An Experimental Study on Tool Wear Rate And Chip Formation During Drilling Process of Mild Steel Plate

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Abstract- *Drilling is probably the most common machining operation applied to mild steel and other composite materials, since components such as steel are made out of mild steel are usually near net shaped and require only holes for assembly integration. In this investigation, experiments were conducted by varying the drilling parameters and determining the optimum cutting conditions for drilling of mild steel using Genetic Algorithm (GA) optimization technique. Tool wear study was performed by drilling 100 holes each with 118° and 130° point angle drills. Less progressive tool wear and better chip evacuation was achievable in 130° point angle drills when compared with 118°point angle drills.*

Keywords- Drilling, Genetic Algorithm (GA),Tool wear, Flank wear , Mild Steel Plate (MS Plate), Chip Profile.

I. INTRODUCTION

Drilling is most widely used for machining processes to produce the holes in various industrial parts. Drilling is a process of producing round holes in a solid material or enlarging existing holes with the help of multi-point cutting tools (drill bits). [1] Drilling is one of the widely used machining processes for various purposes. Nowadays it is frequently used in automotive, aircraft and aerospace and dies or mold industries, home appliances, and medical and electrical equipment industries. Thus, it needs to be cost-effective along with the assurance of the quality specifications within the experimental limit. In today's rapidly changing circumstances in manufacturing industries, applications of optimization techniques in metal cutting processes are essential for a manufacturing unit to respond efficiently to severe competitiveness and the increasing demand of the quality product in the market. Optimization methods in metal cutting processes, considered being a very important tool for continual improvement of output quality in products & processes . The quality of drill depends on cutting tool geometry, workpiece materials, and input parameters [2].

Fig. (a)An Experimental Setup.

Cutting speeds in gun drilling are usually high, and feeds are low. Tolerances typically are about 0.025 mm. The cutting fluid is forced under high pressure through a longitudinal hole (passage) in the body of the drill Fig. (a). In addition to cooling and lubricating the workpiece, the fluid flushes out chips that otherwise would be trapped in the deep hole being drilled and thus interfere with the drilling operation. The tool does not have to be retracted to clear the chips, as is usually done with twist drills.

DRILL MATERIALS AND SIZES

Drills or drill bits are usually made of high-speed steels (M1, M7, and M10) and solid carbides or with carbide tips (typically made of K20 (C2) carbide), like those shown in Fig. (c and d). Drills are now commonly coated with titanium nitride or titanium carbo-nitride for increased wear resistance. Polycrystalline diamond- coated drills are used for producing fastener holes in fiber-reinforced plastics. Because of their high wear resistance, several thousand holes can be drilled with little damage to the material.

In this experiment ,the drill-bit diameter is 8mm ,while plate thickness is taken as 6 mm.

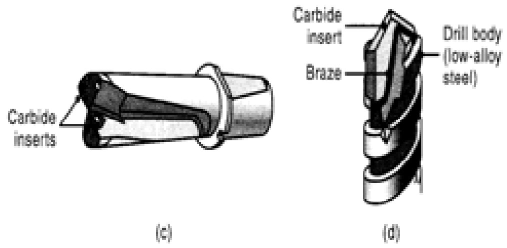

Fig. (c & d)Drill bit specification

II. TOOL WEAR MECHANISM STUDY

Wear is the removal of the material from the surface of a solid body (tool) as a result of mechanical action of the counter body. Wear may combine effects of various physical and chemical processes proceeding during the friction between two counteracting materials such as microcutting, micro-ploughing, plastic deformation, cracking, fracture, and welding, melting and chemical interaction. Various forms of tool wear on the drill tools are flank wear, crater wear, chisel edge wear and chipping. Wear on the flank of a cutting tool is caused by friction between the newly machined workpiece surface and the contact area on the tool flank. The width of the wear land is usually taken as a measure of the amount of wear and can be readily determined by means of a toolmaker's microscope. The flank wear also increase the cutting forces and also heat between the tool and work piece. The wear patter is irregular along the edge of the tool. Often, chipping wear leads to a catastrophic failure early in the life of the tool which masks the failure mode. Mechanical issues such as machine spindle or part fixture vibration will contribute to chipping wear. A tool holder with a large cantilever condition will cause harmonic vibrations to be amplified at the cutting edge. Excessive loads on the tool will cause chipping. [11, 12].In this current research flank wear and chisel edge wear were studied for two types of twist drills of the following specification given in Table 1.

