

Grinding for Precision

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877-484-6776 | sales@improusa.com

www.improprecision.com

For many engineered products, satisfactory performance and ease of assembly depend on components manufactured to tight tolerances. Modern CNC milling and turning machines are capable of high precision and repeatability, but when design requirements exceed what they can do its time for grinding.



The purpose of this eBook is to educate designers about what's involved in grinding when it's needed and what it's capable of. Individual sections address:

- *The limitations of CNC milling and turning*
- *Grinding process fundamentals*
- *Types of grinding*
- *Geometric and surface finish capabilities*
- *Grinding wheel considerations*
- *Constraints of the grinding process*

The Limitations of CNC Milling and Turning

There are limits to the precision these processes can achieve. These stem from how the machine tools are designed and constructed, the nature of the cutting tools used, and the properties of the material being machined.

The fundamental problem is that the cutting tools and machine spindle deflect under cutting forces. The harder the material, the larger these forces, and hence the greater these deflections.

The effects of tool and spindle deflection show up in the accuracy achievable and waviness of the surface. Surface finish or roughness, measured over a much shorter distance than waviness, is related more to the nature of the cutting process, although machine stiffness and cutting tool overhangs also play their parts.

Dimensional tolerances achievable on a regular basis are +/- 0.001 – 0.002” on a dimension of 2” and increase with feature size. For many components, this is good enough, but assemblies that need sliding contacts, and perhaps minimal fluid leak rates, require much tighter tolerances.

Turning, which is a single-point cutting process, leaves a groove on the surface that affects how other surfaces slide over it. Reducing the feed rate and maximizing the cutting tool nose radius reduce the impact of this “lay” but it will still be present.

As a multipoint removal process, milling doesn’t produce the spiral of turning but still leaves distinctive swirl marks over a flat surface.

Practical limits for surface finish are:

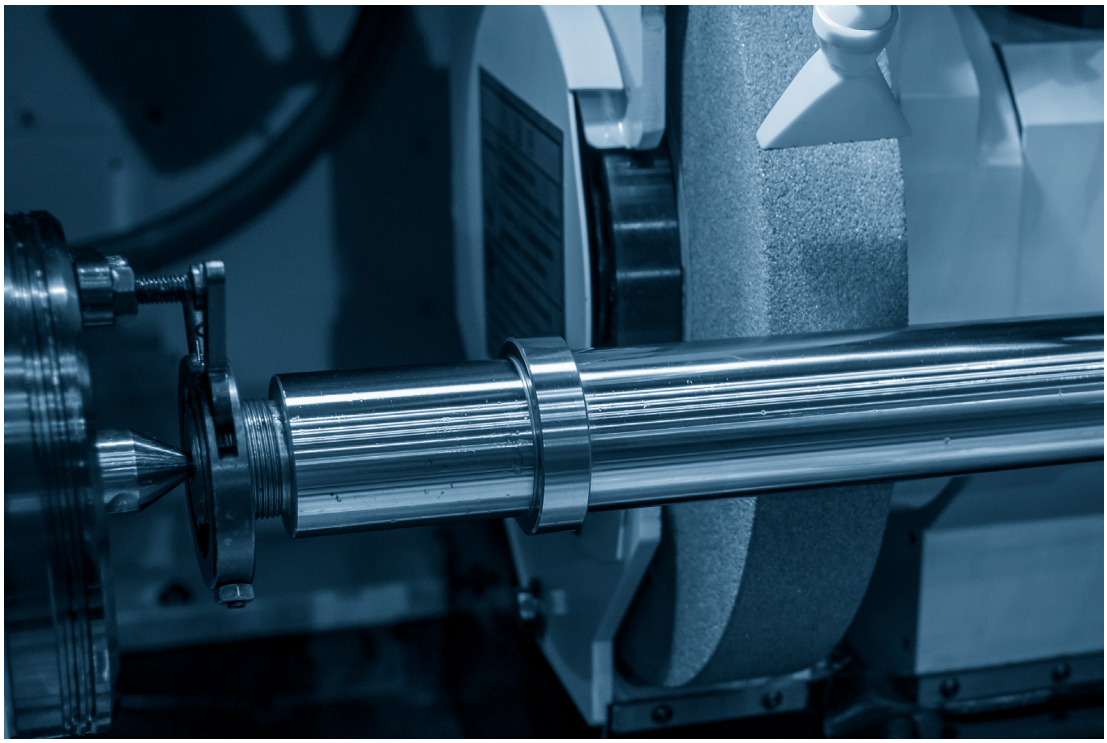
- Turning 30 – 60µ” Ra
- Milling 100 – 200µ” Ra

