IARE
INSTITUTE OF AERONAUTICAL ENGINEERING

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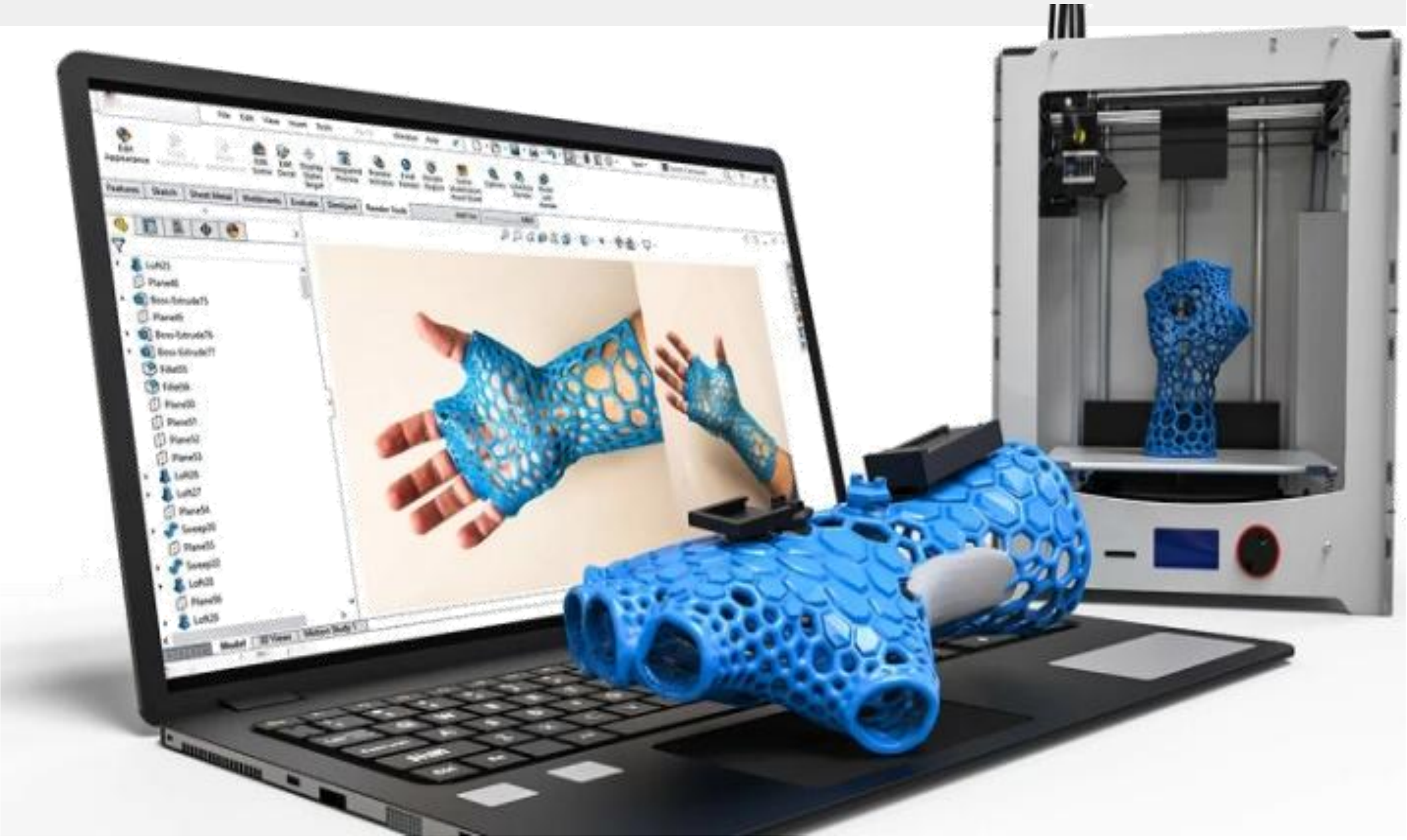
Technology Innovation & Product Support (TIPS)
AM - ADDITIVE MANUFACTURING



Information Packet 2025 -26

INSTITUTE OF AERONAUTICAL ENGINEERING
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Thank you to the IARE students for their enthusiasm and participation in the Additive Manufacturing – AM Project Program at the Institute of Aeronautical Engineering!

Additive manufacturing (AM) is a formal name of 3D printing, a previously used technology for rapid prototyping Additive manufacturing also facilitates the evaluation and testing of designs before producing the finished product. In addition, this technique is a breakthrough in the world of technology, namely the ability to make a prototype at a low cost and a simple proAMss. The application of 3D printing products has also been widely used in the automotive and medical industries.