Table 1. Specifications of Tool

S.No.	Specifications	SGS (SOLID WC-118°)	SGS (SOLID WC-130°)
1.	Point angle	118	130
2.	Helix angle	20	30
3.	Chisel edge thickness	1.215mm	0.450mm

II.A. TOOL WEAR ANALYSIS FOR 118° POINT ANGLE DRILL

The 118° drill had a higher flank wear and chisel edge wear rate which is shown in Table 2. This can be attributed to higher thrust force because of larger chisel (1.215 mm) acting on the tool flank resulting in localized plastic deformation. The plastic deformation results in increased contact area and hence higher friction between drill and workpiece. This increases the temperature of both tool and workpiece at the cutting zone. As a result the ductility of tool flank increases causing a higher flank wear rate after 80 holes.

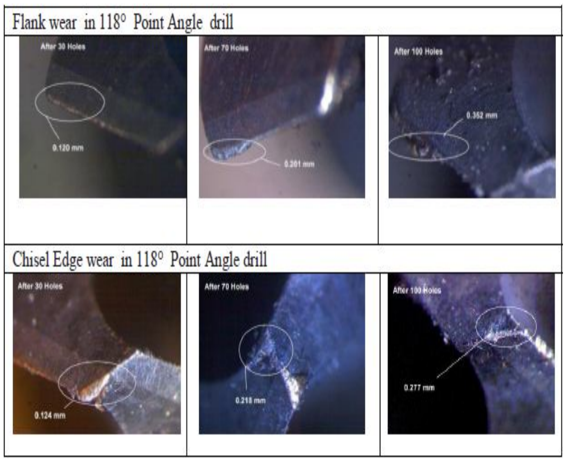

Table 2. Flank and Chisel Edge wear for 118° Point Angle drill

II.B.TOOL WEAR ANALYSIS FOR 118° POINT ANGLE DRILL

The flank wear in 130° drill occurred at a lower rate when compared to 118°. In contrast to the 118° drill tool, the 130° tool produced a very low thrust force. The chisel edge thickness of 0.45 mm is the main reason for low thrust and hence a lower flank wear rate. There was no sudden increase on flank wear rate like 118° drill. The progressive chisel edge and flank wear were presented in Table 3.

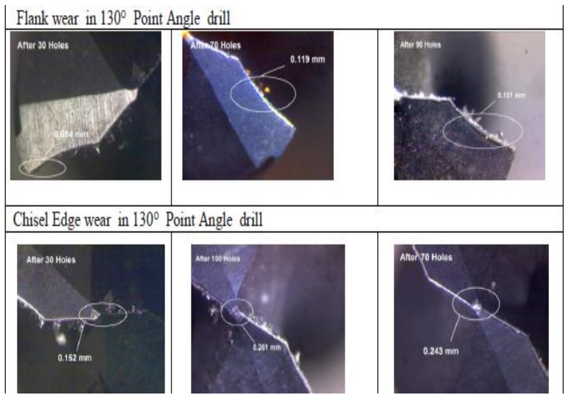

Table 3. Flank and Chisel Edge wear for 130° Point Angle drill

III. CHIP PROFILE STUDY

Chip shape is the most important factor for the smoothness of a drilling process. The drilling process will be smooth if chips are well broken. While drilling Mild Steel Product/Plate, MS chip are continuous and non-discrete type chip was formed which was analyzed in detail during the course of the study. However, most ductile materials do not break during drilling, and instead, form continuous chips. Based on the chip forming mechanisms, continuous chips can be categorized to spiral chips and string chips. When chips are initially generated, because the inner cutting edge moves slower than the outer cutting edge, the inner chip is inherently shorter than the outer chip.

This difference in length within the chip forces it flow to the drill center instead of perpendicular to the cutting edge. Spiral chip which is shown in fig 2 are structurally determined to rotate on their own axis while moving upwards. This motion is only free when the drilled hole is shallow. The chip natural flow angle can be obtained from equation (3 & 4).

