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# A Review of Current Micro Drilling Processes

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**Abstract**

The demand for micro drilling i.e. drilling holes of diameter less than 1mm is gaining importance because of the increase in the use of miniature and micro devices. The major areas of application of micro drilling are automobile, aeronautics, electronics and medical fields. The paper reviews the three major processes that are in vogue namely mechanical (using micro drills bits), electrical discharge machining (EDM) and laser methods for micro drilling.

***Keywords:*** micromachining; micro drilling; EDM; Lasers

## 1. Introduction

The size of the many devices being used in areas like MEMS, electronics, medical, aerospace and automobiles is decreasing faster in recent years. As these miniature and micro devices commonly found in these industries have become smaller, the requirements for drilling holes of diameter of a few microns have become ever more pressing. A number of micro drilling processes are being used to satisfy these requirements. Three out of these many processes, namely mechanical, EDM and laser methods are reviewed here.

1.1. A briefing of the applications of micro drilling

The areas in which miniaturization are employed extensively are:-

i. Consumer products
ii. Aerospace
iii. Automotive
iv. Biomedical
v. Chemical
vi. Optical displays
vii. Wireless and optical communications
viii. Fluidics

The miniature devices used in the afore-mentioned areas are many, such as pressure sensors, accelerometers (inertial sensors), micromirrors, gear trains, miniature robots, fluid pumps, microdroplet generators, optical scanners, probes(neural, surface), analyzers, imagers, etc.

## 2. Micro Drilling Operations

2.1. Micro drilling using micro drill bits

Micro drilling using micro drill bits possesses the same features as that of the macro scale drilling but slightly different ones. This uses a special drill geometry, tool holding devices, drilling cycle and speeds of drilling.

Micro drill bits of diameter larger than 50 micrometers only are of twist drill type. Drill bits smaller than this are of the spade type. In spade type, the cutting edge is formed by two flat planes and this design is called "chisel edge". This drill bit type removes material from a hole at a negative angle of extrusion. The absence of spiraled flutes in spade drills can result in smoother hole-walls. But the removal of chips from the hole is more difficult. Micro drill bits are usually made of cobalt-steel alloy, which is relatively inexpensive. Tungsten carbide is used for greater strength and durability.

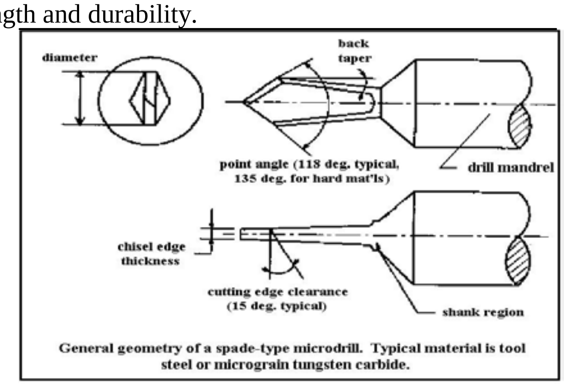


Fig.1 Spade type drill

The micro drill bit and the mandrel are fabricated as a single solid piece. The spindle uses a vee-block bearing arrangement. The mandrel is pressed against four convex diamond surfaces which are the only points of contact. The pressure is provided by a small pulley fastened to the drill mandrel and a drive belt passing around the pulley. The belt drives the drill from an external motor. The belt tension is the only force holding the mandrel against the diamond pads and a slight upward component of the belt tension is used to retract the drill. The top of the mandrel presses against a ceramic material to provide the drill thrust force. In some cases, a sensor is included to gauge drilling force and bit wear.

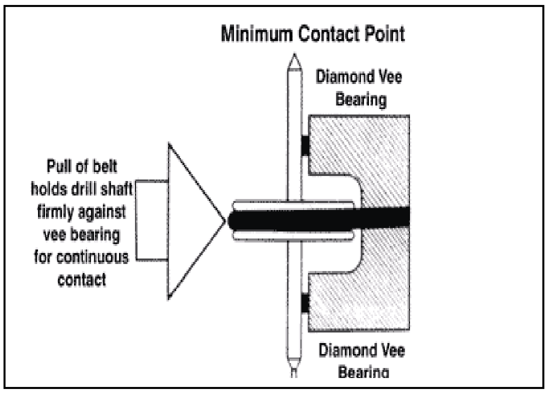


Fig.2 V-block arrangement

Micro drill bits usually operate using a “peck cycle”. A peck cycle alternately inserts and withdraws the drill bit from the hole to remove accumulating chips. This is often clubbed with the application of cutting fluid, such as oil mist to force the chips out of the hole.

