Co-Funded by the Erasmus+ Programme of the European Union

جامعة الزيتونة الأردنية
Al-Zaytoonah University of Jordan

HANDS

Digital Fabrication Vocational Course Road-map

Traditional Craft Heritage
Training , Design and Marketing
in Jordan and Syria
(HANDS)

ERASMUS+Programme
HANDS Project Number : 610238-EPP-1-2019-1-JOEPPKA2-CBHE-JP

DIGITAL FABRICATION

Training Program

610238-EPP-1-2019-1-JOEPPKA2-CBHE-JP

Objectives

Empower participants from diverse backgrounds to creatively explore and apply digital fabrication technologies, transforming ideas into tangible realities across various fields.

1. Trace the evolution of digital fabrication from its early roots to its contemporary applications across diverse disciplines.
2. Develop an understanding of the properties, limitations, and suitability of the materials used in digital fabrication.
3. Provide hands-on experience with various digital fabrication tools.
4. Translate design ideas into functional and fabrication-ready models using 3D modeling software.
5. Explore the diverse applications of digital fabrication across various sectors.
6. Develop troubleshooting skills to overcome common challenges and adapt techniques to specific materials and design requirements.

Program Details

Target Audience

School and university students

Program Duration

Four weeks, two days a week with three hours per day.

Delivery Method

- Presentations
- Training activities
- Brainstorming
- Discussion and dialogue

PROGRAM CONTENTS

1

Program Overview
What is digital fabrication?
Break
The evolution of digital fabrication and its applications
Discussion

2

Digital fabrication technologies (Additive and Subtractive)
Break
Digital fabrication technologies (Forming and Joining)
Discussion

3

Materials used in digital fabrication and their properties
Break
Digital fabrication software and programs
Discussion

4

Sustainability and digital fabrication
Common Challenges and troubleshooting
Break
Machines and digital fabrication works created in Al Zaytoonah University
Discussion

5

Working with laser cutting software
Preparing vector graphics and images for laser cutting
Break
Hands-on laser cutting of prepared designs on desired materials
Assembling and finishing
Discussion

6

Introduction to 3d printing software
Creating designs and adjusting parameters
Break
Create prototype models with different settings and materials
Analysis of results and troubleshooting common issues
Discussion

7

Overview of CAM software
Generating toolpaths and G-code instructions from 3D models
Break
Exploring different cutting tools and their effects on materials
Discussion

8

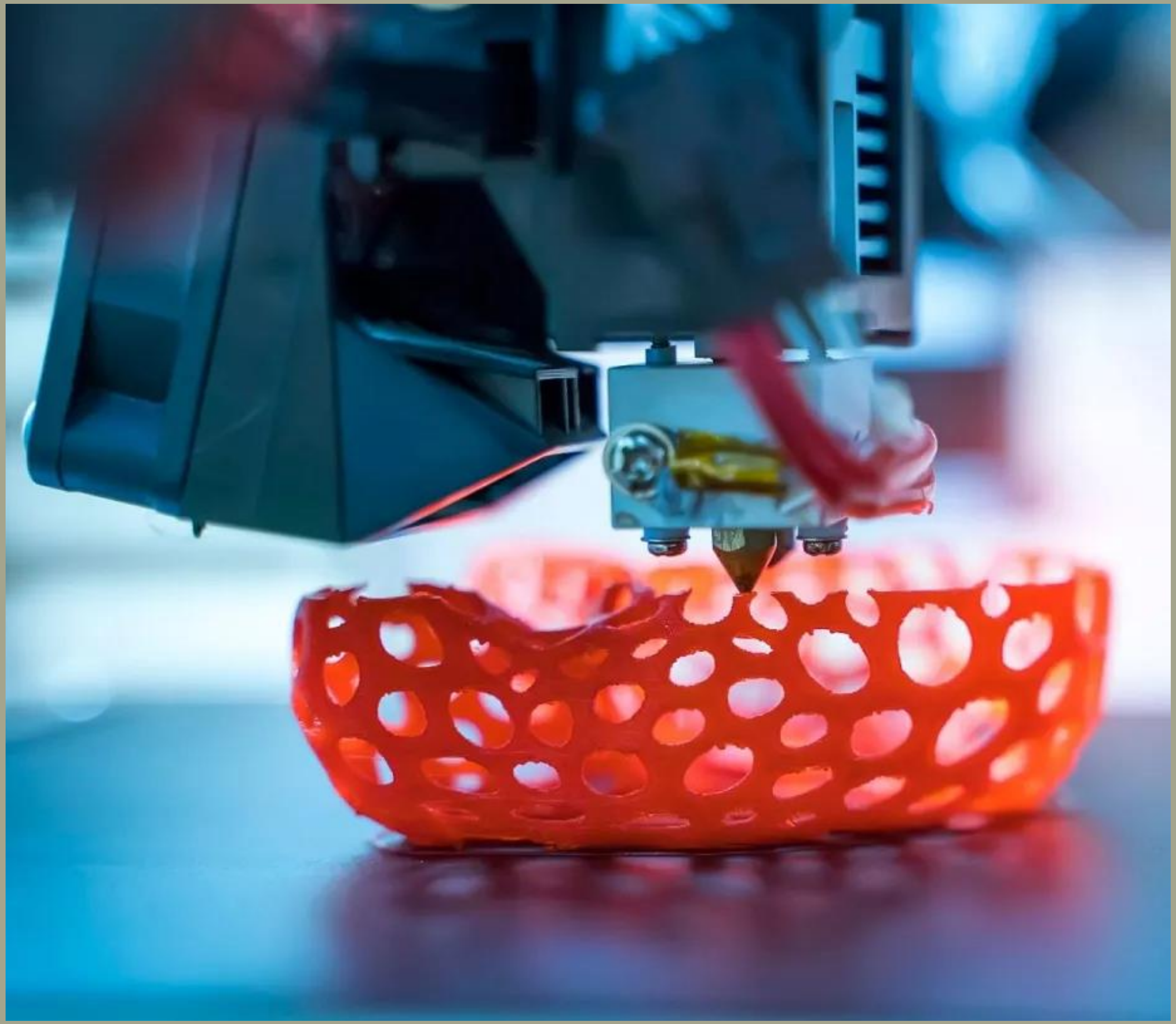
Hands-on practice programming and operating the CNC machine
Break
Optimizing models for efficient machining and material usage
Discussion

WHAT IS DIGITAL FABRICATION?

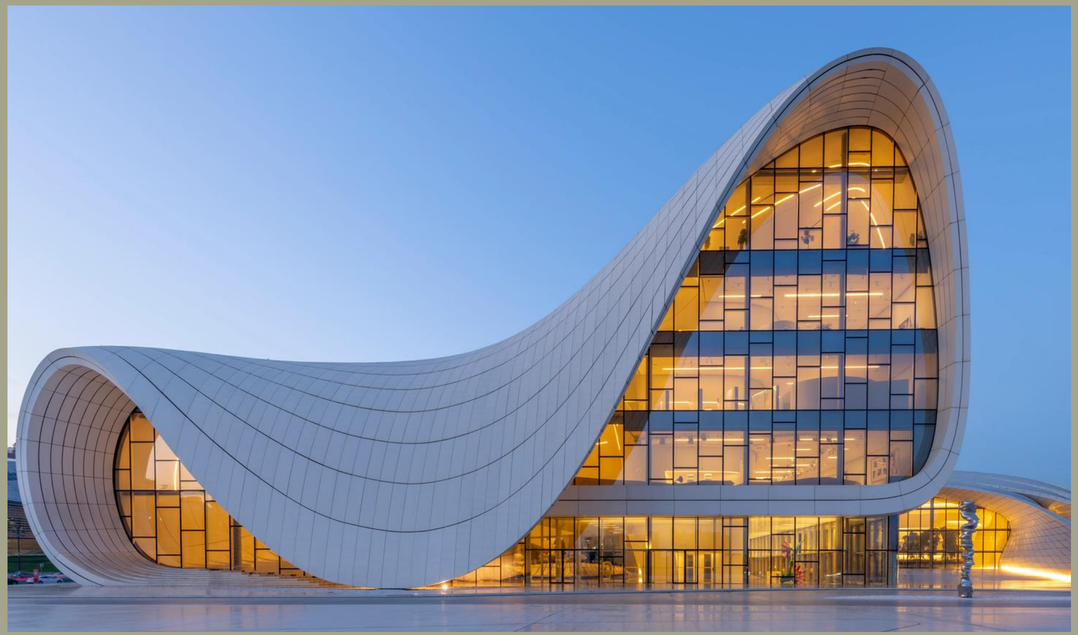
Digital fabrication is the process of creating physical objects from digital designs using computer-aided tools and equipment. It involves a seamless blend of design, technology, and craftsmanship, empowering creators to bridge the gap between the digital and physical realms.

The evolution of digital fabrication

From humble roots in numerical control and computer-aided design, digital fabrication fundamentally altered how we design and produce across diverse disciplines. Pioneering technologies like 3D printing democratized creation, while open-source platforms fostered collaboration and accelerated innovation. Today, digital fabrication empowers architects to sculpt intricate building components, product designers to iterate rapidly through prototypes, and medical professionals to personalize prosthetics and bio print tissues. Its impact extends beyond tangible objects, enabling interactive art installations and personalized consumer experiences.

