Gundrilling: Very Sharp Points

Understanding gundrilling system can help to resolve tooling problems

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Gundrilling System

Gundrills are known for making first pass, high-finish, straight holes of varying depths. Gundrilling is a highly developed and efficient technique for producing either deep or shallow holes in a wide variety of materials from plastics (like fiberglass, Teflon) to special high-strength materials (like P20, Inconel). It offers size, location and straightness accuracy where critical tolerances are important and at lower cost.

The commonly used straight-flute gundrill (Fig.1) has a solid or brazed carbide tip depending on its diameter, with a coolant channel running through its driver, shank and tip. On this flank surface an orifice is located as an outlet for the coolant. Gundrill manufacturers have adopted various shapes for this orifice; one or two circular holes or a single kidney-shaped hole. The standard capabilities range from 0.08-3" (2-76 mm) in diameter and up to 100"(2.5 m) deep in one pass, with a custom length roughly doubling this amount.

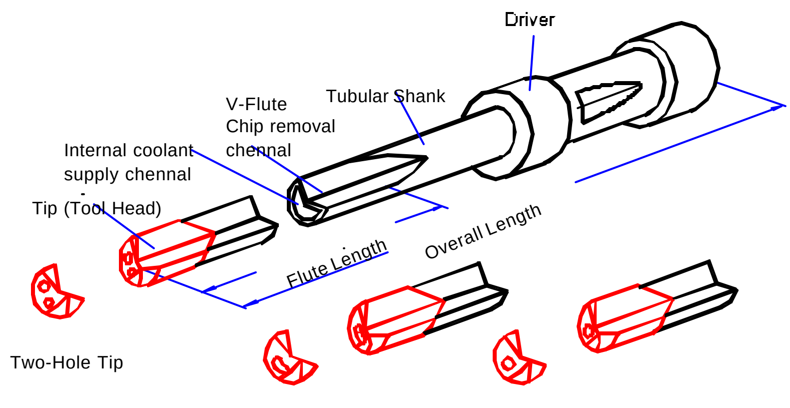


Fig. 1. A common gundrill.

Penetration rate is typically higher than that with twist drills although feed per revolution is smaller. This is because the penetration rate is a product of the tool (workpiece) rpm and feed per revolution. Since the cutting tip is carbide, it allows a much higher rpm than that with HSS that makes the product (penetration rate) higher. Moreover, the coolant supplied to the gundrill at high pressure takes care of the chip evacuation from the hole being drilled so there is no need to withdraw the drill periodically from the hole being drilled to clear the chips as with twist drills.

Optimum drill performance is achieved when the combination of the cutting speed (rpm), feed, tool geometry, carbide grade, and coolant parameters is selected properly depending upon the work material (its hardness, composition and structure), deep-hole machine conditions, and the quality requirements to the drilled holes. To get most out of a gundrilling job, one must consider the complete gundrilling system, which includes everything related to the operation. To keep it simple, the following components of the gundrilling system should be considered: gundrill, machine, fixtures and accessories, workpiece, coolant, programming, control, and operator as shown in Fig. 2.