The existenAM of 3D printing technology in manufacturing has brought major changes to the world. The rapid prototyping technology was first invented by Chuck Hall using a stereo lithographic (SLA) 3D printer. He used UV light to form plastic into layers. Scott Crump introduAMd another technique of 3D printing called fused deposition modeling (FDM) in 1988 by melting and pouring the plastic into a thin layer. Further, he applied the CNC to automate the proAMss. With this technology, his machine melted and layered the plastic filament on a flat surfaAM. 3D printing allows for rapid prototyping and onsite manufacturing of products. Initially done with plastic, 3D printing now uses new techniques with new materials, such as aluminum, bronze, and glass. Biomaterials are also being incorporated, such as 3D printing ear cartilage and liver tissue. As the 3D printing industry grows, 3D printing will become a big part of many engineering fields.

The Goals of AM Projects are

- Enhancing **Design Flexibility and Customization:** AM allows for the creation of complex geometries and highly customized parts that are difficult or impossible to manufacture using traditional methods. This supports innovative product designs tailored to specific applications or individual user needs.

- Reducing **Material Waste and Production Costs:** By building parts layer-by-layer, AM minimizes material waste compared to subtractive methods. It also reduces tooling costs, shortens production cycles, and supports on-demand manufacturing, all of which contribute to cost savings.

- Improving **Product Performance and Functionality:** With AM, components can be optimized for strength, weight, and functionality through topology optimization and material blending. This leads to lighter, stronger, and more efficient parts, especially valuable in aerospace, biomedical, and automotive applications.

- Accelerating **Prototyping and Time-to-Market:** AM speeds up the product development process by enabling rapid prototyping. Designers and engineers can quickly test, iterate, and refine their ideas, significantly reducing the time it takes to bring a new product from concept to market.

The research theme of this AM project also focuses on the challenges presented by the Sustainable Development Goals (SDGs).

IARE Sustainability Development Goals (SDGs) highlighted with Blue Colour Font	
SDG #1	End poverty in all its forms everywhere
SDG #2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG #3	Ensure healthy lives and promote well-being for all at all ages
SDG #4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG #5	Achieve gender equality and empower all women and girls
SDG #6	Ensure availability and sustainable management of water and sanitation for all
SDG #7	Ensure camas to affordable, reliable, sustainable and modern energy for all
SDG #8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG #9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SDG #10	Reduce inequality within and among countries
SDG #11	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG #12	Ensure sustainable consumption and production patterns
SDG #13	Take urgent action to combat climate change and its impacts
SDG #14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SDG #15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG #16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG #17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

The following research domains are recommended for IPDs-AM Projects, and selected students should find the research gap and frame the problem statements from any one of the themes below.

SDG 3 – Good Health and Well-being: In the healthcare industry, AM enables the production of custom prosthetics, implants, and medical tools tailored to individual patients, enhancing treatment outcomes and quality of care

SDG 9 – Industry, Innovation and Infrastructure: Additive Manufacturing drives innovation by enabling the development of advanced products, optimizing supply chains, and fostering smart manufacturing technologies. It supports the modernization of industries through digital transformation.

SDG 12 – Responsible Consumption and Production: AM reduces material waste, minimizes energy use, and supports localized, on-demand production. This leads to more sustainable manufacturing practices with a lower environmental footprint.

SDG 13 – Climate Action: By promoting lightweight structures and reducing overproduction, AM can help lower carbon emissions in transportation and manufacturing sectors, contributing to climate change mitigation.

The following research domains are recommended for Additive Manufacturing projects, and selected students should find the research gap and frame the problem statements from any one of the themes below.

1. Aerospace and Automotive Components
2. Biomedical and Customized Healthcare Devices
3. Sustainable Product Design and Light weighting
4. Manufacturing of Machine Components

.S. No	Name of the Sector	SDGs
1	Aerospace and Automotive Components	SDG#9, SDG#12, SDG#13, SDG#11, SDG#17
2	Biomedical and Customized Healthcare Devices	SDG#3, SDG#9, SDG#10, SDG#12, SDG#17
3	Sustainable Product Design and Light weighting	SDG#9, SDG#12, SDG#13, SDG#4, SDG#17
4	Manufacturing of Machine Components	SDG#1, SDG#8, SDG#9, SDG#11, SDG#12, SDG#17

In order to participate in AM Projects, you must formally apply and be accepted by the project coordinator. To proceed, please mail to the project coordinator, Dr. C Labesh Kumar (c.labeshkumar@iare.ac.in), This will bring up all available open positions tagged as AM projects. When submitting a project document and an updated résumé, include a statement regarding why you are interested in working with the team to which you are applying.