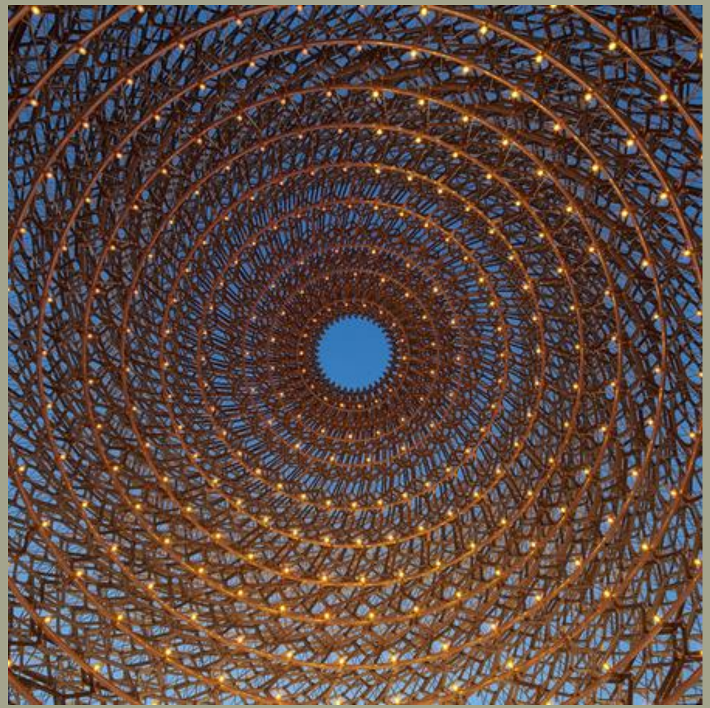


IN ARCHITECTURE



Customizable Building Envelopes
Digital fabrication tools empower architects to design bespoke facades, cladding panels, and even window lattices, adding individuality and architectural expression to projects.

Complex Geometries and Structural Innovation
From organic forms to self-supporting arches and intricate lattice structures, digital fabrication enables the realization of previously unimaginable geometries, pushing the boundaries of structural design.



3D Printing Revolutionizes Construction
This transformative technology paves the way for additive manufacturing of entire buildings with materials like concrete or bio-based composites, potentially reducing construction time, minimizing waste, and creating unique architectural possibilities.

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IN PRODUCT DESIGN

Rapid Prototyping and Agile Iteration

By enabling quick and iterative creation of physical prototypes, digital fabrication tools shorten the design-to-market cycle.

Mass Customization and Personalized Products

Tailored shoes perfectly aligned to your foot or eyeglasses precisely matched to your facial features – digital fabrication unlocks mass customization, catering to individual preferences and niche markets.

Decentralized Production and On-Demand Manufacturing

Local production becomes feasible, empowering small businesses and independent designers to manufacture products without significant upfront costs, minimizing inventory risks and responding to specific market demands.

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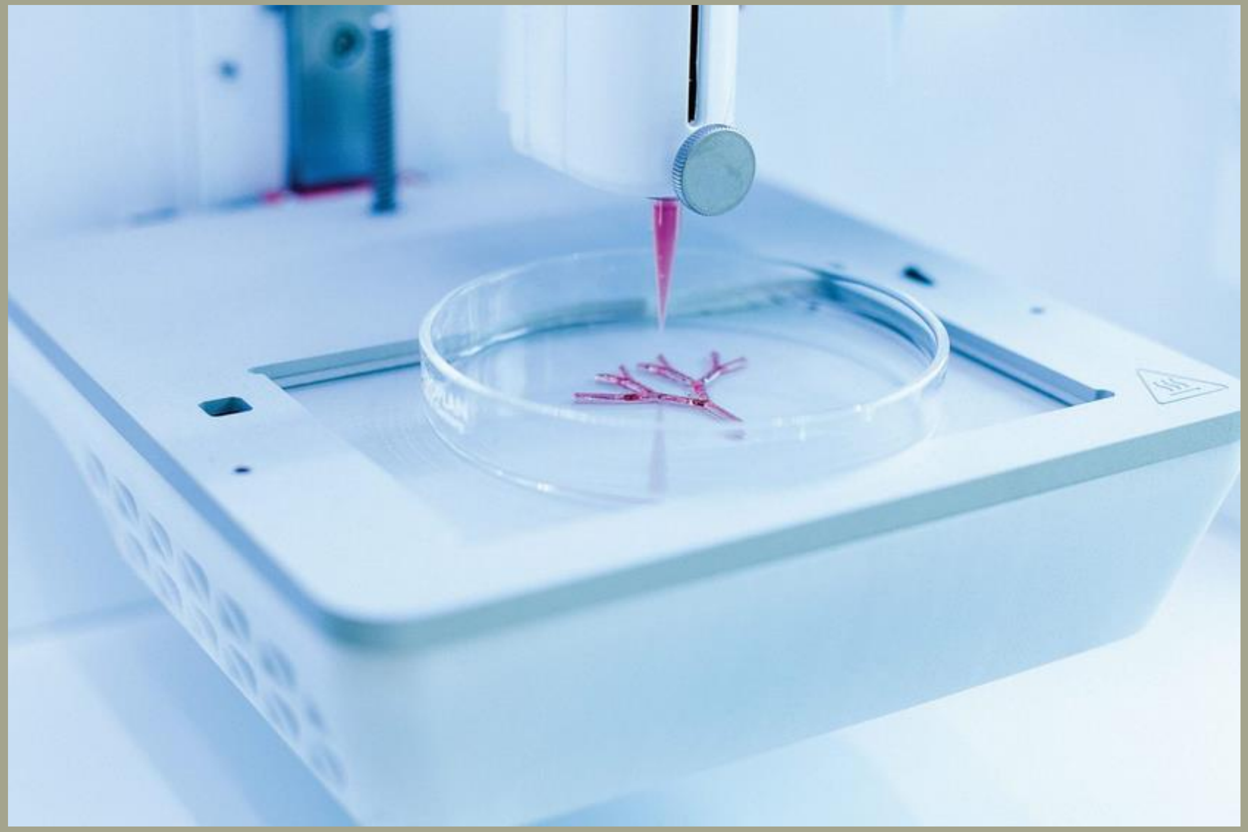
In Healthcare

Bioprinting: A Paradigm Shift in Medicine

This groundbreaking technology opens the door to customized tissue and organ printing based on individual patients' needs, holding immense promise for regenerative medicine, personalized treatment options, and organ transplantation.

Advanced Prosthetics and Assistive Devices

Digital fabrication facilitates the creation of lightweight, comfortable, and highly functional prosthetics and assistive devices, significantly improving the quality of life for individuals with disabilities.



Technologies

The realm of digital fabrication encompasses a diverse array of technologies and techniques that leverage digital information to create physical objects. From the layer-by-layer alchemy of 3D printing to the laser's fiery calligraphy, each technology offers a unique symphony of capabilities, empowering creators to orchestrate the transformation of ideas into tangible realities.

3D Printing (Additive Manufacturing)

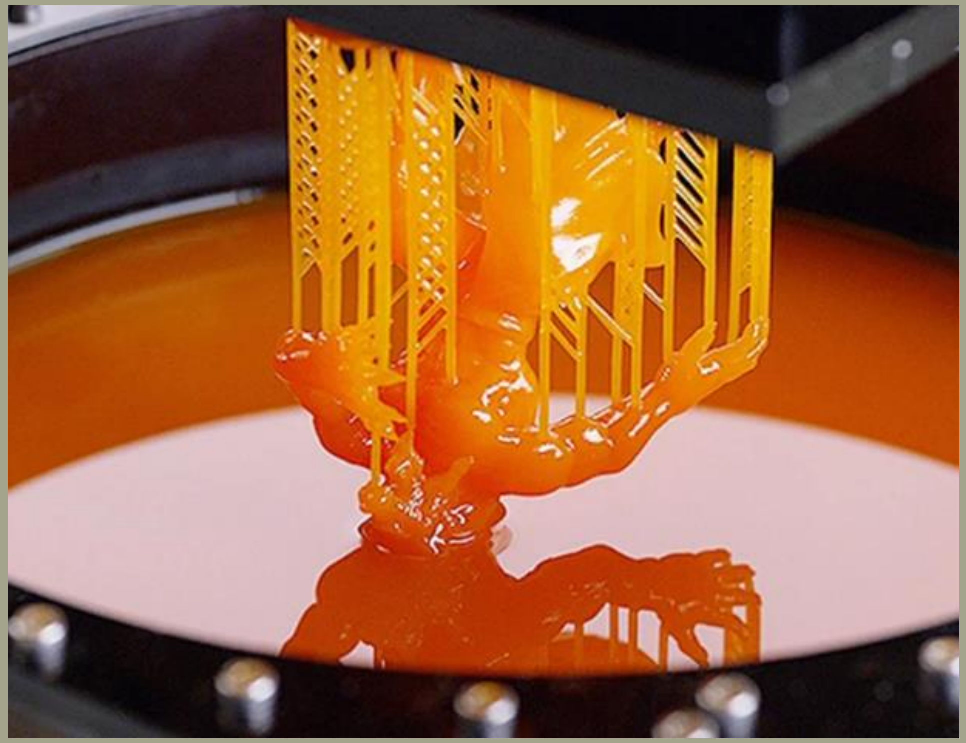
What is it?

3D printing builds physical objects layer by layer, guided by a digital model. Think of it like constructing a tiny building, one floor at a time, using your computer file as the blueprint. Materials like plastic, metal, or even biocompatible materials can be used, depending on the application.

3D Printing (Additive Manufacturing)

How does it work?

