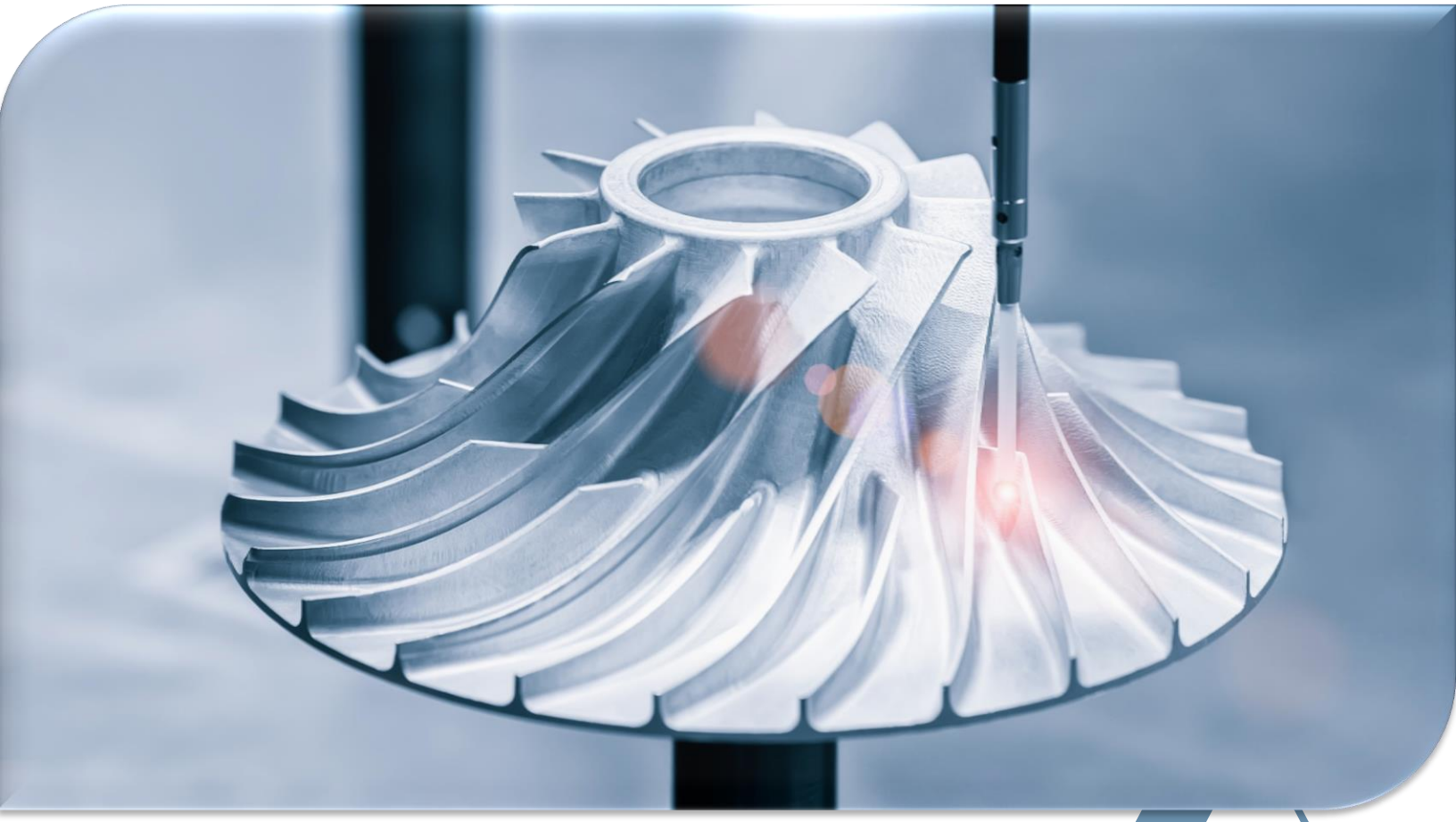
Impro

Precision Machining

DESIGN GUIDEBOOK



www.improprecision.com



Machining is the process of cutting away material to create a finished part or component. After machining this part typically moves to an assembly operation or sequence of operations, perhaps after plating or coating. Here it's joined with other parts to produce the finished product that the customer will buy and use.

Wood, plastics, composites and even ceramics can all be machined. However, this guide will focus on the precision machining of metal as undertaken by Impro. Sections will address:

- Material removal processes
- Types of material machined
- The meaning of "precision"
- Surface Finish
- CNC machining
- Economics of machining
- Examples of precision machined products

MATERIAL REMOVAL PROCESSES

Machining processes divide into those that involve single point cutting and those that use multi-point cutting. This term relates to the number of cutting edges removing material at any given moment. The best known single point cutting process is turning. Multi-point processes include milling and grinding. Drilling is technically multi-point but only involves the simultaneous use of two cutting edges.