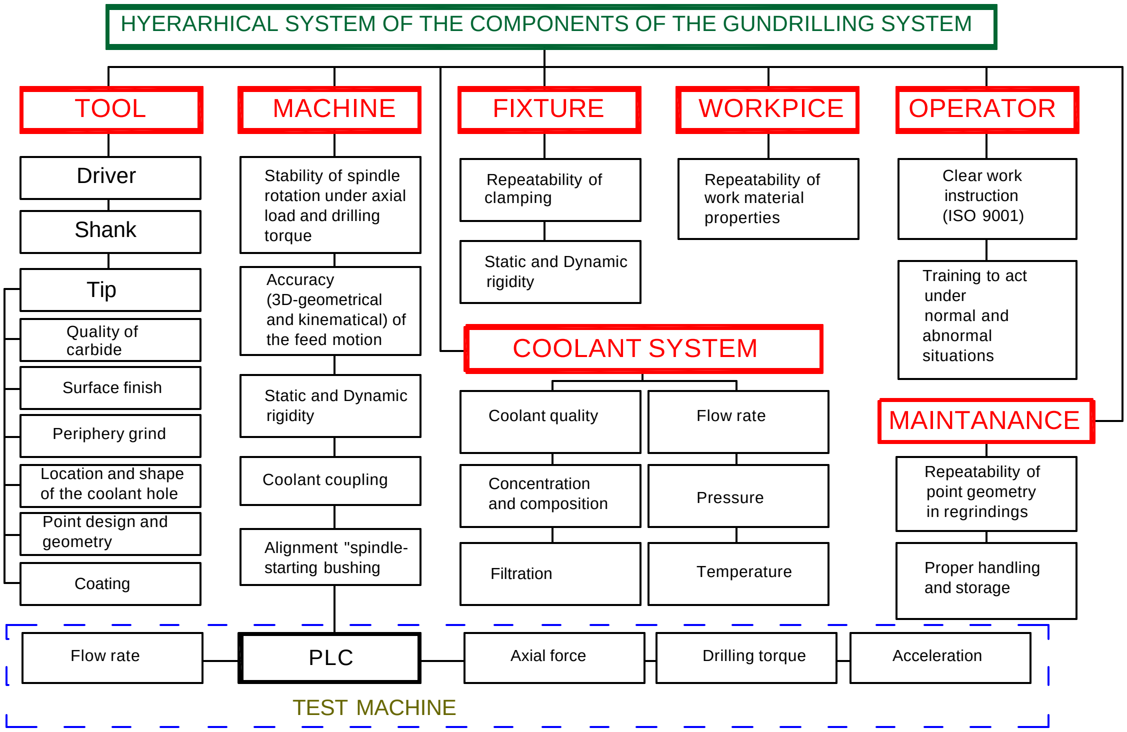


Fig.2. Gundrilling system

Tool Failure is Often a Systemic Problem

According to the system engineering theory it is improper to consider any of these components separately and thus to ignore system properties. Unfortunately " the component approach" is common in today's manufacturing practice where various components are produced by different suppliers and no one is responsible for the system coherence. As a result of poor coherence of the gundrilling components, "unpredicted" drill failures are common which may appear in the forms of drill breakage, excessive wear or deterioration of the quality (surface finish, runout, drifting of the axis, etc) of the hole being drilled. Such failures turned gundrilling into the bottleneck operations in the automotive industry. Unfortunately, the tool manufacture is the only one blamed, although it is unfair in my opinion.

Most gundrill manufacturers sell only the tool. In other words, gundrill manufactures do not sell a gundrilling process, which includes the machine, drilling regime, coolant characteristics (type, pressure, flow rate, temperature, purity, etc.) and so on. Two gundrills of the same design used for drilling the same work material can exhibit diametral opposite performances when used in different gundrilling systems. If a manufacturing engineer (having limited knowledge in gundrilling) in order to save money for his company uses relatively cheap acme twist drill starting bushings instead of expensive precision gundrill starting bushings, it results in poor gundrill performance. Why should the gundrill producer be responsible for this technical illiteracy? Why should the gundrill producer be responsible for poor drill performance if the end user does not supply sufficient coolant flow rate to the gundrill(s); if he uses unsuitable coolant brand, if he uses 'standard' gundrills for making inclined holes; if the distance between the face of the starting bushing and that of the workpiece is excessive; if the alignment "starting bushing – spindle" is more than 5 micrometers (0.0002"), etc?

To exemplify my point, I would like to show a few examples of tool failures (from the automotive industry) not related to gundrill design or its quality. Figure 3 shows a typical tool failure due to excessive misalignment between the starting bushing and the drill rotational axis. Usually, such a failure occurs as 'balk' crash of the drill's tip because the tip is made of a tungsten carbide which cannot take much bending stress caused by misalignment. The situation goes from bad to worse when the drill rotates because this stress is re-applied to different parts of the tip. When it reaches the weakest area (usually, this is the drill corner as shown in Fig. 3) the tip breaks. When a gundrill is sufficiently long, its bending rigidity becomes much smaller. As such, the gundrill's shank would not transmit much bending force to the tip due to misalignment so that the tip would not break. Instead, when the drill rotates, this misalignment causes the shank to bend repetitively with each drill revolution and thus fatigue failure of the shank occurs quite often (Fig 4). End users blame gundrill manufacturers for selecting improper material for the shank, indecent heat treatment, etc. pressing them 'to improve' these issues.

Fig. 3. Drill failure as a result of excessive misalignment.

Figure 5 shows a typical example of drill failure due to excessive clearance in the starting bushing. My analysis shows that when excessive clearance between the starting bushing and the drill tip is the case, the side cutting edge of the gundrill cuts a significant amount of work material. Because this edge is not designed to cut, an excessive cutting force occurring in such cutting breaks this edge as shown in Fig. 5.

