Impro

Common Precision Machining Part

Defects and Their Remedies



People who provide precision CNC machining services know the cost of a mistake rises dramatically as each part nears completion. Avoiding defects in precision machined parts requires skill, experience, well-maintained CNC machine tools and close attention to detail. The smallest error or deviation from ideal conditions could lead to one part, or an entire batch of parts, being scrapped for size, squareness or concentricity errors on a critical feature.

For many precision machined products performance depends as much on surface finish as it does dimensions. A surface that's too smooth or too rough may not retain enough oil, might wear too fast, or could create too much friction for satisfactory operation or to ensure durability.

Aesthetics matter a great deal too for most machined parts. Scratches, dents and burns may not affect performance, (although in some applications they will,) but they give the customer or end user an impression of sloppiness and imprecision that will be hard to shake.

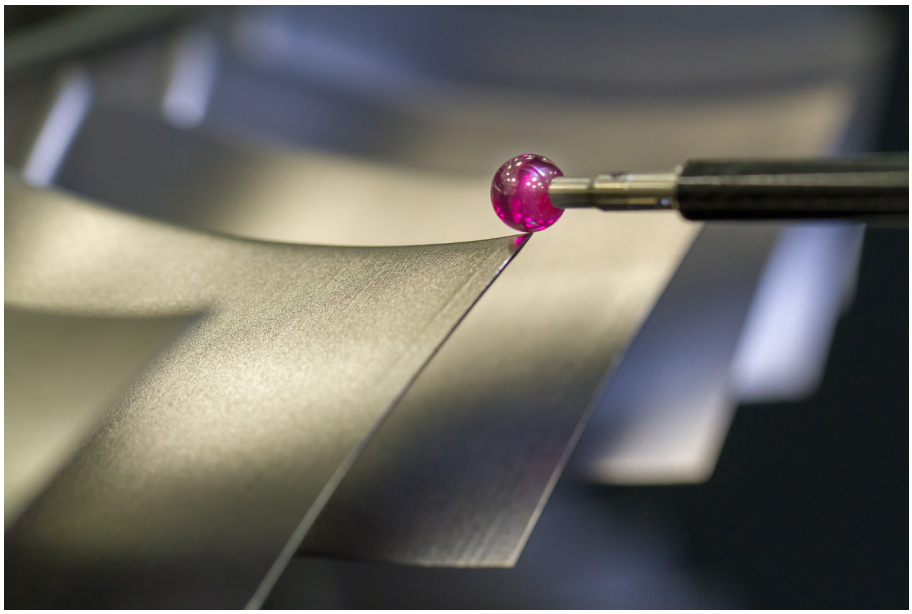
This eBook reviews the defects most likely to occur during precision machining operations and discusses how they can be avoided. Individual sections address:

- **Geometric errors**
- **Flaws in appearance**
- **Surface finish problems**
- **Costs and consequences of defects in precision machined parts**

Geometric Errors

A geometric error or defect can be a feature that's out of tolerance, but it can also mean one feature isn't in the correct relationship to a second feature. It may also refer to a form error.

For examples of dimensional defects, consider a right-angled bracket. This could have the mounting surface milled too thin or bolt holes drilled too large. Examples of defects in relationships between features could be that the two mounting faces aren't at 90° or that the bolt holes are too close to the parallel face.



Form errors are those where the shape is incorrect. They are typically very small deviations from the target shape, of the order of 0.0005" or less. One example is when a nominally cylindrical part like a shaft or valve spool is slightly oval rather than perfectly round.

Form errors can also occur on flat surfaces. For example, they might appear like a wave or have a barrel shape, albeit at a microscopic vertical scale.

Common reasons for geometric errors include:

- **Poor tool setup**
- **Part location/clamping errors**
- **Programming errors**
- **Poor machine condition**

Poor tool setup

Most turning and a lot of milling is done using indexable inserts. These are fitted in a toolholder and measured or set to an exact dimension in a process called “tool presetting”. This provides the CNC machine controller with the information needed to calculate tool offsets. If the insert is in the wrong position the part will be machined to the wrong dimension.

