

DEPARTMENT OF MECHANICAL ENGINEERING
TECHNICAL MAGAZINE
ACADEMIC YEAR 2024-2025 - ODD SEMESTER

Issue 1 (Dec 2024)



Prof. V. Sureshkumar
Head of the Department

"Founded in 2009, Mechanical Engineering is a foundational and versatile branch of engineering dedicated to the study, design, and development of mechanical devices and systems. Its primary focus lies in innovating and optimizing processes and technologies to enhance societal systems and address real-world challenges. The Department of Mechanical Engineering, one of the institute's earliest and most esteemed departments, was established with a visionary goal: to achieve excellence in the field by nurturing skilled, knowledgeable, and confident graduates who are well-prepared to tackle the evolving demands and challenges of the future."

VISION AND MISSION OF THE DEPARTMENT

VISION

To endeavor the excellence in Mechanical Engineering by producing competent and confident graduates to face the future challenges.

MISSION

DM 1: Provide transformative education and improve students' skills to face the global challenges in Mechanical and Allied Engineering.

DM 2: Nurture innovation, attitude, creativity, core competency and serve the society through innovative solutions and products.

DM 3: Inculcate real world challenges, emerging technologies and endeavor the students to become entrepreneurs or employable.

Program Educational Objectives – PEOs

PEO I: Graduates shall excel in the field of design, thermal, materials and manufacturing, as successful engineers or researchers or as entrepreneurs.

PEO II: Graduates will analyze problems, design solutions and develop products as a team member in advanced industrial projects.

PEO III: Graduates shall have professional ethics, team spirit, life-long learning, good oral and written communication skills and adopt corporate culture, core values and leadership skills.

Program Specific Outcomes – PSOs

PSO1: Professional skills: Students shall understand, analyze, design and develop integrated equipment, thermal devices and composite components manufacturing.

PSO2: Competency: Students shall qualify at the State, National and International level competitive examination for employment, higher studies and research.

Program Outcomes - POs

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as,

being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

MESSAGE FROM THE EDITORIAL TEAM

"In the fast-paced world of technology, staying ahead means never topping your learning journey. This issue dives deep into how upskilling and embracing new challenges can pave the way to innovation and success. We hope it inspires you to take that next big step."

– Editorial Team

"Every illustration, every layout tells a story. As you explore this issue, let the visuals guide you through the innovative concepts and inspiring journeys we've highlighted."

– Design Team

Chief Editor: Prof V.Sureshkumar, HoD/Mech

Faculty Advisors: Prof O. Sathish, AP/Mech,
Prof P. Sathish, AP/Mech,
Prof B. Sudhakar, AP/Mech,

Student Editors: Mr.C. Gowtham, IV/Mech
Mr.R. Kamesh, III/Mech
Mr.M. Rajesh Kanna, II/Mech

Design Team: Prof O. Sathish, AP/Mech,
Mr.S. Santhoshkumar, III/Mech
Mr.M. Lokesh, II/Mech

Table of Contents:

S.NO	Topics	Page No
01	THE MODERNIZATION OF INVESTMENT CASTING, A TIME-HONORED TECHNIQUE	01
02	ELECTROPOLISHING'S ROLE IN ENHANCING METAL PROPERTIES	03
03	PLASTIC WELDING EXPLAINED: TECHNIQUES AND INDUSTRIAL APPLICATIONS	05
04	WELDING JOINT TYPES AND THEIR INDUSTRIAL APPLICATIONS	07
05	ENHANCING METAL WITH BLACK OXIDE COATING	09
06	PRECISION TECHNIQUES IN SHEET METAL FABRICATION-SHEARING AND BLANKING	10
07	EXTENDING METAL LIFE THROUGH ADVANCED GALVANIZING PROCESSES	12
08	ENHANCING ALLOY PERFORMANCE THROUGH PRECIPITATION HARDENING	14
09	METAMATERIAL MARVEL: KIRIGAMI CUBES UNLOCK THE FUTURE OF MECHANICAL COMPUTING	16
10	JOURNEY TO QUANTUM SUPREMACY: FIRST STEPS TOWARD REALIZING MECHANICAL QUBITS	19
11	NEW METAMATERIAL FEATURES MECHANICAL PROPERTIES THAT CAN BE REPROGRAMMED	21
12	MIT ENGINEERS LOOK TOWARD ALL-SOLID LITHIUM BATTERIES	23
13	FOLDING THE FUTURE: HOW ORIGAMI MODULES ARE REDEFINING CONSTRUCTION	28

14	INNOVATIVE NEW SCALE ARMOR DESIGN INSPIRED BY CHITON MOLLUSK	32
15	ENGINEERED CAPSULE THAT BUCKLES UNDER PRESSURE	35
16	JAPANESE SCIENTISTS UNVEIL GAME- CHANGING 3D PRINTING BREAKTHROUGH FOR LIGHTWEIGHT CARS	39
17	OVERCOMING CHALLENGES: LASER POWDER BED FUSION (L-PBF)	41

THE MODERNIZATION OF INVESTMENT CASTING, A TIME-HONORED TECHNIQUE



Rubber molds for investment casting

Investment casting, often known as precision casting or lost wax casting, is a revered and age-old technique with a rich historical lineage tracing back to 3700 B.C. Originating in the Levant region for crafting intricate jewelry and idols, this method was later adopted by ancient civilizations such as Harappa, Mesopotamia, and the Egyptians, evidencing its enduring relevance and versatility.

Modern investment casting has evolved, integrating cutting-edge technologies like CAD/CAM, additive manufacturing, and real-time monitoring to enhance efficiency, consistency, and affordability. This process is pivotal in industries where precision is paramount—such as aerospace, automotive, energy, defense, and chemicals—demonstrating its broad applicability and critical role in manufacturing complex and detailed components.

The essence of investment casting lies in its meticulous eight-step process. It begins with creating a master pattern, typically using modern 3D printing to ensure precision. This pattern creates a wax model, which is then coated with a ceramic material to form a robust shell. Once the wax is melted, molten metal is poured into the ceramic mold. After cooling, the ceramic shell is broken away, revealing the cast metal, which is then subjected to various post-processing techniques to achieve the desired finish and specifications.

This method is highly valued for producing components with exceptional dimensional accuracy and smooth surface finishes using a wide range of metals like stainless steel, aluminum, and bronze. Despite its advantages, investment casting requires significant process control and can be cost-prohibitive for low-volume productions due to its extensive and detailed procedural steps.

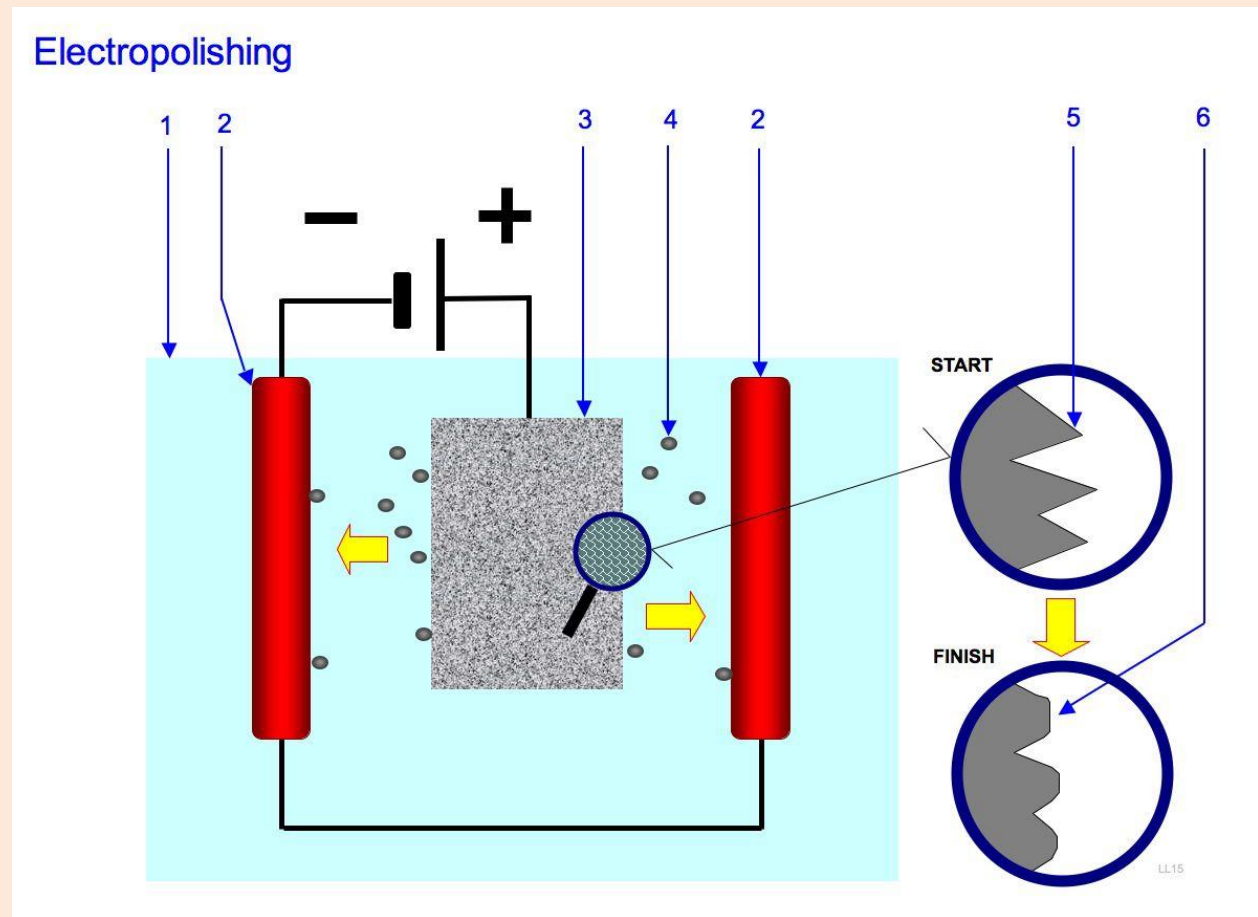
Investment casting's refined capabilities make it an optimal choice for manufacturing complex shapes with high dimensional accuracy, which is crucial in safety-critical applications. The components produced, ranging from turbine blades and firearm components to intricate jewelry, underscore its versatility and capability to meet rigorous industry standards.

However, like any manufacturing process, investment casting comes with its limitations. The complexity of managing numerous variables, the high costs associated with small production runs, and the challenges in casting internal cavities must all be carefully managed to exploit the full benefits of this ancient yet advanced technology.

The fusion of historical craftsmanship with modern technology in investment casting preserves this traditional method and enhances its application across various high-tech industries, ensuring its place as a cornerstone in modern manufacturing. As technology progresses, investment casting is poised to become even more precise and efficient, opening new possibilities for manufacturing excellence.