To conclude, there are limits to the precision and finish achievable through CNC turning and milling. When assembly requirements, functionality, or appearance demand better it’s time to turn to grind.

Grinding Process Fundamentals

The word “grinding” is used in fabrication to describe the cleaning up of welds and in casting for the removal of gates and runners. In the current context though, “grinding” refers to a process of precision metal removal by abrasion.

Grinding is performed with a rotating grinding wheel. This is composed of hard particles embedded in a softer matrix. “Dressing” – a process of moving a sharp point across the outer surface of the wheel – removes debris and soft matrix material to leave the hard particles exposed.



The spinning grinding wheel is brought into contact with the workpiece and the hard particles cut away material. The actual removal process is the same as milling or turning, but performed at a much smaller scale. In addition, the wheel brings thousands of these hard-cutting edges to bear on the workpiece. This results in a smoother surface than is achievable with milling or turning.

Abrasive grinding generates a lot of heat, so coolant is almost always needed. This lowers the temperature of the wheel-workpiece interface and takes away the microscopic metal particles.

Types of Grinding

Both flat and cylindrical forms can be ground. Flat surfaces are produced on a surface or planar grinding machine called a surface grinder. Cylindrical surfaces are ground on a cylindrical grinder.

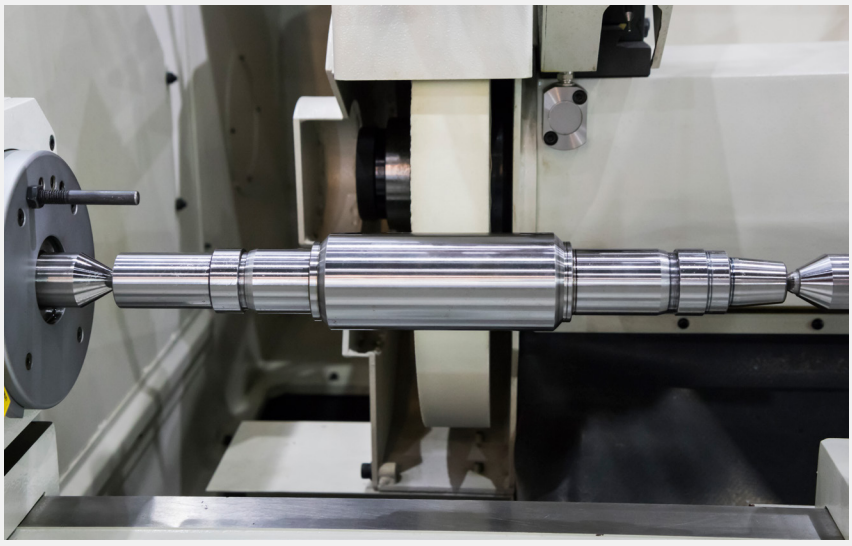
Cylindrical grinding machines come in several configurations. These processes are:

