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Research Article

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Review on Effects of Drilling Parameters on Burr Formation

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Abstract:

Drilling is a process of producing round hole in a solid job by cutting tool having multitooth called twist drill. It is an esteemed process from all machining processes. It has been concluded from a surveys that drilling operation imparts more than 30% of all the metal removing operations done on a job or assembly. But there is problem occur during drilling called burr formation. Burr formation at the entering side and exit side is a very serious problem in assembly making components, which is caused by the improper machining parameters like spindle speed, diameter of twist drill, lip angle, feed, material to be drill, tool geometry, tool material etc. Excessive feed rate, lower spindle speed, higher diameter of twist drill are the causes of higher delamination or burr formation, which requires deburring which increases the cost up to 20% So a serious focus is required to minimize the burr formation. One of the popular method to reduce burr formation is to use cryogenically treated tools which are helpful to minimize the burr formation and to increase the finishing of hole.

Keywords: Drilling, Burr formation, Cryogenics, Delamination.

I. INTRODUCTION

Drilling is most effective and economical way of producing a hole in a solid material. Literally no job or assembly leaves the machine shop without having a hole in it. Drilling can also be described as a process where a multi-point tool is used for removing unwanted materials to produce a hole. The twist drill is a cutting tool with two symmetrical and opposite cutting edges, each removing part from the job in the form of chip and produce a hole in the work piece. The Drilling machines are very useful in an industry for metal cutting operation. It is therefore, essential requirement to optimize the quality and productivity simultaneously. Regarding the quality characteristics of drilled parts, some problems are encountered which are temperatures, Thrust force, Surface roughness, Burr formation, Power consumption, Material removal rate. Among these characteristics, surface roughness and burr formation play the most important roles in the quality of a drilled part. Spindle speed, feed, material of work piece, drill tool type and cooling conditions are the main drilling parameters which highly affect the performance. In order to improve metal removal rate, decrease the machining cost, and to rise the quality of drilled job, it is necessary to select the most appropriate machining parameters for achieving quality.

Drilling tool (Twist drill):-

The twist drill does most of the cutting with the tip of the drill bit. It has two flutes to carry out the chips from the cutting zone to the top of the hole surface where they are cast off. The standard drill geometry with the part name is shown in the figure1:

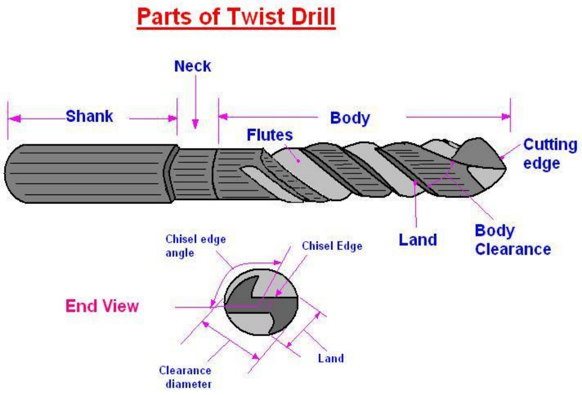

Figure 1

It is made from a round bar of a particular material, and has three major parts: the point(tip), the body and the shank. The drill is held by its shank into the spindle of drilling machine. The point comprises a tip for cutting followed by cutting edges while the body guides the drill in the operation. The two cutting edges of the drill has two helical grooves called “flutes”. The flute forms the cutting edges and also provides the way for removing chips out from the drilled hole. The parts of twist drill are:

1. Point:

The point in twist drill is the cone shaped end and it does the major cutting. The parts are:

- Dead center: It is the sharp edge at the extreme point of the drill tip. This should always be at the exact CG line of the drill.
- Lips: These are the two cutting edges of the twist drill.
- Heel: It is the surface, back to the point from the cutting edge.

2. Shank:

It is the portion of the twist drill by which it is clamped or held in the spindle of drilling machine. The shank may be tapered or straight. Straight shank of twist drills is used with a chuck. Tapered shank drills of twist drill have self-holding tapers that fit directly into the drill press spindle. Taper shank is the also term as tang. This fits into the slot in the spindles sleeve.

3. Body:

It is the portion rest between the point and the shank of twist drill. The body consists of the following parts:

- **Flutes:** Two or more spiral grooves that follow the length of the drill body are called flutes. The major functions of flutes are: provides the way to out the chips from cutting zone, allow the coolant and lubricant to get down to the cutting edge.
- **Margin:** It is the narrow strip extending back to the entire length of the flute. It forms the full diameter of the twist drill.
- **Body Clearance:** It is the portion of the drill body that has been reduced in order to keep the body away from the walls of drilled surface.

