epoxy composites

Manobalan S., Sumangala T. P.*
Vellore Institute of Technology, Vellore, Tamil Nadu, India
Sumangala.tp@vit.ac.in

This study investigates the impact of thickness and cobalt ferrite (CF) concentration on the electrical, thermal, mechanical, magnetic, and electromagnetic interference (EMI) shielding effectiveness (SE) of Epoxy/Graphene/Cobalt ferrite composite samples. Epoxy based composites were prepared via a facile casting method, with CF synthesized through hydrothermal method. To enhance the EMI shielding effectiveness, a conducting and a magnetic filler was added to the epoxy matrix. The conducting filler chosen for this study is a few layer graphene sheets. The concentration of Gr was systematically varied to achieve percolation threshold. Further the thickness of the composites with a fixed quantities of fillers were subjected to EMI Shielding measurement. The optimal thickness was chosen for the further preparation of composites with varying concentration of magnetic nanofiller (CF). The results show that thickness affects electric and magnetic loss in X-band (8.2-12.4 GHz) and Ku band (12.4-18 GHz) frequency ranges. In the study with various CF concentration, an enhancement in EMI SE was initially observed. However, higher loading (above 10 wt. %) lead to agglomeration of CF nanoparticles resulting in a reduction in EMI SE. The optimal compositions exhibited a maximum tensile strength of 21.6 MPa at 7 CF, saturation magnetization of 7.5 emu/g at 15 wt.% CF, and EMI SE values of 16 dB (7 wt.% CF, X-band) and 22 dB (10 wt.% CF, Ku-band). Overall, the composites demonstrated superior absorption properties over reflection in both frequency ranges, highlighting potential applications in EMI shielding.

Keywords: Cobalt ferrite, Graphene, Mechanical properties, Polymer nanocomposites, EMI Shielding

Puli Akshita Govind
National Institute of Technology Trichy

Fabrication of Thermoelectric Materials from High Entropy Alloys

Author1 Puli Akshita Govind[a]*, Author2 R Murgaswamy[b], Author3 Kumaran S[a]

[a]Metallurgical and Material Engineering, National Institute of Technology Trichy, Tiruchirappalli, Tamil Nadu, India

*gauriakshitapuli@gmail.com *412123005@nitt.edu

High entropy alloys (HEA), have attracted over a wide range of engineering disciplines, including the structural and power sectors due to their interesting properties. By considering their merits, in the present paper, the BiSbTeSeSn high entropy alloy was synthesised and consolidated specifically designed for thermoelectric applications. The alloy was prepared using high energy ball milling under optimized conditions in a controlled environment to achieve the desired equi-atomic composition. Powder samples were characterized by X-ray diffraction (XRD) and electron microscopy to investigate the formation of high entropy solid solution and thermal stability was assessed by differential thermal analysis (DTA). Then milled powder samples were consolidated using spark plasma sintering to achieve near theoretical density. The thermoelectric properties, including the Seebeck coefficient, electrical conductivity, and thermal conductivity of the sintered sample, were evaluated to determine the figure of merit (ZT) and power factor. XRD results **BiSbTeSeSn** confirm the formation of nanocrystalline in nature and high-entropy solid solution in the alloys. In contrast, DTA shows good thermal stability for milled powder samples. Despite the challenges often associated with multi-element systems, the study successfully demonstrates the formation of a single solid solution in the 5-element **BiSbTeSeSn** high entropy alloy. This achievement underscores the potential of HEAs to form stable, homogenous phases even with complex compositions, which is crucial for enhancing their thermoelectric properties and broadening their applicability in energy-related applications.

Keywords: High Entropy Alloy, BiSbTeSeSn, Mechanical Alloying, Spark Plasma Sintering.

Dr Pranab Jyoti Barman
Jorhat Institute of Science and Technology

Design and Treatability studies of a low-cost biofilter

Dr Pranab Jyoti Barman[a]*, Hrishikes Gogoi[a],Biswa Saikia[a]

[a] Department of Civil Enginnering, Jorhat Institute of Science and Technology, Jorhat, Assam,India

*pranabjyot@gmail.com

In India, the water shortage is one of the major issues coming from the rural areas area which necessitates water treatment options. To address these issues in rural areas there is need for conceptualizing a treatment scheme to reduce cost. Water is a fundamental source to our existence. As cities expand and population grows, the demand for water is rising. With increase in population, there will be an increase in stress on sanitation and wastewater disposal system. The benefits of well-organized water management scheme is that it offers a tool for coping with water scarcity and reduces the amount of pollution which may enter in the hydrological cycle. Untreated water contains microorganisms, chemical contaminants and physical contaminants. Our study focuses on treatment of water using naturally available materials and to reduce pollutants in laboratory scale with the help of designed biofilters.

In our study, we use low cost biofilters which consists of a bed of random or modular media through effluent percolates, scrubber, sponges and bamboo charcoal. These are advantageous over the other bio-filter media as the surface will not clog up when used with a pre-filter which may happen as in the case of ceramic material with micropores. Sponges and scrubbers help removing floating matters (solid particles) present in water. The treated water can be used for domestic purposes such as washing of utensils and clothes, bathing, and flushing as well as agricultural purposes.

Keywords: Bio-filter, microorganisms, chemical contaminants and physical contaminants

Ms. A. Madhubala
IIT Madras

Influence of parameters on synthesis of MoAlB phase alloys

A.Madhubala[1*], SGK. Manikandan[2], R. Uma Rani[3], K. Jayasankar[4], M. Kamaraj[1]

[1] Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai, India

[2] ISRO Propulsion Complex, ISRO, Mahendragiri, India

[3] U R Rao Satellite Centre, ISRO, Bangalore, India

[4] CSIR- National Institute for Interdisciplinary Science & Technology, Thiruvananthapuram, India

