

Machining

Tools and Parameters Still Play a Key Role in Machining Success

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Introduction

Although the parts, workpiece materials and machining processes they work with differ widely, all manufacturers share the goal of machining a certain number of workpieces of a desired quality, in a specified amount of time, at an appropriate cost.

Manufacturers typically achieve their goals by following a narrow-perspective model that begins with tool selection and application and solves problems on a reactive basis. Reversing that approach will produce cost reductions and increased efficiency. Instead of waiting for problems to arise and then making adjustments to individual machining operations, manufacturers should focus first on proactive preplanning aimed at eliminating rejected parts and downtime. After establishing a stable and reliable process, the concepts of production economics may be applied to achieve a balance between production rate and manufacturing costs. Then, through careful selection of cutting tools and machining parameters, manufacturers can fully optimize their operations and fulfill their production goals.

Selection of tools and cutting conditions

Metal cutting tool selection usually is application oriented: a shop looks for a tool to machine a certain workpiece material such as steel or aluminum, or carry out a specific operation such as roughing or finishing. A more beneficial approach to tool selection begins with consideration of how the machining operation fits into a manufacturer's business overall.

The first priority of such an approach is to ensure process reliability and eliminate the occurrence of rejected parts and unplanned downtime. Reliability, generically described, is a question of respecting rules. If a shop does not recognize and respect the effects of cutting, thermal, and chemical forces on the tool, reliability will be replaced with tool failure.

After establishing a stable process, tooling characteristics and cutting conditions should be chosen to match the overall goals of the metal working business. For example, maximizing output at minimal costs may be the primary consideration in mass production of simple parts. But on the other hand, in high-mix, low-volume manufacturing of valuable complex parts, total reliability and accuracy must be emphasized before addressing manufacturing costs. Flexibility is a requirement of tooling systems applied in such small-batch scenarios.

If cost efficiency is a primary target, the tooling must be selected based on a low cost per cutting edge, and the choice of cutting conditions must be in balance with that selection. Machining parameters should emphasize long tool life as well as process reliability. If, conversely, workpiece quality is the top priority, high performance precision tooling applied at appropriate cutting conditions will be the correct approach. Whatever the target, each different set of goals leads to the selection of different cutting conditions and tools.

Selecting and adjusting cutting conditions

In the initial planning of machining a new part, selection of tooling and cutting conditions should begin with consideration of the machining method, tool geometry and tool material. The part being

machined will largely determine those requirements. For instance, a nickel-base aerospace component may dictate profile milling with a positive-geometry solid-carbide end mill. The choice is guided by the shop's basic goals in terms of production rate, cost and quality of the workpieces, and it is dependent on the depth of cut, feed rate and cutting speed that may be applied to achieve those goals.

A different selection process is appropriate for modifying existing partmaking operations to produce better results in terms of productivity, economy or reliability. In these cases, a step-by-step approach is recommended, beginning with changes in cutting conditions, then geometries, cutting materials, tool concepts and finally machining methods. Notably, most shops work in the opposite sequence and first consider changing tools or machining methods when attempting to improve machining results.

A much easier and usually effective initial approach begins with altering cutting parameters. Cutting conditions have a wide range of influence, and changing cutting speed or feed rate by a nominal amount may solve a problem or boost productivity without the expense or time consumed in changing tools.

If modifying cutting parameters fails to produce the desired effect, changes can be made in the cutting tool's geometry. However, this step is more complicated than simply changing parameters, will require application of new tools, and will increase tool and machine time costs. A switch in cutting tool materials is another alternative, but also will involve greater investment in time and money. Changing the cutting tools or holders themselves may be necessary, but this raises the possibility of moving into custom-made tools, all of which can further increase manufacturing costs.

If all these steps do not provide the desired result, then a change in the machining method may be necessary. The key is to explore the changes in a deliberate, step-by-step fashion that will make clear what factors actually do produce the desired outcome.

Because it appears to be a fast and easy approach, many shops use CAM systems to guide their tool selections. That method is effective in many cases, but may not provide optimum results. A CAM system does not take into account the full range of individual operational characteristics. Applying a milling cutter, for example, is not simply a case of plugging in speed, feed rate, and DOC. Optimal application involves factors ranging from the number of teeth in the cutter, to how well chips are evacuated and the strength of the tool, to the stability of the milling machine. It is necessary to recognize all of those factors to fully attain the goals of a manufacturing operation, be they metal removal rate, tool life, surface roughness or economy.

Speed, feed and depth of cut

Many shop managers believe that simply increasing cutting speeds will produce more parts per period of time and thereby reduce manufacturing costs. However, there are more elements of manufacturing costs than output volume alone. An example is an operation where changing a tool in mid-operation would have detrimental effect on part quality and machining time.

Increasing cutting speed would result in more rapid production, but tool life would decline. Machining costs would rise due to more frequent tool replacements and greater machine downtime during the changes.

Raising cutting speed shortens tool life and may make an operation less stable, while changing depth of cut or feed rate has minimal effect on tool life. Accordingly, the best results come from a balanced approach that involves reduced cutting speeds matched with proportional increases in feed rate and depth of cut. Utilizing the largest depth of cut possible decreases the number of cutting passes required and thereby reduces machining time. Feed rate should be maximized as well, although workpiece quality and surface finish can be affected by feed rates that are excessive.

