- Form Tools -

Combining operations and improving efficiency

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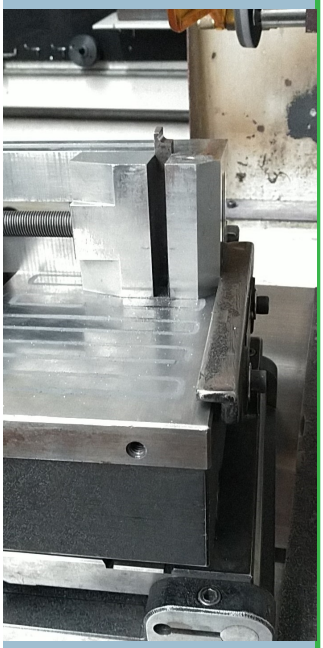
Special points of interest:

- Why are form tools still relevant on CNC Machines
- Tips for improving your form tools
- A look at the economics of using form tools



Written by:

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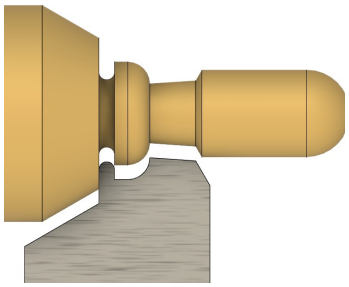
What are Form Tools?

From the primitive beginnings of machining up to todays highest performance CNC machinery, Form Tools serve an important role.

Consider using a lathe to groove a pin, or to thread a shaft. Typically square or round tools are used to plunge into a groove and remove material, leaving behind a square or radiused cutout in the part. Or in threading where a "V" shaped tool traces a spiral path around a shaft to leave a identically shaped "V" thread profile. Likewise, when using an end mill to cut a slot through a block of material, the resulting rectangular slot is shaped by the rotating cylinder which just passed through it.

Form tools are simply a more specific categorization of cutting tool used to impart a specific shape onto a machined part. Typically a "Form Tool" would be a dedicated tool for a single part, or for a family of similar features.

Take a look at the picture to the right. How would you cut this brass part on a lathe? It can be done with generic tools, but it is time consuming and requires careful adjustments to ensure every feature blends together. By using a dedicated form tool we can cut all the features at once while ensuring perfect blend lines in a fraction of the time compared to using multiple tools.



How would you produce the grooves in this pin?

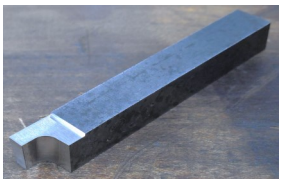
Relief Angles

If you decide to give making your own form tools a try then you may need to consider Relief Angles.

For the sample form tool in the section above, pretend that you are the tool. As the tool advances into the cylinder of material the first machined chips start to be made. But after the leftmost radius enters itself past the tangent point then it's left flank will begin to rub on the side of the groove. This will generate frictional heat and a smeared surface finish.

A small amount of side relief will greatly reduce the friction & pressure while improving surface finish quality. Consider this when designing your tool.

Tooling Example: Manual Lathe



A dedicated tool which combines facing the part to length & forming the corner radius in one plunge cut.

CNC Machining has eliminated the need for many applications of form tools in the machine shop. But some jobs just deserve to run on manual equipment despite this.

We had a job come through where for several reasons we wanted to run it on our toolroom manual lathe. Namely, it is much faster to load high quantities of small parts compared to our CNC lathe.

There was one simple feature that posed a problem. The end of this pin required a corner radius. We took this opportunity to teach our machining interns about foundational machining concepts where we designed & produced a corner rounding tool.

The end product allowed us to produce this run of parts in very short time, and has seen repeated use since our investment in the time to make this custom tool.

Grinding the Tool

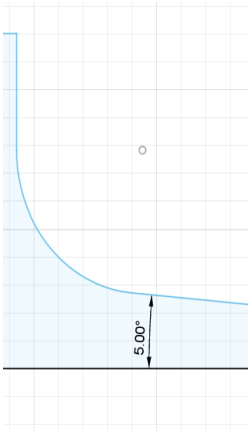
"The end product allowed us to produce this run of parts in very short time"

Before we grind the form tool we must decide a couple things. Based on the workpiece material and the volume of parts to be processed we may choose to make the tool from a few cutting tool materials.

We chose a High Speed Steel tool blank with a modest cobalt content, but we could have chosen a lower or higher grade H.S.S. or even carbide.

First we design the tool in CAD and use those dimensions to dress a custom shaped grinding wheel on our Surface Grinder, essentially the "negative image" of the final machined part. We then mount the H.S.S. tool blank on a 5° tilted & rotated Sine Magnet to give us the relief angles desired for our tool. We then add a small 1° top angle to "sharpen" the cutting edge slightly.