– **CHANDRU B, II-YEAR/MECHANICAL**

ELECTROPOLISHING'S ROLE IN ENHANCING METAL PROPERTIES



Electropolishing is a crucial surface-finishing process used extensively in manufacturing to enhance the appearance, corrosion resistance, and functionality of metal parts. This electrochemical process not only refines the metal's surface roughness but also improves its corrosion resistance significantly, delivering a smooth, shiny finish.

When metal components come off the production line, they often possess imperfections from previous manufacturing stages. Electropolishing, also known as anodic polishing, effectively addresses these issues by using electricity to remove a controlled thin layer from the surface of conductive metals. This removal not only eliminates discoloration and embedded foreign materials but can also deburr sharp edges, as seen in medical applications like hypodermic needles. The typical removal depth ranges from 8 to 20 micrometers, although it can go up to 40 micrometers depending on the application.

The process begins with meticulous surface preparation where the metal is cleaned to remove contaminants that could interfere with the uniformity of the

electrical current. Following this, the metal, now acting as an anode, is subjected to electrolytic polishing where it is immersed in a chemical bath and an electrical current is applied. The positively charged metal ions are drawn away from the surface, smoothing out microscopic imperfections.

Post-treatment involves cleaning the metal to remove any byproducts formed during the electropolishing process. This ensures the surface is not only visually appealing but also free from potential corrosion and staining issues. This step is critical in maintaining the quality and durability of the finish.

Unlike electroplating, which adds material to the surface, electropolishing removes material, making it effectively the reverse of the plating process. It's also considered superior to mechanical polishing as it can uniformly polish complex geometries and internal surfaces that are otherwise difficult to reach.

In practical applications, electropolishing is invaluable across various industries. In the medical field, it's used for cleaning and sterilizing surgical instruments to an exceptionally high standard, aiding in both performance and patient safety. The automotive industry benefits from reduced friction in moving parts, leading to improved performance and longevity of components like gears and fuel lines.

The aerospace, food and beverage, semiconductor, and nuclear industries also rely on electropolishing for its ability to produce ultra-clean surfaces that perform comparably to glass in certain applications. This versatility makes it a preferred method for treating stainless steel, particularly in series 300 and 400, where it significantly enhances corrosion resistance and aesthetic appeal.

– **DHARANEESH P, II-YEAR/MECHANICAL**

PLASTIC WELDING EXPLAINED: TECHNIQUES AND INDUSTRIAL APPLICATIONS



Plastic welding is an innovative fabrication process that joins thermoplastic materials using heat. It has become indispensable in various sectors, including automotive repairs, infrastructure building, and water tank and heat exchanger manufacturing. Unlike previous metal welding, plastic welding involves various techniques suited for different materials and applications, making it an adaptable and essential tool in modern manufacturing.

This process results in lightweight, high-quality joints, as it not only joins materials efficiently but also eliminates the need for fasteners or adhesives. Plastic welding methods include hot gas, ultrasonic, spin, and laser beam welding, each offering unique benefits. For example, hot gas welding uses a portable heat gun and plastic welding rods and doesn't require electricity, making it easier to carry around for various tasks.

Laser beam welding is known for its precision and speed. In this method, a concentrated heat source produces clean, strong welds with minimal post-weld processing. This method, however, requires significant initial investment and is not suitable for thick plastics. Ultrasonic welding, on the other hand, uses high-frequency vibrations to generate heat through friction, creating a bond without direct heat application. It is particularly effective for thin, low-moisture plastics but is limited to overlapping joint configurations.

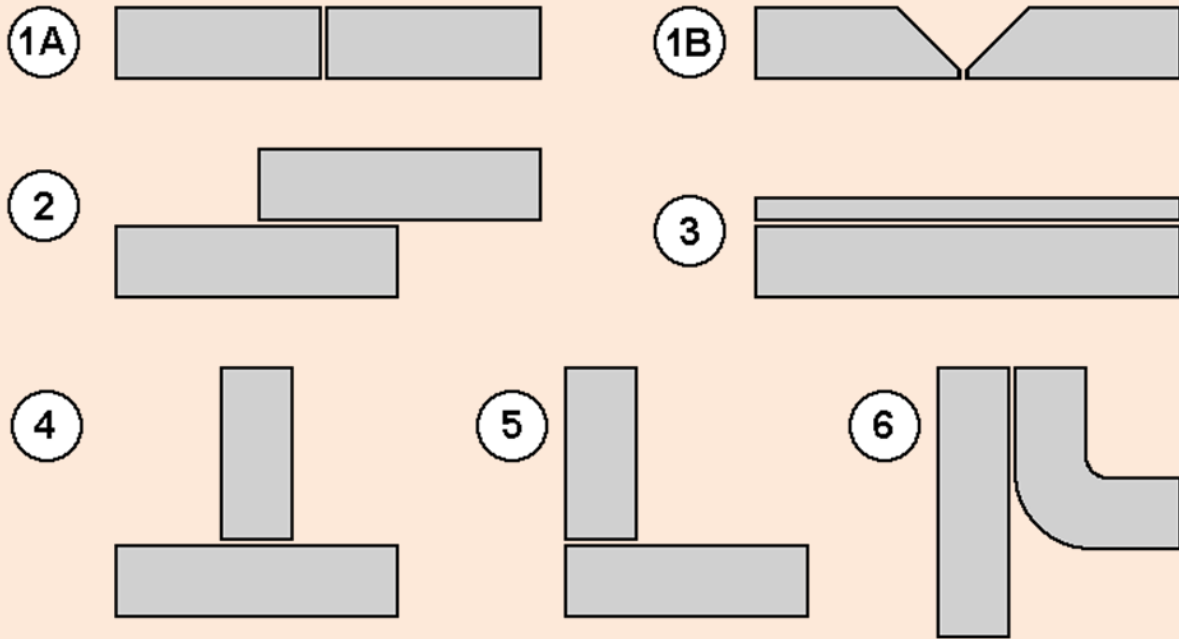
Other notable techniques are spin welding and vibration welding. Spin welding uses rotational friction to generate heat and bond materials, which are ideal for circular plastic parts. Vibration welding, which can be either linear or orbital, involves moving one plastic part against another to create friction and heat, which is suitable for irregularly shaped plastics.

The most robust and large-scale plastic welding method is hot plate welding, in which a hot plate melts the contact surfaces of the plastics. After melting, the plastics are pressed together to form a strong bond as they cool, making this method ideal for larger parts. However, this technique requires regular maintenance of the welding equipment.

Safety should be given utmost importance in plastic welding despite its advantages over traditional methods. Proper ventilation and protective clothing are essential to protect against fumes and burns. Moreover, with the advent of software-operated processes, the precision and safety of plastic welding have significantly improved, minimizing risks and enhancing quality control.

– **KRIFITH PAVITHRAN M, II-YEAR/MECHANICAL**

WELDING JOINT TYPES AND THEIR INDUSTRIAL APPLICATIONS



Joints are the backbone of every structure, holding together the skeletal frameworks of numerous mechanisms and industrial designs. The choice of welding joint significantly dictates the final product's strength, durability, and overall quality, whether it is strength-centric shipyards, precision-dependent aerospace industry, or automotive manufacturing.

Understanding Welding Joints

In simple words, welding joints are the points where two or more metal pieces are joined together. Each joint type is made to withstand specific loads and stresses, making the right choice crucial for any project. The integrity of these joints impacts everything from the design and aesthetics to the functional robustness of the structure.

Butt Joint: The Standard Bearer

Usually seen in pipe systems and frame structures, the butt joint is straightforward yet powerful. It involves aligning two pieces of metal end to end, creating a seam that may be welded without any special preparations for thinner materials. This joint type is particularly revered for its simplicity and effectiveness in providing substantial material continuity.

Tee Joint: The Intersection of Strength

Tee joints are pivotal in constructing frameworks where perpendicular connections are required as they form a T-shaped configuration. They are commonly used in building frameworks and furniture and capitalize on fillet welds to offer enhanced load distribution across the intersecting metals.

Lap Joint: Layered for Extra Security

Ideal for joining overlapping metals, lap joints maximize bond area and offer superior strength. This joint type is particularly beneficial in sheet metal applications, automotive bodywork, and any scenario with varied material thicknesses.

Corner Joint: The Angular Connector

Corner joints form an L-shape in the external corners of frames and boxes. They are integral in furniture making, frame construction, and other applications requiring a rigid right angle. Corner joints can be configured as open or closed, each providing different benefits in terms of accessibility and joint strength.

Edge Joint: The Precise Aligner

Edge joints are formed when two metal plates are placed side by side and welded at their edges. These joints are less common but invaluable in applications requiring a flat welding surface, such as fabricating metal panels or aligning two uneven edges.

Techniques and Innovations

With the introduction of advanced techniques such as laser welding, friction stir welding, and robotic welding, modern welding techniques offer higher precision and efficiency than traditional processes. These innovations allow for stronger, cleaner joints with reduced thermal distortion, pushing the industry towards more sustainable and cost-effective manufacturing methods. As materials and technologies progress, so do welding specifics, ensuring that the bonds formed are as enduring as the materials they join.

– **LOKESH M, II-YEAR/MECHANICAL**

ENHANCING METAL WITH BLACK OXIDE COATING



Black oxide coating stands as a crucial finishing method that is used in various industries to enhance both the aesthetic appeal and functionality of metal components. The process primarily serves industries requiring precision and durability. Black oxide is a chemical conversion process that enhances ferrous metals, stainless steel, copper, aluminum, and zinc without altering the physical dimensions of the base material.

This process is also known as blackening, gun bluing, or black passivating. It transforms the metal's surface into a black, durable layer only one to two micrometers thick—magnetite (Fe_3O_4). Black oxide is widely used in automotive parts, hand tools, and aerospace components due to its numerous advantages. Some of the benefits are corrosion resistance, minimized light reflection, and improved aesthetic quality.

By ensuring minimal dimensional change, the process supports parts with tight tolerances and complex shapes, which are crucial in high-precision sectors. The layer formed is robust enough to withstand harsh environments while maintaining the functionality and appearance of the component.

The process of black oxide coating involves several stages, beginning with thorough surface cleaning followed by rinsing and acid pickling to eliminate any contaminants and prepare the metal for treatment. The core of the process

is the black oxide bath, which uses chemicals like sodium hydroxide and nitrates at high temperatures to convert the surface into magnetite. After achieving the desired shade, parts are rinsed and sealed with oil or wax to enhance corrosion resistance and provide either a glossy or matte finish.

Despite its many benefits, black oxide has limitations. It offers only moderate corrosion resistance and requires additional sealing to fully protect the underlying metal. Furthermore, the black oxide coating can wear off under extreme conditions, potentially exposing the metal to environmental threats.

