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Understanding the entire gundrilling system helps resolve tooling problems.

Gundrilling Know-How

Gundrilling is a highly developed and efficient technique for producing deep holes in a wide variety of materials—everything from plastics, such as fiberglass and Teflon, to high-strength metals, like P-20 and Inconel. The process also ensures size, location and straightness accuracy when tight tolerances and fine finishes are critical.

Successful gundrilling requires a complete understanding of the gundrilling system, which includes the cutting tool, machine, fixtures and accessories, workpiece, coolant, programming, control unit and the operator's skill level. Optimal performance is achieved when the proper cutting speed, feed, tool geometry, carbide grade and coolant parameters are selected. This selection should be guided by the hardness, composition and structure of the workpiece, the deep-hole machine conditions and the quality required for the drilled holes.

In terms of flute style, the straight-flute gundrill is the most common (Figure 1). A gundrill features a solid- or brazed-carbide tip, depending on its diameter, and an internal coolant channel that runs through the driver, shank and tip. The coolant exits an orifice on the tool's flank. A gundrill has one or two circular coolant holes, or a single kidney-shaped hole.

Standard gundrills produce holes from about 0.06" to 3.00" in diameter and, in a single pass, can drill to depths equaling 100 times the tool's diameter. Specials can be ordered for generating holes up to 6" in diameter and 200 diameters deep.

The gundrill's penetration rate is typically greater than a twist drill's, although its feed rate (ipr) is lower. The penetration rate (ipm) equals the feed rate times the speed (rpm) at which the tool or workpiece rotates.

Since the cutting tip is carbide, a much higher speed is possible than with a HSS cutter. This higher speed increases the penetration rate. In addition, when high-pressure coolant is applied, chips are effectively evacuated from the hole being drilled, so, unlike a twist drill, there is no need to withdraw the gundrill periodically during drilling to clear the chips.

A Systemic Problem

According to the "system engineering theory," it's improper to consider any machining operation's components

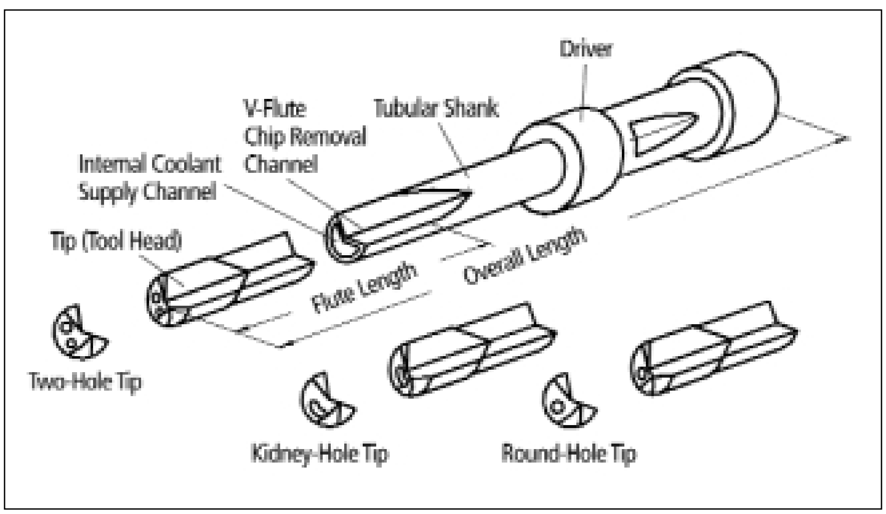

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Figure 1: The various components of a straight-flute gundrill.

Figure 2: Drill failure as a result of excessive misalignment between the starting bushing and machine spindle.

separately. Unfortunately, the "component approach" is a common practice, whereby different metalcutting tool and equipment manufacturers produce the various components and no one assumes responsibility for system cohesiveness.

As a result of nonintegration of the gundrilling components, unpredicted drill failures are common. Potential failures include drill breakage and excessive tool wear. Moreover, these failures lead to deterioration of hole quality, including poor surface finish, excessive runout and drift of the longitudinal axis (position error). Such failures turn gundrilling into a bottleneck operation, especially in the automotive industry.

Unfortunately, the tool manufacturer is often unfairly blamed as the lone culprit. Why should the gundrill producer be responsible for an engineer's technical illiteracy? After all, the engineer is the one responsible for the operation. He should know that it's necessary to apply a special when gundrilling inclined holes, for example, as well as ensure that a suitable coolant is applied at a sufficient flow rate, that the distance between the starting-bushing face and workpiece doesn't exceed 0.0200", and that the alignment of the starting bushing and spindle doesn't exceed 0.0002".

And, if a manufacturing engineer with limited gundrilling knowledge uses relatively inexpensive twist-drill starting bushings instead of expensive precision gundrill starting bushings, the result will be poor tool performance. A gundrill bushing should be made of carbide or high-alloy tool steel, heat-treated to HRC 63 to 65, with an ID surface finish of 16µin. to 32µin., a maximum ID/OD concentricity of 0.00008" and a maximum front-face runout of 0.0002".