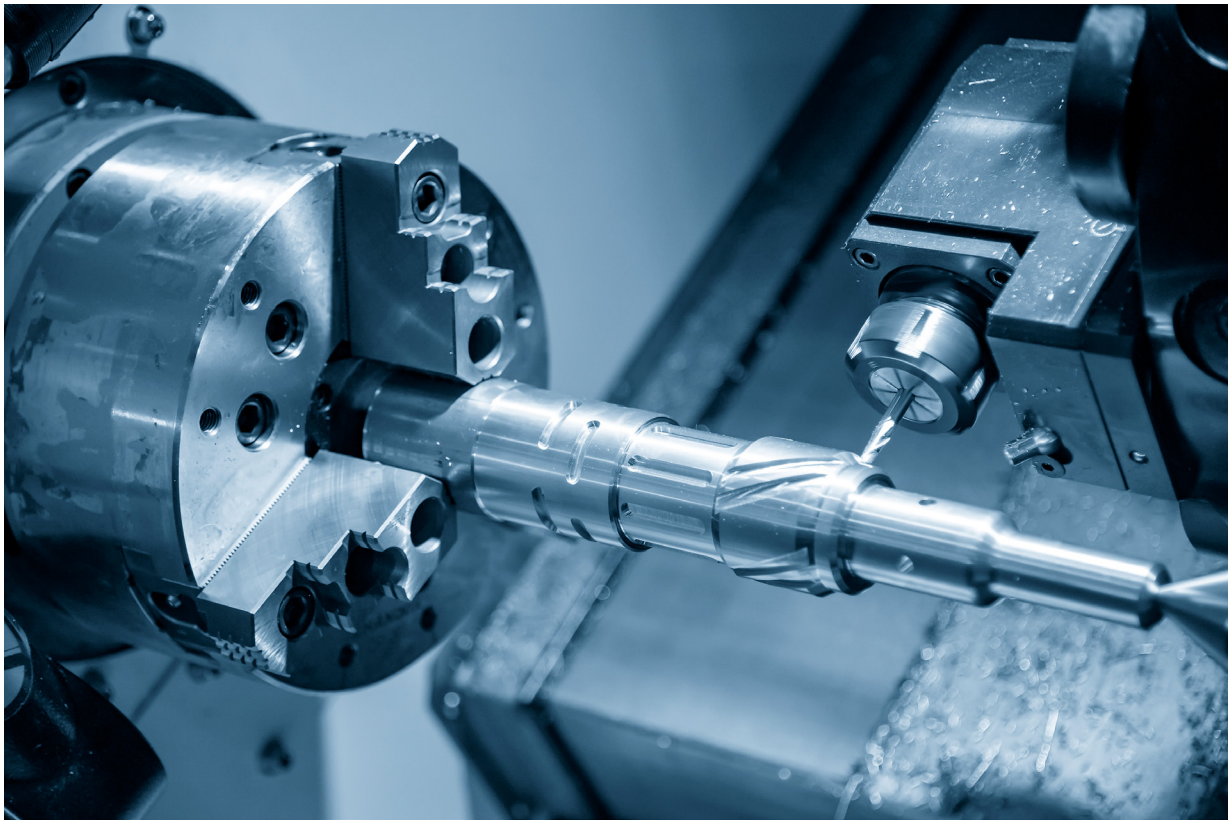


A similar issue can occur if the insert or tool is clamped against a surface that isn’t clean. This will put the tool tip in the wrong position.

Part location/clamping errors

Just as the CNC controller needs to know the position of the tool tip, it also needs the workpiece to be in the right place. In milling this is achieved with fixturing mounted on the machine table. In turning a chuck or collet holds the cylindrical workpiece.

If the fixture is wrongly positioned, or if there's dirt or metal chips on any of the locating surfaces, the workpiece will be in the wrong position. Likewise, dirt or chips in the chuck or collet will put the workpiece slightly off-axis.