Fig. 4. Fatigue failure of the shank

Figure 6 shows two typical examples of drill failure due to the insufficient coolant flow rate supplied to the gundrill. As seen, this flow rate could not remove the amount of chips produced so that these chips become packed in the chip removal passage. The packed chips form a chip plug that causes an excessive torque applied to the gundrill with the result shown in Fig. 6. It is worthwhile to mention here that such plugs are often formed in the V-flute of the tip. As such, the discussed excessive torque causes tip separation from the tubular shank. "Bad" brazing by the gundrill producer is to blame (Fig. 7) although the analysis of the fractured surfaces shows that pieces of carbide are still attached to the shank and thus brazing was even stronger than the tip itself. Nevertheless, the

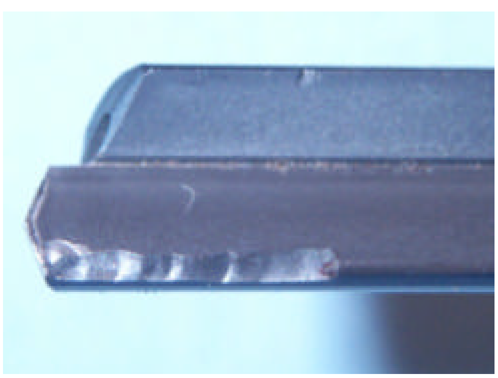
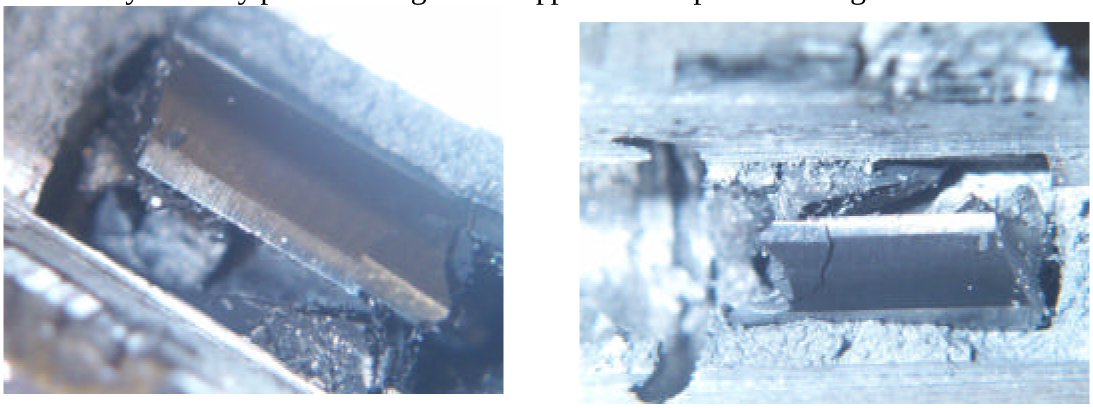


Fig. 5. Drill failure as a result of excessive clearance in the starting bushing.

automotive industry routinely pressures its gundrill suppliers to 'improve' brazing.



A common gundrill producer has no knowledge

Fig. 6. Two examples of drill failure as the result of insufficient coolant flow rate.

on and/or control over any particular gundrill system (or installation). When a problem occurs, gundrill producers (at best) send their trade representative or distributor to learn more about the problem and to fill out a failure analysis form as required by QS 9000 and ISO 9001. When this option is not available, the manufacturing engineer or gundrill operator just fills out a Return Materials Authorization form, known as an RMA. You should see the descriptions of failures in RMA's that come with broken gundrills…Once again, everyone sees that the tool fails and therefore its quality is to blame. I usually try to convince them that even though everyone sees that the sun rises in the morning, moves over the sky during the day, and sets in the evening, it does not matter that the sun orbits the earth. Actually, it is vise versa.

Fig.7. "Bad" brazing as claimed by users.

Lack of Knowledge on Gundrilling Systems

Reading this, a practical manufacturing engineer, process planner, or a tool layout designer could ask a logical question: Where can I learn more about the gundrilling system?" The answer is unfortunately nowhere. The only book available on gundrilling is a small book published by the American Society of Tool and Manufacturing Engineers in 1967 (Bloch, F. et al., Self-piloting drilling, Trepanning, and Deep Hole Machining. Manufacturing data. ASTME, Dearborn (Michigan), 1967, 175p.). Although this book remains a valuable source on drilling practices (naturally, no others), it describes what might be termed as an "evolutionary" stage of development. It fails to explain the different reasons why one or another drill designs and components are being used, which one is better and when, what would happen if a particular parameter is altered, etc. Nothing is even mentioned about the gundrilling system. A limited number of research papers are written on some particular aspects of tool design and thus do not discuss the gundrilling system.