*balamadhu0610@gmail.com

Abstract

MAX phase alloys are atomically laminated ternary transition metal carbides/nitrides. MAB phase alloys, a derivative of MAX phases, consist of metal borides interleaved with aluminum layers, forming a diverse materials family. These alloys are not largely commercialized because of the unavailability of pure precursors and complexity of the group. Despite these challenges, MAB phase alloys have significant potential for applications in heating elements, electrical contacts, burner nozzles, and more. They display a combination of metal and ceramic properties, good oxidation resistance, high hardness, thermal stability, better radiation resistance to amorphization and damage tolerance. These alloys can be synthesized by several routes like pressure-less sintering, Hot pressing, Hot isotactic pressing, Spark plasma sintering and self-propagating high temperature synthesis. The quality and properties of MoAlB phase alloys are influenced by several key parameters like molar ratio, milling time, synthesis temperature, synthesis atmosphere, dwelling time and synthesis route. In the present work, effect of parameters like molar ratio, milling time and sintering temperature during synthesis are explored. Powder metallurgical pressure-less sintering synthesis route is selected for observing the impact of these parameters. Elemental powders are chosen as the precursors for this synthesis. The amount of aluminum present influences the amount of ternary phase formation with respect to the accompanying binaries. Sintering processes are carried out in tubular furnace under argon atmospheric to prevent oxidation and other unwanted reactions. Controlled heating and cooling rate of 5°C/min is maintained during sintering. Ball milling up to 3-4 h reduced the particle size distribution range and increasing the time further promote mechanical alloying. Sintering temperature is varied between 1050°C to 1200°C and their respective outcomes are studied. X-ray diffraction and scanning electron microscopy are used to characterize the powder precursors and synthesized powders.

Keywords: Ball milling; MAB phase alloys; MoAlB; Sintering; Synthesis.

Dr. Anup Kumar Maurya
Indian Institute of Technology Madras, Tamil Nadu, India

Optimizing Surface Roughness of LPBF-CoCrMo Alloys for Enhanced Hydroxyapatite Coatings

Anup Kumar Maurya[a]*, Murugaiyan Amirthalingam[a], Kamaraj M[a]

[a]Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Tamil Nadu, India

*anoop.ideal1@gmail.com

Laser Powder Bed Fusion (LPBF) has emerged as a highly effective technique for producing CoCrMo alloy medical implants, known for their ability to achieve complex geometries with excellent precision. However, LPBF-CoCrMo alloys still face limitations, such as insufficient corrosion resistance, wear durability, and biological inertness. Increasing surface roughness has been found as an approach for improving mechanical interlocking and adhesion in hydroxyapatite (HAp) coatings. This study aims to optimize the surface roughness of LPBF-CoCrMo alloys for HAp coatings applied via plasma spraying by controlling LPBF processing parameters to enhance coating adhesion and performance, thereby advancing the development of high-performance biomedical implants.

Keywords: Laser powder bed fusion (LPBF); Co-Cr-Mo alloy; Microstructure; Surface roughness

Krishna Kumar Yadav
Homi Bhabha National Institute, Mumbai

Process stability, microstructural and mechanical characterization of spiral-weaved 316L stainless steel CMT-WAAM deposit

Krishna Kumar Yadav[a*], Hemant Kumar[a], K.G. Pradeep[b], C. R. Das[a]

[a]Indira Gandhi Centre for Atomic Research, A CI of Homi Bhabha National Institute, Kalpakkam, Tamil Nadu, India

[b]Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai, India

*yadav.krishna054@gmail.com

Wire arc additive manufacturing (WAAM), a subcategory of direct energy deposition (DED), is widely used for printing of near net shape 3D metal object. In the present study, 316L stainless steel (SS) plate was printed using Cold metal transfer (CMT) based WAAM process using spiral weaving of the welding torch for the deposition. Further, a comprehensive study of current-voltage (I-V) waveforms stability, microstructure, and mechanical properties of as-deposited 316L SS plate were carried out. I-V waveform analysis indicated that the mean CMT cycle time near to 20 ± 6 ms and post arcing re-ignitions within 15 %. Photomicrograph of the deposited cross-section revealed presence of vermicular ferrite in the weld pool, which further grows into skeletal and lathy ferrite in the reinforcement region. Vickers hardness is observed to be175 ± 5 HV along the build direction. The average ultimate tensile strength and % elongation along the build direction were observed to be 490 MPa and 40% respectively. The use of spiral weaving technique resulted in double ellipsoidal shaped weld pool, which diverged the dendritic growth away from the weld centerline during solidification and thereby minimized the mechanical anisotropy in the properties within 7%. These variations are within acceptable limit suggesting present deposition technique can produce acceptable 3D printing.

Keywords: CMT; Mechanical properties; Microstructure; Wire arc additive manufacturing; 316L stainless steel.

Vishwas Swarnkar
IIT MADRAS

Analyze the effect of gas flow rate distribution on the melt pool morphology of the single-track experiments fabricated using LPBF.

Vishwas Swarnkar[a]*, Prof. Saravana Kumar [a b], Prof. Murugaiyan Amrithalingam[c]

[a,b]Department of Engineering Design Indian Institute of Technology, Madras Chennai 600036, India

[c]Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai-600036, India

Single-track experiments in Laser Powder Bed Fusion (LPBF) play an essential role in understanding temperature history, bead morphology, microstructure, and thus paving way to optimizing the process parameters. These experiments help understand the optimal process window devoid of porosity and balling. They could assist further in the validation of simulations. The temperature evolution for a given laser power characteristics and material also depends on the base plate preheat temperature and purged gas flow rate. Any variation in these from the set value over the build volume could potentially lead to location specific properties in printed components. Thus in this study we determine the sensitivity of the bead morphology (which is a surrogate to the thermal history) to the variation in the bove said two properties. Single-track test coupons were printed in SS316L using Intech SF1 TM LPBF machine using heat source characteristics (Laser power 200W, Scan speed 820mm/s and hatch distance of 0.11mm) and set values of base plate preheat temperature of 200°C and nitrogen purging with the blower operating at 40% rated speed. To study the effect of base plate preheat temperature and gas flow rate distribution over the build volume, an array of 3x3 substrate cube of dimensions 10x10x5 mm were placed to represent different regions in build plate printable region. Samples were etched and polished to study the sample under optical microscope at 200X and 500X magnification to measure the bead morphology. The difference in the morphology were statistically analysed to study the sensitivity.

Keywords: LPBF, single track study, gas flow rate, base plate preheat temperature, SS316-L, bead morphology.