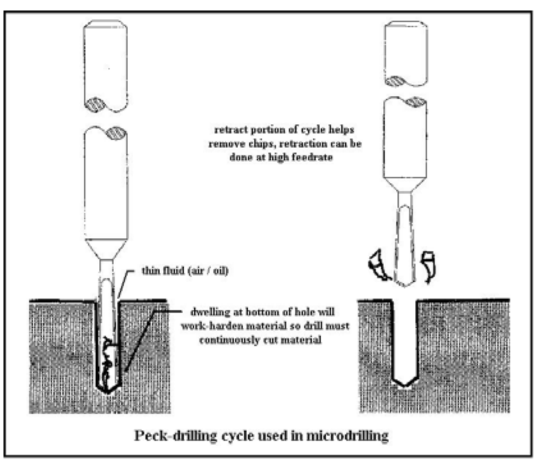


Fig.3 Peck drilling cycle

The speeds and feed rates in a micro drilling operation depends upon the materials which can be drilled. The speeds employed in conventional drilling are typically between 2000 and 4000 rotations per minute (rpm), while in micro drilling the same may be a few revolutions per minute and feed rates are in the range of some micrometers per revolution. Micro drilling often uses lower speeds because allowing the drill to dwell at the base of the hole under high rpm can lead to material hardening.

2.2. Micro drilling using electrical discharge machining (EDM)

EDM is most widely used of all the processes employed for micro drilling. A slightly different variant of the conventional EDM process called micro EDM (MEDM) is used for micro drilling. The later process differs from the former in the following aspects:-

2.2.1. The size and material of the tool used.

The size of the conventional EDM tool is in millimeters whereas the micro EDM tool is of the order of a few micrometers. Owing to its micron-sized diameter, the micro EDM tool develops a large amount of heat when power supply flows through it. So micro EDM is characterized by substantial tool wear. Typically tool wear is 1-5% in conventional EDM whereas in micro EDM it is 1.5-100%. Because of this the tool is usually made of tungsten material.

2.2.2. Power supply

The current strength used in micro EDM is of the order of milli-amperes when the same is in amperes in conventional EDM. In the case of voltage, MEDM uses a third of that used for EDM. The pulse duration ranges from micro seconds to milli seconds in conventional EDM and in MEDM it ranges from nano seconds to micro seconds.

2.2.3. High precision slides

The high amount of tool wear and the extremely small size of the machined features requires a high precision slides i.e. the resolution of the X, Y and Z axes movement must be high. The MEDM slides use a servo system with highest sensitivity and positional accuracy of 0.5 micrometers. This allows setting of a minimized discharge gap width of a few micrometers. This makes MEDM helpful for regular precision engineering work as well as for micro-components fabrication like micro-molds, micro inserts, etc.

2.2.4. Die electric flushing

Die electric flushing is a severe problem due the micron-seized hole. Therefore, normally internal flushing is used.

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## 3. Micro drilling using lasers

3.1. Introduction

Micro drilling by EDM has several disadvantages:-

i. The diameter of the micro hole that can be drilled by EDM is limited by the electrode diameter.
ii. The sacrificial electrode wears out much faster and this requires a highly precise drive system to maintain the gap between the electrode and the work piece.
iii. The drilling region must be surrounded by a dielectric fluid to insulate the electrode and work surface
iv. The dielectric fluid is used to carry away the chips and thus must be either filtered or discarded
v. The very small hole diameters make it difficult for the dielectric fluid to reach the drilling zone.
vi. The cycle time for EDM micro-drilling is much longer than that in laser micro drilling.
vii. The EDM process cannot be used for drilling non-circular holes.
viii. EDM is also limited to electrically conductive materials

Micro-drilling using lasers are employed in a variety of applications involving materials such as metals, ceramics and plastics. Laser micro drilling in fuel injector nozzles used in direct-injection diesel engines is one of the main applications. In a direct-injection diesel engine, fuel is directly injected into the combustion chamber by the fuel injector nozzle. The diesel is delivered in atomized condition and with high energy at the end of the compression stroke. The fuel will ignite when the temperature reaches the ignition point. A typical fuel injector nozzle is shown in figure 4.

Fig.4 Fuel Injector Nozzle

The complete burning of the fuel depends on the degree of atomization. Atomization can be improved by using holes that have a non-circular profile rather than a simple, straight-walled, cylindrical shape. A reverse tapered hole, for example, may help delay the pressure drop so that the fuel maintains a high energy level and atomizes more effectively. Other hole profiles may also help promote more complete atomization as shown in figure 5.