Unfortunately, there are no books or papers written on the gundrilling process and/or on the design of gundrill machines. As a result, any user who orders a new gundrilling machine cannot find the answers to his vital questions which range from simple "What should be the power of the spindle drive unit?" to much more sophisticated: "What should the dynamic rigidity and natural frequency of the installation be?" Failing to find these answers, the users has no choice but to accept the "default characteristics" suggested by the machine producer hoping that "they are specialists and thus they must know." In reality, they do not.

To the best of my knowledge, no one gundrilling machine producer in this country has a gundrill test machine dedicated to conducting studies on gundrilling. As a result, the designs of gundrilling machines, particularly for the automotive industry, suffer severe flaws. Often, it is very difficult to check and/or to change the starting bushing, it is next to impossible to check and adjust misalignment, the coolant distribution systems on multi-spindle machines "starve" some gundrills while the other are over flooded. The control systems of such machines measure irrelevant process parameters. For example, the coolant pressure is measured instead of the coolant flow rate; the amperage of the drive motor is measured to check the drill load instead of the actual force on the drill. No wonder such control systems cannot 'predict' drill failures.

It is worthwhile to discuss here another example of 'fixing problems' in deep-hole machines. Understanding the need of high-pressure coolant supply for gundrills of small diameters, Interface Devices Co developed a 21 MPa (3,000 psi) Gundrill Coolant Intensifier Pump aimed for small diameter gundrilling to retrofit the existing low-pressure coolant supply systems (http://www.interfacedevices.com/Gundrill.html). Two different issues strike me about this information. First, why don't gundrill machine producers equip their machines with coolant supply systems capable of delivering high-pressure coolant, which is mandatory for gundrills of small diameters? Second, because the drill rotates in most gundrilling applications, a rotating connector, which is also known as the pressure joint, is a part of the machine to supply the coolant into rotating spindles. With these connectors, however, the maximum allowable pressure of the coolant is up to 7 MPA (1000 psi) and, besides this is way too low for gundrills of small diameters; it makes it impossible to use a high-pressure coolant pump.

Having noticed problem with chip removal when the coolant flow rate is insufficient due to relatively low inlet pressure, gundrill manufacturers, instead of understanding the structure of the coolant pressure loss in gundrilling, arrived at a 'simple' solution, which became known as the stepped-slash design shown in Fig. 8. According to this design, the coolant hole in the gundrill tip located on the stepped-slash flank surface, which is far behind the cutting edges and the bottom of the hole being drilled. Because the coolant has a huge opening, the apparent flow rate increases significantly for the same inlet coolant pressure. However, a number of other problems, which gundrill manufacturers refuse to admit, arise. First, most of this increased flow rate it directed by the bottom of the hole being drilled and not to the cutting edges to help chip formation, but into the chip removal channel as shown in Fig. 7. Chips have a hard time joining this flow as can be easily observed using a transparent workpiece made of Plexiglas. Second, because the coolant has an easy way to escape,

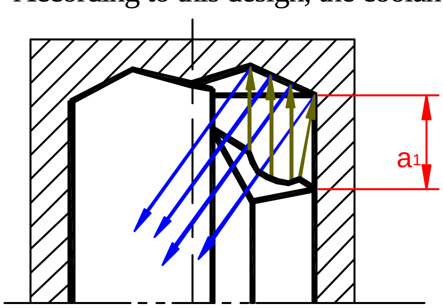


Fig. 8. Stepped-slash design.

it does not flow to the relief surfaces where its presence is mostly needed.

System Training Needed

The need is felt to provide special training to the manufacturing engineers, process planners, tool and machine engineers responsible for the design, selection, application, running, and maintenance of gundrilling systems. It is particularly important for the automotive industry because:

- Significant volume of gundrilling operations is carried out;
- Gundrilling problems are severe and thus gundrilling operations represent bottlenecks;
- Properties of parts' material are subject to wide variations (for example, cast aluminum for engine blocks) from batch to batch, from one supplier to another.
- Gundrilling machines are the parts of production lines and they enjoy the sheared the coolant supply systems for entire line. Often, such coolant supply makes it impossible to deliver coolant of sufficient flow rate, pureness, composition, temperature, etc.
- Design of most machines does not allow checking and maintaining the essential system parameters as the starting bushing, alignment, etc).

This is the first article on a series of articles on gundrilling systems. In the following articles, the essential system components (gundrills, machines, coolant supply systems) and parameter will be considered. A number of practical recommendations on gundrilling system will be given.

Want More Information?

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