Midhun Shah
University of Calicut

Graphite sintered $Sr_{1-x}Pr_xTiO_3$ for thermoelectric applications

Midhun Shah[a,b]*, Jamshina Sanam.P.K[a], Pradyumnan.P.P[a]

[a] Department of Physics, University of Calicut, Kerala, India

[b] Department of Physics, Farook College, Kozhikode, Kerala, India

*midhunshah@farookcollege.ac.in

Thermoelectric generators have proved their capacity to directly convert heat energy into electricity. The ability of thermoelectric materials to convert heat into electricity even at very slight temperature gradients compared to their ambient conditions makes them ideal candidates for capturing waste thermal energy. Here Pr^{3+} was introduced in the Sr^{2+} site in $Sr_{1-x}Pr_xTiO_3$ (x=0.05, 0.075, 0.10, 0.125, 0.15, 0.20) system followed by two step graphite burial sintering. Powder reduction helps to increase the carrier concentration and the doped sample pellet reduction minimizes Double Schottky Barrier (DSB) generated by strontium and oxygen vacancies at grain boundary by regulating the point defects. Samples with x≥0.10 shows splitting and asymmetry of (200) and (310) peak in XRD indicating structural transformation from cubic to tetragonal phase. XPS spectra of the samples confirmed the formation of oxygen vacancies and reduction of Ti^{4+} to Ti^{3+} induced by graphite burial sintering resulting in enhanced carrier concentration. Elimination of DSB, the resistive grain boundaries inhibiting thermoelectric performance, resulted in increased career mobility. Reduction process also promoted Pr nanoparticle precipitation which act as scattering centers to reduce thermal conductivity. A maximum power factor of 1.8 mW/mK^2 was obtained for $Sr_{0.9}Pr_{0.1}TiO_3$ samples at 673 K. Reduced thermal conductivity due to porous structure, Pr defect centers, oxygen vacancy clusters together with enhanced power factor lead to a maximum figure of merit 0.33, making this an ideal candidate as n type legs in thermoelectric generators.

Keywords: Burial sintering; Double Schottky barrier; oxygen vacancy; Seebeck coefficient; Thermoelectric figure of merit; XPS analysis.

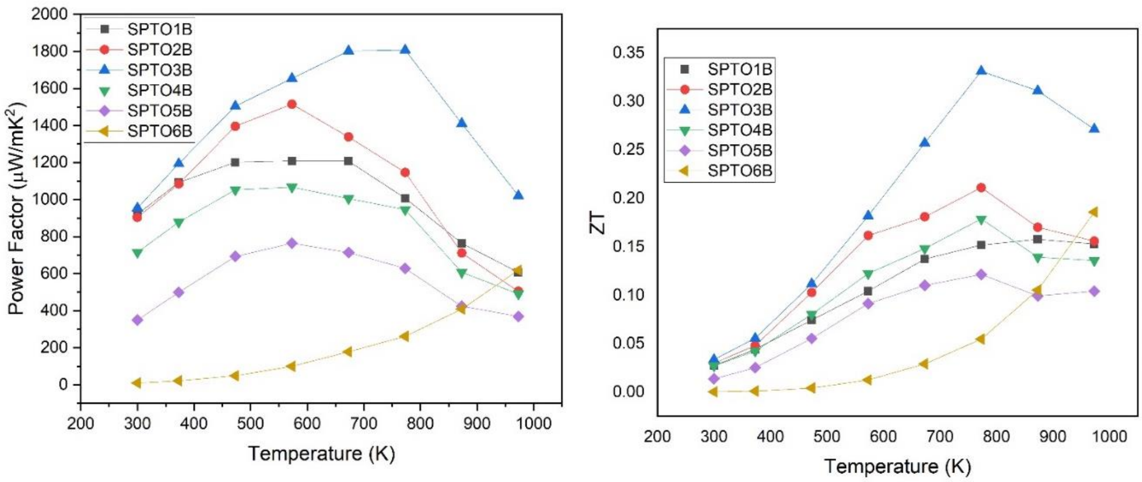


Fig 1. Temperature dependent power factor and figure of merit Pr substituted $SrTiO_3$

R. Ramesh
Indian Institute of Technology Madras

Effect of Post-Processing on Microstructure and Mechanical Behaviour of an Additively Manufactured AlSi10Mg Alloy

R. Ramesh a,b *, Saurabh Gairola b , M.Kamaraj a , R. Jayaganthan b

a Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai - 600036, Tamilnadu, India

b Department of Engineering Design, Indian Institute of Technology Madras, Chennai - 600036, Tamilnadu, India

**mm20d306@smail.iitm.ac.in*

AlSi10Mg alloy finds critical applications in the automotive sector such as cylinder heads, engine blocks and wheels. These applications often demand intricate parts that are well-suited for fabrication through additive manufacturing. In addition to tensile properties, the fatigue life of an additively manufactured AlSi10Mg ought to be ensured for its applications under dynamic loading conditions. AlSi10Mg alloy has been fabricated using laser powder bed fusion using optimized process parameters in the present work. The as-built (AB) samples, upon heat treatments (HT), were subjected to shot blasting to induce compressive stresses and improve the fatigue life of the component. The mechanical properties were assessed using tensile, hardness and high cycle fatigue and correlated with the microstructural features examined using electron back-scattered diffraction. The AB samples showed a high tensile strength of 413 MPa; however, the ductility was low (8.34% elongation). The ductility of the AB specimen was improved by 30.34% after HT (10.87% elongation) and by 38.37% after shot blasting (11.54% elongation). The fatigue life of the AB condition was improved by 15.14% after heat treatment and by 32.64% after shot blasting at a lower stress amplitude of 40 MPa. The fractography of the fatigue-tested samples was characterized by using SEM to elucidate the failure mechanisms of AlSi10Mg under high cyclic fatigue loading conditions.

Keywords: Additive Manufacturing, AlSi10Mg alloy, Tensile, Fatigue, EBSD.

Balasubramani V
Thiagarajar College of Engineering

Mechanical Characterization of Natural Epoxy composites reinforced with Banana fibre and Flax fibre

Balasubramani V[d], Swetha S[b], Sadhana Sakkthi C J[c], Sai Priyadharshini K[a]
[a]Thiagarajar College of Engineering, Madurai, Tamilnadu, India
[d]vbalasubramani1976@gmail.com

Abstract

Banana fibre is a natural, biodegradable fibre from banana plants which is popular for its better strength, biodegradability, eco-friendly and it is light weight. Flax is also a natural fibre which is also appreciated for its strength, durability and eco-friendly. Both fibre reinforced composites become better alternative material in automotive, aerospace and construction industries. Composites made from these fibres separately can be used for manufacturing body panels, chassis components, and interior parts in automotive industries. Traditional materials like steel and aluminium, while durable, contribute to high energy consumption and toxic gas emissions The motivation for this present work stems from the need to reduce reliance on energy-intensive metal production, which has substantial environmental impacts.

