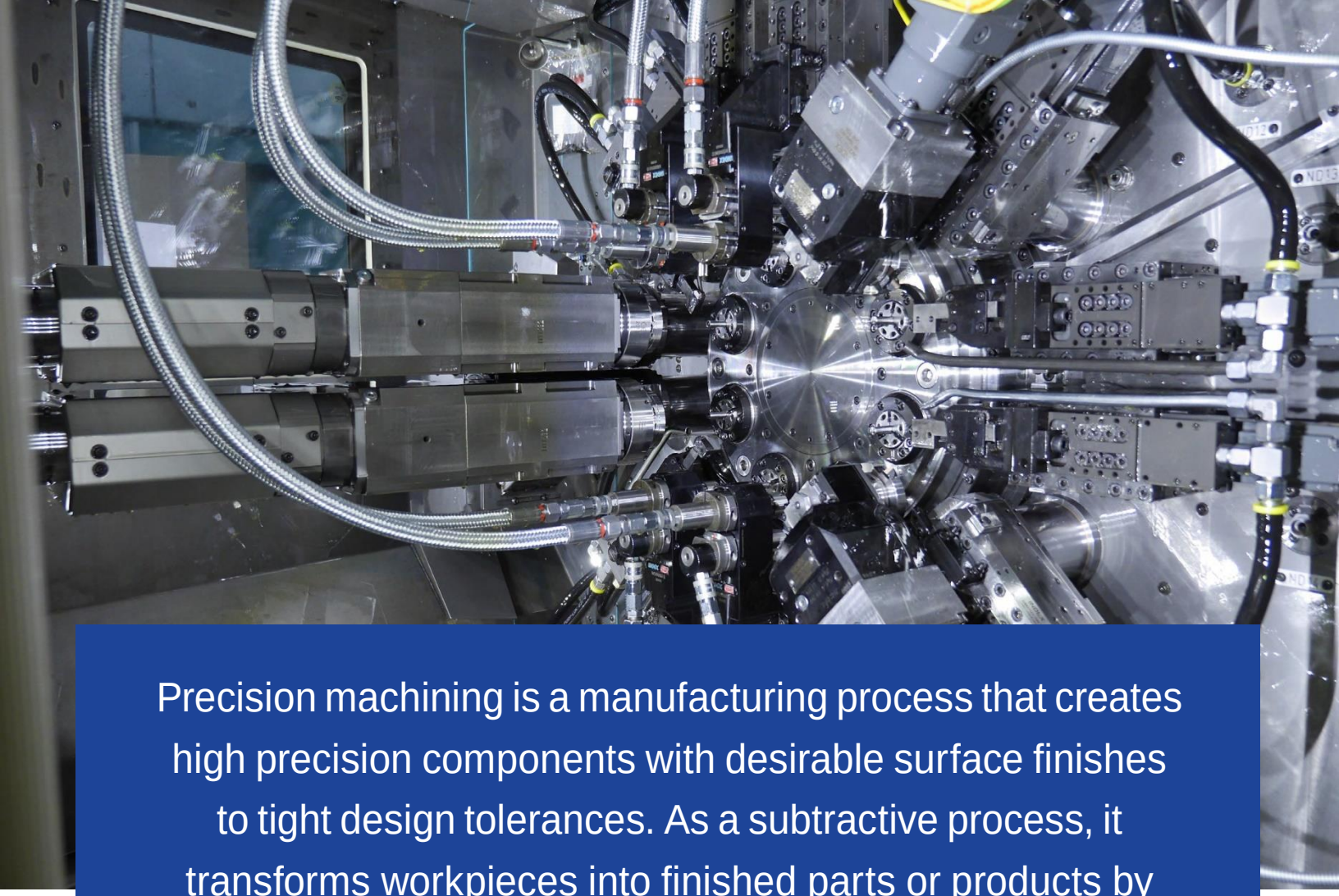
A Complete Guide to Precision Machining: Components, Process Types, and Future Market Outlook

Impro



Precision machining is a manufacturing process that creates high precision components with desirable surface finishes to tight design tolerances. As a subtractive process, it transforms workpieces into finished parts or products by precisely removing material through a variety of operations, such as turning, drilling, milling, and grinding. The precision machining process can handle various types of materials such as alloy steel, carbon steel, stainless steel, aluminum, bronze copper, titanium, and other special alloys.

The following eBook provides an overview of precision machining, outlining the different types of precision machining processes, equipment employed, typical components produced, and what the current market trends are saying about the future of the process.

Types of Precision Machining

Precision machining is an umbrella term that encompasses a wide range of processes. Combined with heat treating, surface treating, and quality inspections, these processes produce finished products from bar stock material or billets.