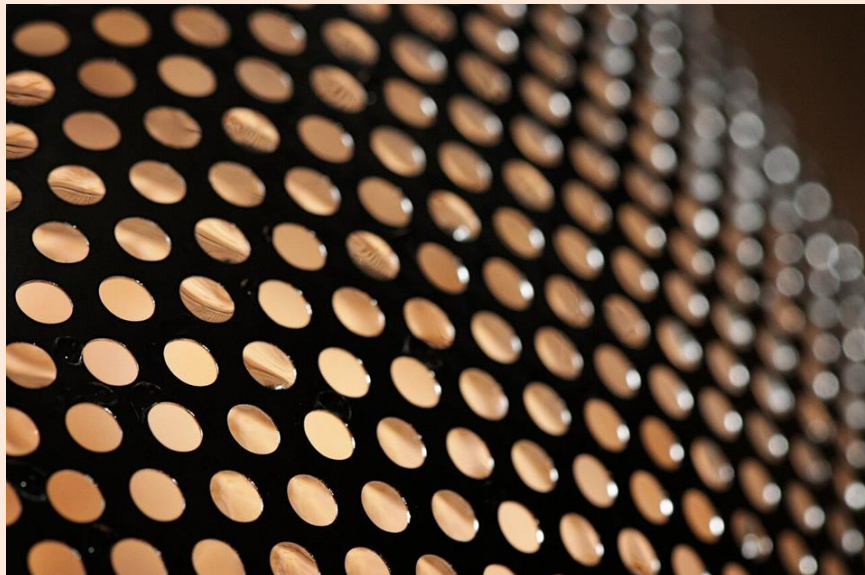
Yet, the process remains a favored option for many applications due to its cost-effectiveness and high-quality finish. Black oxide is also valued for its ability to produce a visually appealing and protective surface, minus the complications and costs of more intensive treatments like electroplating.

Black oxide processes are still evolving into more efficient coating methods. However, they remain an essential technique in metal finishing, creating a balance between performance, aesthetics, and cost.

– RAJESH KANNA M, II-YEAR/MECHANICAL

–

PRECISION TECHNIQUES IN SHEET METAL FABRICATION–SHEARING AND BLANKING



Sheet metal fabrication processes such as shearing, blanking, punching, and piercing play are imperative in crafting reliable components for several industries.

Metal Shearing and Its Industrial Relevance

In metal shearing, sheet metal is placed between two blades using guides or stops. The lower blade remains stationary while the upper blade, often powered manually, electrically, pneumatically, or hydraulically, slices through the metal. Unlike other thermal cutting processes, this shearing process maintains the integrity of the metal sheet.

Due to its setup cost and time, shearing is more suitable for larger production runs and less cost-effective for smaller batches where techniques like laser cutting are economically feasible. Metal shearing is especially beneficial for cutting soft metals like aluminum, brass, and low-carbon steel, which do not wear down the shearing blades like harder materials would.

Blanking and Punching: Precision in Metal Fabrication

Blanking is a shearing process that uses massive shearing forces to cut parts out of metal sheets with precision. It is a highly efficient method for creating specific shapes, such as automobile parts or electronic components. The desired piece is punched out, and the rest of the material becomes scrap.

Punching, however, involves creating holes or shapes on a metal sheet, and the removed material is considered waste. It is commonly used across various sectors for making simple holes and even complex patterns. Punching is cost-effective and allows for higher customization using different dies and punches.

Other Techniques in Metal Cutting

Piercing is a less common but equally important method, similar to blanking. However, it generally results in the punched-out metal being discarded as scrap. Other techniques include slotting, perforating, and notching, which cater to more specialized fabrication needs and allow for detailed customization in metal fabrication projects.

– **RANJITH KUMAR S, II-YEAR/MECHANICAL**

EXTENDING METAL LIFE THROUGH ADVANCED GALVANIZING PROCESSES



Galvanization - a critical industrial process that ensures the durability and longevity of steel and iron components by coating them with zinc. With exceptional corrosion resistance, it is an essential process for components used in harsh environmental conditions. Let us understand the mechanics, benefits, and applications of galvanizing steel.

What is Galvanization?

Galvanization involves coating a base metal with steel or iron with a protective layer of zinc to shield it from corrosive elements. Zinc is the sacrificial layer that corrodes in place of the metal to extend the material's service life. This process helps strengthen components and prepares them for moist environments where rust is a major concern.

The Galvanizing Process Explained

Hot-dip galvanizing is the most common way to apply zinc coating. Steel parts are taken for a molten zinc bath. This method is highly efficient for large-scale operations and complex structures. The components are prepared through degreasing and acid pickling to ensure that zinc forms a strong metallurgical bond with the steel.

Electrolytic galvanizing is another technique that offers precise control over the thickness of the zinc layer through electrical current. This method suits smaller parts or when a uniform coating is essential.

Benefits of Galvanizing

- Prolonged lifespan of steel structures by two to five times compared to non-galvanized steel
- Cost-effective solution that reduces the need for expensive maintenance and replacements
- Galvanized steel is ready for use immediately after processing, eliminating the need for further treatment
- The long life and recyclability of galvanized steel contribute positively to the environment

Applications Across Industries

Galvanized steel is used in the construction sector for framing, roofing, and outdoor fixtures. In transportation, it protects vehicle bodies and highway guardrails from wear and tear. The utility and telecommunications industries rely on it for poles and structural components, built to last in varying weather conditions.

Challenges and Considerations

Galvanizing offers numerous advantages, but the process must be controlled to avoid issues like zinc embrittlement or uneven coating. While it effectively protects against corrosion, it can be damaged if not handled correctly during installation.

By understanding and applying galvanization correctly, mechanical engineers can ensure the longevity and performance of their metal components.

– **RIZWANA K, II-YEAR/MECHANICAL**

ENHANCING ALLOY PERFORMANCE THROUGH PRECIPITATION HARDENING



Precipitation hardening, also known as age hardening, is an age-old heat treatment process used to improve the strength and durability of various metal alloys, including aluminum, nickel, and steel. Alfred Wilm discovered this process in 1906, which marked the beginning of precipitation hardening as a method used across various metals to improve mechanical properties like hardness, strength, and corrosion resistance.

He found that applying quenching techniques used for steels to aluminum could significantly increase the metal's yield strength. This discovery led to the development of age hardenable aluminium-copper alloys, such as Duraluminium.

This method essentially involves three key stages, namely solution treatment, quenching, and aging. These steps collectively modify the internal structure of the metal to block dislocations and prevent cracks.

The Science Behind Precipitation Hardening

Precipitation hardening works by dissolving impurities within a metal alloy and then redistributing them to form a fine precipitate phase within the metal's matrix. These precipitates act as barriers to dislocation movement, a key mechanism of metal deformation. This blockage drastically improves the yield strength and hardness of the alloy while maintaining or improving ductility and corrosion resistance.

The initial stage of the process, solution treatment, involves heating the alloy above the solvus temperature to dissolve the precipitate completely into a solid solution. The alloy is then rapidly cooled or quenched to retain this supersaturated solution at room temperature, creating a metastable phase. Aging is the final step that involves heating the alloy to a lower temperature, which allows the precipitates to nucleate and grow to harden the alloy.

Applications and Advantages

Precipitation-hardened alloys are extensively used in industries and applications where high strength-to-weight ratios are required, typically in aerospace and automotive. Critical components like turbine blades, aircraft fuselages, and engine parts are often made from precipitation-hardened aluminum alloys due to their improved strength and resistance to mechanical wear and varying temperatures.

But, the process is not just limited to enhancing strength and hardness. It also improves the corrosion resistance of alloys, which is crucial for applications involving exposure to harsh environments, such as marine hardware and outdoor sculptures.

Challenges

While precipitation hardening offers several benefits, such as increased strength and improved mechanical properties, the process requires careful control of temperature and time to avoid issues like overaging. Despite these challenges, precipitation hardening remains a valuable tool in manufacturing.

– **SAKTHI KUMAR M, II-YEAR/MECHANICAL**

METAMATERIAL MARVEL: KIRIGAMI CUBES UNLOCK THE FUTURE OF MECHANICAL COMPUTING

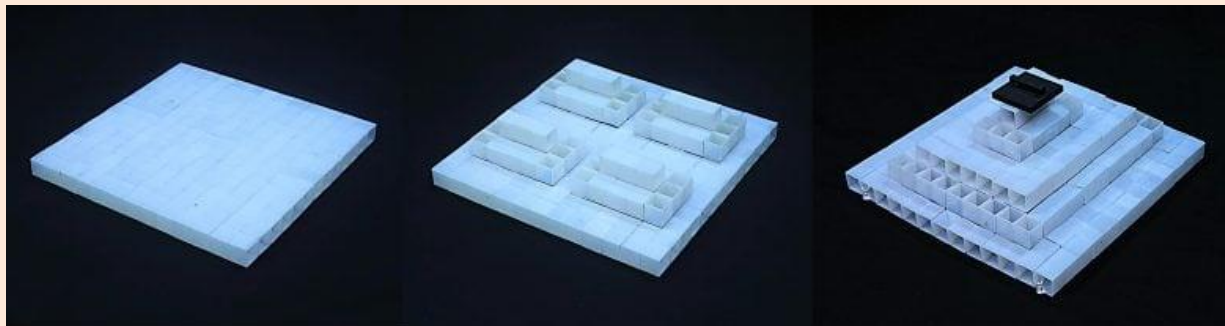


Researchers from North Carolina State University have introduced an innovative mechanical computer, inspired by the traditional Japanese art of kirigami. This new system employs an intricate assembly of rigid polymer cubes designed to store, manipulate, and retrieve data independently from electronic components. By doing this, the team aims to revolutionize mechanical computing and create a foundation for advanced data encryption mechanisms and haptic systems.

The unique architecture of the mechanical computer allows these interconnected polymer cubes to assume multiple stable states, which expands the traditional binary computing model. This evolution potentially permits additional data states beyond the conventional '0' and '1' operations, significantly broadening the computational capabilities of mechanical systems. The researchers articulate that their design enables complex structures for data storage and computation, exemplified in their published paper titled “Reprogrammable and Reconfigurable Mechanical Computing Metastructures with Stable and High-Density Memory” in the prominent open-access journal, *Science Advances*.

Mechanical computers, unlike their electronic counterparts, operate using purely mechanical components. Historically, devices like levers and gears have represented this field. The emerging wave of mechanical computing, however, explores multistable structures — items that can exist in more than one stable position. During their work, the research team was driven by dual objectives. First, they aimed to construct a stable mechanical framework efficient in data storage. Second, while their initial proof-of-concept envisaged basic binary functionalities (data represented by cubes either pushed up as '1' or down as '0'), they foresee that further complexities could emerge. With their advancements, multiple states can be realized; experiments indicated that these cubes could potentially convey up to five distinct states, paving the way for conveying values like '2', '3', and '4'.