$$\theta = (\rho_p/2) - \eta \qquad (3)$$

$$\eta = \sin^{-1}((D_b - W_b)/D_b)*\sin(\rho_p/2)) \qquad (4)$$

Where,

Point angle- ρ_p D_b - Diameter of the drill W_b - Drill web thickness

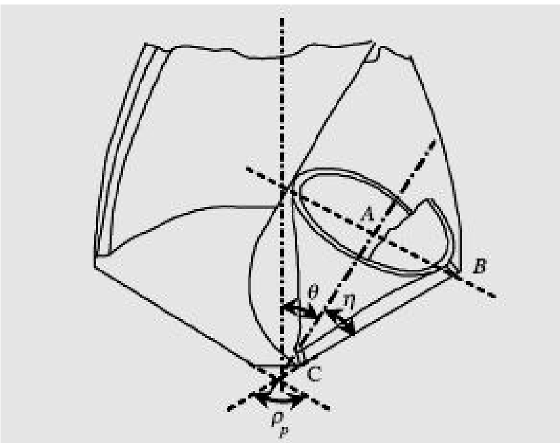

Fig. (c)Chip flow formation

III.A. CHIP PROFILE ANALYSIS DURING DRILLING USING 118° POINT ANGLE DRILL

Chip shape for first the 40 holes was spiral cone chip which is easier to be ejected, so the length of spiral cone chip can be considered as a scale to evaluate the difficulty for chip evacuation in drilling. Therefore short chips are preferred and also tight helix chips provide better surface finish. As the wear progress after 40 holes up to70 holes the length of the spiral cone decreases and the bending effect comes into picture where ribbon chips of large lengths are formed. This is due to the chips not able to rotate around its own axis. After 70 holes the wear becomes severe due to which thrust force increases rapidly. This makes the chip to reduce its thickness and the pitch starts increasing. Since the helix angle is 20° in this drill, chip instead of flowing through the flute freely it gets bent heavily with large lengths. Long ribbon chips are not ideal in terms of both chip evacuation and surface finish of the machined hole. A detailed chip shape transformation is shown in Table 4.

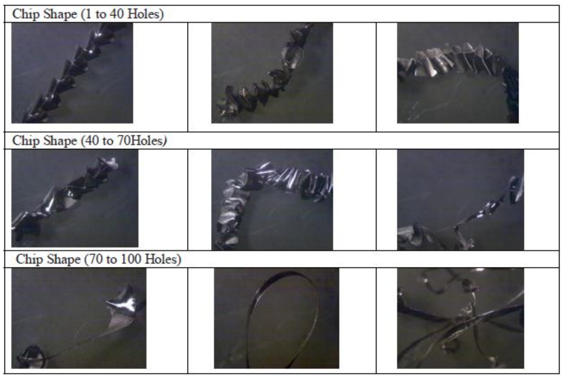

Table 4. Chip formation during drilling of mild steel using 118° point angle drill

III.B. CHIP PROFILE ANALYSIS DURING DRILLING USING 130° POINT ANGLE DRILL

Chip formation for 1 to 40 holes is ideal which is short spiral one. Once the number of holes in increases from 41 to 70 spiral chip length is less and the remaining is ribbon shaped.

During the drilling of 70 to 100 holes chisel edge is totally worn out and this again increases the thrust force which pushes the chip to unwound. The unwound chip changes its pitch and when it equals the pitch of the drill the transition from spiral to string chip takes place. This highly creates the chip evacuation problem which even leads to breakage of tool when proper chip breaking is not provided. A detailed chip shape transformation from 1 to 100th hole is given in Table 5.

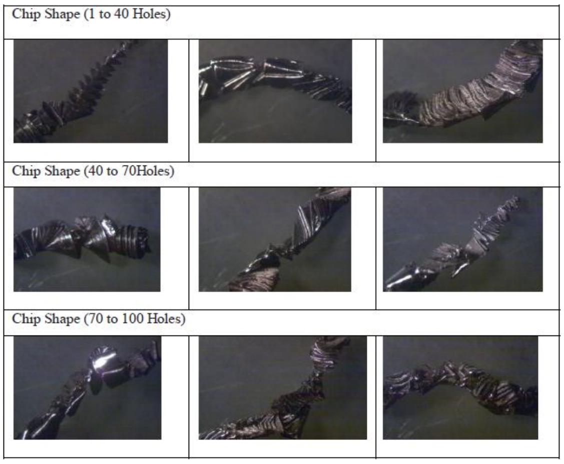

Table 5. Chip formation during drilling of mild steel using 130° point angle drill

IV. RESULTS AND DISCUSSION

IV.A. EFFECT OF POINT ANGLE ON FLANK WEAR

Abrasion is the major mechanism for flank wear. Generally flank wear is independent of spindle speed. The complex hard phase within MS abrades the flank surface after shearing the 3D microstructure. Due to the rapidly evolving flank wear with number of holes, the thrust force increased more rapidly at the higher spindle speed over the lower spindle speed. When drilling MS product, the cutting temperature became high enough to activate high adhesive affinity and to soften the WC drill. Softening of the WC drill is due to the softening of the cobalt (Co) binder that holds the carbide grains together. The flank wear is therefore extended by the mechanism of carbide grains pulled out of the Co binder as the Ti adhesion is removed while drilling through the MS in the next hole, in addition to the abrasion by the hard phase in the MS alloy. In metal drilling, the cutting edges can be partially protected due to the BUE of the cutting edges maintaining the edges more consistently. This is why MS drilling had a greater effect on flank wear. A detailed comparison between flank wear and number of holes is presented in fig 3.