Please note that participation by the AM project team requires registration for the accompanying research statement from any of the specified domains. More information will be provided to all selected AM project applicants who have been offered a position.

If you have any questions about a particular team, please contact the team's faculty mentor(s).
We encourage you to contemplate this fascinating new opportunity. We look forward to receiving your application submission!

Aerospace and Automotive Components

Dr C. Labesh Kumar, Assistant Professor
Faculty Mentor

Goals

The primary goal in the Aerospace and Automotive sectors is the development of advanced components and systems that are lightweight, structurally robust, and performance-oriented. This is vital because vehicles in these industries are subjected to extreme operating conditions, such as high aerodynamic loads, intense thermal gradients, pressure fluctuations, and rapid dynamic motions. The structural integrity of components must be maintained while simultaneously minimizing their weight to improve overall system efficiency.

Additionally, there is a growing global emphasis on sustainability, fuel economy, and emission reduction. This has driven a shift towards greener propulsion systems (e.g., electric and hybrid drives), lightweight structural materials, and optimized aerodynamic profiles to reduce drag. The integration of energy-efficient systems such as regenerative braking in automotive or drag-reduction surfaces in aerospace further supports these goals. The components designed must not only perform efficiently during regular operations but must also exhibit long-term reliability and minimal need for maintenance, which reduces life cycle costs and enhances safety.

Methods & Technologies

The design and development process in aerospace and automotive sectors rely heavily on **virtual engineering tools**, especially **Finite Element Analysis (FEA)** and **Computational Fluid Dynamics (CFD)**. FEA is used to simulate structural performance under static and dynamic loads, allowing engineers to identify stress concentrations, deformation patterns, and potential failure points. CFD helps analyze **aerodynamic behavior**, **cooling systems**, and **fluid interactions** in engines and HVAC systems, optimizing performance while reducing drag and energy consumption.

Another key technology is **topology optimization**, which enables the design of lightweight components by removing unnecessary material without compromising strength. This is particularly useful in aircraft structures, suspension systems, and engine parts. Integrated CAD/CAM platforms support the generation of **manufacturing-ready geometries**, bridging the gap between design intent and production feasibility. Advanced visualization tools and digital twins also allow real-time design validation and lifecycle simulation.

Additive Manufacturing (AM) plays a transformative role in rapid prototyping and final part production, especially for complex, weight-sensitive components. Laser Powder Bed Fusion (LPBF), Directed Energy Deposition (DED), and other metal AM methods are used to manufacture high-strength titanium and aluminum parts with intricate geometries. At the same time, **CNC machining** and **composite fabrication** methods remain essential for producing high-precision components and multi-material assemblies.

Material science is at the core of technology deployment, with extensive use of **titanium alloys, high-strength steels, aluminum-lithium alloys**, and **carbon fiber-reinforced polymers (CFRPs)**. Material selection is based on performance criteria like **temperature resistance, fatigue strength, stiffness-to-weight ratio**, and corrosion resistance. Advances in coatings, surface treatments, and joining methods (e.g., friction stir welding) also enable enhanced part performance and durability.

Majors & Areas of Interest

This field lies at the intersection of **Aerospace Engineering**, **Mechanical Engineering**, and **Materials Science**. The academic curriculum typically includes subjects like **aerodynamics, propulsion systems, structural analysis, mechanics of materials**, and **thermodynamics**, providing a strong foundation for designing and analyzing high-performance systems.

A major area of interest is **structural mechanics and design optimization**, where engineers develop components like wings, fuselages, or automotive chassis using simulations, experimental testing, and reliability analysis. Emphasis is placed on optimizing geometry and material selection to meet performance and weight targets under safety constraints.

Vehicle dynamics and control systems is another important domain, involving the modeling and analysis of suspension systems, braking mechanisms, and steering behavior. In aerospace, this extends to **flight stability, vibration control**, and **active aeroelastic structures** to manage in-flight deformations.

Researchers also focus on **thermal management systems, fatigue life prediction**, and **impact/crash safety analysis**, which are vital for ensuring durability and occupant safety. Cross-disciplinary knowledge in **robotics, embedded systems, and AI-based diagnostics** is increasingly important in the development of autonomous and intelligent mobility platforms.