The mechanical computer employs small, 1-centimeter plastic cubes organized into functional units of 64 interconnected elements, bringing high-density data storage into reality. This design draws directly from the principles of kirigami, which involves cutting and folding paper to create intricate structures. The researchers translate this artistic technique into three-dimensional crafting, resulting in adaptable and versatile computing units.



Jie Yin, a co-corresponding author of the study and associate professor of mechanical and aerospace engineering at NC State, expressed enthusiasm about the implications of their findings. The team's ambition extends beyond merely creating a novel computing method; they envision exploring its potential for practical applications in areas like mechanical encryption, where the absence of electronic components could enhance security, and haptic technology, where tactile feedback can be implemented using these mechanical systems.

In summary, the kirigami-inspired mechanical computer represents a groundbreaking leap in the domain of mechanical computing, promising more than just a novel data storage mechanism. With its ability to operate without electronic components, manage multiple data states, and unlock new capabilities in various applications, this innovation sets the stage for a transformative future in computational methodologies and data management technologies.

When any of the cubes in a designed functional unit are manipulated—either pushed up or down—this action alters the geometric configuration of connected cubes. This manipulation can occur through physical means or via the application of a magnetic field using a magnetic plate attached to the cube, thereby allowing for remote adjustments. The 64-cube functional units can be assembled into intricate metastructures, enhancing their capability to store larger volumes of data and perform intricate computations.

These cubes are interconnected by thin elastic bands, which allow for a flexible configuration. To modify the data stored in these functional units, a user must alter the arrangement of the cubes. This process requires pulling the edges of the metastructure, which stretches the elastic tape, enabling cubes to be pushed up or down. Once the user releases the structure, the tape contracts, stabilizing the cubes' new positions and thus preserving the adjusted data.

Potential applications of this technology are promising. For instance, it opens avenues for generating three-dimensional mechanical systems for encryption and decryption purposes, as highlighted by Yanbin Li, the lead author and a postdoctoral researcher at NC State. A unique arrangement of functional units could function as a 3D password, enhancing security measures. Significantly, the density of information that can be housed within these systems is noteworthy; using a binary framework where cubes represent two states (up or down), a simple structure of nine functional units has an astounding number of over 362,000 possible configurations.

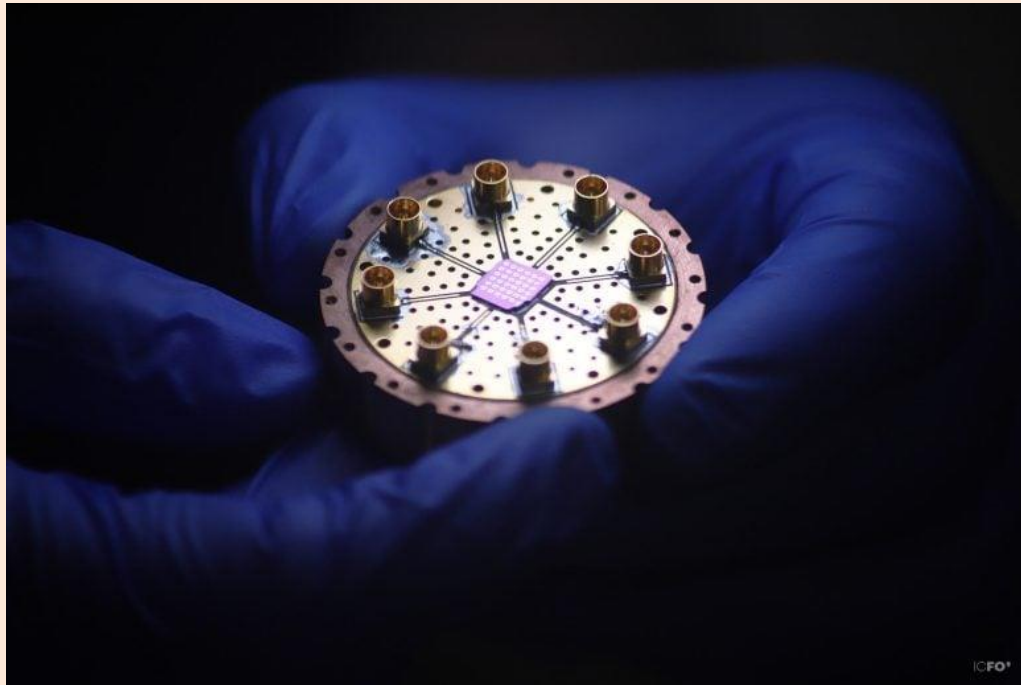
Moreover, the application is not confined to a binary system alone. Each functional unit, comprising 64 cubes, can be formed into diverse configurations, with heights reaching up to five cubes. This versatility paves the way for computing methodologies that go beyond traditional binary code. Although the current research provides a foundational understanding of these diverse

architectures, the research team acknowledges that they have yet to establish coding that utilizes these possibilities effectively. They express an eagerness to collaborate with other researchers to exploit the coding capabilities of these innovative metastructures.

In addition to the processing and storage capabilities, there is also keen interest in investigating the potential of these metastructures to develop haptic feedback systems that convey information spatially, challenging the conventional display of data as mere pixels on a screen. This could revolutionize how we interact with and experience data, providing a tangible touch to digital information.

– ABARAKEERTHIK S, III-YEAR/MECHANICAL

JOURNEY TO QUANTUM SUPREMACY: FIRST STEPS TOWARD REALIZING MECHANICAL QUBITS



A platform featuring an array of 36 mechanical resonator devices has been developed, with a nano-resonator fabricated and connected electrically within the setup. This assembly is housed inside a cryostat for measurement purposes. Quantum information (QI) processing stands on the brink of transforming technology through its extraordinary computational capabilities, security, and detection sensitivity. At the heart of quantum computing are

qubits, which serve as the fundamental units for processing quantum information. Ongoing debates continue to determine the optimal types of qubits. The surge in research and development within this field is looking for the standout system or platform among various candidates, which include superconducting Josephson junctions, trapped ions, topological qubits, ultra-cold neutral atoms, and diamond vacancies.

So far, a limited number of qubit platforms have shown promise for quantum computing, achieving milestones such as high-fidelity controlled gates, efficient qubit-qubit coupling, and robust isolation from environmental disturbances, ensuring extended coherence times.

Nano-mechanical resonators could potentially join this select group of viable platforms. These resonators act like oscillators, akin to springs or strings, generating harmonic or anharmonic sounds based on the driving force applied. A significant aspect of nano-resonators is their behavior at near absolute zero temperatures, where their energy levels become quantized, leading to characteristic zero-point motion manifested from the Heisenberg uncertainty principle. This implies that even in the ground state, the resonator remains in motion.

For a mechanical qubit to exist, it is crucial that the quantized energy levels within the resonator are not evenly spaced. The challenge lies in maintaining significant nonlinear effects while navigating the quantum regime, where the oscillator's zero-point displacement is exceedingly subtle. Successfully achieving this could enable the manipulation of the system between its two lowest quantum levels, paving the way for its use as a qubit without engaging higher energy states.

– CHARLI J, III-YEAR/MECHANICAL

NEW METAMATERIAL FEATURES MECHANICAL PROPERTIES THAT CAN BE REPROGRAMMED



Researchers have made significant strides in metamaterials, developing types that possess reprogrammable mechanical properties even after fabrication. Over the last two decades, scientists have worked on metamaterials—engineered substances that do not occur naturally, which derive their mechanical characteristics from structural design rather than chemical makeup. While their practical application in everyday items remains limited, advancements may soon change this.

Tian Chen, a postdoctoral researcher at EPFL's Flexible Structures Laboratory and Geometric Computing Laboratory, has pioneered a metamaterial designed to alter its mechanical properties post-manufacture. His findings are published in *Nature*. Chen explores whether it's feasible to change a material's internal geometry after its creation, aiming to create a single material capable of showcasing diverse physical properties such as stiffness and strength, thus reducing the need for frequent replacements. An illustrative example is provided: when spraining an ankle, a person might need a stiff splint initially, transitioning to a more flexible one as it heals. Chen's ambition is to develop a singular material that can transition between these functionalities without needing complete replacement.

The metamaterial Chen crafted comprises silicon and magnetic powder, characterizing a complex internal structure that enables variable mechanical properties. Cells within this structure function like electrical switches. By applying a magnetic field, individual cells can be activated or deactivated, thus modifying the metamaterial's internal state and, inherently, its mechanical properties. Chen likens this programmable material to computer devices like hard drives, which allow real-time writing and reading of data. His metamaterial features programmable bits, or "m-bits," which can be toggled to adjust material stiffness or flexibility according to specific requirements, offering customizable mechanical properties on demand.

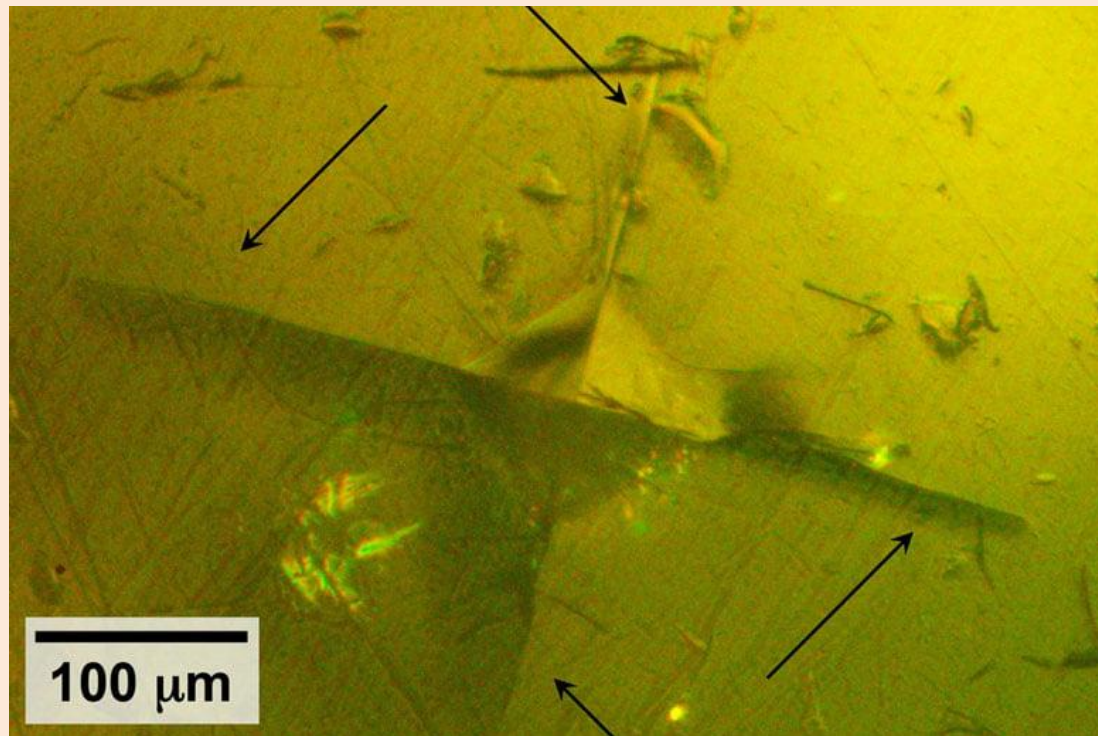
Chen's work incorporates techniques from computer science and mechanical engineering, making his project unique, according to Pauly. He dedicated significant time to empirically testing his material across different states, discovering its ability to be programmed for varying levels of stiffness, deformation, and strength.

