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Effect of external magnetic field on drilled hole quality during drilling operation

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Abstract

The improvement of the machinability of mild steel during drilling operation can be achieved by considering the optimized cutting conditions. This study aims to investigate the magnetic field effect on drilled hole quality in terms of surface quality, behavior of the chips and the circularity of the drilled hole. The comparison has been made between the machinability responses for both normal drilling and drilling with applying magnetic field. Magnetic field of unlike poles is applied to the both sides of the work piece using electromagnets during drilling process. The strength of the magnetic field is constant during the experiment by ensuring a constant current through the magnetic winding. Same cutting condition is used for both magnetic cutting and non magnetic cutting. The results show a better quality of the drilled surface, less serrated chips and more accuracy in the circularity of the hole when external magnetic field is applied compared to that obtained during cutting without using magnetic field.

Keywords: *Machinability, magnetic field, drilling, surface roughness, circularity etc..*

1. Introduction

The quality of drilled hole on a work piece is defined by several machinability factors among which the circularity of the hole, roughness of the inside surface are the two most important ones. The objective of the current study is to investigate the effect of applying strong magnetic field on the machinability responses. The first study of the effect of magnetic field on the machining process was performed by Bagchi and Ghosh [1,2]. They investigated the effect of EMF created by a magnetic field on the wear characteristics of cutting HSS tools while machining mild steel. An improvement of the tool life was found in their study. Pal and Gupta [3] investigated the effect of an alternating magnetic field on the wear behavior of HSS drills in drilling gray cast iron and malleable cast iron under dry cutting condition. The magnetic field was applied on both the work piece and tool in case of gray cast iron whereas for malleable cast iron the magnetic coil was kept over the work piece so that the field lines are mainly applied on the tool. Satisfactory result was obtained for improvement of tool life. More significant explanation of the above phenomenon was given by Muju and Ghosh [4-,5], when conducting tool wear experiments. Mansori et al [6] studied the magnetic field effect on the tool wear and the feed force during drilling a mild steel work piece. A considerable decrease in tool wear and feed force has been observed during the experiment. The effect of magnetic field on surface roughness of the finished work piece during the turning process of mild steel has been studied by Anayet U Patwari et al. [7]. The authors observed a decrease in the surface roughness due and significant improvement of tool life to the application of magnetic field. Serene [8] in her study investigated the effect of magnetic field on the accuracy of the drilled hole with respect to change in the strength of the magnetic field and the polarity of the magnetic field. It has been shown in her study that the magnetic field creates a damping effect on the drill bit which reduces the tool vibration and hence improves the tolerance. The exposed length of the drill bit was considered as another variable whose vibration affects the tolerance of the drill hole. In the current study, the accuracy and quality of the drilled hole was identified by its circularity and surface roughness. To find out the change in vibration nature of the drill bit during drilling process, when external magnetic field is applied, chip morphology was done.

2. Experimental Details

The work piece used in the experiment was mild steel. The diameter of the drill bit is 11 mm. The constant speed of 900 rpm of the spindle was kept constant throughout the experiment. controlled experiment was done, considering without magnet and with magnet. A total of four holes were drilled on the work piece for each condition. The feed used in the experiment was 20 mm/min. The experimental set up is shown in figure 1.

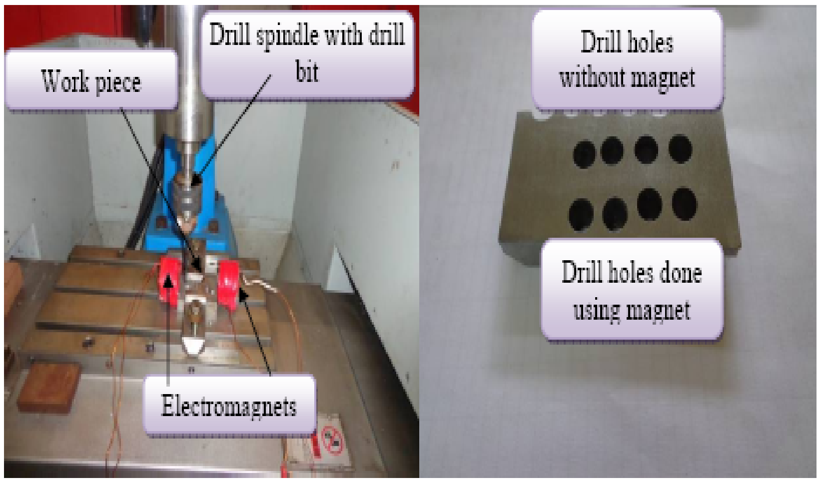


Fig. 1: (a) Experimental setup, **(b)** Work piece with drilled holes on it

200 V a.c.from the main line is converted to 12 V d.c using a transformer and an a.c. to d.c. converter circuit which is kept constant to ensure a constant current through the magnetic winding around the iron core of rectangular cross section. Two magnets are attached on both sides of the work piece.

