Understanding the Gundrilling Process and its Advantages
1 INTRODUCTION

The origins of modern day gundrilling have their roots in Europe during the late 19th and early 20th century. Early gun barrels were produced either by roll-forging or “Damascus” spiral welding. The advent of more powerful propellants led to the need for stronger, more dependable steel barrels. Drilling of alloyed steel bars proved necessary.

Drilling with twist drills welded to extended shafts was laborious, time consuming and liable to drift and wander.

There already long existed methods used in woodworking for the drilling of long holes, for example musical instruments, that employed long, straight grooved or D section augers. Such tools, ground with eccentric cutting edges had been found to provide very straight, controlled results. The introduction of these ideas to the cutting of metal greatly improved hole quality.

The final step to bring the gun drill to today’s design occurred in the 1930’s with the idea of attaching the cutting tip to a formed tubular shank through which cutting oil could be passed. In turn this flowed through an adjoining hole in the tip to lubricate, cool and flush chips.

Within the modern metal working industry, gundrilling has become an important process for shops trying to improve their efficiency and profitability. Gundrilling is now a highly developed and efficient technique for producing either deep or shallow holes in a wide variety of materials. It offers size, location, and straightness accuracy where critical tolerances are important and lowering costs is crucial.

Secondary operations cost money. Each requires a machine, skilled machinist, fixtures, variety of machine tools, and valuable floor space. Also, each operation is costly in machine and tool depreciation. Tools must be sharpened, stored, and replaced. There is also additional expense for maintaining inventory. Each secondary operation increases chances for normal machining errors, work hardening, scrap, and inspection costs.

Does gundrilling offer anything better? It does! It is a simple routine job. One pass through a workpiece can produce a high-tolerance, high-finish hole: straight, true, and round. The job is done once. It is a push-button job requiring only a properly engineered setup. The work is simple routing and the operator only loads and unloads a machine. Accuracy is automatic and pre-determined.

2 PRECISION HOLE DRILLING

Simply stated, precision hole drilling is a single machining technique for drilling holes in metals using a single lip cutting tool through which cutting oil is pumped under high pressure. The principle of precision hole drilling is that a self-piloting tool guided by a close tolerance bushing will follow in the direction it is pointed. The self-piloting capability is derived from the high length-to-diameter ratio of the tip and the close tolerance and minimum back taper ground on this tip.

The majority of precision hole drilling machines built today rotate and feed the cutting tool into the stationary workpiece. Precision hole drilling offers the user many advantages, some of which are unattainable in any other machining technique. These advantages are:

- Straightness, Drift, and Depth of Hole
- Close Tolerance of Hole
- Surface Finish
- Productivity
- Unique Capabilities
2.1 STRAIGHTNESS, DRIFT, AND DEPTH OF HOLE
With a properly designed machine and cutting tool, it is possible to precision-drill holes with depth-to-diameter ratios of 100:1, 200:1, and even 300:1. The self-piloting characteristic of a precision hole drill, when properly used, is capable of maintaining the drift of a hole to within .0005” per inch of hole depth.

The straightness of a precision drilled hole can be held to approximately .001” per foot of depth.

“Bowing” or “banana shaped” holes are a condition where the actual centerline of the hole varies from a theoretical straight centerline connecting the ends of the hole.

Although normally thought of as a machining process for deep holes, precision hole drilling is fast becoming a technique for shallow holes as well.

2.2 CLOSE TOLERANCE OF HOLE
As in all other machining operations, the material and hardness are critical to the results obtainable. However, gundrills with carbide tips are uniquely able to drill holes in most materials, and, under favorable conditions, hole tolerances of .0002” can be maintained. Production tolerances of .0005” and .001” are most realistic and are routine in many shops.

2.3 SURFACE FINISH
Using carbide tipped precision hole drills, it is possible to maintain high surface speeds in drilling, as opposed to the slower speeds of conventional high speed steel twist drills – and, with precise control of the chip thickness, it is possible to obtain surface finishes as low as 3 to 4 microinches under ideal conditions. Production runs with surface finishes of 20 to 60 microinches are common.

2.4 PRODUCTIVITY
Conventional machining of many holes normally specifies multiple operations to obtain the required tolerance and surface finish. With precision hole drilling, it is possible to obtain these same results IN ONE PASS of the tool with the resultant cost savings.