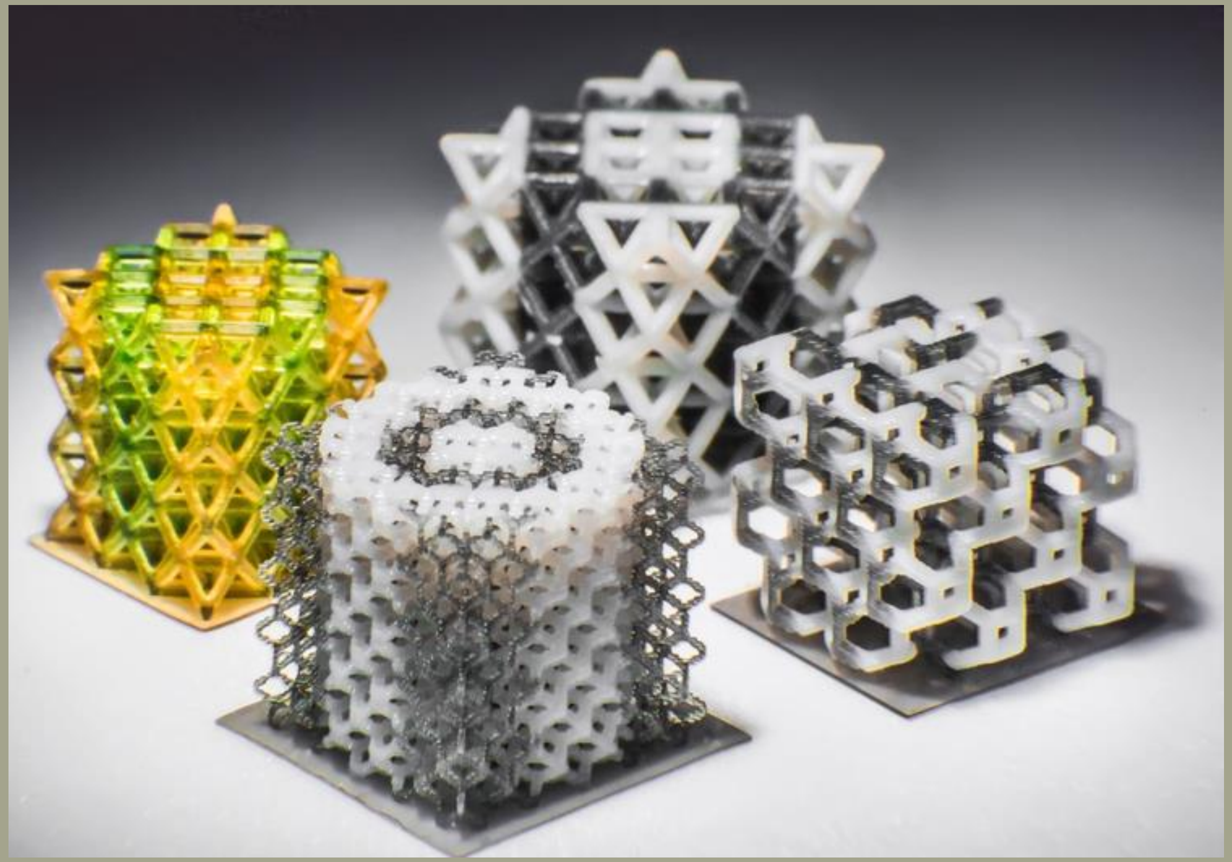
Fused Deposition Modeling (FDM): Melted plastic filament is extruded through a nozzle to create layers. Simple, versatile, and widely used for prototyping and hobby projects.



Stereolithography (SLA): A laser cures liquid resin layer by layer, creating high-resolution and smooth-surfaced parts. Ideal for intricate details and medical applications.

Selective Laser Sintering (SLS): Powdered material like nylon or metal is fused together by a laser, creating strong and heat-resistant parts. Used for functional prototypes and small batch production.

3D Printing (Additive Manufacturing)



What are the benefits?

- Design freedom: Create complex shapes and geometries impossible with traditional manufacturing.
- Customization: Personalize objects or tailor them for specific needs.
- Rapid prototyping: Quickly test and iterate on designs, reducing development time.
- Reduced waste: Material usage is efficient compared to subtractive methods like machining.

What are the limitations?

- Material limitations: Not all materials are suitable for 3D printing, and some have strength limitations.
- Post-processing: Some technologies require cleaning, support removal, or finishing steps.
- Printing time: Complex parts can take a long time to print.
- Cost: High-end technologies and materials can be expensive.

CNC Machining (Subtractive Manufacturing)

What is it?

CNC machines wield various cutting tools, from drills and mills to lasers, meticulously chipping away at metal, wood, plastic, or even stone, translating your digital design into a tangible masterpiece.

CNC Machining (Subtractive Manufacturing)

How does it work?

- CNC stands for Computer Numerical Control: Your digital model dictates the toolpath, telling the machine exactly where and how much material to remove.
- Various CNC machines exist: 3-axis machines move in three directions, while 5-axis offer even greater freedom and complexity.
- Different tools tackle different materials:

Drills bore holes.

Mills create intricate shapes.

Lasers offer precise cutting and engraving.

CNC Machining (Subtractive Manufacturing)

What are the benefits?

- Exceptional accuracy and precision: CNC machines achieve tolerances in fractions of a millimeter.
- Versatility: Handles a wide range of materials and creates diverse features, from simple holes to intricate carvings.
- Repeatability: Once programmed, the machine can produce identical parts consistently, ideal for mass production.
- Strong and durable parts: Subtractive manufacturing often yields robust components capable of handling high loads and stresses.

What are the limitations?

- Material limitations: Certain materials cannot be easily machined without specialized tools or techniques.
- Waste generation: Material is removed during the process, creating scrap that needs proper disposal or recycling.
- Time investment: Complex parts can take considerable time to machine, especially for large pieces.

Laser Cutting (Forming and Joining)

What is it?

Laser cutting uses a concentrated beam of light to melt, vaporize, or remove material, following a digital design path and creating clean cuts. Its versatility, precision, and speed make it a powerful tool in the digital fabrication toolbox, shaping the future of design and manufacturing.

Laser Cutting (Forming and Joining)

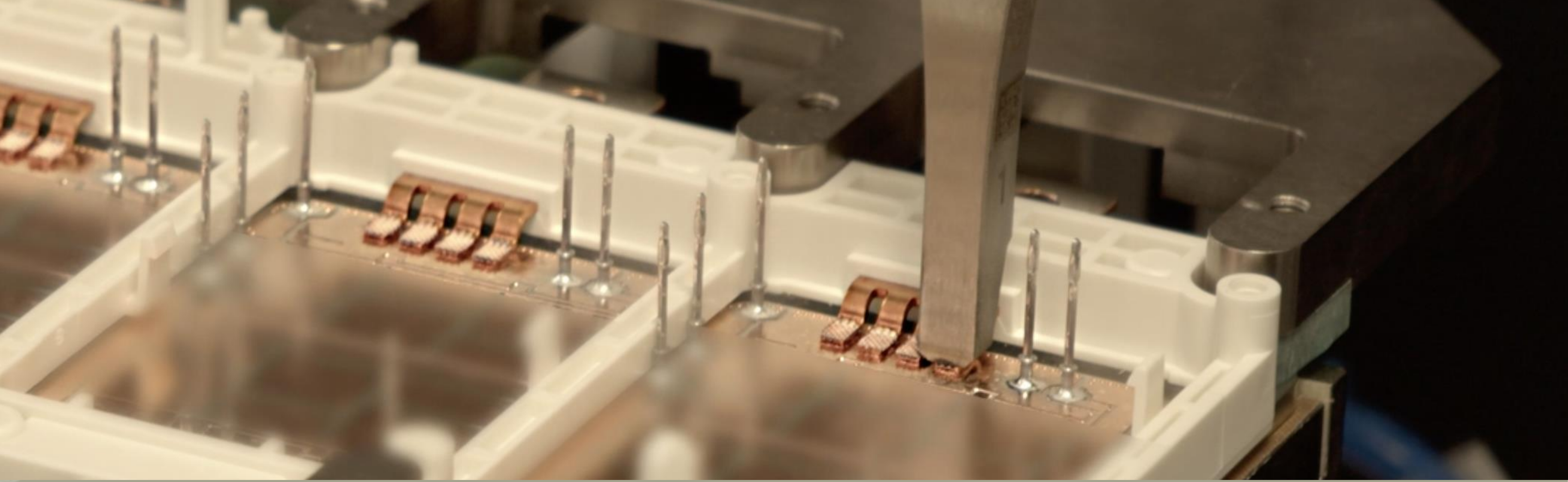
What are the benefits?

- Versatility: Cuts, engraves, and even performs simple welds on diverse materials.
- Precision and detail: Creates intricate designs with sharp edges and minimal heat-affected zones.
- Speed and efficiency: Cuts quickly and cleanly, minimizing waste and production time.
- Non-contact process: No physical tool touches the material, reducing wear and tear and minimizing risk of damage.
- Scalability: Handles small projects with ease and can be adapted for larger productions.

Laser Cutting
(Forming and Joining)

What are its limitations?

- Material limitations: Not suitable for all materials, especially highly reflective or heat-sensitive ones.
- Thickness limitations: Thicker materials might require multiple passes or higher-powered lasers.
- Fumes and dust: Cutting certain materials generates fumes and dust, requiring proper ventilation and safety measures.
- Initial investment: High-quality laser cutting equipment can be expensive.



Ultrasonic Welding (Joining)

What is it?

Ultrasonic welding utilizes a specially designed tool that vibrates at frequencies beyond human hearing (typically 20-40 kHz). These vibrations create friction and heat at the contact points between the materials, causing them to soften and fuse together without melting.

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What are the advantages?