The vertical pictures of the holes are then taken to process them using developed code by Anayet U Patwari et.al [9] in order to find out the circularity of the holes. The holes are cut in the middle to take the microscopic picture of the surface using Kruss metallurgical optical microscope. The surface is then processed using image processing technique developed by Anyet U Patwari et al [10]. The whole process sequence of the digital image processing (DIP) technique for a certain sample of surface is given below.

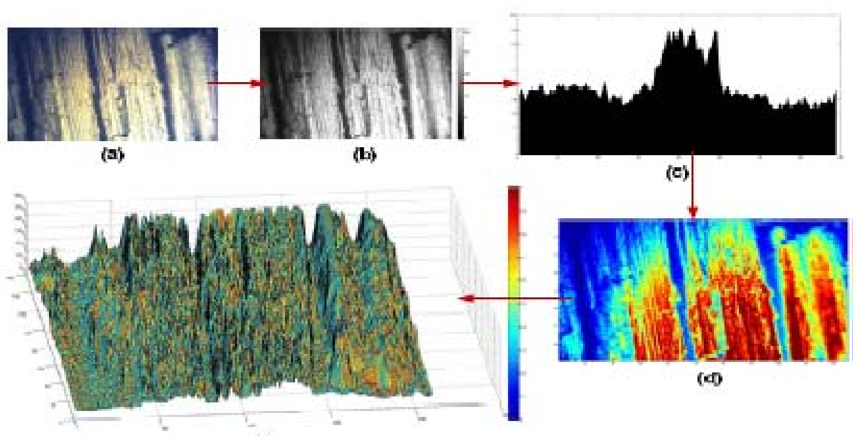


Fig. 2: (a) 10X zoom RGB microphotograph, (b) grayscale, (c) profile plot, (d) 2-D colored contour plot, (e) 3-D colored contour plot

In order to investigate the chips formed during drilling process, they are first collected for each condition, i.e. magnetic cutting and non magnetic cutting, and mounted using a mixture of resin and hardener. The mixture was stirred for about one minute and left to solidify. The solidified mixture is called mounting. The next step is to grind the mounting surface to reveal the chip to the surface. In order to remove the scratches on the surface, the mounting is then polished using alumina. Finally 2% nitol solution is applied to the surface. Then the mounting is ready to be viewed under the microscope to capture the structure of the chip. Figure 3 illustrates the mounting of the chips and the microscope used for viewing the surface roughness and the cross section of the chips.

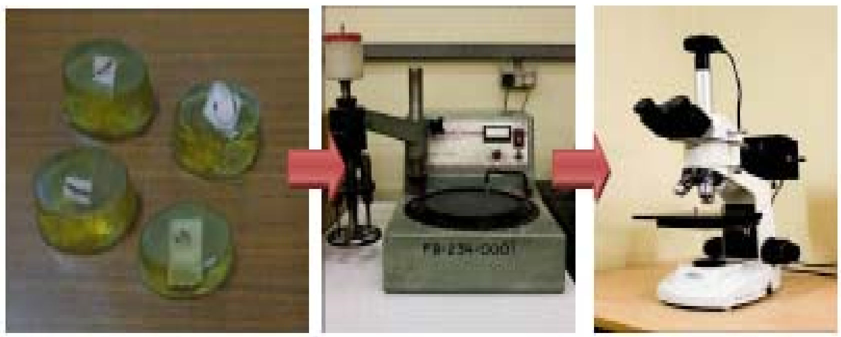


Fig. 3: (a) samples of mounted chips (b) polishing wheel (c) Optical microscope

3. Result and Discussion

Surface roughness

The surface quality of the drill hole shows significant improvement when external magnetic field is applied compared to the case when no magnet is used during drilling process. The following figure shown in Figure 4 illustrates the samples of the surface pictures taken by the optical microscope which are then processed by image processing software to get the exact value.