Programmable metamaterials resemble machinery, such as robots, featuring intricate, energy-requiring electronic systems. Chen's research strives to balance the characteristics of static materials with mechanical functionality. Reis recognizes substantial potential for further studies utilizing Chen's advancements. He envisions the design of methods for constructing three-dimensional forms, given that their current work has only explored two-dimensional structures. Furthermore, there exists the possibility of downsizing the scale to develop even smaller metamaterials.

Chen's breakthrough represents a pivotal advancement, being the first instance of a truly reprogrammable mechanical metamaterial. This innovation opens a plethora of promising research pathways and potential cutting-edge applications in industry.

– **KALAISELVAN N, III-YEAR/MECHANICAL**

MIT ENGINEERS LOOK TOWARD ALL-SOLID LITHIUM BATTERIES



A team of engineers at MIT has successfully investigated the mechanical properties of a sulfide-based solid electrolyte material, aiming to assess its performance for use in batteries. The innovative study utilized a pyramidal-tipped probe to create indentations on the surface of the material, with post-test observations revealing cracks around the indentations. These cracks provide insights into the mechanical characteristics crucial for the effectiveness of solid electrolytes in battery applications. The results of this research were published in the journal *Advanced Energy Materials* and involved contributions from MIT graduate students Frank McGrogan and Tushar Swamy, along with Professor Krystyn Van Vliet and Professor Yet-Ming Chiang, alongside other team members, including an undergraduate participant from the National Science Foundation Research Experience for Undergraduates program.

Traditionally, batteries utilize two electrochemically active layers known as electrodes, separated by a polymer membrane infused with either a liquid or gel electrolyte. Recent research has shifted towards developing all-solid-state batteries, which would replace potentially flammable liquid electrolytes with solid ones. This transition could significantly improve energy density and enhance safety.

Lithium-ion batteries, which power many contemporary gadgets such as smartphones and electric vehicles, exemplify a prevalent energy-storage method. These batteries rely on liquid electrolytes to facilitate the movement of lithium ions between electrodes during charging and discharging cycles. However, such liquid electrolytes pose risks of chemical instability and flammability. By incorporating solid electrolytes instead, all-solid-state lithium-ion batteries can yield improved energy storage capacity while also minimizing risks linked to unwanted dendrite formation—tiny metallic projections that can penetrate the electrolyte and cause short circuits.

Highlighting the advantages, Van Vliet emphasizes that solid-state battery components not only enhance performance but also present safety improvements. Current lithium-ion batteries operate efficiently; yet, their dependency on liquid electrolytes creates vulnerabilities due to their instability. Solid electrolytes could mitigate these risks, resulting in smaller, lighter battery designs. The study by the MIT team marks a pivotal step towards realizing the potential of these safer all-solid-state batteries.

Throughout the research, leading-edge technology was employed to understand the mechanical dynamics of the sulfide-based electrolyte. The activation of cracks during indentation tests revealed critical information about the material's structural integrity under stress. This understanding is instrumental in developing solid electrolytes capable of handling the pressures encountered in real-world battery applications.

The overall findings indicate great promise for solid-state battery technologies, pushing the boundaries of conventional lithium-ion battery designs. As the industry faces pressing demands for higher energy efficiency and enhanced safety measures, research like this by the MIT team could forge the path toward a new generation of batteries that promise to be both safer and more effective.

In conclusion, the investigation into the mechanical properties of sulfide-based solid electrolytes represents a significant advancement towards developing robust all-solid-state batteries. The transition from traditional liquid electrolytes to solid forms holds the potential for marked improvements in battery performance and safety, addressing challenges currently associated with lithium-ion technologies. The collaboration of MIT researchers highlights

the ongoing effort to enhance energy storage solutions, thereby contributing to the future of high-tech devices and electric mobility.

The main concern regarding all-solid batteries revolves around the mechanical stresses that the electrolyte material may endure during the repeated cycles of charging and discharging. As the electrodes undergo these cycles, they expand and contract due to the movement of lithium ions within their crystal structures. This periodic dimensional change can induce high stress levels in a stiff electrolyte. If the electrolyte material is brittle, such conditions may lead to the development of cracks, ultimately hampering battery performance. Moreover, cracks can create pathways for the formation of dendrites, a problem commonly associated with liquid-electrolyte batteries. However, if the electrolyte is fracture-resistant, it may accommodate such stresses without succumbing to rapid cracking.

Traditionally, the assessment of the mechanical properties of sulfide-based electrolytes has been hindered by their extreme sensitivity to ambient laboratory air. To overcome this hurdle, the research team conducted their mechanical tests in a mineral oil bath. This approach protected the samples from chemical reactions with air and moisture, enabling the team to gather precise measurements of the mechanical properties of lithium-conducting sulfides—a promising candidate for use in all-solid-state batteries.

"There are many different candidates for solid electrolytes available," remarked McGrogan. While other research groups have attempted to study the mechanical properties of lithium-ion-conducting oxides, sulfides had received less attention despite their potential advantages in terms of efficient and rapid lithium ion conduction.

Previous efforts to understand the mechanical behavior of these sulfides involved acoustic measurement techniques, where sound waves were transmitted through the material. However, this methodology does not provide a quantifiable assessment of fracture resistance. The new study diverged from this approach by utilizing a fine-tipped probe that engaged the material directly, allowing researchers to monitor its responses and collect comprehensive data on crucial properties such as hardness, fracture toughness, and Young's modulus, which reflects the material's ability to stretch non-permanently under applied stress.

“While other research teams have focused on measuring the elastic properties of sulfide-based solid electrolytes, fracture properties have largely gone unexamined,” noted Van Vliet. The investigation into a material's fracture characteristics is essential for predicting its behavior under operational conditions, particularly whether it is likely to crack or break during battery use. This understanding is critical for the development of robust all-solid batteries capable of meeting performance and longevity expectations.

In conclusion, the exploration of sulfide electrolytes for all-solid-state battery applications reveals a complex interplay of mechanical behaviors influenced by the dimensional changes of electrodes. While challenges associated with the sensitivity of sulfide materials to environmental conditions have presented significant roadblocks, innovative testing techniques such as immersion in mineral oil have enabled researchers to obtain vital mechanical property data. By refining the assessment of fracture toughness alongside other critical properties, scientists are moving closer to unlocking the full potential of sulfides in the realm of solid-state batteries. The research work discussed highlights a significant advancement towards understanding and mitigating the risks associated with mechanical stresses, paving the way for improved battery performance and efficiency.

The research conducted by a team, including MIT scientists, uncovered that a specific material exhibits properties akin to those of silly putty or salt water taffy. This material deforms with ease under stress but can also fracture like glass when subjected to excessive stress. With a clear understanding of these mechanical properties, researchers can predict the stress threshold at which the material might break, which is crucial for designing battery systems effectively. According to Van Vliet, this knowledge allows for the calculation of the material's stress tolerance, guiding the development of battery systems that can accommodate its limitations.

However, the material's brittleness poses a challenge for its application in batteries. McGrogan explains that, despite its brittleness being less than ideal, the potential for battery use remains viable as long as the properties are thoroughly understood and factored into the design process. This adaptation is essential to ensure that the system functions effectively within the material's constraints.

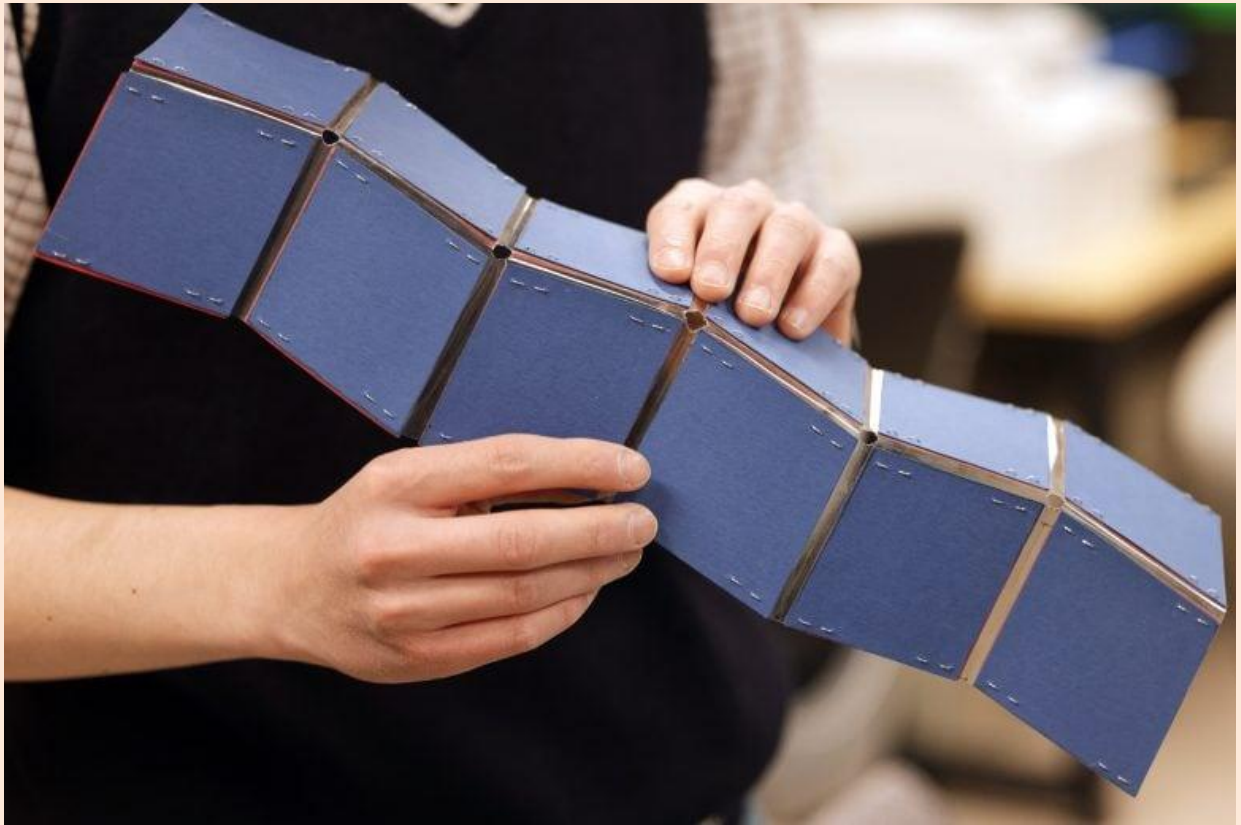
Jeff Sakamoto, a mechanical engineering professor at the University of Michigan, who was not part of the study, emphasized the importance of understanding the mechanical properties of solid-state electrolytes. He noted that the cycle life of contemporary lithium-ion (Li-ion) batteries is predominantly limited by the stability of the liquid electrolyte and its interaction with the electrodes. In contrast, he points out, the stability and durability of solid-state batteries are likely governed by mechanical degradation. This highlights the essential nature of studying solid-state electrolytes' mechanical characteristics for advancing battery technology.