Penetration rates – equal to or better than more conventional methods – are possible in addition to the other advantages.

2.5 UNIQUE CAPABILITIES
Precision holes requiring tedious and costly multiple drilling operations can be machined in one pass using gundrilling techniques (Figure 2). This capability not only saves time and tooling in the actual drilling operation, but permits significant savings to be achieved by the part designer by providing him or her with options not otherwise available. Complex workpieces can be reduced to far simpler units, frequently eliminating up-line fabrication and machining operations commonly required for multi-piece castings or assemblies.

Figure 1: DeHoff 30120 BTA machine
3 Precision Gundrilling System

A near perfect combination for practically any precision drilling requirement is to use properly designed tools with a machine system that has been designed, engineered, and built for the purpose. A machine designed specifically for precision drilling, from the ground up, avoids design weaknesses usually inherent in traditional equipment adapted for this technique. The basic elements of a Precision Hole Drill System consists of the following:

- Cutting tool
- Bushing
- Machine
- Fixturing
- Coolant System

An understanding of the part each of these elements plays in the make-up of a Precision Hole Drilling System is essential to a successful precision hole drilling experience. Each element will be explained in detail and the complete drilling system discussed in its entirety (Figure 3).

4 Cutting Tool

Many types of tools have been developed for precision hole drilling and reaming holes using coolants under pressure. The most widely used of these tools is the External Chip Removal gundrill which is made up of three parts:

- Tip
- Shank
- Driver

These parts are usually built solidly together into one correctly aligned unit (Figure 4).

Figure 3: External Chip Removal Gundrill

Figure 2: Precision Hole Drilling System
4.1 Tip
Most critical of the three elements, the tip cuts the hole and maintains precision as it pilots the assembly through a straight hole. Producing true, high finish walls.

The finest carbide grade is used for tips to assure longest possible service life. A properly designed carbide tip can drill precision holes at high speed through almost any material. Long tool life minimizes machine downtime resulting from tool changes. Moreover, a good carbide tip can be resharpened almost back to the shank.

The tip is slightly larger in diameter than the shank, thus enabling the shank to rotate freely without contacting the hole wall. Through the tip is an oil hole which lines-up with the shank’s oil channel, to facilitate a generous flow at high pressure to the cutting area.

Precision gundrill tips are ground with wear pads opposite to the cutting edges to support the tip against cutting forces present during operation.

4.2 Shank
One end of the shank is attached to the driver, the other to the tip. Length may vary with hole depth to be drilled, plus space for machine components.

The shank must maintain proper alignment and be strong enough to absorb cutting torque and thrust as well as centrifugal forces. Stiffness of the shank with transfer minor misalignment in the machine to the tip. On the other hand, it should not be flexible enough to sag or whip out of the machine.

The shank of a gundrill is made from flexible heat treated steel tubing, slightly smaller in diameter than the drill tip, into which has been formed a lengthwise vee groove to match the cut-out in the tip. This vee groove (or V-flute) provides the passageway for the chips and coolant from the hole. The front end of the shank has a flute to match the pointed end on the rear of the drill tip. The cutting and cooling oil is forced through the hollow shank from the driver to the tip, from which it is flushed out through the flute, as seen in Figure 5.

4.3 Driver
The driver of a gundrill provides a means of adapting the drill to the machine spindle. The most common style of shank is the straight diameter with a center section undercut or notched to provide a seat for the locking set screws in the spindle nose.

When securely fastened to the machine, the driver (and entire assembly) may revolve as it drills through a stationary workpiece as seen in Figure 6. Or, the workpiece may revolve with the drill remaining stationary as seen in Figure 7.
The purpose of a bushing in the precision drilling machine is to guide the gundrill tip as it enters the workpiece. The accuracy with which this bushing is made and the care with which it is aligned relative to the spindle and the work locating surfaces, determines the direction in which the hole is drilled. The ability of a precision drill to produce a straight hole, within a few thousandths of an inch per foot of depth, is dependent on an accurate bushing for its start. For these reasons, the concentricity and parallelism of the spindle to the bushing should be held to within .0002” per inch.

Commercial grade bushings used with twist drills have tolerances too large to ensure precision results when drilling and should not be used.

Bushings should be ordered with hole sizes .0001” to .0003” over maximum drill size and with O.D. to I.D. concentricity within .0002” T.I.R. and should have a bearing surface length equal to two times the diameter of the drill as seen in Figure 8.