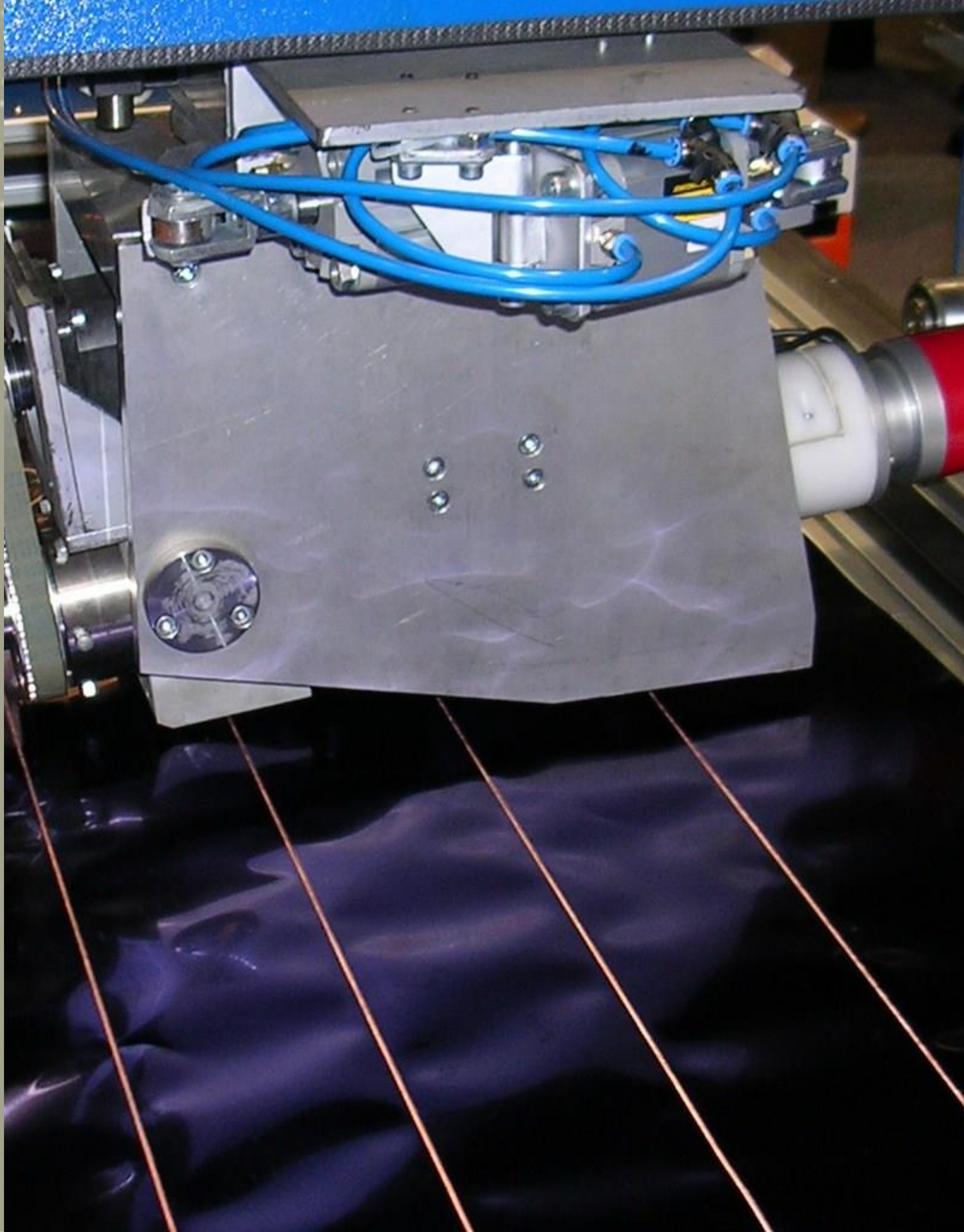
- Clean and precise: No heat or open flames, meaning minimal distortion or damage to the materials. Ideal for delicate electronics and heat-sensitive components.
- Strong and reliable: Creates strong, hermetic seals, perfect for medical devices, food packaging, and automotive applications.
- Versatility: Works with various materials, including plastics, metals, and even fabrics, expanding design possibilities.
- Speed and efficiency: Quick weld times compared to traditional methods like soldering or adhesive bonding.
- Control and repeatability: Precisely controlled vibrations ensure consistent and reliable results.

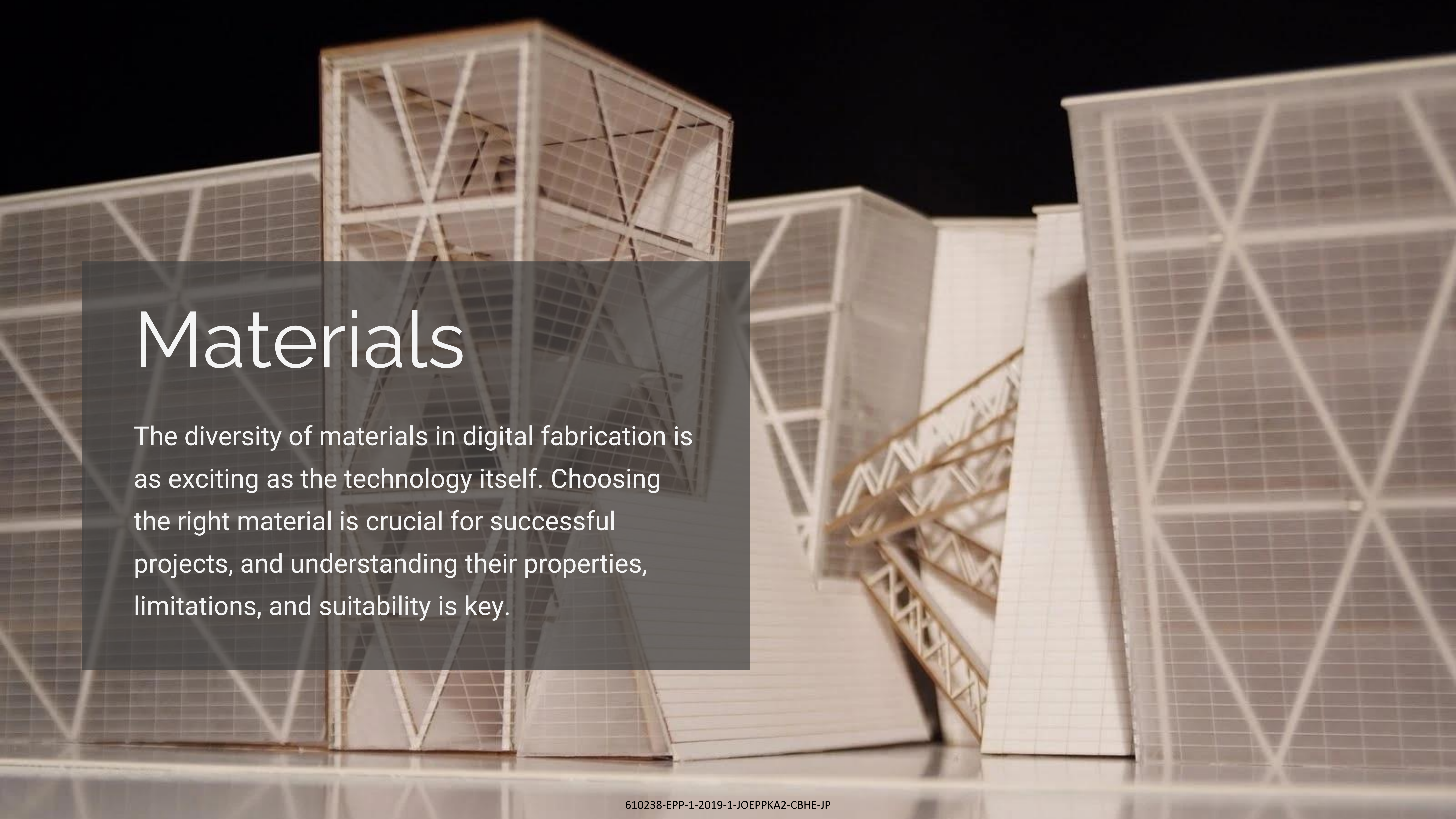
Ultrasonic Welding

(Joining)

What are the limitations?

- Material compatibility: Not suitable for all materials, particularly those with high acoustic impedance or low melt temperatures.
- Joint thickness: Works best for thinner materials (typically below 5mm).
- Initial investment: Ultrasonic equipment can be expensive compared to simpler joining methods.
- Limited visual feedback: The invisible nature of the weld requires specialized testing for quality control.





Materials

The diversity of materials in digital fabrication is as exciting as the technology itself. Choosing the right material is crucial for successful projects, and understanding their properties, limitations, and suitability is key.

Thermoplastics

Properties

Versatile, lightweight, durable, easy to print, come in various colors and textures.

Limitations

Lower heat resistance, potential for warping, limited strength for load-bearing applications.

Suitable for

Prototyping, functional parts, consumer products, toys, decorative objects.

Examples: PLA, ABS, PETG, Nylon.

Photo-polymers

Properties

High detail resolution, smooth surface finish, wide range of colors and resins, biocompatible options.

Limitations

Brittle, less robust than thermoplastics, susceptible to UV light degradation.

Suitable for

Jewelry, figurines, dental models, medical devices, prototypes with intricate details.

Examples: SLA, DLP, Polyjet resins.

Metals

Properties

Strong, high heat resistance, durable, suitable for structural and high-precision applications.

Limitations

Requires specialized printers and expertise, higher cost, slower printing speed.

Suitable for

Jigs and fixtures, aerospace components, medical implants, functional prototypes that require strength and heat resistance.

Examples: Stainless steel, aluminum, titanium, Inconel.

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Biomaterials

Properties

Sustainable, biocompatible, can be infused with medical-grade functionality, promotes cell growth for tissue engineering.