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PARTNERS & SPONSORS

None

Biomedical and Customized Healthcare Devices

Dr B. Vijaya Krishna, Assistant Professor
Faculty Mentor

Goals

The primary goal in the field of biomedical and customized healthcare devices is to **improve patient care through personalized solutions**. Unlike conventional one-size-fits-all medical devices, customized devices are designed to align with the specific **anatomy, physiology, and medical conditions** of individual patients. This personalization improves fit, function, and comfort, which is especially critical in orthopedic implants, dental restorations, and prosthetic limbs. The overall aim is to **enhance the quality of life**, reduce complications, and promote faster recovery.

Another important goal is to ensure **biocompatibility and long-term performance** of medical devices and implants. Since these products are in contact with living tissues, they must not trigger any adverse immune responses, allergic reactions, or toxicity. Devices should maintain **structural integrity and functional reliability** under physiological loads and biological conditions for extended periods. This demands rigorous material selection, surface engineering, and long-term durability testing to ensure **clinical safety and effectiveness**.

Reducing **invasiveness of procedures** and enhancing **minimally invasive and non-invasive interventions** is also a significant goal. Healthcare trends are moving towards procedures that minimize trauma, pain, and recovery time. Devices like flexible endoscopes, micro-surgical instruments, and targeted drug delivery systems are designed to operate within constrained environments with **greater precision and control**. These innovations help reduce hospitalization time, lower the risk of complications, and improve patient outcomes.

Finally, the field aims to ensure that **innovative healthcare technologies are accessible, scalable, and cost-effective**. A major challenge is making high-quality, customized healthcare solutions available to a broader population, especially in low-resource settings. Therefore, the goal includes developing **economical fabrication methods**, integrating **digital health platforms**, and using **telemedicine-compatible devices** to expand the reach of medical care. Balancing **technological sophistication with affordability** is essential to address global health disparities and support inclusive medical innovation.

Methods & Technologies

Biomedical device development starts with **medical imaging technologies** like **CT, MRI, and ultrasound**, which provide high-resolution anatomical data. These images are converted into 3D models using software tools for **reverse engineering and anatomical reconstruction**, allowing personalized designs. CAD tools are then used to model implants, prosthetics, or surgical tools, incorporating both patient-specific geometry and functional requirements.

Simulation tools such as **FEA** and **multiphysics modeling** are essential to evaluate **mechanical behavior**, **stress distribution**, and **thermal or fluidic interactions** in biomedical devices. For example, FEA is used to ensure that hip implants can withstand body weight, while CFD can model blood flow in vascular stents or artificial heart valves. These simulations help optimize shape, material thickness, and surface interfaces before clinical trials.

Additive Manufacturing (AM)—especially technologies like **Selective Laser Sintering (SLS)**, **Electron Beam Melting (EBM)**, and **bioprinting**—is widely used for producing **custom implants, anatomical models, surgical guides**, and even **tissue scaffolds**. Materials include **biocompatible metals** (e.g., titanium, cobalt-chromium), **bio-inert ceramics**, and **medical-grade polymers** like PEEK or PMMA. Surface modifications using **plasma treatment, nanocoatings**, or **bioactive materials** improve tissue integration and reduce infection risks.

Additionally, **smart sensors**, **microelectromechanical systems (MEMS)**, and **wireless technologies** are integrated into wearables and implantable devices to monitor physiological parameters like glucose levels, cardiac rhythms, or joint loads. These systems enable **remote diagnostics, personalized therapy, and continuous patient monitoring**, forming the foundation of digital and connected healthcare.

Majors & Areas of Interest

This interdisciplinary domain brings together **Biomedical Engineering, Mechanical Engineering**, and **Biomaterials Science**. The academic focus is on **biomechanics, tissue engineering, medical device design**, and **physiological modeling**, with practical training in anatomy and clinical practices.

A primary area of interest is **implant design and biomechanics**, where the goal is to mimic the mechanical properties of human tissues to ensure proper load transfer and integration. Students explore the use of **FEA for simulating joint loads, bone-implant interfaces**, and **fracture mechanics** under various physiological conditions.

Another growing field is **medical device innovation**, including the development of **surgical tools, stents, catheters, wearable sensors**, and **rehabilitation aids**. These designs must meet both engineering specifications and **clinical usability standards**, making collaboration with medical professionals essential.