Milling

This entails using a rotating cylindrical cutter with multiple edges to produce flat surfaces. Milling machines are defined by the orientation of the cutter axis: horizontal or vertical. Advanced milling machines have additional motion axes that enable machining of contoured surfaces.



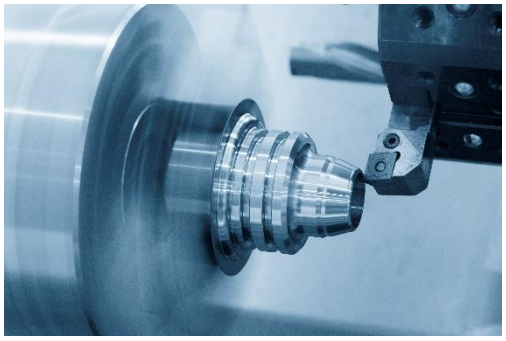
Drilling



This process produces holes. Drilling machines usually have a vertical axis with the workpiece being moved underneath, although horizontal versions exist. When the depth-to- diameter ratio of the hole being drilled exceeds 10:1 the process is considered deep hole drilling, sometimes also called gun drilling, and requires specialized tools and techniques. Milling machines can usually perform drilling as well as milling.

Turning

This probably gets its name from the rotation of the workpiece against a fixed tool. Turning is performed on lathes, of which there are many configurations. A subset of turning undertaken by Impro is “hard turning”. This refers to single point turning of very hard parts that are more commonly machined by grinding.



Grinding



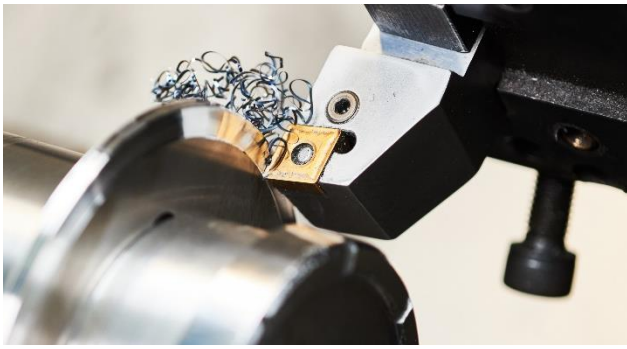
Used on very hard materials, grinding uses a wheel of abrasive grit to wear away the workpiece. At the microscopic level each piece of grit cuts in a similar way to a milling cutter, but removes a very small amount of material. Material removal rates with grinding are lower than other processes but it is capable of achieving very high precision and excellent surface finishes. In consequence it's usually employed as a finishing process.

Grinding is applied to shafts, cylindrical surfaces, cylindrical bores and flat surfaces. Grinding of shafts and other cylindrical surfaces is performed on an OD (outside diameter) grinder. Internal cylindrical surfaces are ground on an ID (internal diameter) grinder. Surface grinders are used for flat surfaces.

A limitation of grinding in volume manufacturing is that machines need each workpiece to be loaded individually, which slows down the process. For OD grinding this is addressed by centerless grinding. A centerless grinder consists of two opposed grinding wheels with a rail or guide between them. Cylindrical workpieces are pushed along this guide from one side, emerging on the other. The major limitation of this is that only a single diameter can be produced.

Honing

Honing is another abrasive material removal process and is used to bring cylinder bores to size and shape while imparting specific surface finish characteristics. Unlike grinding, honing uses reciprocating motion of abrasive pads coupled with rotation to achieve this result.



Honing is used to finish the bores of engine blocks and hydraulic system components. By correcting defects like waviness, barrel form and taper it enables the tighter piston and ring tolerances that improve efficiency and reduce leaks and emissions. In addition, the crosshatched pattern resulting from honing retains oil, so improving lubrication and sealing.

TYPES OF MATERIAL MACHINED

Machining is used to finish castings and forgings as well as to produce parts from solid billet material or bar or tube. At Impro materials machined include:

- Aluminum
- Cast iron
- Copper
- Many different types of steel – low, medium and high carbon
- Various grades of stainless steel
- Inconel
- Titanium

Contact Impro directly to discuss machining of materials not on this list.

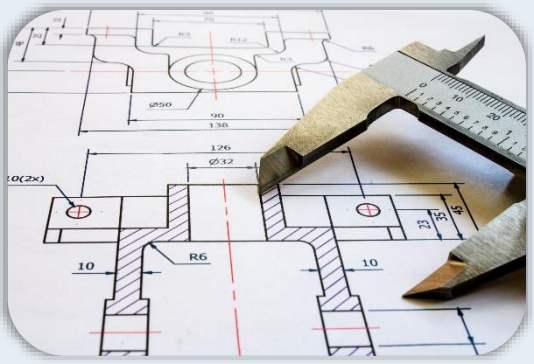
THE MEANING OF "PRECISION"

"Precision" encompasses both accuracy and repeatability. Accuracy is a measure of how close an actual machined dimension is to the target. Repeatability is a measure of the spread of accuracies achieved over multiple attempts to machine a feature to a specified dimension. The repeatability attainable on a specific machine or by a particular process is a major determinant in deciding the tolerances that can be applied.