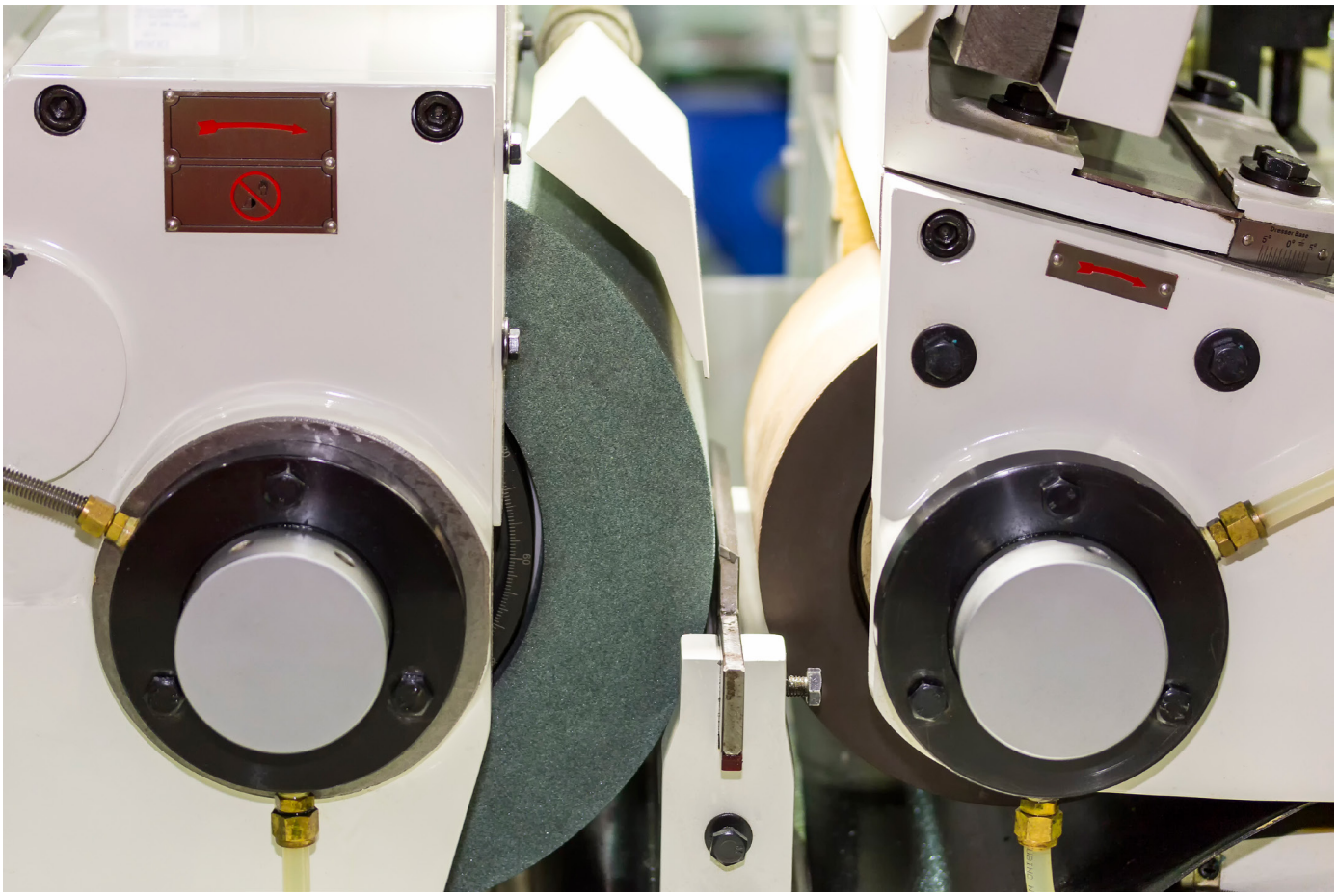
- Cylindrical grinding
- Centerless grinding
- ID grinding



In cylindrical grinding, the workpiece is held in a chuck or “between centers”. This latter term refers to holding it on an axis between two conical points. This avoids the deflection that results from holding the workpiece at one end only.

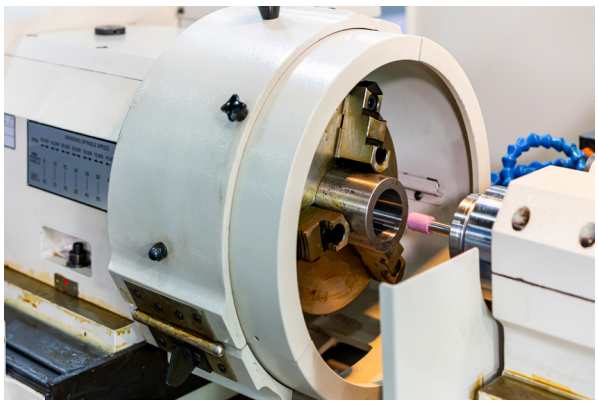
The workpiece and wheel both rotate, and the wheel is moved in to contact the surface and start the machining process. If the wheel continues to advance the process is “plunge grinding”. More commonly though, the wheel traverses axially along the workpiece to produce a cylindrical shape.