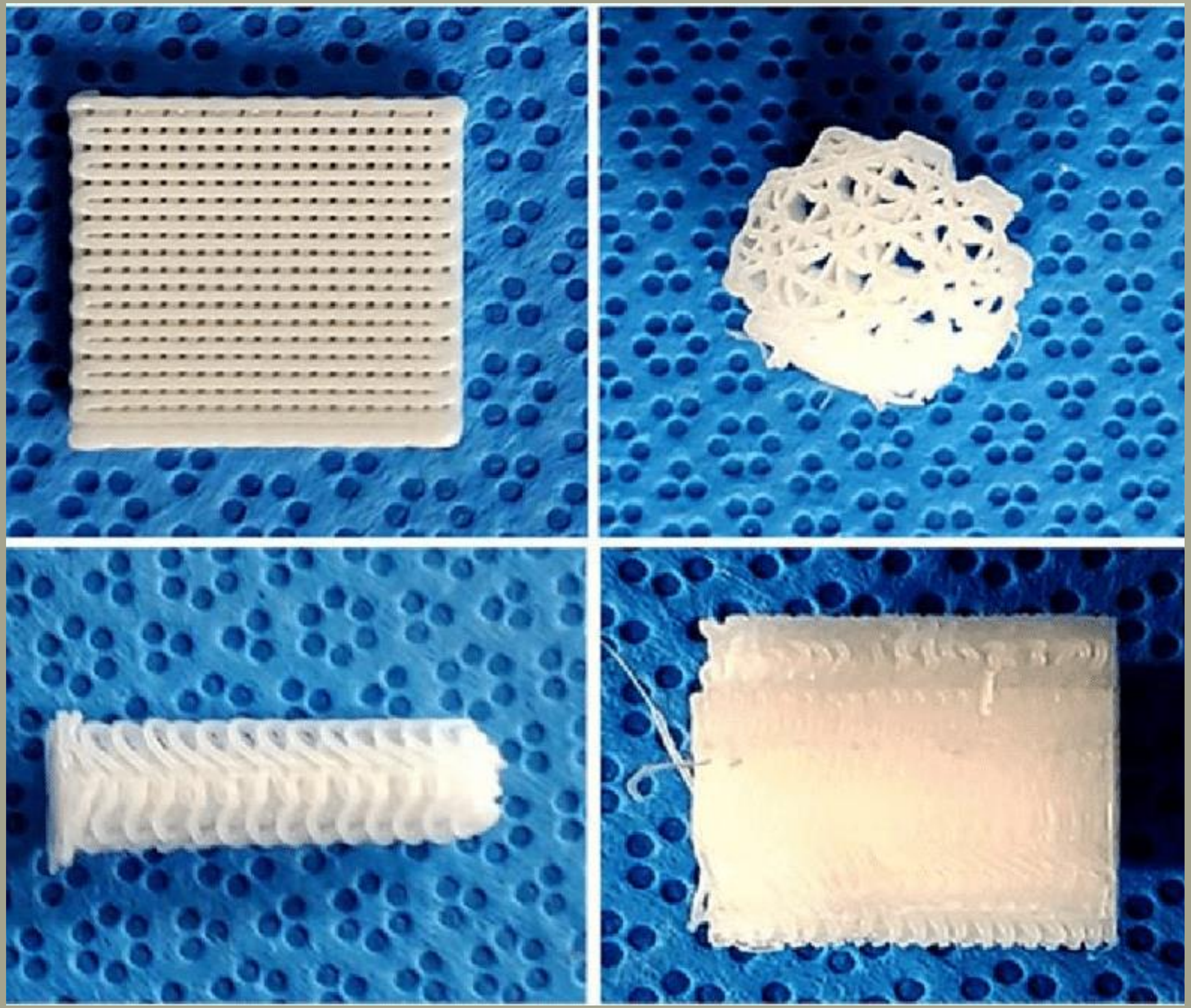
Limitations

Requires specialized printers and materials, lower mechanical strength, research and development stage for some applications.

Suitable for

Medical implants, prosthetics, personalized medical devices, tissue engineering research.

Examples: Cellulose, Chitosan, PCL, PLA composites.



Composites

Properties

Combine strength and lightness, customizable properties like stiffness and conductivity, offer unique aesthetic possibilities.

Limitations

Requires advanced expertise for material selection and printing parameters, high cost for some materials.

Suitable for

Lightweight structural components, drones, sporting goods, high-performance tools, design-driven objects.

Examples: Carbon fiber composites, wood-polymer composites, metal-polymer composites.

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Other Materials

Ceramics

High heat resistance, chemical resistance, for specialized applications like dental crowns and high-temperature tools.

Sand

Sustainable, low cost, used for casting molds and rapid prototyping.

Food-grade materials

Enables 3D-printed food experimentation and customization.

Software

The software landscape in digital fabrication is expansive and diverse, catering to various stages and processes.

Illustrator

Can be used to create design templates for laser cutting and engraving.

ArtCAM

Translates 3D models into toolpaths and G-code instructions for CNC machines, controlling their movements and machining operations.

Creo

Excels in parametric modeling and assembly design, ideal for complex mechanical parts and systems.

Software

The software landscape in digital fabrication is expansive and diverse, catering to various stages and processes.

3dsmax

A powerful option for organic shapes and animation, often used in visual effects and product design.

Flashprint

Offers a user-friendly interface and efficient slicing algorithms, catering well to beginners and experienced users alike.

AutoCAD

While known for its 2D drafting capabilities, also offers 3D modeling tools and can be used for generating basic models for 3D printing or CNC machining.

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Digital Fabrication and Sustainability

The intersection of digital fabrication and sustainability is a fascinating and increasingly important area. While some aspects of digital fabrication raise concerns about resource consumption and environmental impact, it also holds remarkable potential for positive change.

Digital Fabrication and Sustainability

Challenges and Concerns

- Material use: Certain technologies like 3D printing can waste material if not carefully optimized. Discarded prints and support structures add to plastic waste.
- Energy consumption: Running digital fabrication machines requires energy, potentially contributing to carbon emissions.
- E-waste: Discarded electronics used in machines and fabrication processes become another source of e-waste if not managed responsibly.

Digital Fabrication and Sustainability

Opportunities

- Resource efficiency: Digital fabrication allows for precise material usage, minimizing waste compared to traditional manufacturing methods.
- On-demand manufacturing: Production only occurs when needed, preventing unnecessary resource consumption and overproduction.
- Design for disassembly: Products can be designed for easy disassembly and repair, extending lifespans and facilitating recycling.
- Biocompatible materials: Research into sustainable and biocompatible materials for 3D printing opens doors for eco-friendly applications.
- Empowerment and customization: Digital fabrication democratizes manufacturing, enabling communities and individuals to create and repair objects directly, addressing local needs and reducing reliance on global supply chains.