The tightest tolerances normally applied to the machining processes listed above are:

- Milling +/- 0.0004" (0.010mm)
- Drilling +/- 0.0010" (0.026mm)
- Turning +/- 0.0004" (0.010mm)
- OD Grinding +/- 0.0005" (0.013mm) on diameter, roundness 0.00002" (0.0004mm)
- ID Grinding +/-0.0002" (0.005mm) on diameter
- Honing +/-0.0002" (0.005mm), roundness of 0.0001" (0.0025mm)

However, these will vary depending on machine type and condition and the care taken during setup.



A point to note is that precision is about more than just linear and diameter dimensions. For example, a hole may be drilled to the right size but be in the wrong position or at an angle. Thus position, concentricity and squareness are important considerations. For example, maintaining tight tolerances on the diameters of a valve spool only ensures smooth assembly and operation if the different diameter sections are all concentric to within very close limits. Likewise, a housing may not bolt to another machined surface correctly if the bolt holes are not square to the flat base.

SURFACE FINISH

Each machining process produces a very distinctive surface finish. This ranges from the screw thread-like finish created by the single point tool on a lathe to the crosshatched pattern made by honing. There are various ways of quantifying surface finish and selecting the one that's most appropriate should be dictated by the intended application. However, the most widely used measure is Ra (roughness average) and for comparison typical ranges achievable are listed below.



- Milling 16-250µinch (0.8-6.3µm)
- Drilling 30-250µinch (0.8-6.3µm)
- Turning 30-250µinch (0.4-6.3µm)
- Grinding 0.1-1.6µinch (0.1-1.6µm)
- Honing 0.2-0.8µinch (0.050-0.2µm)

CNC MAC

The overwhelming majority of machine tools used in industry today employ CNC (Computer Numerical Control). This refers to computer control of the various motion axes in accordance with a part program that defines the machining sequence and cutting tool positions. The exception is very high volume machining operations, as found in some automotive machining operations, where parts are machined on dedicated transfer lines. However, these too increasingly employ CNC.

Advantages of CNC machining include:

- Excellent repeatability – the first part off the machine will be almost identical to the last
- High speed – CNC machines usually perform multiple operations in quick succession, maximizing throughput
- Stable cycle time – simplifies production planning and control



ECONOMICS OF MACHINING

The cost of machining is driven by the tolerances called out on the part prints, the surface finishes required, and the amount of machining needed. Tight tolerances and fine surface finishes often require grinding after turning and/or milling. Besides being slow and expensive, these secondary operations add handling and extend lead time. Inspection time and expense also rise as tolerances become more demanding.

Cylindrical parts can, depending on design, be machined economically on lathes equipped with bar feed mechanisms. In some cases, hard turning is a cost-effective alternative to grinding for bringing such parts to final size.

For parts needing multiple holes drilled in the same direction, a multi-spindle drill machine saves time and reduces cost.

Billet machining – cutting a part from a solid block, is typically very expensive due to the machine tool time needed plus time taken for setups. This method is generally reserved for one-offs and prototype parts or parts of low volume or features that cannot be achieved via other methods.

Machining costs can be reduced by casting the part and then machining only those features with tight dimensions or finishes. For example, cast a valve body and machine only the bore and areas around bolt holes.

Note that investment casting produces parts that are closer to the net shape than sand casting. The additional cost of using this process may be offset by savings in machining.

Examples of Precision Machined Products

While many industries require precision machined components, three of note are:

- Automotive
- Aerospace
- Hydraulics and pneumatics

In the automotive sector, cylinder heads and blocks require precision milling, drilling, boring, and honing, and pistons go through precision turning. Likewise, pump housings and manifolds are machined after casting for the fit of internal components and mounting to the vehicle or engine. Fuel injection components are a family of parts with especially tight machining tolerances.

The aerospace industry demands high precision machining of castings and forgings for brackets and housings of many kinds. These are often produced in aluminum or titanium.

Pump and valve components are precision machined for companies in the hydraulics and pneumatics industries. These products often have demanding requirements for diameters, concentricity, and surface finish.



Precision Machining Services Available From Impro

Meeting demanding dimensional and surface finish requirements requires precision machining. Impro has made substantial investments in CNC machining capabilities with machines from proven manufacturers like Hardinge, Doosan, Index, Micron, and Pemamo and is capable of meeting every precision machining need.

Impro is a leading producer of precision machined parts for customers in industries from automotive and power generation to hydraulics and agricultural equipment. Capabilities include milling and turning, including hard turning, plus OD, ID, and centerless grinding and honing. Heat treatment services are also available. Contact us to learn how Impro could meet your needs for precision machined parts.

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