Hardened steel bushings are suitable for short run jobs, but tungsten carbide bushings should be specified for all production work.

Bushings must make full contact with a finished surface on the workpiece to prevent the escape of the coolant oil pressure. It is common practice to contour the bushing to match a shape on the workpiece to provide the seal necessary.
There should be a sharp corner on the bushing hole where it contacts the workpiece to prevent chips from becoming caught between the bushing and the workpiece.

6 MACHINE

Precision Hole Drilling Machines have been designed to accomplish many types of drilling operations and for drilling a great variety of parts. The single spindle, horizontal way machine is undoubtedly the most common of the machines (Figure 9), while multi-spindle machines have wide acceptance (Figure 10). Machines with moving work tables in the X and Y axes are common (Figure 11), while many machines today have electronic controls (Figure 12).

Essential to a good precision drilling machine design are the following features:

- Precision Alignments
- Spindle Motor Horsepower
- Positive Feed Control
- Suitability of the Machine
- Chip and Coolant Containment

Figure 9: DeHoff BTA 4060

Figure 10: DeHoff G534-R6

Figure 11: Eldorado KM75-30

Figure 12: Eldorado machine controls by Beckhoff
6.1  **Precision Alignments: Rigidity and Stability**

Any misalignment in a precision drilling machine which causes the drill to point other than on its true axis will cause a drill to drift away from the intended direction of the hole.

As discussed in the section on Drill Bushings, precise alignment of spindle and bushing are essential to good precision drilling results. It is for this reason that the base or supporting structure be both rigid and stable to ensure that alignments once established are not lost by distortion. Stress relieved, cast-iron bases provide the rigidity and stability required. Travel of the drill slide must be parallel to the axis of the bushing.

6.2  **Spindle Motor Horsepower**

The size of the spindle motor should bear a relationship to the size of holes to be drilled. A motor too small for a given drill size will overload when the drill dulls. However, a motor which is considerably oversized for a given drill size will not reflect any small increase in load caused by a dull drill – with the result that the load-meters on the spindle motors will not provide the protection for which they are intended.

Whether a spindle drive should have fixed speeds or be infinitely variable depends upon the particular application. Frequent job changes, or work of an experimental nature, should have the flexibility of the variable speed drive; whereas, a high production run would be better served with lower cost, fixed speed motors. Tachometers to indicate spindle speeds are very desirable and useful.

6.3  **Positive Feed Control**

The control of the feed rate in a precision hole drilling machine in unquestionably one of the most critical elements in the design of a machine and any system should precisely control the advance of the tool at a uniform rate, that is, without dwells or surges. Precision drills, and particularly small precision drills, cannot tolerate sharp increases in torque loading, and a positive control of the tool advance is critical. Mechanical drives, using precision ball screws with infinitely variable motor control, provide the best feed arrangement for precision drilling. Feed meters to indicate drill penetration rates are a valuable aid to successful drilling.

6.4  **Suitability of the Machine to the Operation**

Any machine which is too large or too small for an operation is always a problem and this is particularly so in a precision drilling operation.

Underpowered spindles cause overloads, drill breakage and downtime, while overpowered spindles lack sensitivity to overloading and result in broken drills.

Over-hanging spindles, tables, and tooling set-ups create potential vibration sources which result in rapid tool wear and chipped and broken tools, in addition to reduced feeds and speeds.

While precision drilling set-ups can be improvised, the best results are obtained with factory engineered machines and tooling.
6.5 CHIP AND COOLANT CONTAINMENT

The ideal chips from a gundrill are two small, tightly curled chips – one from each cutting edge – which flow easily down the flute of the drill. The least desirable chips are the long, stringy type, either flat or coiled, which become entangled on the drill shank and cause overloads and downtime.

Increasing or decreasing the feed rate, while observing the chip formation, will change the chip thickness per revolution and often produce an acceptable chip. Minor changes in spindle speeds will also accomplish similar results.

Chip boxes, troughs, and chip chutes should be designed without sharp corners and with sufficient slope to allow the free movement of the chips and coolant out of the machine without hang-ups.

7 FIXTURING

Work holding devices for parts to be precision drilled must support the work rigidly and without vibration and distortion of the work. They should be designed for ease in loading and unloading and should register the part from established locating surfaces and provide the required alignment. Examples can be seen in Figures 14, 15, and 16.