Additionally, Sakamoto highlighted the advantages of lithium metal anodes over traditional graphite anodes. He noted that lithium metal anodes have the potential to significantly increase the capacity, translating to approximately a 100% increase in energy density compared to traditional Li-ion technologies. This suggests that advancements in battery materials and designs could lead to batteries with substantially greater energy efficiency and capacity.

The inclusion of MIT researchers—Sean Bishop, Erica Eggleton, Lukas Porz, and Xinwei Chen—in this work signifies a collaborative effort to understand and innovate within the field of battery technology. Their research is supported by the U.S. Department of Energy's Office of Basic Energy Science, which focuses on the chemomechanics of far-from-equilibrium interfaces. This involvement reflects the interest and importance of deeper investigation into materials that can enhance energy storage solutions, addressing the growing demand for efficient batteries in various applications.

In summary, while the research reveals that the material possesses desirable deformability and increased potential for energy density in battery applications, its brittleness must be properly managed through informed design and material understanding. The collective work aims to pave the way for solid-state batteries that can outperform existing technologies while ensuring that mechanical integrity is maintained. This research not only contributes to academic knowledge but also has significant implications for the future of energy storage systems, ultimately influencing the development of more efficient and reliable battery technologies that could benefit a wide range of industries and consumers.

FOLDING THE FUTURE: HOW ORIGAMI MODULES ARE REDEFINING CONSTRUCTION



Yi Zhu, a Research Fellow in Mechanical Engineering, showcases a novel origami design that can fold compactly to fit into a pocket while also has the capability to expand into elongated structures. This innovation, developed by engineers at the University of Michigan, demonstrates that load-bearing structures—such as bridges and shelters—can be constructed using modular origami components that can fold easily and take on various shapes.

This advancement presents significant opportunities for rapid community recovery following natural disasters, enabling the quick rebuilding of facilities and infrastructure that may be damaged or destroyed. Moreover, this technology holds promise for construction in areas previously deemed impractical, such as outer space. It also offers potential applications for temporary structures that require fast assembly and disassembly, like concert venues and event stages.

Evgueni Filipov, an associate professor in Civil and Environmental Engineering and Mechanical Engineering and a co-author of the study published in Nature Communications, emphasized the unique adaptability and load-carrying capabilities of their system, which allows the construction of structures suited for modern building practices. The origami principles facilitate the folding of larger materials into compact forms, making them easier to store and transport as modular systems become more widely adopted.

Zhu and Filipov are applying these origami principles to develop what they term Modular and Uniformly Thick Origami (MUTO), which is geared toward creating large-scale, load-bearing, adaptable structures. This work focuses on designs that can support temporary uses like concert stages or more permanent applications such as buildings and bridges in response to emergencies.

Researchers have faced challenges in creating origami structures that maintain the necessary weight capacities while also allowing for rapid deployment and flexibility. The University of Michigan engineers have developed a solution to this problem with their innovative origami system. The capabilities of this new approach suggest a future where adaptable structures can be engineered efficiently and effectively, paving the way for diverse applications in disaster recovery and space exploration.



Overall, the work being done at the University of Michigan exemplifies how integrating origami art into engineering can lead to groundbreaking developments in construction technology, expanding the potential for ingenious solutions for varied and complex problems in modern society.

The introduction of a new origami-inspired design approach has led to the development of innovative structural systems. Researchers have engineered a column measuring 3.3 feet in height that can support an impressive weight of 2.1 tons, despite its own weight of just over 16 pounds and a base footprint of less than one square foot. In parallel, they've designed a versatile package that can expand from a compact 1.6-foot-wide cube into various structures, which include a 13-foot-long walking bridge, a 6.5-foot-tall bus stop, and a 13-foot-tall column.

The breakthrough in this research stems from a fresh methodology introduced by Yi Zhu, a research fellow in mechanical engineering and the study's lead author. Zhu points out that traditional origami designs are often based on the premise that materials are paper-thin. However, to fabricate practical structures such as bridges and bus stops using origami concepts, it is crucial to

incorporate mathematical tools that accommodate material thickness right from the outset of the design process.

Evgueni Filipov, an associate professor immersed in both Civil and Environmental Engineering and Mechanical Engineering, provides further insight into the design's operational dynamics by demonstrating various folds and configurations with a smaller model in the lab. The U-M team emphasizes the necessity for uniform thickness in the construction of their origami-based designs. Other researchers have sought to increase load-bearing capability by selectively thickening materials at certain points; however, Filipov remarks that mismatches in thickness across different areas lead to bending and structural weaknesses.



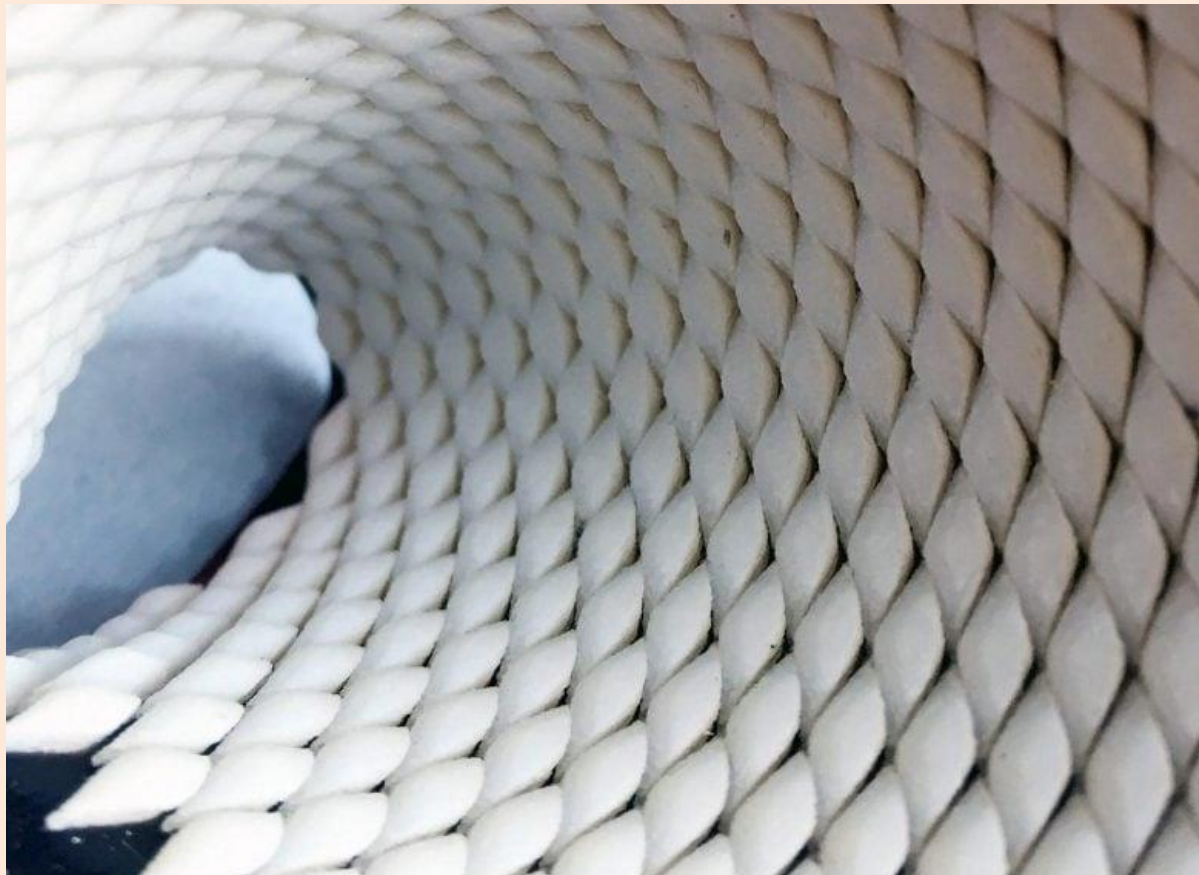
Therefore, achieving uniformity in the thickness of components is paramount and often overlooked in many current origami structures. This consistency, combined with effective locking mechanisms, ensures that loads can be evenly distributed throughout the structure, enhancing stability and performance.

The system developed by the researchers, termed the Modular and Uniformly Thick Origami-Inspired Structure, demonstrates remarkable versatility. It can

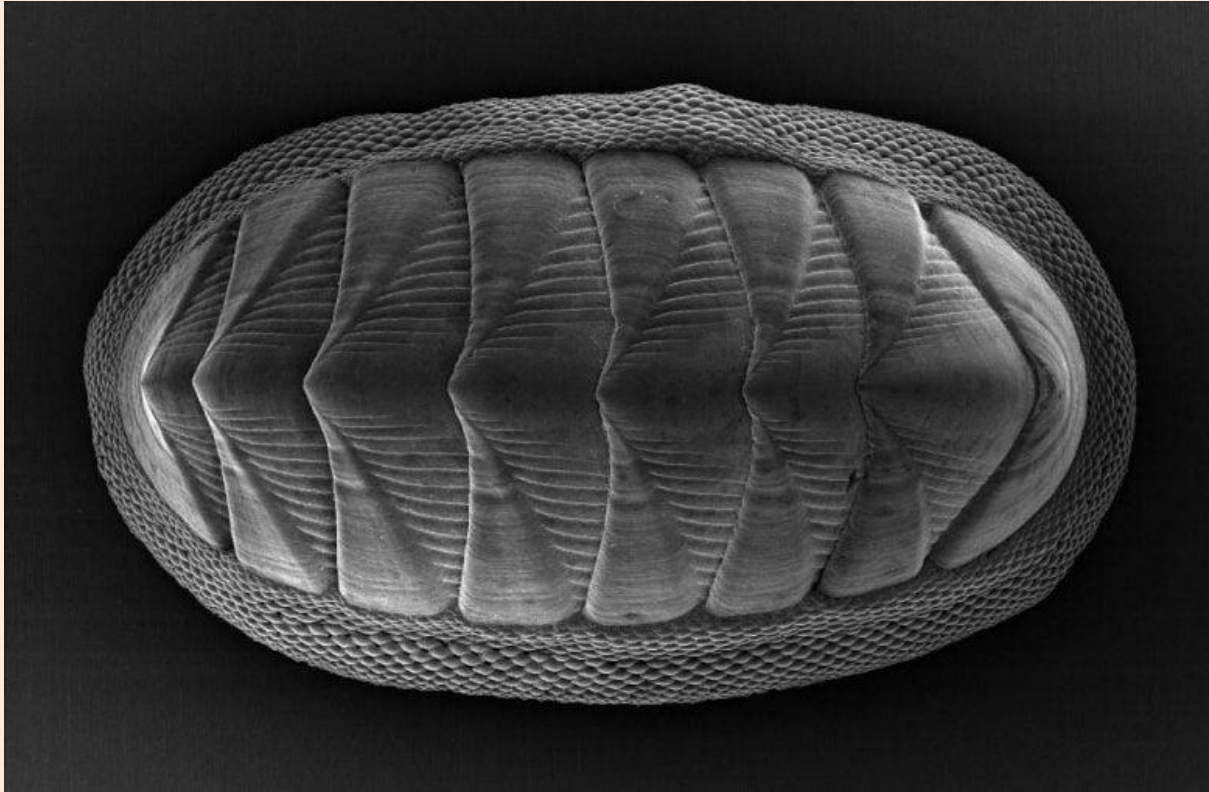
transform into an array of functional forms, spanning bridges, walls, floors, and columns, facilitating a myriad of applications. This innovative approach not only highlights the potential of origami principles in engineering but also sets the stage for future advancements in the design and construction of lightweight, yet durable, structures.