Lead Out Angle



We added a 5° flare at the tangent point. Form Tool shaded in blue

While a Form Tool is excellent at reproducing an exact copy of itself into the part, this can also be a downfall. If we were to overshoot the position of the corner radius then we would have cut into the OD of our part and left a diameter step mark.

To eliminate this unwanted byproduct we chose to add a Lead Out Angle, or "Flare" to the tool. Where we intentionally ground a 5° slope tangent to the quadrant of the corner radius. This way, if we overshot the cut on the manual lathe then we still had a very smooth transition out to the OD of the pin with no blend lines.

Not all applications permit this trick, but it is an elegant way to simplify the application of the tool. In our case the corner radius was not critical. Therefore flaring the transition was perfectly acceptable.

Tooling Example: CNC Mill

CNC Machines also benefit from form tools. Despite their ability to cut complex shapes, some forms are difficult, impossible, or extremely time consuming to generate with CNC.

We had a job come in which required an undercut beveled step. The initial job we chose to run on a manual mill with a tilted head. But the job repeated—in higher quantity too. We needed a better, more repeatable solution.

The feature was a 90° notch, but tilted 20°. While we could have installed a large sine plate in the CNC Mill, it would have taken up most of the machines travel limits, and more importantly it would require us to re-establish our datums on the part in an awkward way which reduced accuracy and required a more skilled operator to run this repeat job every time.

And lastly, this extra setup added time. We did not want to tie up our primary machine to run an additional setup.

Notice the double angle cutter profile.

Economics

We have a relationship with a local tool and cutter grinding shop. When we approached them with a sketch of the tool we'd like produced they immediately had an idea.

While they could have produced a custom tool from scratch for us, they actually had a perfect candidate tool on the shelf which only needed modified to become our new bevel step cutter. It was done the next day—for less cost than a typical end mill.

The new tool worked on the first try with only a minor size adjustment made in our CAM software.

This new tool allowed us to cut the bevel step, in the same setup as all of it's referenced datums, and it left a great surface finish, much better than our manual milling method. The tool paid for itself by multiples on it's first batch and has seen repeat use since.

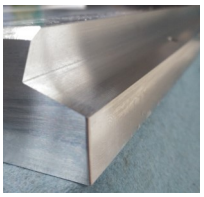
"The tool paid for itself by multiples on it's first batch "

Reduced Error

With the old method of production we had the issue of locating the datums accurately because we had to tilt the part. Whereas our new method cuts the beveled profile in the same orientation as we inspect it, and during the same setup as all the referenced datums.

The old method also had the potential for human error in fixture loading, where a minor angular error in placement could lead to a major tolerance violation over a 20" distance.

The old method also had the risk, where we are performing a final critical operation on an otherwise finished part which has lots of time invested into it. Whereas the new method occurs as just another operation in a pre-existing setup. Once we dial in the process it is very repeatable with an extremely low scrap risk.



The custom CNC Milling Form Tool left a great finish and produced a very accurate result.

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What "Progressive Manufacturing" means to us...

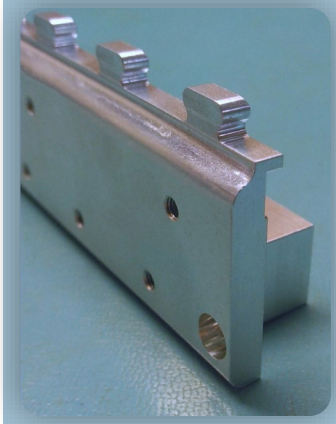
Progressive Manufacturing is our business's tagline and motto because it reflects our mindset.

We do not possess the most advanced equipment or tools. We do not use the most expensive software. But we do strive to make continual improvements in our processes and our people.

For example :

- *We continually invest in new inspection equipment*
- *When we add equipment, we look to add new hardware and software capabilities rather than just to replace existing ones*
- *Employees are given continual access to training programs, and are cross trained on equipment*
- *New tools are always being trialed to improve process reliability and part quality*

Please do reach out with any questions or comments regarding this article, we hope you found it helpful and entertaining!



Solving Complex Problems with Ingenuity

We had another challenging part come through the door. This part required very accurate and cosmetically critical surfaces to be machined in an expensive aluminum alloy.

The parts were long bars with lots of detailed machining. But along the entire length had a step, where the top of the step had a corner radius and this immediately blended into a tangent floor fillet on the lower level of the step.

The radii were tight tolerance, as was their surface finish requirement. While we could source a corner rounding tool, and a bull-nose end mill in the required radii, we knew getting a perfect tangential blend was going to be a challenge.

Notice the carefully blended tangential radii and flat floor finisher profiles.

Instead we had a custom form tool made of the entire profile—for almost the same cost as buying the two separate tools. Therefore we eliminated the risk of not blending the two tools perfectly, and we saved multiple tool changes while also milling the profile complete in a single pass.