This work is concentrated on the natural epoxy composites made with combined banana and flax reinforcement and epoxy resin and these composites possesses better stiffness and shock absorbing properties. So, overall mechanical performance of composites is improved by providing strong adhesion providing both strength and lightweight properties. The epoxy resin has a density of 1.25$g/cm^3$and the composite plates have dimensions of 200mm × 200mm × 3mm and the plates are stacked in the following patterns: [0/0/0/0]s, [0/90/90/0]s, and [0/90/0/90]s using hand lay-up method processing method.

To evaluate the viability of the hybrid composite, mechanical testing was conducted including tensile, impact, and flexural tests. These tests assessed the material's properties. Tensile tests were performed to measure the material’s ultimate tensile strength. Impact test is influential, as they assess the composite’s ability to absorb and dissipate energy during collisions, which is crucial for the safety performance of door trims. Additionally, flexural tests were carried out to determine the material's stiffness and ability to maintain structural integrity under bending forces, ensuring that the door trim remains functional during use.

Overall, the banana-flax-epoxy composite was identified as alternative material for car door trims due to its promising mechanical properties. Tensile testing revealed maximum ultimate tensile strength of 15.4MPa. Flexural testing demonstrated a flexural strength of 501.71 MPa and a flexural modulus of 67000 GPa, highlighting its resistance to bending. Additionally, these composites exhibited an impact strength of 383.528J/m², suggesting its ability to absorb energy and protect occupants in collisions. These combined properties make the banana-flax-epoxy composite a suitable and sustainable choice for car door trims.

Keywords: Hybrid Composites; Sustainability; Natural reinforcements; Flexural strength; Impact strength; Ultimate Tensile strength.

Koilakuntla Veerendra
Indian Institute of Technology Goa

Generation of Realistic 2-Dimensional Microstructure of Fiber Reinforced Composites: Incorporating Voids, and Resin-Rich Pockets

Koilakuntla, V[a]*, Singh, H.[a]

[a]School of Mechanical Sciences, Indian Institute of Technology Goa, Farmagudi, Goa, India

Realistic micro-structures for transversely isotropic composites might include inhomogeneities of a variety of shapes and sizes, resin rich pockets as well as voids. In this regard, this work presents a methodology to develop a Representative Volume Element (RVE) which takes account of these disparate features while still preserving geometric periodicity as well as having a minimum distance between these inhomogeneities. The methodology provides for initially constructing the geometries for the inhomogeneities, pore spaces or resin rich areas, followed by a strategic process to achieve the final RVE configuration. In order to measure the randomness and quality of the synthesized RVEs, statistical measures such as the nearest neighbor distance (NND), nearest neighbor orientation (NNO), Ripley's K, G and L functions and coefficient of variation (CV) of the areas of cells formed by Voronoi tessellations are used. These measures proved the compliance to randomness of the generated RVEs.

Keywords: Fiber Reinforced Composites; Microstructure; Representative Volume Element; Resin-Rich Pockets;

C-78

Poonam
Chandigarh College of Engineering & Technology (Degree Wing), Chandigarh, India

Pre-Earthquake Rapid Visual Screening (RVS) & Earthquake Safety Assessment of RCC and Masonry buildings located in Chandigarh Area (India)

Poonam[1], Anil Kumar[1] and Dr. Rajesh Kumar[2]
Chandigarh College of Engineering & Technology (Degree Wing), Chandigarh, India
poonam@ccet.ac.in, anilkumar@ccet.ac.in

Abstract

The northern part of India, situated along the Himalayan fault line, faces heightened earthquake risk due to the convergent boundary between the Indian and Eurasian Plates, resulting in frequent seismic activity and potential large earthquakes. Rapid urbanization of this region called for rampant construction and a quick seismic assessment of these buildings may save human sufferings and economic losses. Rapid Visual Screening (RVS) of buildings is such a method which can be used to quickly assess the seismic vulnerability of buildings based on their visual characteristics. In the work presented here, RVS of 179 reinforced cement concrete (RCC) and 120 masonry buildings located in the Chandigarh (India) region was carried out. It is found 102 (57.3%) are deemed unusable for earthquake safety, while 40 (22.5%) are tagged as yellow, indicating that they can be made usable through temporary interventions or seismic retrofitting techniques. Additionally, 36 (20.2%) buildings have been classified as green and are deemed safe for use. Moreover, among the 120 masonry buildings, 91 (75.8%) have received a red tag or are deemed unusable, 14 (11.7%) require temporary intervention, and 15 (12.5%) are usable. These findings are pivotal for making critical decisions, such as determining whether buildings require further investigation, retrofitting, or reconstruction. This risk and vulnerability assessment holds the potential to safeguard human lives and mitigate the economic losses stemming from future earthquake events. As only a few (12 to 20%) of the assessed buildings are found usable, urgent steps are needed for seismic intervention to prevent the occurrence of cascading disasters and damage thereof.

Dr. Sreekanth M. S.
Vellore Institute of Technology Vellore, Tamil Nadu,

Enhanced interfacial properties of silane modified carbon fiber grafted MoS_2/MWCNTs based epoxy nanocomposites for structural application

Arun Sam Varghese [a,b], Sreekanth M. S. [a*]

[a] Department of Manufacturing Engineering, School of Mechanical Engineering, Vellore Institute of Technology Vellore, Tamil Nadu, India – 632014

[b] Department of Mechanical Engineering, Carmel College of Engineering and Technology, Punnapra, Alappuzha, Kerala, India – 688004