– GOVINDHARAJ N, III-YEAR/MECHANICAL

INNOVATIVE NEW SCALE ARMOR DESIGN INSPIRED BY CHITON MOLLUSK



Ling Li, an assistant professor of mechanical engineering, draws inspiration from the chiton mollusk for engineering projects due to its unique combination of flexibility and protection. Unlike other mollusks with rigid shells, the chiton features eight mineralized plates and a girdle of small scales resembling fish scales. This distinctive biological armor system provides both flexibility and protection, serving as the foundation for the innovative system Li has developed.



The chiton mollusk, measuring 1 to 2 inches and characterized by eight large plates surrounded by a flexible girdle of smaller scales, inspired a novel 3D printed armor. A study led by Li, published in Nature Communications on December 10, 2019, involved collaboration among researchers from institutions like MIT, Dana-Farber Cancer Institute, California State University, Max Planck Institute, and Wyss Institute at Harvard. Since the chiton's girdle scales had not been extensively studied, the team conducted a thorough analysis of the mollusk's material and mechanical properties. This included quantifying its internal microstructure, chemical composition, and studying the scale variations across species as well as their assembly using 3D tomography techniques.



3D printed flexible armor on broken glass.

The research team created a parametric 3D modeling methodology to replicate the geometry of individual scales, assembling them on flat or curved substrates. They utilized 3D printing to fabricate bio-inspired scale armor models, featuring rigid scales atop a flexible substrate. Li noted that these prototypes allowed for mechanical testing under controlled conditions to understand the dual protection and flexibility of the biological armor system. The scale armor functions by allowing scales to converge inward under force to form a solid barrier, while at rest, they can shift over one another for flexibility based on their shape and arrangement. Li highlighted that the organization and geometry of the scales are key to their strength. With the help of Mirzaeifar's computational modeling, the team explored how the scales lock together under critical external loads.

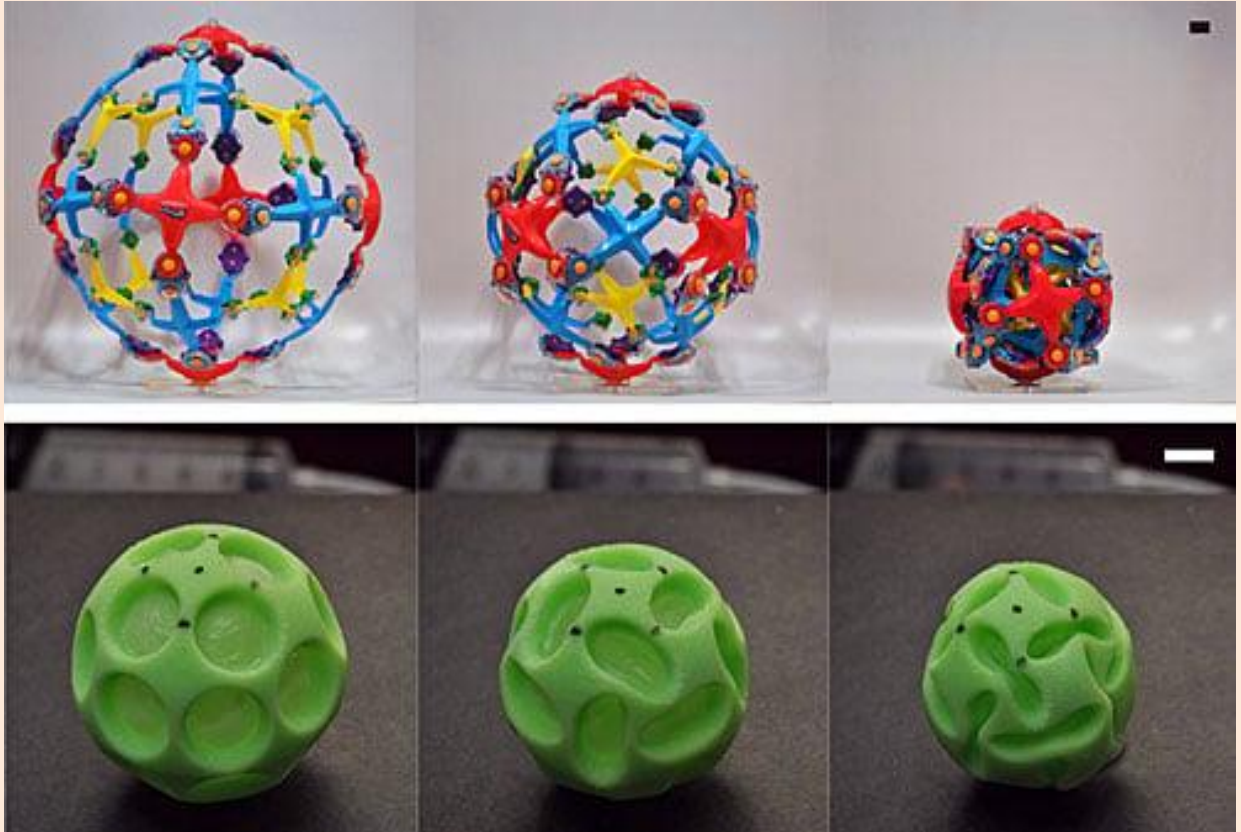
In designing place-specific armor, the size of the scales is crucial, with smaller scales providing flexibility in certain regions and larger scales offering protection in others. The collaboration aims to tailor armor for different body locations, as flexibility and protection needs vary between areas like the chest and joints. Initially funded by the Department of Defense during Li's time at

MIT, the project has continued without formal sponsorship since he joined Virginia Tech in 2017. Li expressed a pure motivation to discover multifunctional biological materials that combine flexibility and protection, a challenging task for synthetic systems. He plans to expand research beyond the biological model while conducting tests under various load conditions. While the years-long process has been lengthy, Li emphasized its unique approach, integrating fundamental biological research with bio-inspired innovation for improved armor solutions.

– NOOR MOHAMMED D, III-YEAR/MECHANICAL

ENGINEERED CAPSULE THAT BUCKLES UNDER PRESSURE

Katia Bertoldi, an assistant professor at Harvard's School of Engineering and Applied Sciences, along with postdoctoral fellow Jongmin Shim, has collaborated with MIT researchers to create an innovative capsule called the "buckliball." This one-piece silicone sphere represents the first morphable structure that utilizes buckling as a beneficial design feature, capable of reducing its size by 46%. Inspired by toys that expand and collapse, the buckliball leverages mechanisms reminiscent of natural phenomena, like the snapping of a Venus flytrap and the swelling of pollen in moisture. The research was led by Bertoldi and Pedro Reis from MIT, and their findings were published in the Proceedings of the National Academy of Sciences.



Researchers at Harvard and MIT, inspired by an expanding and collapsing toy, have designed a novel folding structure called the "buckliball," a hollow silicone sphere known for its pressure-induced buckling behavior. The name reflects both the structure's mechanics and its resemblance to buckyballs, spherical carbon molecules named after architect Buckminster Fuller. According to Katia Bertoldi, this innovation not only opens avenues for designing foldable structures across various scales but may also serve as a foundational component for creating new materials with unique properties, particularly those capable of dramatic contraction in multiple directions.

The engineers aimed to identify the simplest three-dimensional configuration that could utilize mechanical instability for reversible collapse. Initially challenged in their search, inspiration struck when one of them encountered a complex spherical toy boasting 26 solid moving components and 48 rotating hinges. This intricate design prompted the team to explore a more simplified version, leading to the creation of the buckliball, which has no moving parts. Instead, it is constructed with 24 strategically placed dimples.

When air is removed from the buckliball using a syringe, the thin ligaments connecting the dimples collapse. This collapse triggers a phenomenon described as a "cooperative buckling cascade," in which the thicker ligaments situated in rows between the dimples engage in simultaneous counterclockwise and clockwise rotations. This collaborative movement transforms the initial circular dimples into vertical and horizontal ellipses, ultimately closing them completely. As a result, the buckliball shrinks to a rhombicuboctahedron form, approximately 46 percent of its original size.

Bertoldi emphasizes that the buckliball is the first of its kind to incorporate buckling as a beneficial element in engineering design. Traditionally, buckling is associated with structural failure in civil engineering, where it is crucial to avoid buckling, particularly in columns, for safety reasons. Reis points out the paradigm shift this research represents, aiming to transform typical perceptions of failure into an advantageous feature for soft mechanical structures. The buckliball stands as a pioneering example of this approach, with aspirations for more such innovations in the future.

Morphable structures like the buckliball present a groundbreaking opportunity for diverse applications, leveraging their fully reversible collapse without any mechanical components. These innovative structures could revolutionize the design of collapsible roofs and walls for large buildings, create tiny drug-delivery systems, or enable flexible joints in robotics that require no intricate machinery. A proposed application includes a robotic arm constructed from a uniform material, with strategically crafted dimples that serve as pivot points. When activated via a pressure signal, these dimples allow the arm to bend and function effectively.

The inspiration behind this pioneering work comes partly from toys like the Hoberman Twist-O, which provided significant insights to researchers. The collaboration between Bertoldi's research group at Harvard and Reis' team at MIT has been instrumental in developing the buckliball. Bertoldi's group employs continuum and computational mechanics to explore the behaviors of soft structures, while Reis' team conducts precise lab experiments alongside mathematical analysis to uncover the fundamental physics of material mechanics. By merging advanced digital fabrication techniques, including 3-D

printing, with detailed computational assessments, they crafted objects with highly accurate geometries for their experiments.