There are many other instances in manufacturing when the gundrill producer is blamed for improper application. The following are a few examples from the automotive industry.

Gundrills often fail when there's excessive misalignment between the starting bushing and the drill's rotational axis. Usually, such a failure occurs as a "balk" crash of the drill's tip. This type of crash causes the tool to fracture into numerous pieces, because the brittle carbide tip cannot withstand the bending stress caused by the misalignment.

The situation goes from bad to worse when the drill—rather than the workpiece—rotates, because this stress is reapplied to different parts of the tip. When the stress reaches the weakest area, which is usually the corner of the drill, the tip breaks (Figure 2).

Another example relates to tool length. As gundrill length increases, rigidity decreases. The shank of a longer gundrill does not transmit much bending force to the tip when misaligned, so the tip does not break. Instead, misalignment causes the shank to flex with each revolution, often resulting in fatigue failure (Figure 3).

Drill failure also occurs when there is excessive clearance between the starting bushing and the drill tip. When this happens, the edge of the gundrill cuts a significant amount of work material. Because this edge is not designed to cut (it has a zero clearance angle due to the circular margin attached to this edge), the excessive cutting forces cause the edge to break (Figure 4).

Insufficient coolant flow is another common cause of gundrill failure. It causes chips to pack in the flute. These impacted chips form a plug, which causes excessive torque to be applied to the gundrill. And when a plug is formed in the V-flute of the tip, the tip separates from the shank (Figures 5a and 5b).

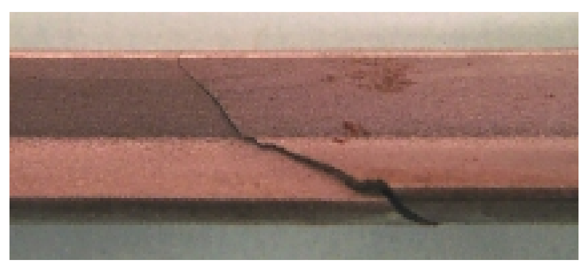


Figure 3: A shank that experienced fatigue failure.

Figure 4: Excessive clearance between the starting bushing and drill tip can cause edge breakage.

End users often blame poor brazing by the gundrill producer when a tool's tip separates from the shank. However, an analysis of fractured surfaces often shows pieces of carbide still attached to the shank, meaning the braze was stronger than the tip itself and, therefore, should not be blamed (Figure 6).

Although frequently blamed for tool failures, a gundrill producer can't control the installation and operation of a particular gundrill system. Yet when a problem occurs, gundrill producers—at best—send a sales representative to learn more about the problem and fill out a failure-analysis form, as required by QS 9000 and ISO 9001. Often, such a representative doesn't have the expertise to distinguish between system- and tool-related problems, so he ends up blaming the tool as well.

More Information Needed

Having read this far, the manufacturing engineer, process planner or tool layout designer might ask: "Where can I learn more about gundrilling systems?" The answer is, unfortunately, very few places. Little has been published about gundrilling, and the available information doesn't explain the different reasons why a particular drill design should be applied, which drill designs and components work best and what happens when a specific parameter is altered. And even though research papers have been written about particular aspects of tool design, they often fail to discuss the gundrilling system as a whole.

Moreover, to the best of my knowledge, no U.S. machine builder dedicates a machine to conduct gundrilling studies. As a result, the designs of gundrill machines, particularly for the automotive industry, are severely flawed. The designs of these machines make it difficult to check and/or change the starting bushing and nearly impossible to check and correct any misalignment.

In addition, the coolant distribution systems on some multispindle machines "starve" the cutting edges while others overflood them. This is because the controls on such machines measure irrelevant process parameters. For example, the coolant pressure is measured instead of the coolant flow rate, or the amperage of the drive motor is measured to check the drill load instead of the actual force on the drill. Such control systems cannot predict drill failure.

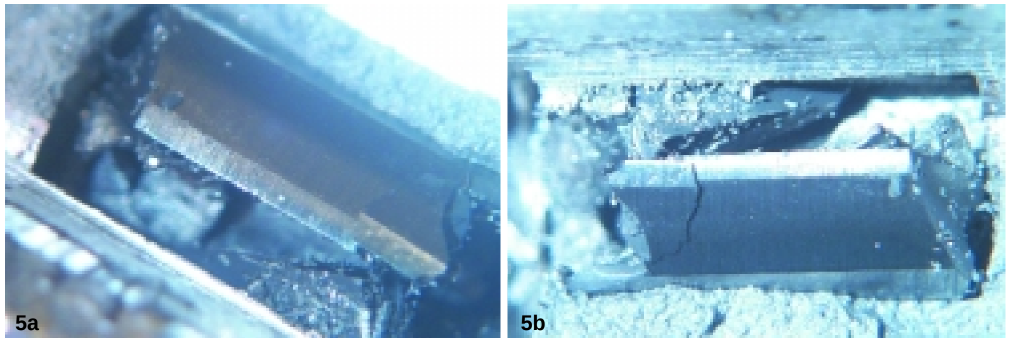
When gundrilling holes smaller than 0.125" in diameter, it's essential to understand the need for high-pressure coolant. Unfortunately, most gundrill machine builders equip their standard machines with relatively low-pressure coolant-delivery systems. High-pressure, retrofittable systems are available. And one manufacturer has developed a coolant intensifier pump, along with a high-pressure rotary union, for gundrilling small-diameter holes (Figure 7). The variable-pressure pump delivers coolant at pressures up to 3,000 psi and costs less than high-pressure systems.