*sreekanth.ms@vit.ac.in

Carbon fibres grafted with multiwalled carbon nanotubes have attracted huge research interest due to their enhancement in mechanical properties caused by better interfacial interaction between epoxy resins and carbon fibres. These improved interfacial properties created due to the chemical interaction between MWCNTs and epoxies impact negatively on the fracture toughness properties of epoxies as this suppresses the interfacial failure, which acts as a major prerequisite for the toughening mechanism. The major downfall in functionalizing MWCNTs over CFs is its reduced flexural strain and increased stiffness properties. 2D molybdenum disulfide nanoparticles act as an excellent reinforcement for enhancing fracture toughness properties and can be easily functionalized over carbon fibres using silane grafting technique using (3-glycidoxypropyl) trimethoxy silane (GPTMS). MoS_2 functionalized MWCNTs act as a novel reinforcement nanoparticulate, which show promising reinforcing capabilities with excellent dispersion properties in the aqueous GPTMS solution. Carbon fibres that were grafted separately with MWCNTs, MoS_2 and MoS_2 functionalized MWCNTs nanoparticles using the GPTMS-aided silane sizing technique were used to prepare epoxy composites. Flexural test and interlaminar shear strength (ILSS) of hybrid composite samples were compared with epoxy/CF composites. Maximum ILSS and corresponding strain values of epoxy/CF composites were 35.31 MPa and 1.072% respectively. Epoxy/GPTMS CF/MWCNTs composite showed an improved ILSS value of 42.03 MPa but a reduced shear strain value of 0.98%. Epoxy/m-CF/MoS_2 composite showed a comparable ILSS value of 41.03 MPa with an improved shear strain value of 1.26%. In the case of the proposed Epoxy/m-CF/MoS_2-MWCNTs composite showed the highest ILSS value of 46.97 MPa and the highest shear strain value of 1.42%. FTIR and XPS characterizations showed new covalent bond formations between CFs, nanoparticles and epoxies. Morphological analysis using FESEM was conducted to prove the improved interfacial interaction mechanism caused by the thicker interface.

Keywords: Carbon fibre, multiwalled carbon nanotubes, molybdenum disulfide, nanocomposite, interlaminar shear strength, interface

Devi Prasad Moyye
National Institute of Technology, Trichy

Achieving superplasticity in bulk nickel based superalloy processed by multi axial forging

Devi Prasad Moyye[a], S S Satheesh Kumar*[b], D Nagarajan[a], I Balasundar[b]

[a] Metallurgical & Materials Engineering Department, National Institute of Technology, Trichy, Tamilnadu, India

[b]Near Net Shape Group, Directorate of Advanced Materials and Manufacturing Processes, Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad, India.

*ssatheesh.dmrl@gov.in

Abstract

SUPERNI-718 is a work horse nickel based superalloy widely used for producing rotating components for high temperature applications in aircraft and power generation turbines. This alloy is mainly strengthened by the combination of coherent DO22 structured γ″ (Ni3Nb) and L12 structured γ′ (Ni3Al) precipitates in face centered cubic austenite matrix. Although multiple thermomechanical processing (TMP) methods have been reported for obtaining superplasticity in sheet forms, development of novel TMP techniques are required for achieving superplasticity in bulk form which can be used a feedstock for subsequent component manufacturing. The current work is focused on devising an appropriate TMP scheme for achieving fine grained structure (microcrystalline/sub-microcrystalline) through isothermal multi axial forging. Solution treated superalloy samples (30 × 26 × 15 mm3) are subjected to isothermal multi axial forging by imposing 50% compressive deformation along each direction in a 200kN servohydraulic test facility thereby imposing an effective plastic strain of 2.1 after each cycle. The samples are deformed up to 4 MAF cycles (□ =8.4) by decrementing the deformation temperature during successive MAF cycles. The deformed samples subjected to multiple characterization techniques (light microcopy, scanning electron microscopy, and electron back scattered diffraction) revealed sub-micron sized structure of ~0.5 μm prevalent with high angle grain boundaries. The optimized MAF scheme was subsequently validated on large size billet (80 × 76 × 52 mm3) through isothermal multi axial forging in 2000T hydraulic press. In order to evaluate the superplasticity, the strain rate sensitivity (m) at various temperatures are evaluated through strain rate jump tests and the maximum estimated m was determined to be 0.43 at 850□C and lower strain rates (0.0001-0.001 s-1). The superplasticity was further validated through high temperature tensile tests and MAF processed superalloy exhibited superplasticity over temperatures ranging from 750□ to 850□C and maximum elongation to failure of ~778% was obtained at 850□C. The tensile strained samples are also characterized for microstructural evolution and the results obtained are corroborated to the superplastic deformation mechanisms.

Keywords: multiaxial forging; nickel superalloy; superplasticity

Milan Shahana
Indian Institute of Technology Madras

Microstructural Insights and Atomic-scale Analysis of Gas Atomized Inconel 718 Coatings Processed by Cold Spray and Heat Treatment

Milan Shahana[a]*, M Sadhasivam[a], K G Pradeep[a], Srinivasa Rao Bakshi[a], M Kamaraj[a]

[a]Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai, Tamil Nadu, India

*milan.shahana@gmail.com

Cold spray technology has gained significant attention for its application in repair services, offering unique advantages over other thermal spray methods due to its low-temperature process. This ensures that the coating powder most likely retains its original properties, with minimal oxidation and negligible phase changes during deposition. In this study, Inconel 718 (IN718) powder was deposited on a wrought IN718 substrate using the cold spray process. The as-sprayed coatings, characterized by highly deformed surfaces, were subjected to heat treatment at 1200°C followed by a double aging treatment. Heat treatment promoted stress relaxation and equiaxed grain growth. Transmission Kikuchi Diffraction (TKD) analysis indicated the inherent microstructural heterogeneities along the cross-section of the as-sprayed coating, highlighting distinct grain morphologies across different zones. Zone 1 displays dendrites, Zone 2 features dislocation cells, Zone 3 contains elongated cells, and Zone 4 comprises nano-grains. The highest geometrically necessary dislocation density was observed in Zone 4, with a significant proportion of recrystallized grains, attributed to rotational dynamic recrystallization. Advanced characterization techniques, including Atom Probe Tomography (APT), revealed a uniform distribution of alloying elements in the as-sprayed condition. Following heat treatment, nano-precipitates were observed, with Nickel (Ni) forming $Ni_3(Al,Ti)$ with Aluminum (Al) and Titanium (Ti), and a separate Ni_3Nb precipitate with Niobium (Nb).

Keywords: Cold spray; Coatings; Microstructure; Nano-precipitates

Farhanuzzaman Khan
Indian Institute of Technology Madras Chennai 600036, India

Influence of laser scan strategy on morphological characteristics of sheet-based Schwarz diamond TPMS lattice structure manufactured by LPBF.