II. FACTOR AFFECTING THE PROCESS

- Cutting speed
- Feed rate
- Drill diameter
- Point angle
- Cutting fluid mixture ratio
- Back support with proper clamping
- Material to be drilled
- Drill tool material
- Modes of cooling

III. DELAMINATION AND BURR FORMATION:-

The two forms of burr formations are:

3.1 Peel-up at entrance

Peel-up delamination occurs as the drill enters the laminate of fibre layer as shown in Figure 2(a) and when the cutting edge of the twist drill keep in contact with the laminate of fibre layer, the cutting force acting in outward direction is the driving force for peel-up delamination. It produces a peeling force in the axial direction through the slope of the drill flutes. The cutting edges tend to push away the upper laminas and the material spirals up before it is machined completely. This action results in separation of the upper layer from the uncut portion held by the downward acting thrust force and forming a peel-up delamination zone at the top surface of the laminate. The peeling force is caused by tool geometry and friction between the tool and work piece.

3.2 Push-out at exit

Push-out delamination occurs when the twist drill reaches the exit side of the material and is shown schematically in Figure 2(b). As the twist drill approaches the exit end, the uncut thickness gets too short and the resistance to deformation decreases.

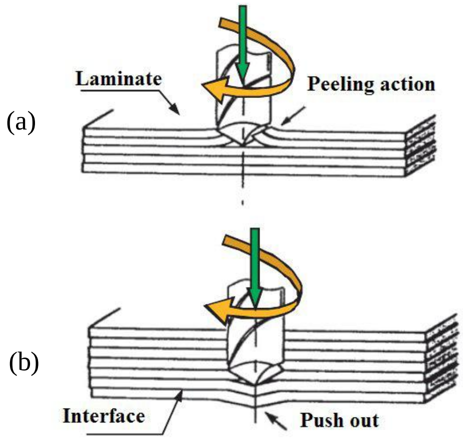

Figure 2. Mechanisms of delamination: (a) peel-up at entrance and (b) push-out at exit.

At that point, the thrust force exceeds the interlayer bond strength causing outer layer to come out from the surface and pierces through the exit side. This occurs before the layers are completely penetrated by the twist drill. Proper drill geometry and cutting parameters can reduce the push-out delamination by optimizing the thrust force. By experimentally it has been found that the push-out length of delamination is more than that of peel-up length.

Burr formation is same as delamination but the difference in these two terms is that in delamination there is a breakage of lamination in the sense delamination occurs in those material having saparation of one layer to the next corresponding layer filled by a different material of layer and burr formation is extension of material at entering side and at exit side of material while drilling. Burr formation occurs in every material with improper machining parameters which further needs deburring for getting accuracy. There are some types of burr formation given as uniform burr, transient burr and crown burr as shown in figure 3.

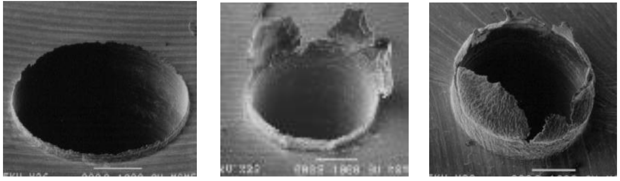
uniform burr transient burr crown burr

Figure 3

IV. CRYOGENIC TREATMENT

Cryo processing is a additional process to conventional heat treatment process, by which it converts the retained austenite into martensite which remains after heat treatment process and due to martensite formation there is further increase in wear resistance, dimensional stability, hardness. This reduces tool consumption up to large extent and hence increase the intervals between tool replacement which reduces the down time for the machine tool set up leads to cost reduction. Some researcher developed their own system to control the drawback of cryogenic treatment so that the developments of cutting forces can be reduced by use of secondary liquid nitrogen supply while machining. Various methods are employed to maintain low temperature at machining zone by use of liquid nitrogen, dry ice, adding nano particles to conventional cutting fluid.

Cryogenic processing will make the metal harder & more brittle, Cryogenic processing has no effect on cast iron, low carbon steel, and non ferrous metal. Cryogenic processing makes changes to the structure of the materials being treated and dependent on the composition of the material, it performs three things; retained austenite turned to martensite, stress is relieved, carbide structures are refined. Cryogenic processing itself is not a heat treatment or hardening process like quenching and tempering, it is an additional treatment to heat-treatment means it is done after the heat treatment process for some reasons. The benefits of this process include; adhesive wear, reduction of abrasive and improved machining properties resulting from the permanent change of the structure of material, reduction of catastrophic tool failure and reduction of the frequency and cost of tool remanufacturing due to stress fracture.