Furthermore, because the drill rotates in most gundrilling applications, a rotating connector—also known as a pressure joint—is required to supply coolant through the rotating spindle. Standard connectors, however, allow a maximum coolant pressure of only 1,000 psi—too low for gundrilling small diameters. Such a connector makes it impossible to incorporate a high-pressure coolant pump.

Sometimes, gundrill manufacturers deserve the blame for gundrilling problems rather than end users or machine tool builders. For example, tool manufacturers noticed that chip-removal problems arose when the coolant flow rate was insufficient, a result of the structure of coolant-pressure loss when gundrilling. In response, toolmakers came up with a "simple" solution: Produce tools with what is known as a "stepped-slash" design.

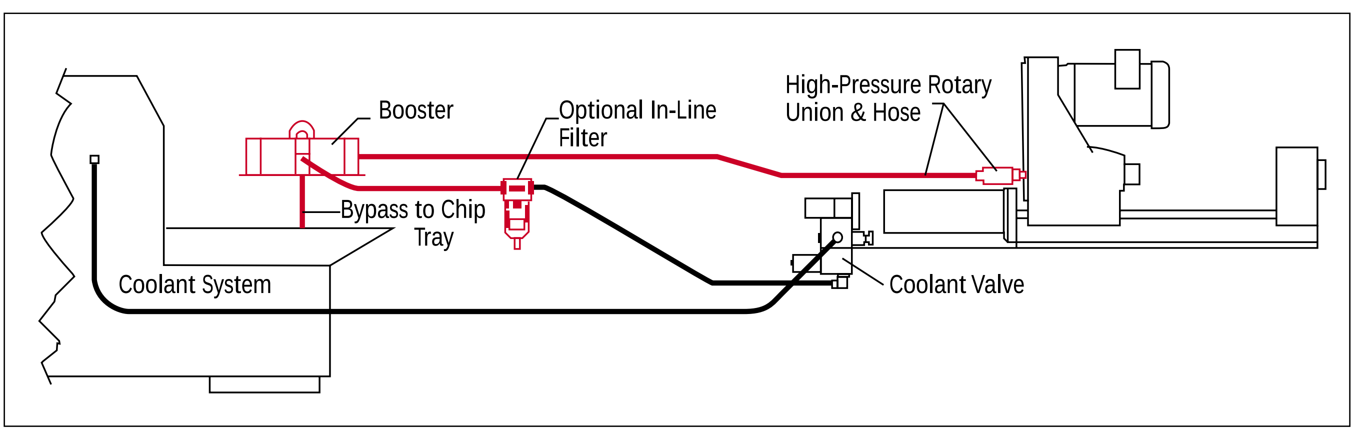
With this design, the coolant hole is located on the stepped-slash flank surface of the gundrill tip, which is far behind the cutting edges and at the bottom of the hole being drilled. Because the coolant opening is relatively large, the flow rate appears to increase significantly, even though the inlet coolant pressure is the same.

This causes a number of problems to arise, which gundrill manufacturers refuse to acknowledge. First, the bottom of the hole deflects most of this increased flow rate into the flute—not to the cutting edges to help chip formation. Chips formed at the cutting edges



Figures 5a and 5b: Examples of tool failure as a result of insufficient coolant flow rate.

Figure 6: An analysis of fractured surfaces shows pieces of carbide still attached to the shank, meaning the brazing was stronger than the tip itself.



Interface Devices

Figure 7: Interface Devices Inc., Milford, Conn., developed a system for gundrilling small holes. The components of the fluid-to-fluid booster (shown in red) intensify coolant-delivery pressure.

have a hard time joining this coolant flow, which can be observed using a transparent workpiece. Second, because the coolant has an easy way to escape, it does not flow to the relief surfaces where it's most needed.

Training is Key

To overcome these obstacles, manufacturing engineers, process planners, and tool and machine engineers responsible for the design, selection, application, operation and maintenance of gundrill systems require special training. This is particularly important for the automotive industry, which performs a significant amount of gundrilling.

In addition, the workpiece properties of automotive parts, such as cast aluminum engine blocks, vary greatly from batch to batch and from one supplier to another. To compound matters, gundrilling machines are typically integrated into an automotive facility's production lines and share the entire line's coolant supply. Such a delivery system makes it impossible to supply coolant of sufficient purity, composition and temperature at the necessary flow rate.

Despite the inherent challenges, when everyone responsible for the design, selection, application, operation and maintenance of a gundrill system is trained thoroughly and every component of the system is integrated properly, gundrilling is a very effective method for producing deep holes.

About the Author

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