In a generalized example, raising the cutting speed from 180 m/min to 200 m/min will increase metal removal rate by only about 10 percent, but will have a negative effect on tool life. Increasing feed rate

from 0.2 mm/rev to 0.3 mm/rev will increase metal removal rate by 50 percent, with minimal, if any, effect on tool life.

In most cases, increases in feed rate and depth of cut at the same or lower cutting speeds will raise the metal removal rate of an operation to that achieved by higher cutting speeds alone. Among the benefits of working with a combination of lower cutting speeds with greater feed rates and smaller depth of cut is reduced consumption of energy.

The final step in optimization of cutting conditions is selecting an appropriate criterion in terms of minimum cost or maximum productivity and using cutting speed to fine-tune achievement of that criterion. A model developed at the beginning of the 20th century by American mechanical engineer F.W. Taylor can guide that choice.

The model demonstrates that for a given combination of depth of cut and feed, there is a certain window for cutting speeds where tool deterioration is safe, predictable and controllable. When working in that window, it is possible to qualify and quantify the relation between cutting speed, tool wear and tool life. The target is a higher cutting speed that reduces machine time costs but does not excessively raise cutting tool costs via accelerated tool wear.

Tool substrate and geometry

Additional steps in optimizing tool application can include fine-tuning of the characteristics of the tool substrate and geometry. Just as adjusting cutting conditions involves dealing with tradeoffs dependent on the results desired, maximizing productivity through changes in the tool substrate requires a balance of tradeoffs among the substrate properties.

Because a tool's cutting edge must be harder than the material it cuts, hardness is a key tool characteristic. High hardness, especially at elevated temperatures generated in high speed machining, will prolong tool life. A harder tool, however, is also more brittle. Uneven cutting forces encountered in roughing, especially in interrupted cuts involving scale or varying depths of cut, can cause a hard cutting tool to fracture. Instability in the machine tool, fixturing or workpiece can also precipitate failure.

Conversely, boosting a tool's toughness by including a higher percentage of cobalt binder, for example, will enable a tool to resist impact. But at the same time, reduced hardness makes a tool subject to rapid wear and/or deformation in higher-speed operations or when machining abrasive workpieces. The key is to balance tool properties in light of the workpiece material being machined.

Choosing tool geometries also involves tradeoffs. A positive cutting geometry and a sharp cutting edge reduce cutting forces and maximize chip flow. However, a sharp edge is not as strong as a rounded one. Geometric features such as T-lands and chamfers can be manipulated to strengthen the cutting edge.

A T-land – a reinforcing area behind the cutting edge – set at a positive angle can provide sufficient strength to handle specific operations and workpiece materials and minimize cutting forces as much as possible. A chamfer squares off the weakest part of a sharp cutting edge, at the price of increased cutting forces. "Hard" chip control geometries guide the chips through a relatively acute angle to curl and break them immediately. These geometries can be effective with long-chipping materials but place extra load on the cutting edge. "Soft" chip control geometries put less load on the cutting edge, but generate longer chips. Different geometric features – as well as tool edge treatments such as hones – can be combined to optimize cutting performance in specific workpiece materials.

Conclusion

It must be noted that while shop floor personnel and perhaps production engineers are quite concerned with cutting conditions and the productivity they represent, higher level managers are not as concerned with those numbers as they are with the business objectives of the manufacturing operations as a

whole. Those who make the choices of cutting conditions and cutting tools should think first about the broader targets of their company's machining operations and use them to steer selection of cutting conditions and tools that provide performance that will make achieving those goals possible.

Tool versatility for modern production scenarios

Manufacturing is moving from high-volume mass production to high-mix, lower volume machining scenarios as a result of increased utilization of just-in-time production strategies and the growth of outsourcing. Subcontractors increasingly produce smaller batch sizes on an intermittent but repetitive basis. Balancing productivity and tool cost considerations requires tooling that offers versatility and flexibility over a broad application window. Minimizing the number of different tools in the workshop reduces tool-handling time and increases the time available for machining operations.

The traditional way to increase productivity in an individual operation involving long runs of identical parts is to apply tooling specially designed for that specific process. Designing and implementing special tooling is worthwhile when the expense can be amortized over a long production run.

However, balancing productivity and tool cost considerations in variable, smaller-batch situations is better accomplished with versatile "universal" tooling that offers flexibility over a broad window of application. These tools reduce downtime by minimizing the time needed to switch in a new tool when the workpiece changes. They also eliminate the need to set up and test run new tools.

An example of such tooling is the Seco Turbo milling cutter range. These tools offer versatility in a broad range of applications to provide a combination of cost effectiveness and high performance. The cutters' positive cutting geometry reduces power consumption, leading to longer tool life and the possibility for increased depths of cut and feeds.

Another approach to universal tooling involves assembling a set of tools that suits a variety of applications. Seco Selection tools are engineered to provide flexibility. The selected group includes a limited number of tools that may not necessarily provide absolute maximum productivity or cost efficiency in every application. The tools will, however, be the best and most economical choice when maximum flexibility is desired to machine a rapidly changing variety of workpiece materials and components.

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