Programming errors

Errors in part programs can range from the relatively minor, like having a feed rate too low, to the major, as when the wrong tool is loaded and used. Consequences of programming errors can range from spending more time cutting to a catastrophic collision that damages tool, workpiece and machine.



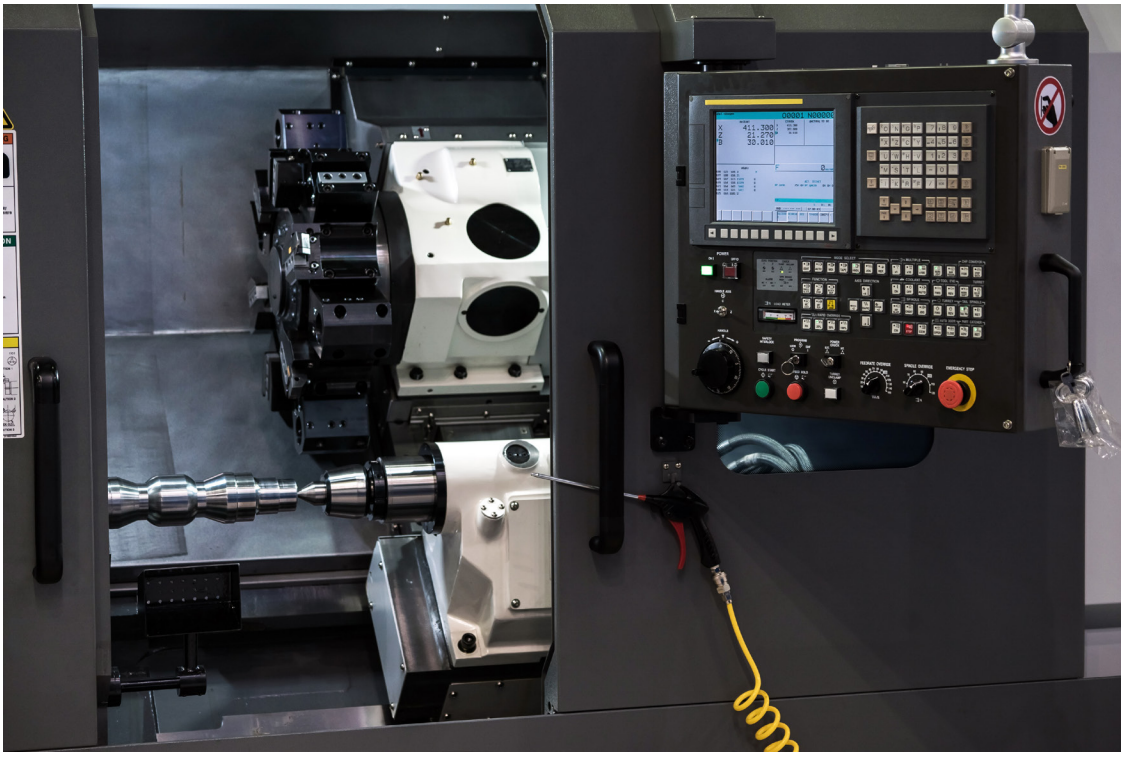
Poor machine condition

A poorly maintained machine tool will never produce high precision parts. Wear in bearings, spindles and slideways will lead to dimensional and geometric errors and poor part-to-part repeatability.

Avoiding Geometric Errors

Precision CNC machining is impossible with a dirty machine or one that's in poor condition. Regular maintenance and good housekeeping disciplines are essential. Businesses performing a lot of precision CNC machining will often use ball bar devices to check that axes and the spindle remain in good alignment.

Tool presetting must be undertaken with extreme care to minimize variation and ensure CNC machine controllers have the correct values. Part programs must be proven-out carefully, without workpiece or cutting tools, to ensure there won't be any collisions.



Surface finish affects wear rates, part appearance, oil-retention and other aspects of part performance. Causes of incorrect surface finish include:

- *Wrong machining conditions*
  A scalloped or grooved surface is a sign the feed rate is too high for the radius of the cutting insert.