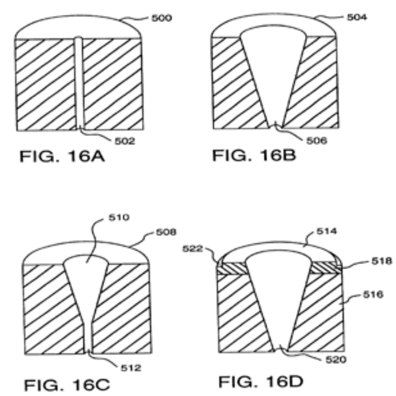


Fig.5 Hole-profiles for improving atomisation

The laser power source for micro drilling must satisfy three main requirements:

i. short pulse duration,
ii. high peak power, and
iii. short wavelength

The most commonly used laser for drilling is the solid state, diode-pumped, pulsed Nd-YAG laser. A schematic of the Nd-YAG laser is shown in figure 6.

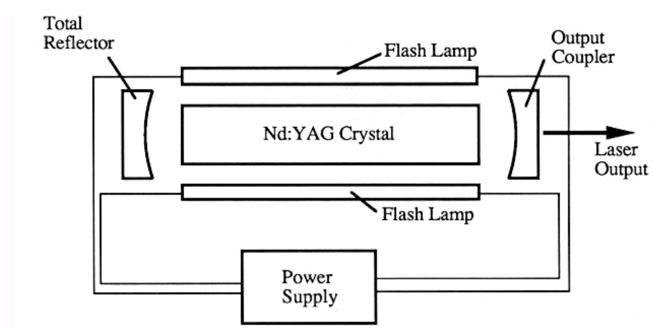


Fig.6 Schematic of Nd-YAG laser system

For micro-drilling applications, the laser power is delivered in discrete, high-energy pulses. Usually Nd-YAG lasers with pulse length of several tenths of milli-seconds are used to drill such holes when a certain degree of inaccuracy of diameter and shape as well as thin recast layer can be tolerated. In cases where higher accuracy is needed, laser drilling with millisecond pulses does not meet the requirement. This means that to increase precision of the micro hole, a reduction of pulse length is necessary.

3.2. Techniques of laser micro drilling

There are various techniques of laser micro drilling as shown in the figure 7.

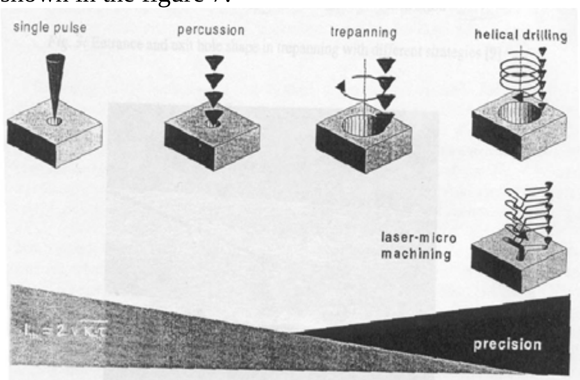


Fig.7 Techniques of laser micro drilling

3.2.1. Single-Pulse micro drilling

In this case, a single laser pulse with comparatively high pulse energy is used to make the hole. This technique is used for producing a large number of holes in an extremely short amount of time. However, the method is limited to less deeper and less precise holes.

3.2.2. Percussion micro drilling

In percussion drilling, the hole is produced using many short-duration, low-energy laser pulses. This method is used for making deeper, more precise holes than single-pulse micro drilling and also enables smaller-hole diameters.

3.2.3. Trepanning

Trepanning is similar to percussion micro drilling in that this also uses multiple short-pulse lasers. In this technique, a pilot hole is first made using percussion drilling. The laser is then used for enlarging the pilot hole, moving over the work piece in a series of increasingly larger circles.

3.2.4. Helical micro drilling

In helical micro drilling, the laser beam begins moving in circles over the material as the pulses are delivered, with a large amount of material being expelled upward in the process. The laser beam moves down the hole in a downward spiral. The focus can be adjusted so that it is always at the base of the hole. Once the laser has pierced through the material, it can complete a few more revolutions to enlarge the base of the hole and smooth out the edges. Helical drilling makes it possible to produce very large and deep high-quality holes.

## 4. Conclusions

The process of micro drilling using drill bits is used for materials that have good machinability. The process requires simple set up and is characterized by shorter cycle durations. The EDM process is suited to difficult-to-machine materials. However, the cycle times are longer and output is low. It can be used for producing holes of diameter smaller than those made using drill bits. The laser micro drilling process can produce the smallest holes of all the three processes and the productivity is more owing to shorter cycle times. The heat affected zone (HAZ) is also very small.

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