V. LITERATURE REVIEW

Sung-Lim Ko et. al. [1] observed that in conventional drilling, the phenomena of burr formation can be changed by varying the twist drill’s geometry, i.e. the step angle, point angle, helix angle etc. To minimize burr formation, it is proposed that a step drill with proper step length and step angle can be used. The step drill performs front edge cutting by the tip at extreme position before step edge cutting. The burr formed in first cutting by front cutting edge or by tip is be removed in second cutting by step edge and new burrs are formed through the second cutting when material cutting takes place by step edge. It can be minimized by changing the drill’s geometry. A laser sensor is used to measure the burr formed in the drilling. By experimentally the geometrical specification of the conventional twist drill with a 140^0 point angle and the step drills are used to compare burr formations. Two kinds of drills with a cutting speed of 35 m/min and the feed rates at 50, 100, 150, 200, and 250 mm/min were used for SM45C alloy steel. the burr formation process is checked in dry condition without use of coolant. A conventional carbide twist drill with a 140^0 point angle is used and a step drill was designed to contain two different cutting edges The front cutting edge in conventional drill with 8 mm diameter and 140^0 angle performed the drilling. The step cutting edge with a 75^0 step angle and 10 mm diameter at stepped portion removed the remaining part that results a 10 mm hole. It was finally observed that burr formation by a step drill with step edges were quite smaller in size as comparing with those produced by a conventional drill with a point angle that was larger than 130^0. The effect of the change of burr length in the step drill’s geometry was analyzed. A step angle of less than 75^0 was very efficient to minimize burr formation as compared with a step angle that was larger than 130^0. The step size did not have much effect on burr formation.

V. Firouzdore et. al. [2] observe the effect of deep cryogenic treatment on wear resistance and tool life of M2 HSS twist drill in high-speed dry drilling configuration of carbon steels. The experimental result indicates that 77% and 126% improvement in cryogenic-treated and cryogenic temper-treated twist drill were seen, respectively. Additionally, transformation that takes place from retained austenite to martensite played an effective role to improve hardness values. Three types of drill tools were tested experimentally, reference drills (R) with no treatment, cryogenic-treated twist drill (CT) and cryogenic with a 1hr tempered at 200^0 C treated drill (CTT) and then Drilling test was performed on a rigid bench drilling machine. Blind holes by these twist drill were drilled in normalized CK40 carbon steel blocks. Depth of hole, feed and cutting speed were kept constant as 50mm, 0.11mm/rev and 350 m/min, respectively. Five drills were observed for each group. The total number of holes that every drill tool drilled before failure was examined as drill life. Wear rate was measured by keeping out of drills from the spindle chuck of drill machine after drilling of 10, 15, and 20 holes and measuring the width of flank wear scar using a tool marker's microscope having X50 magnification. Compare the drill tool live and its hardness values of three drill families. And it is observed that the influence of cryogenic treatment on hardness values which is higher in CT than R and for CTT drills it is higher than CT & R. It is also noted that drill life improves approximately 77% for CT drills whereas it increases about 126% for CTT drills. And by Comparing the flank wear width on the flank surface after drilling of 10, 15, and 20 holes it is observed that is very less wear taken place for CTT tool as compare to R.

V.N. Gaitonde et. al. [3] investigates the application of genetic algorithm (GA) for burr minimization in drilling of AISI 316L stainless steel by HSS twist drills. The mathematical models for burr height and burr thickness were developed using response surface methodology (RSM) taking feed, drill diameter, point angle, cutting speed and lip clearance angle as performance parameters. The developed RSM models were then subjected with GA, which is a search algorithm to determine the optimal process parameters for a given drill diameter that results in minimum burr height and burr thickness which gives the resulting values of the point angle and cutting speed have significant effects in minimizing burr size.

The experiments were conducted on a three-axis CNC vertical drilling machine with a Fanuc controller with a 15 kW drive motor with high range of selecting the feed and spindle speed. the optimal values of feed rate are low to medium (in the range 0.04–0.07mm/rev) taking drill diameter ranging 4–28mm. The optimal point angle required is directly proportional to the twist drill diameter and thus at higher drill diameter values it will be optimize to take larger point angle in order to minimize burr size. The minimization of burr size require lower values of lip clearance angle ranging 8–10^0 for all drill diameter.

Martin Dix b et. al. [4] concentrates on energy consumption for drilling operations which is influenced by the cooling strategy. But cryogenic machining provides the option of coolant-free processing and also resulting in low tool wear, even at high metal removal rates, due to efficient reduction of temperature of tool. Different process models showed that the position of the cooling channel is basic for efficient cryogenic drilling process. DEFORM 3D V10.1 was also used for performing modeling of machine. Work piece material on screen was modeled by tetrahedral mesh. The tool was taken as a rigid body with thermal properties (like solid carbide WC). The contact among the tool and work piece was modeled to bring friction value 0.3 and a heat flow of 4kW/m2 K. The simulation was done for drilling of normalized 42CrMo4 steel with a 7 mm diameter drill using cutting speed of 105 m/min and a feed rate per revolution of 0.21 mm, which corresponded to high-performance drilling of this material.