- *Worn or damaged cutting tool*
  A worn tool is similar to using one with the wrong nose radius for the feed rate: it will create a scalloped surface. A tool that's chipped can leave raised lines on the machined surface.

- *Tool vibration*
  Vibration displaces the tool tip, which leaves raised and lowered lines in the surface

- *Poor machine condition*
  Play in bearings and slideways leads to inconsistent positioning between tool tip and workpiece.

Avoiding Surface Finish Problems



Ensure the feed rate is appropriate for the nose radius. Make sure tools are held securely in position and minimize overhangs that can cause vibration. Perform regular maintenance to keep machine tools in good condition

Flaws in Appearance

Flaws include scratches, chips, dents, burrs, and burns. Depending on size and severity these may or may not affect assembly, performance and life, but many customers will consider them unacceptable regardless.

Scratches, chips and dents

These often result from poor handling. Dropping parts, knocking them during loading and unloading or letting them bang together while in transit are the most common causes.

Softer materials like aluminum and brass are particularly susceptible to this kind of damage. They may also be dented by clamping forces that are too high or concentrated in a small area.

Burrs

A burr is a small piece of metal that's been pushed over an edge. They are a problem for several reasons. They can break off in service and cause scratches, they can injure people handling the part, and they can prevent parts assembling together. Part prints will often specify maximum acceptable burrs or specify where burrs must be removed.

Burns

While a metal bar, billet or casting won't burn if it gets too hot, it can become scorched. This gives the overheated area a blue-black discoloration. The high temperature can also lead to undesirable changes in the microstructure in the burnt area.

Avoiding Appearance Flaws

Damage caused by handling is addressed in several ways. Use totes or other dunnage that prevents parts from knocking together. Ensure work tables have softer surfaces than the metal of the parts being machined. (Aluminum or other specialized mats are good choices.) Provide lifting devices that make it easier to load and unload machine tools.



Burrs are virtually impossible to eliminate but they can be reduced in magnitude and severity. Ensure cutting tools are sharp and try to cut in a way that pushes metal into the part and not away from it and over an edge.

Cutting chamfers along 90° edges reduces burring, but secondary deburring operations may still be needed. Depending on the size of the part, this may be done by hand with a knife or file, with a mechanical deburring tool or by bead blasting (which also changes surface appearance.)

Another method sometimes used on complex parts like valve bodies and manifolds is explosive deburring. The parts are placed in a chamber which is sealed and filled with a flammable gas. The gas is lit and the rapid temperature rise vaporizes the burrs.

Burns are usually a sign of excessive friction. A dull cutting tool can cause this, as can cutting without fluid or trying to cut too fast. Burns can occur in grinding if the part being ground doesn't turn fast enough.

Costs and Consequences of Defects in Precision Machined Parts

If a defect is found in a machined part it can either be reworked or scrapped. Choosing between the two comes down to three factors:

1. *Can the part be reworked to a condition where it will perform and look like a defect-free part?*
2. *How does the cost of reworking the part compare with the cost of making a replacement?*
3. *Is there enough time and material to make a new part?*

Regardless of whether the decision is to rework or make new, the defect will be costly. More time, labor and possibly material will be expended than was budgeted for when the job was quoted. Machine capacity will be taken up which was intended for production of other parts.

Furthermore, the additional time needed, especially if a replacement part must be cast, may well result in late delivery. This is almost certainly something the customer will be unhappy about.

From this discussion it should be clear: a professional precision machine shop will endeavor to avoid machining defects rather than devoting resources to putting them right.

Precision CNC Machining Services From Impro

Many things can cause machining defects. Poor machine condition, mistakes in part mounting or tool setup, careless handling and poor condition of the machine tools can all play a part.



If a defect does occur it's often expensive and may delay shipment, leading to a dissatisfied customer. Businesses like Impro that provide high quality precision CNC machining services understand the importance of avoiding defects and take great care in preventing them. If you'd like to learn more about our approach to precision machining, contact us to arrange a discussion.

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