Fig. 4: (a) Inside surface of the drilled hole machined without magnet, (b) surface of the drilled hole machined with magnet

The exact values of the surface roughness of all four drill holes are given in the following table.

Table 1. Roughness of the inside surface of the drill holes

Drill hole number	Surface roughness(With magnet)/µm	Surface roughness(Without magnet)/ µm
1	0.422	0.594
2	0.482	0.558
3	0.423	0.480
4	0.465	0.493

The 3D contour profile of the surface for the first set of samples for both magnetic and non magnetic are shown in Figure 5. From the contour diagram it has been observed that the surface roughness improved in magnetic cutting compared to non magnetic cutting.

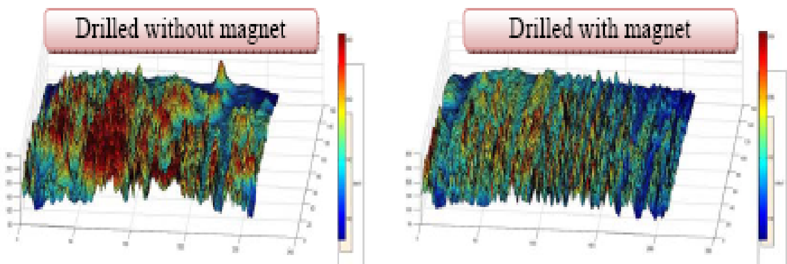


Fig. 5: 3-D contour diagram of the surfaces for the first set of samples

Circularity

The samples pictures of the circularity of the holes as processed by the MATLAB developed code are given below.

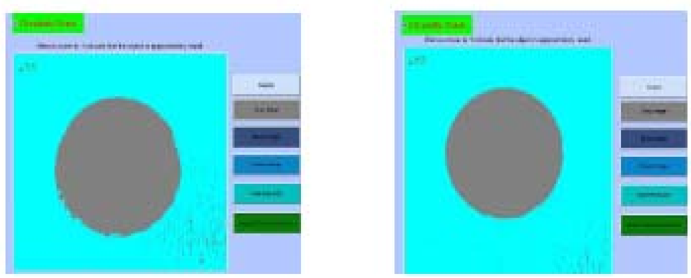
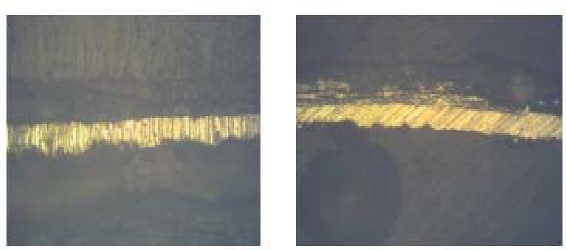


Fig. 5: sample picture of the circularity of the drill hole; (a) drill hole with magnet, (b) drill hole without magnet

In the circularity check, the index 1 means the hole is completely circular. Lower the value of the circularity index indicates less circularity of the drilled hole shape. From the circularity test it is clear that external magnetic field causes the drill bit to produce a almost uniform circular hole compared to non-magnetic cutting.

Chip morphology

The behavior of the chips during drilling process indicates the vibration characteristics of the drill bit. The chips for magnetic cutting are more continuous than that produced during non magnetic cutting. The following figure 6 shows the microscopic view of the chips.



(a) Non-Magnet cutting (b) Magnetic cutting

Fig. 6: Cross section view of chip formed at different cutting condition

From the figure, it is clearly visible that the serration behavior of chips greatly decreased due to the application of magnetic field and the tooth of serrated chip is larger in case of non magnetic cutting. This phenomenon is a clear indication of change in vibration characteristic of the system in different condition.

4. Conclusions

From the current experiment, it is obvious that the presence of magnetic field during drilling process can improve the quality of the drilled hole in terms of the decrease in the surface roughness of the inside of the drilled hole and circularity of the hole. From the results it found that significant improvement can be achieved in the surface quality of the drilled hole by applying magnet externally. The holes become more circular by the magnetic field. This is due the decrease in the vibration of the drill bit. It results in the in-line movement of the drill bit. This phenomenon is also supported by the reduction of the serration behavior of the chips and the tooth size of the cross section of the chips.

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