An effective temperature reduction was found by using cryogenic cooling as compared to dry drilling. Moreover, it was found that the tool geometry and specially the position of the cooling channels are important for the distribution of temperature during machining. From all these they concluded that cryogenic cooling is mainly suitable for high-performance drilling where a large amount of heat released during drilling.

D. Biermann et. al. [5] works on research regarding a new burr minimization method for drilling operations by using a cryogenic process cooling. Indexable insert drill tool having diameter 25 mm was used to drill the steel 34CrNiMo6. This steel has a high strength along with good ductility. During the machining procedures, the exit side of the work piece was cooled using CO2 snow jets to influence the burr formation. Cooling devices with many CO2-nozzles were constructed to cool the area of burr formation. The CO2 snow jet has its lowest temperature ($T \approx -78.5$ °C) directly at the nozzle exit. After defining different parameters for the new cooling method, comparative tests with flood lubrication and dry machining were performed.

For the machining of both, the quenched and tempered steel 34CrNiMo6 and the aluminum alloy AlMgSi1, the burr height can be decreased due to an impact on the materials ductility as a result of the cryogenic cooling. Moreover, the surface quality can be improved for the considered drilling depth. The results were verified for wide range of cutting data. The cooling method does not lead to an improvement of diameter or roundness deviation of the drilled holes.

However, particularly for drilling of the aluminum alloy AlMgSi1, drilling done without cooling lubricant can lead to risks regarding poor process reliability. As the cooling of the backside of the work piece is comparable to the dry machining at the working zone and minor flank face, the material can adhere to tool and may influence the quality of the drilled holes. The tests conducted showed that the possible benefits of a cryogenic process cooling using carbon dioxide snow jets during drilling, especially when comparing to dry machining. For example, the cooling method can be used for improving implemented dry drilling operations about burr formation.

Desh Bandhu et. al. [6] conducted a literature survey on the drilling of composite materials, particularly on drilling of carbon fiber reinforced plastics. Aspects like tool materials and geometry, machining parameters along with their influence on the thrust force and torque are examined. Additionally, the quality of the holes produced is also examined, with special attention to the delamination damage.

Thrust force and torque both lead to delamination while drilling of composites but still there is no comprehensive mathematical model involving thrust force, torque and feed rate. All classical models which are available have modeled thrust force or torque independently with feed rate. The variable feed rate method in which feed rate is lowered towards the exit of the hole has been addressed for drilling composites with delamination- free holes. There is no work in literature in which thrust force and torque are controlled simultaneously while drilling.

Sanjib Kundua et. al. [7] used the application of the method suggested by Taguchi to minimize drilling burr of an aluminium alloy using HSS drill. Parameters used were cutting velocity, feed and machining environment. The effect of process variables on burr height is explored, and the optimum condition for minimizing burr height using a back-up support is determined by the analysis. Analysis of variance was undertaken to find out the influence of process parameters on the response noted. Predicted values are finally checked for accuracy through a confirmation test. It is found out that back-up support yields much better result than that of normal drilling process. Moderate cutting velocity, low feed and wet condition with water cooling were observed to minimize burr height using a back-up support. Uncoated 9 mm diameter taper shank HSS twist drill, Work piece material Aluminium alloy, {Composition: Cu (0.1%), Fe (0.74%), Mg (0.6%), Zn (0.28%), Pb (0.02%), Si (0.37%) and Al (remainder)} were used. Size of flat: 100 mm x 50 mm x 5 mm was used as Back-up support and the material of back up support was Same as work piece material. Cutting velocity 12.5 m/min, 20 m/min and 32 m/min, Feed 0.032 mm/rev, 0.08 mm/rev and 0.125 mm/rev were used with Cutting environment Dry, wet with water, and wet with soluble oil. Optimum testing condition using a back-up support is obtained to reduce burr height by about 33%.

VI. CONCLUSION

It has been concluded from the literature that spindle speed, drill diameter, point angle, feed rate, tool material etc. are the major factors that affect greatly the burr height and thickness made during drilling operation. It is also concluded that excessive feed rate, by increasing dia of drill, lower spindle speed, high point angle increases the burr formation with huge percentage. So a serious concentration is required to optimize these performance parameters to minimize the burr formation. Cry-treated tools with backup support are also helpful to minimize the burr formation.

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