Provisions must be made to prevent loss of oil under pressure at the entrance and the breakout of the hole. Unless otherwise impossible, a machined surface on the workpiece should be brought against the end of the drill bushing to provide a tight seal face. Similarly, on through holes, a cap or cover of some design must be used to avoid spraying or leaking of oil under pressure. It is possible to drill interrupted holes with precision drills, provided the drill is supported by an intermediate bushing between the drilled portions.
8 COOLANT SYSTEM

The purposes of the coolant in a precision hole drilling system are: support and lubrication of drill wear pads, improvement of tool life, dissipation of heat, and the flushing of chips. A coolant system should provide an adequate supply of filtered oil to the precision drill at the correct pressure and temperature. Examples of coolant systems for precision drilling machines can be seen in Figures 17 and 18.

Two separate tanks or compartments are used in most installations. One tank, usually the larger one, is to store most of the oil and to permit the settling of dirt and inclusions. The second tank or compartment is used to store a supply of clean, finely filtered oil for the high pressure pumps to deliver to the drill. A diagram of the typical coolant system for precision drilling machines can be seen in Figure 19.

Both fixed and variable displacement type pumps are used to provide the high pressures required. A pump should be selected to supply the highest pressure for the smallest drill to be used and the highest volume for the largest drill to be used.
Filtering of the dirty oil is done by means of paper cartridge type filters, magnetic separators, centrifuges, or similar equipment. Any dirt or contamination in a system can do serious damage to valves and pumps as well as scratch the finish of the drilled holes. It is for this reason that a filtering system should be capable of filtering the coolant oil to 5 or 10 microns.

When operated on a continuous basis, the temperature of the cutting oil should not exceed 110 to 120°F. Provisions for cooling the oil should be available either with a water cooled or air cooled heat exchanger or with a refrigeration system – all thermostatically controlled. Contaminants such as lint or fine chips can plug the small orifices in the smaller size drills and it is recommended that flow meters be used to detect any obstruction to the free flow of oil in these drills.

8.1 Coolant Inductors

Machines with rotating spindles require the introduction of the cutting oil into the back end of the spindle from a stationary coolant hose by means of a rotating transfer device known as a coolant inductor, coolant gland, or coolant union.

These coolant inductors have lapped seal faces and should transfer oil while rotating without loss of oil or pressure.

9 Precision Drilling Oils

When buying oil for precision drilling, it is recommended that a reliable supplier of lubricants be called in to make recommendations on available products. Consideration to the following characteristics should be given – namely; viscosity, anti-weld and extreme pressure properties, sulfur and chlorine contents, anti-gumming properties, and low foaming action.

Extreme pressure and anti-weld additives are often added to base oil when difficult drilling jobs are encountered. Sulfur and Chlorine in the amounts of 1% to 4% are compounded into oils to improve machinability. Many cutting oils are made with anti-gumming additives to eliminate problems with sticky valves and anti-foaming additives prevent cavitation of pumps when air bubbles are entrapped in the oil.

10 Conclusion

It is sometimes necessary, for budgeting reasons, to convert available equipment for gundrilling. On the other hand, the best solution usually is to install equipment that is expressly made for this purpose and is flexible.

One should keep in mind that the gundrill is a precision tool, designed to produce high quality, close tolerance holes. The machine setup should remove the requirement of judgment from the operator, permitting the tool to accomplish the results for which it is designed. Gundrilling is, and should be, a push-button job that releases skilled operators for work on machines where judgment is needed, and enables an inexperienced operator to produce high quality holes.

There are precision drilling machines available in which all elements required are built-in and self-contained. DeHoff and Eldorado gundrilling machines, designed and built in the USA by Kays Engineering, are two prime examples.

Both the DeHoff and Eldorado products are carefully engineered and specifically designed precision drilling machines that provide assurance of precision in holding tolerance of accuracy, size, finish, location, and straightness in deep or shallow holes.
DeHoff and Eldorado precision drilling machines are available with a choice of components and arrangements for practically any gundrilling job. With industry leading performance and a worldwide reputation for reliability and excellence, DeHoff and Eldorado are the obvious solution to any precision hole drilling problem. For more information or to request a quote, visit www.kaysengineering.com or contact the Sales department at sales@kays-dehoff.com or (660-886-9929).