Farhanuzzaman Khan[a,*], Gurunathan Saravana Kumar[a,b], Jayaganthan Rengaswamy[a.b]

[a] Department of Engineering Design, Indian Institute of Technology, Madras Chennai 600036, India

[b] Additive Manufacturing Group - Centre of Excellence in Materials and Manufacturing for Futuristic Mobility, Indian Institute of Technology Madras, Chennai, India

*ed21d001@smail.iitm.ac.in

A sheet-based Schwartz diamond (SD) lattice structure is a minimal surface-based lattice that offers higher strength and more surface area per unit volume, making it suitable for lightweight, thermal management, and bio implant applications. However, such lattices with higher surface area per unit volume are more sensitive to manufacturing deviations in terms of morphology from the design, as reported in some articles. The performance of these structures can be sensitive to such manufacturing-induced variation. To reduce the deviations during the manufacturing process of such lattice structure, one potential solution is to investigate the effect of different scan strategies, which is the focus of the present study.

In this study, SS316L powder material was used to manufacture a 0.5 mm thick SD lattice structure with a 50% volume fraction using the LPBF manufacturing process with two scan strategies, namely, bidirectional and contour offset. The energy density for both scan strategies to manufacture the lattice structure was 60.97 W/mm3. The morphological aspect of the printed lattice structure was investigated. Results showed that the surface morphology was better in the contour offset scanned part with less deviation from the designed thickness and volume fraction than in the part fabricated with a bidirectional scan strategy. The surface quality was also better in the former scanning strategy. However, powder agglomerates are more visible in the down skin and island parts of the lattice in the contour scan strategy. The printed part density was slightly lower in the contour offset compared to the scanned lattice structure. In conclusion, the morphological aspect and surface quality are improved in the contour offset scanned lattice structure, and improvement in process parameters may be required to address the powder agglomerate and part density of the SD lattice structure.

Keywords: Additive manufacturing; bi-directional; contour offset; LPBF; scan strategy; Schwarz diamond TPMS lattice

Dr Pavani Udatha
Assistant Professor

Characterization of a Palm Tree Trunk, a Natural Functionally Graded Structure

Dr. Lakshmana Rao B[a], Dr. Pavani Udatha[a]*

[a]Department of Mechanical Engineering, RGUKT, Nuzvid Campus, Andhra Pradesh, India
*pavaniudatha@gmail.com

Trees have been in existence for 370 million years. They will sustain during tough climatic conditions, such as cyclones and heavy winds due to anchored roots and woody trunk. A woody trunk is formed by secondary growth, meaning that the trunk thickens each year by growing outwards. Herbaceous plants (ferns and monocots) such as palms, bamboo, and papaya do not have secondary growth, and they may "pseudo-wood" by lignifying cells formed by primary growth. In the present work, around 60 year old palm tree (Arecaceae Family) is considered for the work and observed that variation in the type of fibers and amount of fibers along the thickness and length direction. The fibers at the centre portion (Pith) of the trunk are soft and less in number, and they are hard and more in number in the outer portion (Cambium). The physical and mechanical properties of the trunk vary along the cross-section. The tensile test samples are made at radii of 70, 80, 90, and 100 mm, and compressive test samples are made from 40 mm to 100 mm in steps of 10 mm. The density variation along the cross-section is also calculated, and the value increases from the pith to the cambium. The specific density value at 20mm, and 100 mm radius are 0.4 and 1.2, respectively. The mechanical tests are conducted as per ASTM standards using Zwick Roell UTM. The tensile and compressive results show an increase in the strength and modulus from the inner to outer radius. The cambium has maximum strength, and at the pith, strength is lower. Tree experiences bending and require good bending stiffness. The present work concludes that the trunk possesses good strength and stiffness at the outer radius and can withstand bending. Hence, the palm tree trunk has the desired properties in the required position, making it as naturally formed functionally graded structure.

Keywords: Experimental studies; Palm tree trunk; Tensile and compressive properties

Alwin B
Indian Institute of Technology-Madras

Wear behavior of T400 reinforced Ni-20Cr coatings at room and elevated temperature

Alwin B[a]*, S.R. Bakshi[a], M. Kamaraj[a]

[a]Surface Modifications and Additive Research Technologies Laboratory, Department of Metallurgical and Materials Engineering, Indian Institute of Technology-Madras, Chennai, Tamil Nadu, India

alwin47@gmail.com

The wear properties of Ni-20Cr (Nickel-20% Chromium) coatings are not appreciable due to the absence of a suitable hardening mechanism. The capability of the alloy and its application domain can be extended if its wear resistance can be improved. This work attempts to improve the wear resistance of cold-sprayed Ni-20Cr coating by reinforcing Laves phase strengthened Co-based alloy, Tribaloy 400 (T400). The composite coating was deposited by cold spraying mixtures of T400 and Ni-20Cr powder. The deposition efficiency of composite coatings was lower than that of Ni-20Cr coating. The fraction of T400 in the composite coating (maximum of ~17 %) was far less than in the powder mixture, and it increased with the increase of T400 in the powder mixture. The microhardness of the composite coating was ~50 % more than the Ni-20Cr coating due to the presence of T400 particles and the rise in hardness of its matrix. The sliding wear test of coatings showed that the wear rate of the composite coating decreased by more than ~85 % at room temperature (RT). An abrasive and tribo-oxidative wear mechanisms were commonly observed in both coating and in addition, splats' debonding also occurred in Ni-20Cr coating. High hardness, the load-bearing effect of the T400 particles, better oxide coverage, and the absence of debonding of splats resulted in better wear performance of the composite coating compared to Ni-20Cr coating at RT. At 600 °C, the wear rate of the composite coating was reduced by ~25 % compared to Ni-20Cr coating. The load-bearing effect of the T400 particles and the formation of relatively protective MML helped composite coating to perform better. A combination of abrasive and oxidative mechanisms of wear was observed commonly in the coatings.