Common Challenges and Troubleshooting

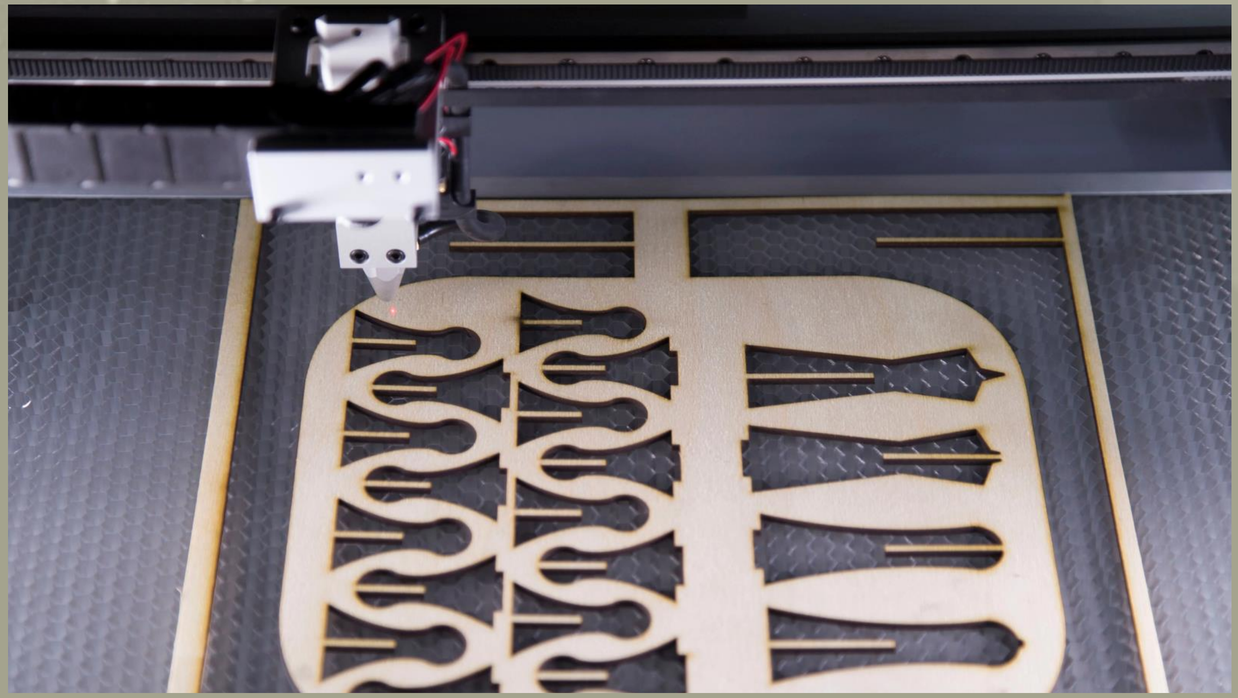
Common Challenges and Troubleshooting

Laser Cutting

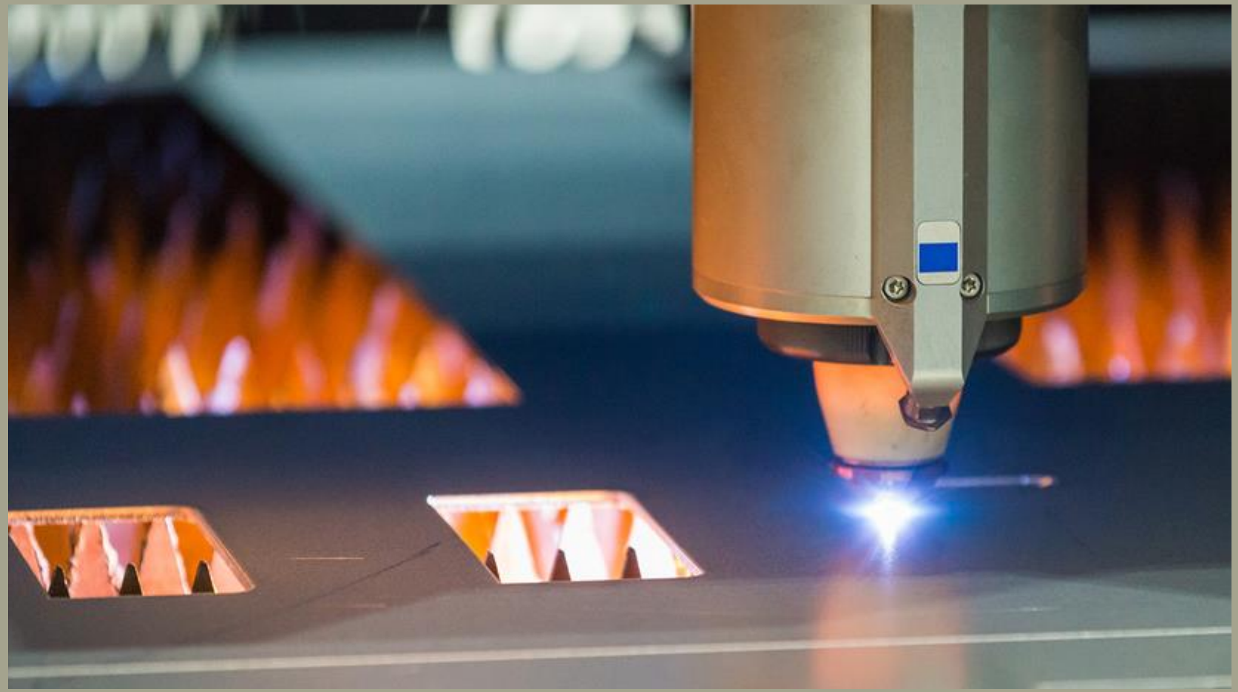
Challenge: Rough edges or incomplete cuts on specific materials.

Adaptation strategies:

- Adjust laser power and speed: Optimize settings based on the material thickness and desired cut quality.
- Focus the laser beam: Ensure proper calibration and alignment for precise cuts.
- Hold-down clamps: Secure the material to prevent movement during cutting, improving edge quality.
- Multiple passes: For thicker materials, perform additional cutting passes with reduced power.
- Experiment with different laser types: CO_2 lasers excel in wood and acrylic, while fiber lasers are better for intricate metal cuts.



CO2 Laser



Fiber Laser

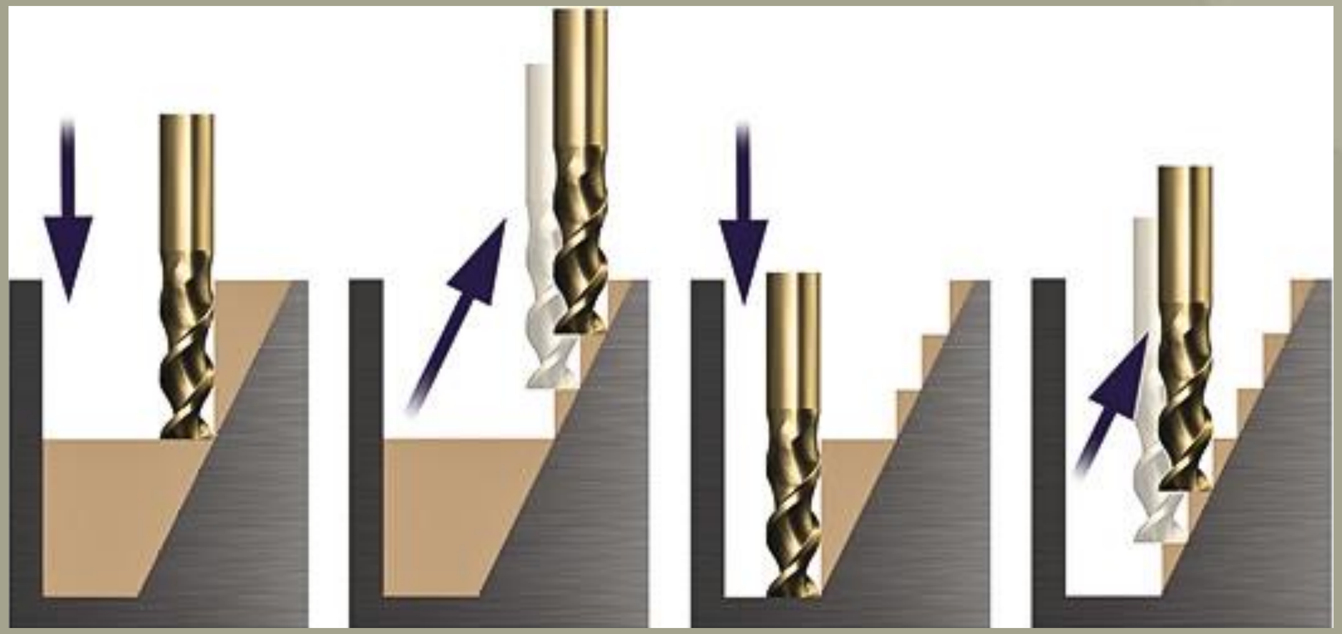
Common Challenges and Troubleshooting

CNC Machining

Challenge: Tool breakage or excessive wear during machining.

Adaptation strategies:

- Choose the right tool material and geometry: Match the tool to the material being machined for optimal performance.
- Adjust cutting parameters: Reduce feed rate or depth of cut to minimize stress on the tool.
- Coolant and lubrication: Use appropriate fluids to reduce heat and friction, extending tool life.
- Clamp the workpiece securely: Prevent movement and vibration during machining to protect both tool and workpiece.
- Use toolpath optimization software: Generate efficient toolpaths to minimize tool wear and tear.



Large, aggressive down-cuts are followed by fast, smaller up-cuts. This efficient cutting strategy removes the maximum amount of material with the minimum number of step-downs, significantly reducing cycle times.

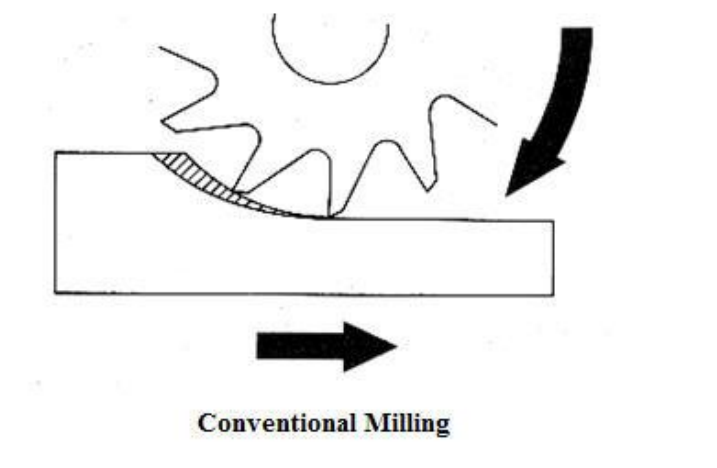
Common Challenges and Troubleshooting

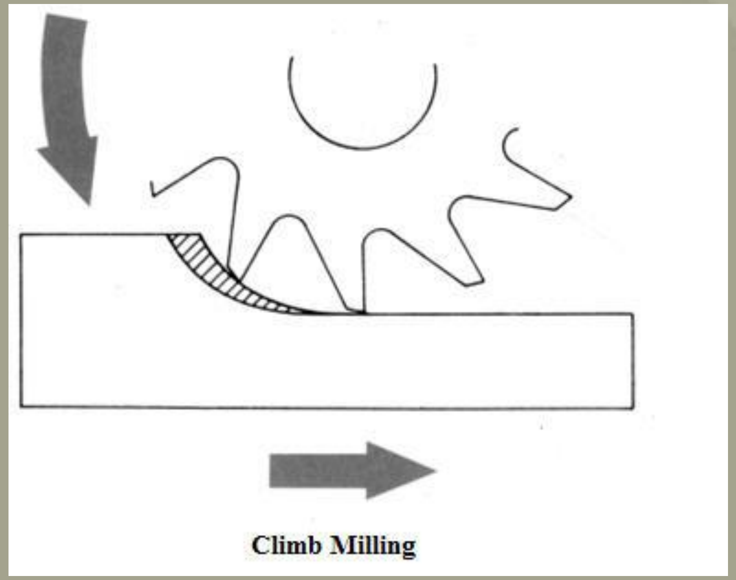
CNC Routing

Challenge: Tear-out or chipping along cut edges, especially in wood or laminates.

Adaptation strategies:

- Use climb cutting for smoother edges, especially on delicate materials.
- Choose appropriate cutting bits for the material and desired finish (e.g., compression bits for smoother edges).
- Adjust feed rate and depth of cut to minimize material stress.
- Use backing material or sacrificial boards to support the workpiece and prevent tear-out.