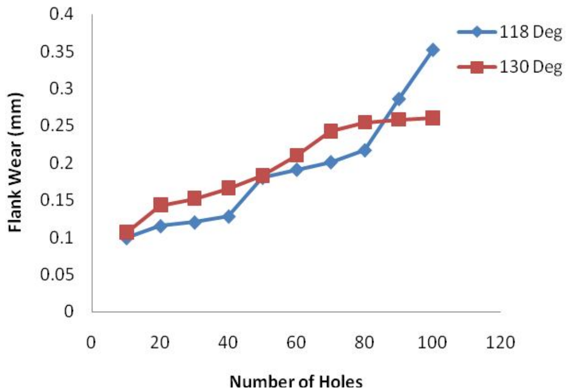

Fig. (d) Effect of Flank Wear on point angle

IV.A. EFFECT OF POINT ANGLE ON CHISEL EDGE WEAR

The chisel edge wear depends on the feed rate and relief angle. The wear increases with increase in feed rate. Smaller relief angles are not recommended because their contribution to chisel edge wear is high. Furthermore MS alloy adhesion causes built up edge (BUE) on the chisel edge.

When these BUE break up, the rate of chisel edge wear is increased substantially. Chisel edge wear causes an increase in thrust force due to increased bluntness of tool. Given that the stacking sequence of the stacks is Mild Steel stacks on top of the Product, Ti adhesion is observed on all the drills after drilling a set of 20 holes. Adhesion is a well-known characteristic in MS drilling due to the high chemical affinity to most of the tool materials [13].The adhesion leads to build-up edge (BUE) formation, which is an accumulation of work material on the cutting edges. The BUE deteriorates the hole quality and leads to the tool chipping or fracture when the BUE breaks off from the cutting edges. The adhesion was formed as soon as MS drilling started, and covered a large part of the flank surface especially at the higher spindle speed. The amount of Ti adhesion is directly related to the chemical reactivity of Ti, which increases with temperature. A detailed relationship between chisel edge wear and number of holes is presented in fig 4.

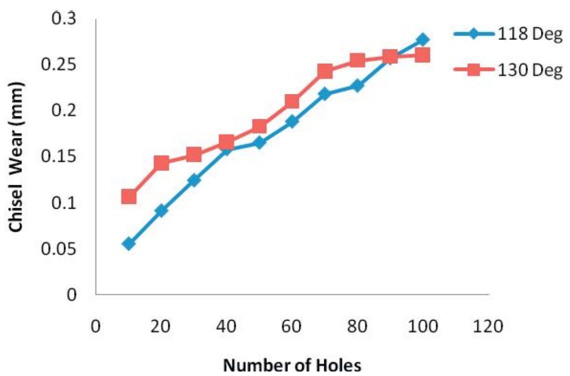

Fig. (e) Effect of chisel Edge Wear on point angle

V. CONCLUSION

The machining parameters (cutting speed and feed rate) are optimized using Genetic Algorithm and the result on the effect of tool wear over the optimized machining conditions were given below-

In 118° point angle drill there was a rapid increase in flank wear increases rapidly after 80th hole wear reaches to the maximum value of 0.352 mm at 100th hole. While compared with the 130° point angle the flank wear was 0.138mm by the end of 100th hole. Chisel edge wear was greatly influenced by the thrust force for both 118° and 130° point angle drills. Chip formation has a significant influence on the thrust force and tool performance. Tool fails when the chip produced has a long ribbon shape. The overall performance of 130° point angle drill is more better than 118° point angle drill because of smaller chisel edge thickness and increased point angle. In general as number of holes increases the chip shape varies from spiral cone to ribbon chip and after the 68th hole the string chip transformation take place and very long continuous string chips are formed and chip clogging take place. Due to this the drill may eventually fail if proper chip braking method is not used.

VI. FUTURE SCOPE

The present method adopted to solve the optimization problem of Drilling process is simple enough and is flexible in selection of objective functions for such manufacturing processes. During the solution of the problem, it has been found that the results obtained by the Genetic Algorithm towards the exact solutions. This approach may be coupled to other optimization algorithms to get multistage multi-criterion optimization by Genetic Algorithm. Then this method will be able to show its importance in real life complex manufacturing problem solution.

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