Keywords: Cold Spray; composite coating; high temperature wear; Ni-20Cr; Tribaloy

Amiya Prakash Das,
IIT Madras, Chennai

Mechanical Characterization of Manganese Rich Polymetallic Nodules

Amiya Prakash Das[a], Shakti Swaroop Choudhury[a], Amudha Krishnan[b], Ratna Kumar Annabattula[a]*

[a]Department of Mechanical Engineering, IIT Madras, Chennai, India

[b]Deep-sea Mining Research Group, NIOT, Chennai, India

*ratna@iitm.ac.in

Polymetallic nodules are mineral concretions composed of manganese, nickel, and rare earth elements, and are viewed as a key resource for green technology. Polymetallic nodules are typically mined from the seabed at exceeding depths of nearly 5-6 km. The extraction process requires crushing these nodules to facilitate transport and further processing, raising concerns about the materials' behavior under mechanical stress. A detailed understanding of their mechanical properties is essential to optimize crushing and wearing processes. This study combines compression testing, macro-indentation hardness measurements, and X-ray computed tomography (CT) to comprehensively characterize the mechanical behavior and internal structure of polymetallic nodules. The CT images offer a high-fidelity reconstruction of the nodules' internal structure and surface profiles, while the mechanical tests provide critical data on strength and hardness. This multi-faceted approach enables us to generate relevant data for finite element and discrete element simulations, for modeling the breakage and wearing behavior during mining and transport. The intended outcome will improve the design and efficiency of crushing and transport processes.

Keywords: Polymetallic nodules, particle breakage, discrete element method, deep-sea mining

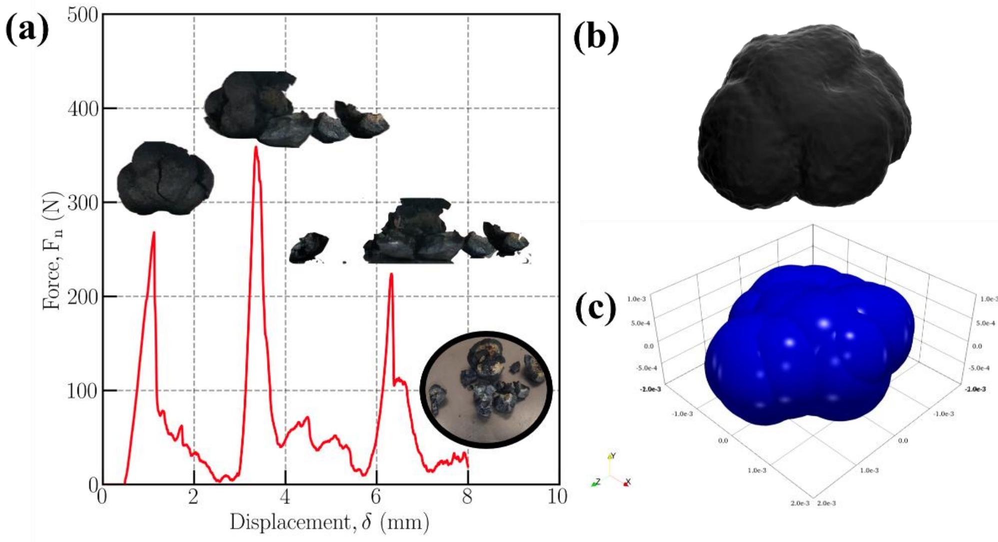


Figure 2: (a) Force-displacement curve obtained from the compression test of a polymetallic nodule, illustrating three distinct peaks corresponding to the major cracking and fragmentation events. Each peak is accompanied by an image showing the physical state of the nodule at that different phase of the compression. (b) CT scan of a pristine polymetallic nodule, for particle breakage simulations in finite element. (c) A multi-sphere approximation based on CT images, developed for discrete element simulations.

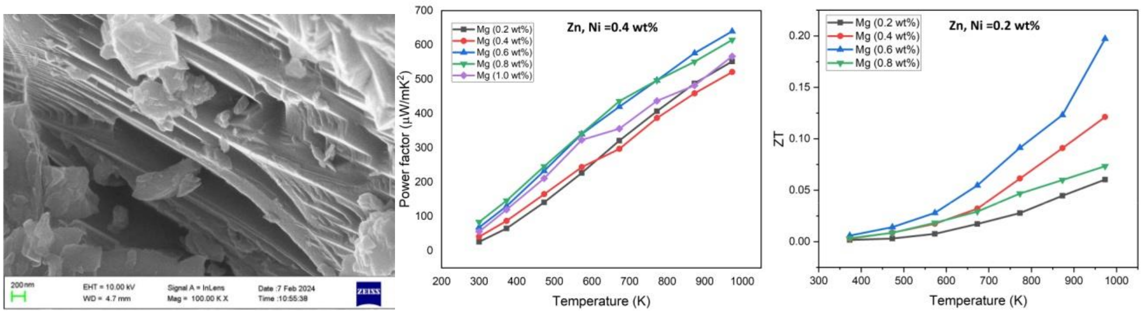
Jamshina Sanam P.K
University of Calicut

Designing Low Band Gap high performing Thermoelectric Material of $CuCrO_2$ via multi cation doping for Synergistic Photovoltaic Energy Conversion

Jamshina Sanam P.K[1*], Midhun Shah [1, 2], P.P.Pradyumnan
[1]Department of Physics, University of Calicut, India
[2]Department of Physics, Farook College, India
*jamshinasanampk@gmail.com

Abstract

Thermoelectric (TE) materials with lower band gaps present a promising avenue for enhancing the efficiency of photovoltaic (PV) systems through hybrid TE-PV integration. These materials improve overall solar energy utilization by effectively capturing both IR spectrum and waste heat. In our study, we have introduced three different cations (Zn, Ni, and Mg) into the Cr^{3+} sites of $CuCrO_2$, resulting in the formation of a layered structure with interlamellar pores. These structural changes are a direct consequence of the diffusion of the doping cations. The analysis using nitrogen adsorption/desorption isotherms reveals that the material contains a combination of mesopores and macropores, with pore diameters ranging from 10 to 70 nm. This unique microstructure, facilitated by the Kirkendall effect and nanopore formation, significantly impacts thermal conductivity. As shown in FESEM images, the presence of nanopores disrupts phonon movement, which effectively reduces the thermal conductivity to 2.4 W/mK at 973 K. The material also exhibits high electrical conductivity of 5265 S/m and a Seebeck coefficient of 400 µV/K, leading to an exceptional power factor of 640 µW/mK² and a figure of merit (ZT) of 0.24 at 973 K. The optical properties, as determined by UV-Vis spectroscopy, show a reduced optical band gap of 2.38 eV. This lower band gap enhances the material's ability to absorb a wider range of wavelengths, making it particularly suitable for hybrid TE-PV systems. In such systems, the PV cell converts sunlight into electricity, while the TE material utilizes the residual heat or absorbed infrared (IR) radiation to generate additional electrical power. This dual-function capability allows for a more efficient conversion of solar energy, optimizing overall system performance and making the material an excellent candidate for advanced energy harvesting applications.