Among the findings, Elizabeth Chen, an alumnus of the University of Michigan, identified only five spherical geometric forms capable of reversible buckling-induced collapse—one notable example being Fuller's 12-hole rhombicuboctahedron, which can transform into a cuboctahedron. Key design parameters of buckliballs include the dimensions of the dimples, thickness of the internal thin shell, and the stiffness of the material utilized in production.

Interestingly, nature has demonstrated similar principles, as observed in the way viruses operate. They can inject nucleic acids into host cells through a reversible transformation that relies on opening or closing 60 holes in response to shifts in acidity, akin to the concept of reversible collapse seen at the nanoscale in artificial applications.

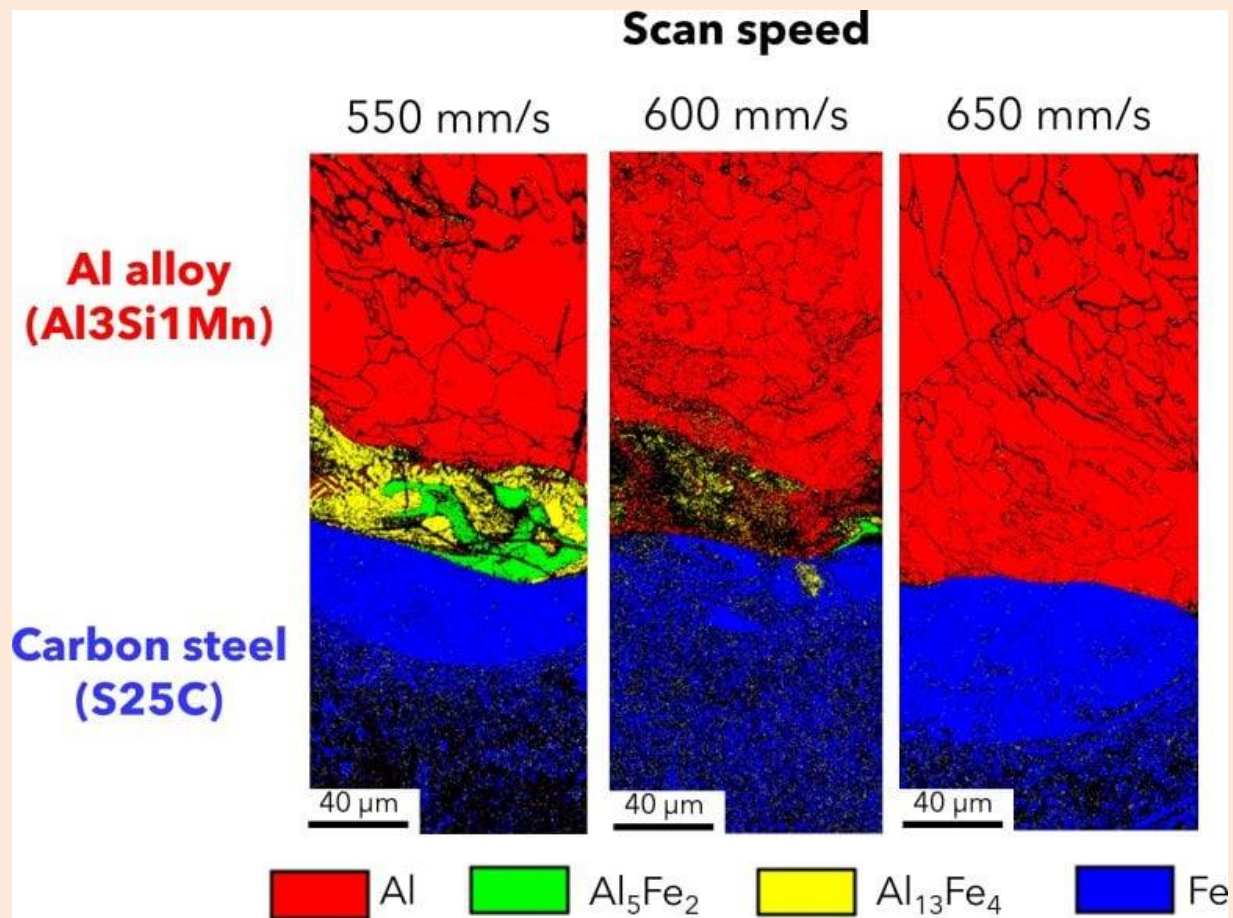
The research positions the buckliball within a broader conceptual framework known as "buckligami," which conceptualizes the folding behavior of materials akin to origami. The buckling actions involved mimic the folding motions found in paper, further illustrating the intricate relationship between design, function, and the mechanics of materials. As attention spreads from microscale to macroscale applications, the potential implementations range widely, promising to impact various sectors from construction to healthcare and robotics. This innovative approach not only improves current technologies but also opens new avenues for future research and development in morphable structures.

– **GOWTHAM C, IV-YEAR/MECHANICAL**

JAPANESE SCIENTISTS UNVEIL GAME-CHANGING 3D PRINTING BREAKTHROUGH FOR LIGHTWEIGHT CARS



Researchers at Tohoku University have pioneered a revolutionary multi-material 3D printing method with Laser Powder Bed Fusion (L-PBF), producing lightweight and durable automotive components. By enhancing laser scan speed, they effectively reduced brittle intermetallic compounds in steel-aluminum alloys, leading to the world's first full-scale 3D-printed suspension tower. This achievement showcases advanced laser techniques that address brittleness challenges, highlighting the potential of 3D printing in creating innovative automobile parts. The layer-by-layer process of metal printing ensures precision and reduces material waste compared to conventional manufacturing methods.



A significant advantage of 3D printing lies in its ability to create "multi-material structures," effectively combining various materials to enhance performance. For example, using aluminum with steel in automotive components can decrease weight while preserving strength. This has sparked substantial interest among researchers globally, highlighting its potential for manufacturing innovation. However, challenges persist, particularly regarding the formation of brittle intermetallic compounds at the interfaces of certain metal combinations, like steel and aluminum. Thus, while 3D printing can produce lighter materials, it may inadvertently result in increased brittleness.

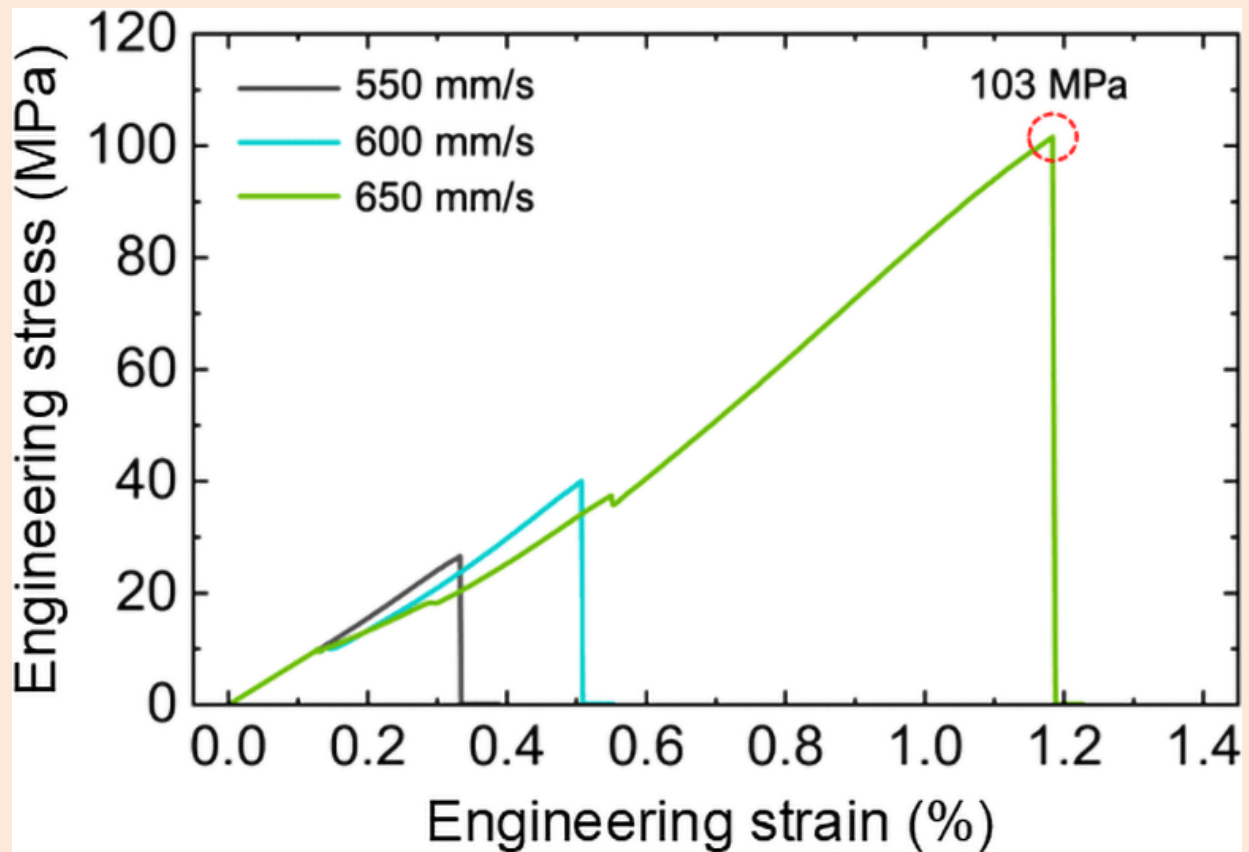


Full-scale prototype of a topologically optimized automotive suspension tower manufactured via L-PBF.

– HARI PRASATH S, IV-YEAR/MECHANICAL

OVERCOMING CHALLENGES: LASER POWDER BED FUSION (L-PBF)

This study aimed to create a lightweight steel-aluminum alloy without sacrificing strength, utilizing Laser Powder Bed Fusion (L-PBF) for metal 3D printing. Researchers found that increased laser scan speed reduced brittle intermetallic compounds' formation, promoting non-equilibrium solidification. This method minimized solute partitioning, eliminating weak points in the material, resulting in a product with strong bonding interfaces and improved structural integrity.



Interfacial strength for steel/Al alloy multi-materials obtained using L-PBF at different scan speeds.

Researchers investigated interfacial strength in steel/Al alloy multi-materials produced via L-PBF at varying scan speeds. Assistant Professor Seungkyun Yim emphasized the importance of understanding the in-situ alloying mechanism. This led to the successful prototyping of a world-first automotive multi-material component, the suspension tower, and aims to enhance bonding in other metal combinations for broader applications.

– **MADHANKUMAR S, IV-YEAR/MECHANICAL**