In centerless grinding, the workpiece is placed in the “vee” gap between two opposed wheels. One holds it in place and provides rotation while the abrasive wheel removes material. Centerless grinding can be performed in plunge or through feed modes. Through feed refers to passing a stream of identical parts past the wheels to achieve consistent size and form. It is an economical method for high-volume production.

ID grinding is where a small wheel is moved into a bore or recessed region of a workpiece. Valve bodies and housings may need ID grinding to maintain precise dimensional limits. The axial depth of ID grinding is limited by the need to avoid deflection in the grinding wheel shaft.



Two other forms of grinding, mentioned here for completeness only, are lapping and creep feed grinding. Lapping is more like polishing than grinding, with an abrasive wheel being used to smooth the surface beyond what regular grinding can achieve. Creep feed grinding is used to make a deep cut that forms a complex profile in a single pass. A prime example is grinding the roots of jet engine vanes.

Geometric and Surface Finish Capabilities

As with any other CNC machining process, holding tolerance and producing a smooth finish requires a rigid and well-maintained machine tool. Cutting tool, (grinding wheel, in this case,) type and condition and feeds and speeds are also factors. Even with these provisos though, grinding is capable of holding much tighter tolerances than milling and turning.

Achievable ranges under normal conditions are:

- Geometric tolerance: +/- 0.0005”
- Surface finish: 10 – 32µ” Ra

Grinding Wheel Considerations

Wheel composition and grit size and distribution play a large role in the metal removal rates and surface finishes achieved by grinding. The most widely used wheels are those made from aluminum oxide. These work well with mild, stainless, and tool steels, although they can suffer from high wear rates.

For high metal removal rates, zirconia alumina wheels are an alternative. These last longer and withstand higher loads. Grinding wheels designed for high productivity tend to incorporate less grit into the matrix as this allows more room to carry material away from the cut.



Higher performance is achieved by using super abrasive grinding wheels. Cubic boron nitride (CBN) is used for grinding steel, and diamond is paired with non-ferrous materials like tungsten carbide. On many such wheels, a high ratio of space or voids to grit ensures good material removal rates.

Unlike most conventional bonded matrix wheels, super abrasive wheels don't need dressing. This helps maintain part size control over long runs and improves productivity.

Constraints of the Grinding Process

Low metal removal rates are inherent to grinding. To keep costs down designers should try to avoid calling out tolerances and finishes that require it. When grinding is unavoidable, it should be minimized by first removing as much metal as possible through turning and milling.

The grinding process is most effective on hard materials like carbon and tool steel. Some soft materials, aluminum, for example, will clog the grinding wheel, necessitating frequent dressing. Brass, copper, and cast iron are other materials that tend not to grind well. Titanium and Inconel® can be ground, but require ceramic alumina grinding wheels.

Specialist Advice on Precision Machining

When tolerances are tight or the specification calls for very low surface roughness, it may be necessary to follow milling and turning by grinding. Grinding processes can maintain very tight tolerances and deliver smooth finishes but low metal removal rates make them uneconomic for all but very specialized finishing operations.

It should also be noted that ductile materials like brass, copper, and aluminum in general do not grind well. Superalloys and nonmetals can often be ground, but require careful wheel selection and optimization of feeds and speeds.

In general, engineers designing parts would be advised to avoid features and specifications that require grinding. When this is not possible, use milling and turning to minimize the amount of grinding needed. Hard turning should also be considered as an alternative.

As a precision machining specialist, Impro has deep expertise in all types of machining operations, including turning, milling, and grinding. Our specialists can review your designs to identify potential machining challenges and suggest
changes to make them easier to produce. Contact us to discuss your precision machining needs.

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