Pre-heat treatment Machining

Precision machining operations take place before the metal is heat treated which generally include:

- **CNC Turning.** This process ensures metal blanks and stock are precisely formed before the finer details are machined into the metal. Turning the piece increases part accuracy, total production speed, and ease of processing.
- **CNC Milling.** Milling processes whittle away excess material to create the final exterior shape of a part. The blade spins throughout the process to develop uniform, precise cuts. CNC milling is frequently used to create custom parts to tight tolerances.
- **Drilling.** Drills machine holes into workpieces to meet a part's interior requirements. In drilling operations, the workpiece is clamped in a stationary position as a rotating drill cuts into the material.
- **Gear Cutting.** If you are looking to produce gears, a common machining process includes hobbing (or cutting) splines or teeth into the outer perimeter of the circular blank. Hobbing and shaping can create bevel, helical, spur, and worm gears.

Heat Treatment

Once the initial machining processes are complete, the metal often needs to undergo heat treatments. Typical treatments include:

- **Carburizing and Carbonitriding.** Carburizing and carbonitriding are thermochemical processes used to treat the surfaces of steel workpieces. They make the metal harder, stronger, and more resistant to wear.
- **Quenching.** Quenching rapidly heats and cools metal to "lock in" the microstructural changes caused by extreme heat. It results in metal parts with greater material hardness.
- **Tempering.** Some metals, such as 1045 and A36 mild steels and 4140 and 4240 alloy steels, are brittle. Tempering can reduce the brittleness of these materials, improving the mechanical performance of parts that are made out of them.
- **Freezing/Cryogenic.** Certain types of steel – such as stainless steel and alloy steel - contain a high alloy content that often yields retained austenite, a solid solution comprised mostly of iron and carbon. Through deep freezing/cryogenic treatments (from -120°F to -300°F below zero), retained austenite can be transformed into untampered martensite, which is characterized by high strength, low fracture resistance, and low ductility.

Post-Heat Treatment Machining

Machining operations take place after the metal has been soft machined and heat treated. As the workpiece materials are typically much harder following these operations, manufacturers require specialized equipment—such as diamond-tipped tools—to perform further machining operations.

Post-heat treatment machining processes include:

- **Hard Turning.** Depending on the required finish of the piece, hard turning serves as either a pre-grinding stage or a replacement for the grinding process. On post-heat treated parts, turning removes excess material on pieces with a hardness range of 45 HRC to 68 HRC to create a semi-smooth surface.

- **Grinding.** Grinding creates a finer, smoother surface than turning. High-precision outside diameter centerless grinding is suitable for the production of very smooth shafts with dimensions of up 200 mm in diameter and 400 mm in length. It produces a smooth finish and leaves parts with diameter tolerances of 0.001 mm and cylindricity of 0.0005 mm.

- **Gear Grinding.** Gear cutting and gear grinding can both be used as standalone or combined processes to create gear teeth.
- **Honing.** Honing creates interior bores or finishes pre-drilled holes. It is commonly used with parts that have tubing interiors or cylinder bores.

Additional Processes

After machining and heat treating, the precision machining process ends with finishing operations. These steps ensure the parts are ready for packaging and use, and include:

- **Deburring.** Machining processes may leave behind excess material or surface deformations. Deburring can be a manual, mechanical, or chemical process – depending on what will work best for the specific parts and materials - that removes or corrects these imperfections.
- **Inspection and Measurement.** To ensure that every piece meets its specifications, operators carefully inspect the parts. They evaluate the parts to ensure every critical dimension stays within tolerance levels.
- **Assembly.** If needed, more complex parts or products can be assembled from discrete parts.

Common Types of Equipment Used

Each stage of the precision machining process requires specialized equipment. Depending on the part specifications and material being machined, more specialized tools—such as high-speed robotics and photochemical equipment—may be required. Some of the most commonly used machine tools include:

- Lathes
- Milling machines
- Electric discharging machines (EDMs)
- Grinders
- Saws

CNC Machines

Typically, precision machining operations use CNC—or computer numerical control—systems to automate the machining process. To create parts with a high degree of accuracy, manufacturers first use CAD/CAM software (or ProE and UG programs) to produce three-dimensional models of the intended part. These design files are then converted into machining instructions for the CNC machine. Once the instructions are ready, operators can load them to the machine and execute the machining operation.

For CNC turning and milling operations, the machines facilitate proper workpiece positioning to ensure the parts are machined as per the design. At Impro, our milling and turning centers produce parts with machining accuracies between ±0.005 mm and ±0.01 mm and repositioning accuracies between ±0.002 mm and ±0.004 mm.