Climb cutting, unlike conventional cutting, engages the material by pulling the cutting tool in the direction of the feed. It can be a valuable strategy for achieving better cut quality, extending tool life, and expanding material compatibility in CNC machining.

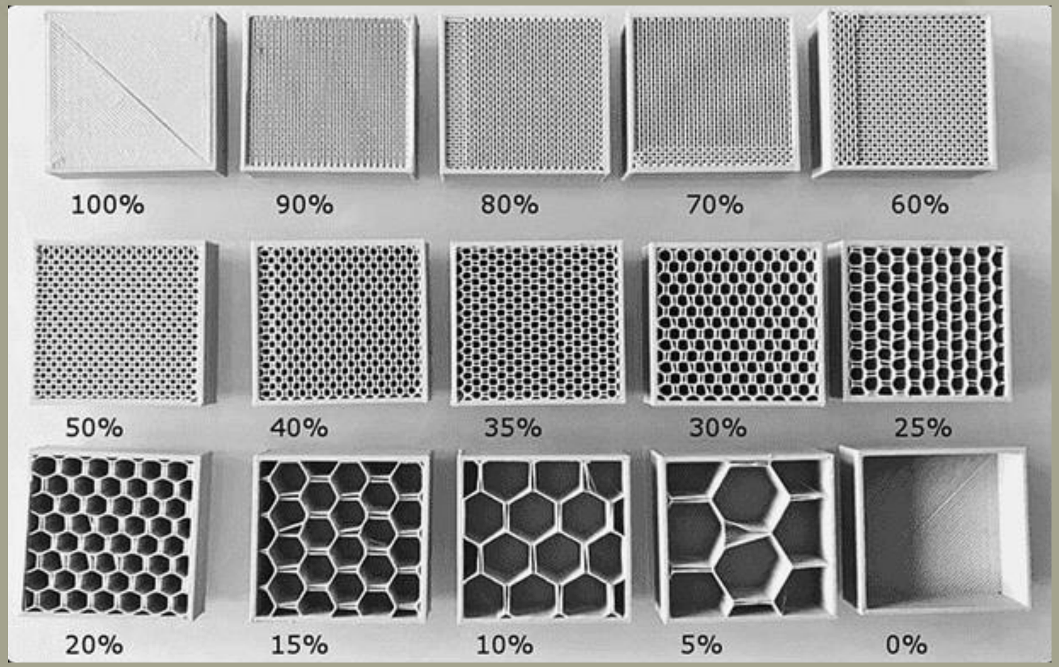
Common Challenges and Troubleshooting

3D Design and Printing

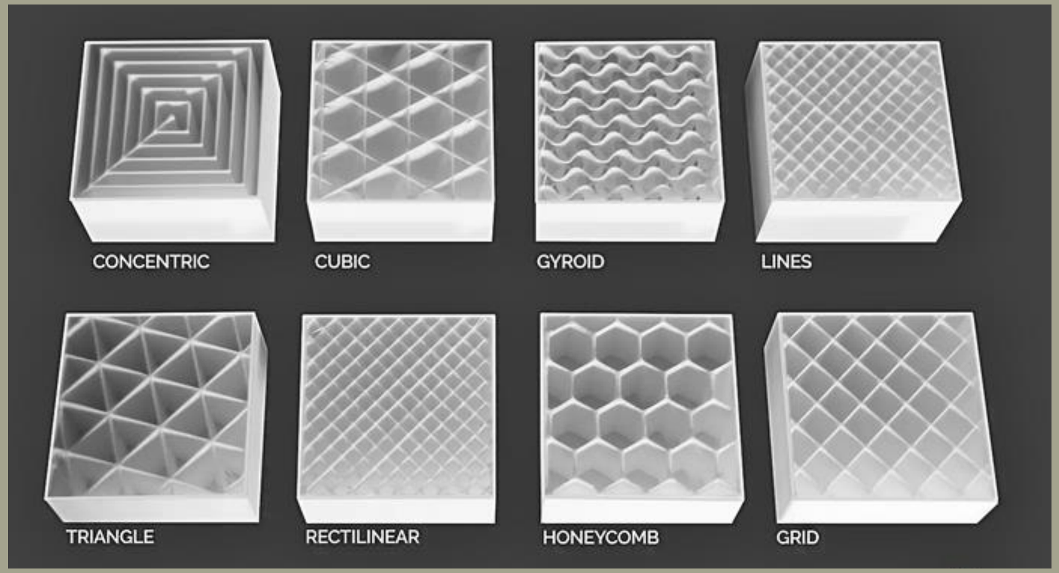
Challenge: Weight concerns, Material waste and difficulty in removing supports without damaging the object, leaving marks or requiring extensive post-processing.

Adaptation strategies:

- Optimize support settings: Choose support types and densities based on your model complexity and desired finish.
- Design for support-free printing: Analyze your model and adjust its geometry to minimize support dependence when possible.
- Advanced infill patterns: Use optimized patterns that offer good strength-to-weight ratios and minimize internal voids.
- Variable infill density: Apply different infill percentages to different areas of the model, prioritizing strength in critical areas and reducing density where less support is needed.