Additional focus areas include **biosignal acquisition, smart healthcare systems**, and **3D printing of patient-specific implants and anatomical models**. The integration of **IoT, AI, and wireless communication** into healthcare devices is transforming the way diagnostics, remote monitoring, and personalized therapies are delivered.

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PARTNERS & SPONSORS

None

Sustainable Product Design and Light weighting

Dr Ch Sandeep, Professor
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Goals

The foremost goal in sustainable product design is to **minimize the environmental impact** of products throughout their entire lifecycle—from raw material extraction, manufacturing, and usage to end-of-life disposal or recycling. Designers strive to reduce **carbon footprint, energy consumption, and waste generation** by adopting eco-friendly materials, low-emission processes, and circular design principles. The intention is to create products that are not only functional and market-ready but also **environmentally responsible** in both their creation and usage.

Another critical goal is to implement the philosophy of **"Design for Sustainability (DfS)"**, where environmental, economic, and social sustainability are built into the core of the product development process. This involves balancing **resource efficiency** with **user needs**, ensuring that the products serve their intended purpose effectively while being **repairable, reusable, or recyclable**. By extending product life and supporting closed-loop systems, sustainable design contributes to reducing reliance on virgin resources and lowering the environmental burden.

In parallel, the goal of **light-weighting** has emerged as a powerful strategy to improve **energy efficiency, reduce transportation costs**, and enhance product performance, especially in sectors like transportation, aerospace, packaging, and consumer electronics. Lighter products consume **less fuel or energy** during use, which translates to lower operational costs and reduced emissions. Designers aim to use **advanced materials and optimization techniques** to reduce mass while maintaining or even improving structural integrity, durability, and safety.

A long-term strategic goal is to **promote sustainability as a competitive advantage** and a driver of innovation. Companies and engineers are increasingly focusing on sustainable design not just to comply with regulations but to meet growing consumer demand for **eco-conscious products**. Sustainability is being integrated into brand identity, market differentiation, and corporate social responsibility frameworks. This shift requires collaboration between **designers, engineers, supply chain managers, and policy makers** to embed sustainability into every layer of product development, manufacturing, and distribution.

Methods & Technologies

Sustainable design begins with **Life Cycle Assessment (LCA)** tools that help evaluate the environmental impact of materials and processes across the product's lifecycle. Designers use **eco-design software** and **material databases** to select low-impact materials, minimize energy usage, and assess recyclability. This enables decision-making that aligns with sustainability goals from the conceptual stage onward.

Computer-Aided Design (CAD) platforms integrated with **generative design** and **topology optimization** algorithms allow engineers to explore thousands of design permutations aimed at reducing material usage and weight. These tools analyze performance requirements and iteratively suggest the most resource-efficient structures. Such approaches are especially useful in the design of lightweight structures for packaging, consumer electronics, and mobility solutions.

Manufacturing methods that support sustainable production include **additive manufacturing**, which reduces material waste by building parts layer by layer; **modular design**, which simplifies repair and upgrades; and **remanufacturing techniques**, which extend product life. Use of **recycled materials**, **bio-based polymers**, and **natural fiber composites** is increasing in response to environmental regulations and consumer demand.

To further reduce environmental impact, **energy-efficient processing techniques** like **low-temperature sintering**, **dry machining**, **solvent-free coatings**, and **renewable-powered factories** are being adopted. Digital manufacturing systems and **IoT-based resource monitoring** ensure minimal waste generation and optimal use of water, energy, and raw materials, contributing to **closed-loop production ecosystems**.

Majors & Areas of Interest

This field is primarily rooted in **Industrial Design, Mechanical Engineering**, and **Sustainable Engineering**. The curriculum emphasizes **eco-design principles, green materials, life cycle analysis, and product development** that balance technical performance with environmental responsibility.

Key interest areas include **generative and topology-optimized design**, where students use algorithm-driven tools to reduce material usage while maintaining structural efficiency. Courses also cover **biomimicry, circular economy strategies**, and **cradle-to-cradle product development** that prioritize longevity and recyclability.

Material innovation for sustainability is another strong focus. Students work on projects involving **natural fiber composites, biodegradable plastics, lightweight alloys**, and **recyclable polymers**. These materials are evaluated based on their environmental impact, mechanical properties, and processing feasibility.

The domain also integrates **systems thinking and life cycle costing**, ensuring that sustainability is not only about ecology but also about **economic and social performance**. The application of **Industry 4.0 technologies**—like digital twins and energy monitoring—offers real-time insights into resource efficiency, enabling continuous improvement in sustainable design practices.