Keywords: Band gap; Kirkendall effect; Nano pore; Optical properties; thermal conductivity;

Vanguri Premrajkumar
Rajiv Gandhi University of Knowledge Technologies, Nuzvid campus

Effect of various supplementary Cementitious Materials on the properties of Pervious Concrete

Vanguri Premrajkumar[a]*, Amarendra Kumar Sandra[b], SSSV.Gopala Raju[c], Yatin Chaudhary[d], Singamsetti Bobby Sathish[e]

[a]Department of Civil Engineering, Rajiv Gandhi University of Knowledge Technologies Nuzvid, Andhra Pradesh, India

[d]Rigid Pavement Division, Central Road Research Institute, New-Delhi

*premrajkumar.vanguri@rguktn.ac.in

Pervious concrete, characterized by its high porosity and permeability, has gained significant attention due to its potential to mitigate urban stormwater runoff and enhance groundwater recharge. This study investigates the effects of incorporating various supplementary cementitious materials (SCMs), namely Silica Fume (SF), Fly Ash (FA), and Ground Granulated Blast Furnace Slag (GGBFS), on the mechanical, hydrological, and durability properties of pervious concrete to improve its strength and performance. The research objectives involve examining the influence of different SCMs on both conventional pervious concrete and modified pervious concrete. The investigation focuses on the effects of single SCM combinations with cement replacement levels at 5% and 10%. For dual SCM-modified mixes, the replacement levels are at 20% to 30% (SF5FA15, SF10FA20, SF5GB15, SF10GB20, FA10GB10, FA15GB15). The mechanical properties include compressive strength, flexural strength, and split tensile strength were examined. Additionally, hydrological properties such as Falling Head Permeability, Infiltration Rate, and Clogging Resistance are observed to assess the material's water permeability and drainage capabilities. Durability aspects are also explored through water absorption and abrasion resistance tests.

It is observed that a significant enhancement in strength was attained with the control mix when compared with the modified pervious concrete mixes. Notably, the combination of silica fume and GGBFS demonstrated promising results in terms of improving strength properties. The hydrological properties showcased favorable outcomes across all mixtures, and results indicate that SCMs have a limited impact on permeability characteristics.

Keywords: Pervious concrete; Silica fume; Fly Ash; GGBFS; SF5FA15; SF10FA20; SF5GB15; SF10GB20; FA10GB10; FA15GB15; Compressive Strength; Flexural Strength; Split Tensile Strength; Water Permeability; Density; Porosity; Abrasion Resistance; Clogging Resistance.

Deepak K Pawar
IIT Madras

Investigating Contact Force Models in Drained Triaxial Compression of Granular Materials: Insights from DEM Simulations

Deepak K Pawar*, Ratna Kumar Annabattula, and Narasimhan Swaminathan

Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai 600036, India

Granular responses under drained triaxial compression were investigated through Discrete Element Method (DEM) based simulations employing linear and nonlinear contact force models, utilizing the open-source DEM tool LIGGGHTS[1]. The effects of various micro-mechanisms of contact force models were analyzed to evaluate their influence on the behavior of the granular material.

The results indicated that tangential interactions had a more significant impact on deviatoric stress than normal interactions. Furthermore, the study did not observe any substantial effect of the coefficient of restitution, rolling friction and damping coefficients on deviatoric stress. However, the introduction of rolling stiffness resulted in distinct changes in the granular response, suggesting the critical role of rolling frictional forces in the granular response of particle-based materials.

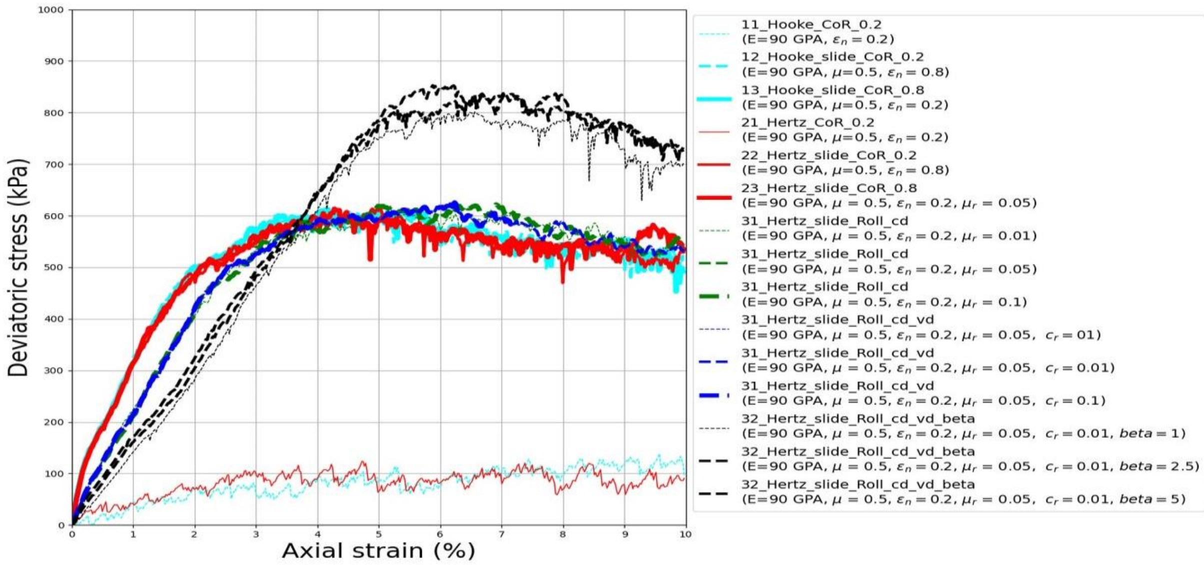


Figure 1: Deviatoric stress (vs axial strain) from a triaxial compression simulation of 5,000 particles (Lithium based pebble) for different contact force models with a 400 kPa confinement stress.

Keywords: Granular material, LIGGGHTS, Contact force model, Rolling friction

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Historical Sights & Beach Delights

"Unity in diversity is India's strength and discipline is the glue that binds us together." - Sardar Patel