4 and 5-Axis CNC Machines

One of the most commonly used pieces of machining equipment is a 4 or 5-axis CNC machine. This equipment has multiple spindles so it can machine a workpiece from five different axes at once. Each spindle can use different tools for simultaneous processing and overall faster production.

They offer a number of advantages, such as:

- Machining capabilities for more complex parts, especially for industries such as aerospace
- Single-setup machining; the workpiece only requires one set-up from start to finish
- Better part access, as the cutting tool and table can be tilted as needed
- Longer tool life and faster cycle time due to the tilting capabilities

At Impro, we have 5-axis, 4-axis, and 3-axis CNC machines to provide our customers with fast and precise machining services.

Additional Precision Machining Equipment

In addition to the equipment mentioned above, Impro also employs other specialized precision machining equipment:

- **For grinding:** Centerless grinding and cylindrical grinding machines
- **For heat treatment:** Multipurpose and vacuum heat treatment lines
- **For inspection:** ZEISS, GE, ZWICK, and ELTRA machines and devices

Applications, Industries, and Typical Products

Precision machining is a versatile manufacturing process that can create a wide variety of products from an equally broad range of materials. Any application that requires highly precise metal parts can benefit from precision machining. Some of the most common applications by industry include:

Aerospace

For components of air and fuel, engine, hydraulic, flight control, environmental control, landing control, and auxiliary power systems. At Impro, we frequently produce adapters, driveshafts, flanges, housings, port caps, rod ends, and valve seats.

Automotive (commercial and passengervehicles)

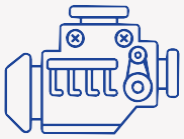
For chassis and body systems, fasteners, steering systems, and decorative components. At Impro, we frequently produce components for fuel injectors, fuel pumps, and engines.

Energy and oil and gas

For components of gas distribution systems, flame and smoke detection equipment, and transmission systems for wind turbines.

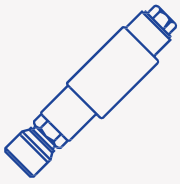
Engines

For components of cooling systems, crank-connecting rods, EGR systems, exhaust systems, and fuel supply systems.



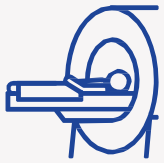
Hydraulics

For components of fuel supply systems, plungers, sleeves, and valve bodies and spools.



Medical

For components of medical equipment, implants, and surgical instructions. At Impro, we manufacture parts for laboratory, MRI, radiology, and surgical equipment.



Other industries that can take advantage of precision machining's benefits include agriculture, construction, food processing, forestry, recreation, telecommunication, and more.

Precision Machining Global Market Trends and Future Outlook

According to the Roland Berger Report, the precision machining market's expected compound annual growth rate (CAGR) is approximately 4% to 2022, following the upwards pattern of the past 5 years. The high-end market segment is expected to lead this growth, from 24% in 2017 to 33% in 2022.

One of the core reasons for these expected growth trends is the rising popularity of independent one-stop solution providers. These providers offer a wide range of services at a single facility, allowing for more streamlined design and production operations. One-stop solution providers will be able to provide the following:

- Research and development capabilities
- Advanced machining equipment
- Broad industry expertise
- Automated and digitalized operations

Having complete and unified control over precision machining operations allows one-stop solution providers to produce higher-quality products. As there is a growing demand for such products, these companies are expected to gain more market share over the upcoming years.

Precision Machining Services at Impro

Precision machining operations produce high-quality, high-precision metal parts. The stages of pre-heat treatment machining, heat treating, post-heat treatment machining, and finishing result in parts that are stronger and of an improved quality than alternative manufacturing processes.

At Impro, we provide precision machining services to customers across a wide range of industries. Our team of experts have the skills and knowledge to produce high precision, high complexity parts for simple to mission-critical applications. From initial concept and design to after-sales servicing - and everything in-between - our team provides one-stop machining solutions for our domestic and international customers.

Choosing Impro means:

- Upfront investment and technical expertise
- Fully equipped manufacturing facilities and a talented, experienced workforce
- In-house rapid prototyping
- In-house testing and inspection capabilities
- In-house heat treatment and surface treatment capabilities

To learn more about the precision machining capabilities at Impro, contact our team today.

About Impro

Impro is a global leading manufacturer of high-precision, high-complexity and mission-critical casting and machined components for diverse end-markets. We supply customized casting and machined products and provide surface treatment services to a well-diversified global customer base. Our global leading position is underpinned by our integrated business model with comprehensive capabilities of offering one-stop solutions to our customers.

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