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None

Manufacturing of Machine Components

Dr G Hima Bindu, Assistant Professor
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Goals

The primary goal in the manufacturing of machine components is to ensure the **precision, functionality, and reliability** of parts that serve as the building blocks of mechanical systems. These components are integral to a wide range of industries—including automotive, aerospace, robotics, energy, and industrial automation—and must perform consistently under **varying mechanical loads, temperatures, and operational environments**. The design and manufacturing processes are therefore focused on achieving **tight tolerances, dimensional accuracy**, and high surface finish standards to ensure smooth assembly and long-term operation.

Another crucial goal is to **enhance productivity and cost-efficiency** in the manufacturing process. This involves minimizing cycle time, reducing material waste, and optimizing tool usage. To achieve this, manufacturers adopt lean principles, process automation, and real-time monitoring systems that enable high-throughput production without sacrificing quality. Efficient use of materials and energy during machining or fabrication also contributes to **lower production costs and sustainable resource usage**, making manufacturing processes more economically and environmentally viable.

An important parallel goal is to improve the **durability and performance of machine components**. This means selecting appropriate materials and surface treatments to resist wear, fatigue, corrosion, and thermal degradation. Components like shafts, gears, bearings, and housings must be manufactured to withstand repeated loading cycles and harsh operating conditions. Hence, a major goal is to integrate **advanced material science** and **mechanical design principles** to develop components with **longer service life** and **minimum maintenance requirements**.

Finally, modern manufacturing aims to integrate **smart technologies and digital tools** to enable **intelligent and adaptive production systems**. This includes embedding sensors for tool condition monitoring, using AI and machine learning for process optimization, and implementing Industry 4.0 principles for full factory integration. The goal is to create a manufacturing environment that is **flexible, data-driven, and responsive**, capable of handling complex geometries, customization, and small-batch production with the same efficiency as mass manufacturing.

Methods & Technologies

Conventional manufacturing processes such as **turning, milling, grinding, and drilling** remain the backbone of machine component production. However, these are now enhanced through **CNC automation**, which allows precise control over tool paths, speeds, and feeds. Multi-axis CNC machines can fabricate complex geometries in fewer setups, reducing production time and improving repeatability.

Non-traditional machining techniques like **Electrical Discharge Machining (EDM)**, **Electrochemical Machining (ECM)**, **Laser Beam Machining (LBM)**, and **Ultrasonic Machining (USM)** are employed for machining **hard, brittle, or delicate materials**. These methods offer superior accuracy and surface integrity, particularly useful in dies, molds, and micro-scale components.

Advanced metrology and inspection technologies such as **Coordinate Measuring Machines (CMMs)**, **laser scanning**, **optical profilers**, and **machine vision systems** ensure **dimensional accuracy, geometric tolerances**, and **surface finish** compliance. These tools are often integrated with **real-time monitoring systems**, allowing for **in-process quality control**, predictive maintenance, and traceability throughout the production line.

Emerging technologies include the integration of **IoT**, **digital twins**, and **AI-driven predictive analytics** in manufacturing setups. These smart systems optimize tool wear management, adapt machining parameters based on real-time sensor data, and minimize downtime. There's also a growing adoption of **green manufacturing practices**, including **minimum quantity lubrication (MQL)**, **dry machining**, and **energy recovery systems** to support sustainability goals.

Majors & Areas of Interest

This core area of **Mechanical and Production Engineering** focuses on the **design, machining, testing, and assembly** of components used in industrial systems. Fundamental subjects include **manufacturing processes, tool design, metrology, materials science**, and **machine dynamics**.

A major area of specialization is **machining science**, which studies the mechanics of cutting, tool wear, chip formation, and heat generation. Students learn to select optimal parameters for turning, milling, and grinding operations based on material behavior and desired tolerances.

Another critical interest area is **precision engineering and metrology**, focusing on surface quality, dimensional control, and tolerance stack-up. Hands-on training with **CMMs, surface profilers, and digital inspection tools** helps engineers ensure product conformance to specifications.

Emerging fields include **smart manufacturing, process automation, and cyber-physical systems**. With increasing digitization, engineers now engage in **sensor integration, real-time monitoring, and data analytics** to make machine shops smarter, safer, and more responsive. These areas bridge traditional manufacturing with **Industry 4.0 paradigms** like **predictive maintenance, adaptive control**, and **energy-efficient machining**.

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None