Infill patterns with different densities



Types of infill patterns

Machinery and Works

By ZUJ

Workshops and Labs

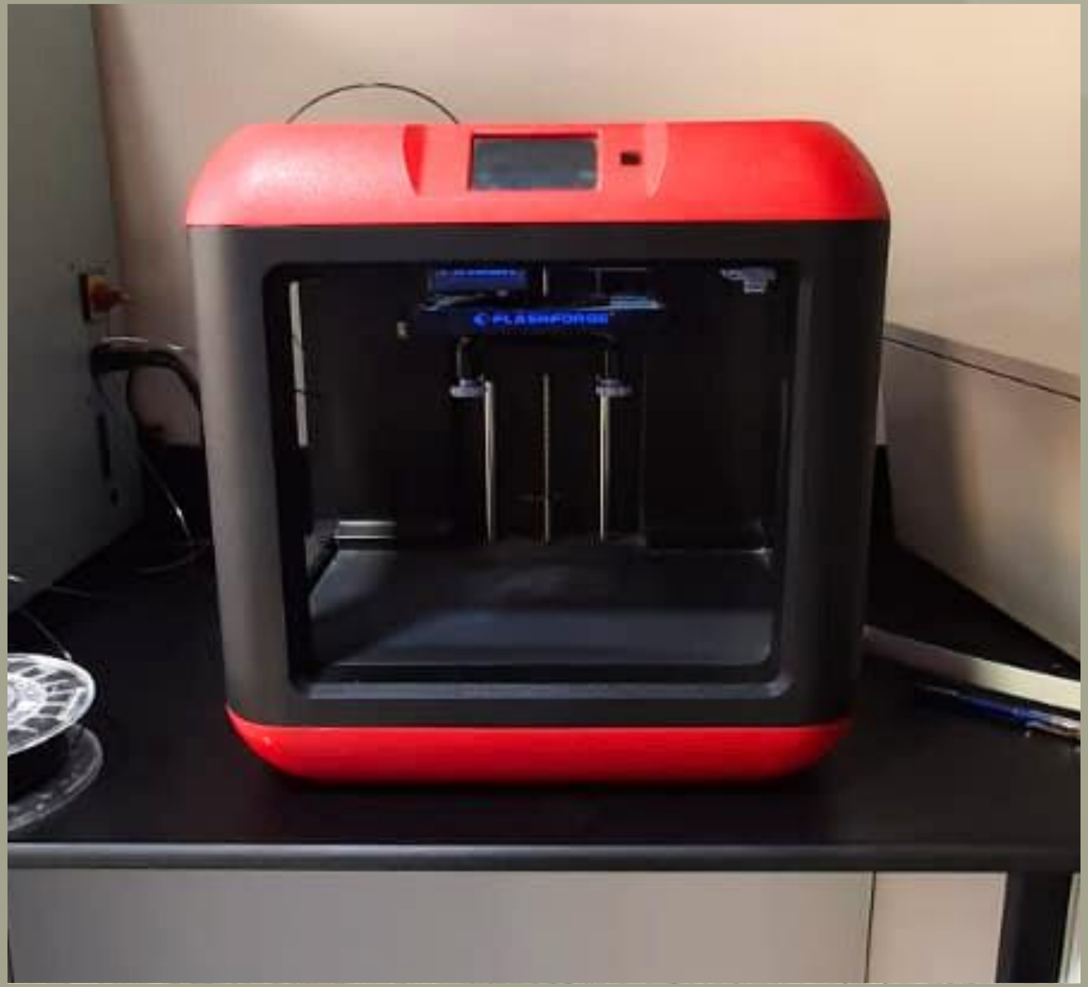
Models Workshop

Advanced Design and Manufacturing Center

Machinery

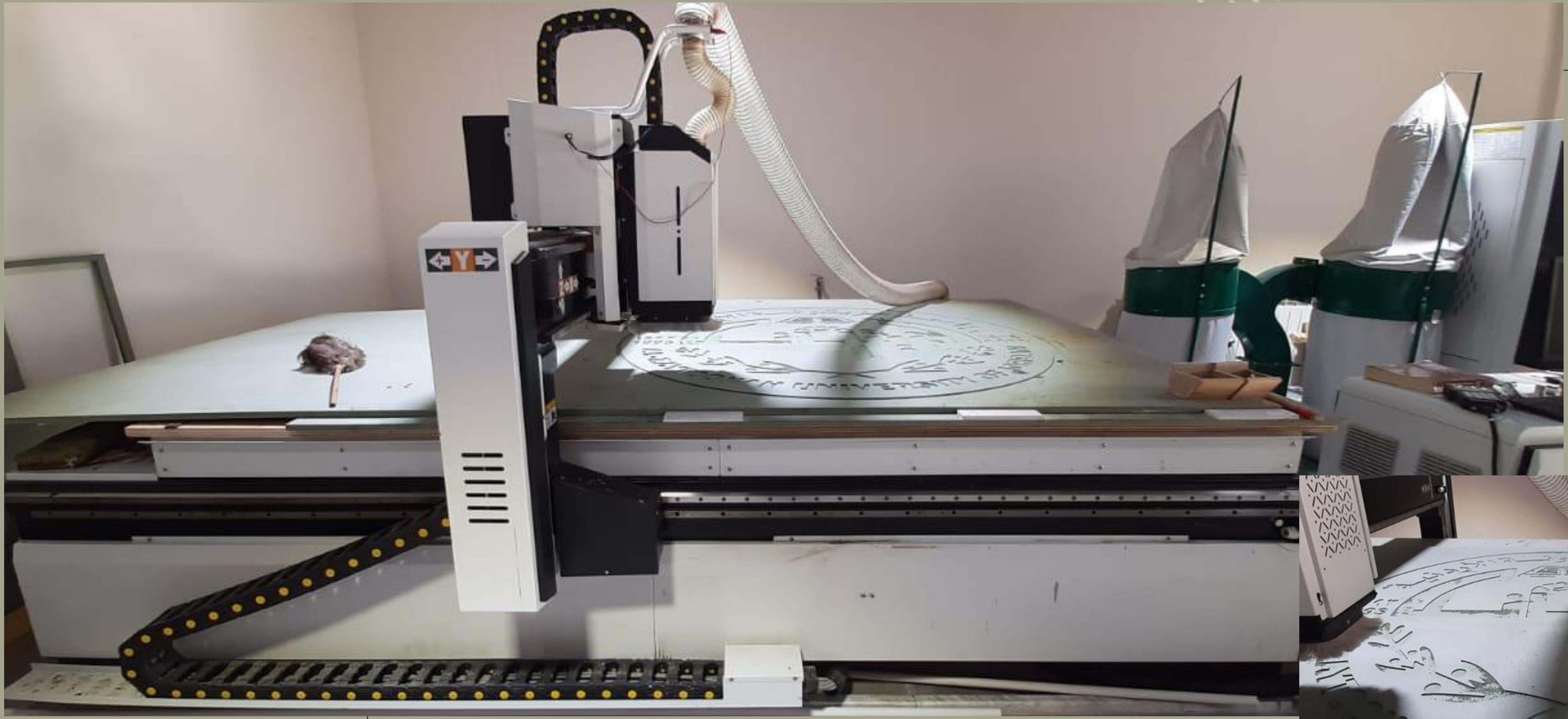
Laser Cutting Machine

UV Printer



3D Printer

Machinery



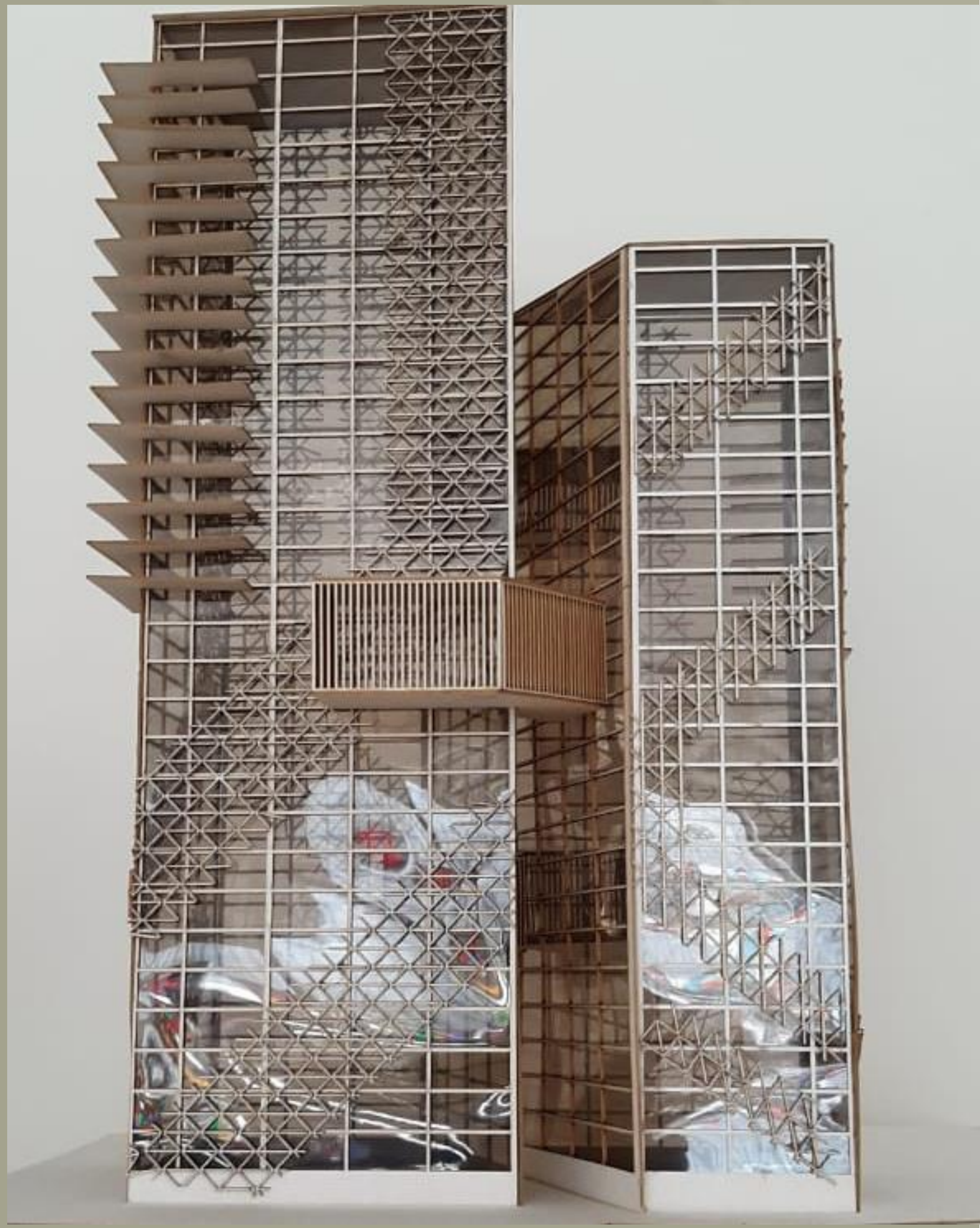
CNC Router

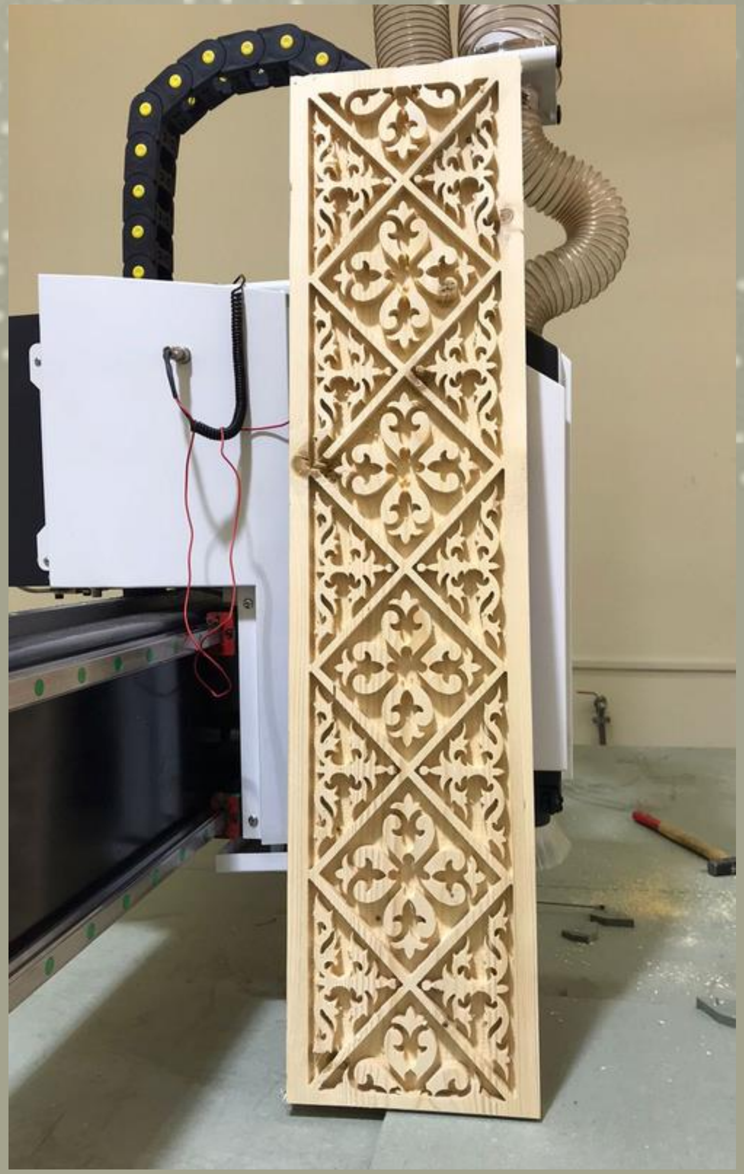
Machinery

CNC Mill

Lathe Machine

LASER CUTTING WORKS





CNC MACHINING WORKS

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