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Improvement of Machinability of Mild Steel during Turning Operation by Magnetic Cutting

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***Abstract*—This paper presents the details of improvement of machinability of mild steel using magnetic cutting during turning operation. Improvement of machinability was evaluated in terms of tool life, surface roughness and chip morphology. Machine tool chatter is a type of intensive self-excited vibrations of individual components of Machine-Tool-Fixture-Work (MTFW) system. Chatter causes unwanted excessive vibratory motion in between the tool and the work-piece causing adverse effects on the product quality and machine-tool and tool life. In addition to the damage of the work-piece surface due to chatter marks, the occurrence of severe chatter results in many adverse effects, which include poor dimensional accuracy of the work-piece, reduction of tool life, and damage to the machine. Chatter is formed as resonance phenomena during machining because of the instability of the closed-loop system formed by machine tool structure and metal-cutting process. In this study, magnets were used to avoid the chatter formation zone and its effect on machinability was investigated. Improvements in tool life and surface finish were observed during magnetic cutting of the mild steel. An obvious change in the chip behaviour was also present. These observations further enhance the possibility of using this magnetic cutting to eliminate the chatter formation zones and hence eliminate the adverse effect of chatter on machinability.**

***Keywords*— Magnetic cutting; tool wear; surface roughness; turning operation; chip morphology.**

I. INTRODUCTION

Machining of steel materials, especially turning, is one of the most common and popular process in industry because it offers numerous advantages. For turning process it is very important to know the cutting tool wear function. Tool wear which leads to tool failure is an integral part in all machining processes. High speed machining uses high cutting speed and feed rate and ultimately generates high cutting temperature which not only reduces tool life but also impairs the product quality. The most important surface quality requirement in turning is surface roughness. Therefore, it is important to address the factors affecting surface quality and tool wear mechanism in turning [1-5]. For continuous turning the maximum tool wear land width (V_{Bmax}) shows a near linear increase with cutting distance after initial rapid wear [6].

The productivity of a machining process is not only determined by the use of low cost-high performance alloys, but also by the capability to transform a specific steel alloy to the required surface finish and geometry by machining at sufficiently high speed [7]. Machining productivity is limited by tool wear which indirectly represents a significant portion of the machining costs. However, by properly selecting the tool material and cutting conditions an acceptable rate of tool wear may be achieved and thus lowering the total machining cost [8]. The performance of a cutting tool is normally assessed in terms of its life. Wear criteria are usually used in assessing tool life. Mostly, flank wear is considered, since it largely affects the stability of the cutting edge and consequently the dimensional tolerance of the machined work surface [9]. In a more recent attempt to increase tool life of inserts, effects of electromotive force created by a magnetic field on wear characteristics of cutting tool while machining has been studied. Tool life of inserts had been observed to increase with application of magnetic field using a direct current source [10]. The effect of introducing magnetic field in case of tool wear reduction and surface roughness in milling process has already been observed [11]. Anayet U Patwari et al have observed that chatter arising during end milling and turning is a result of resonance, caused by mutual interaction of the vibrations due to serrated elements of the chip and the natural vibrations of the system components, e.g. the spindle and the tool holder [12-13]. The chatter phenomena were indicated by the some of the researchers as a resonance effect where system components played a vital role. This paper presents the results of an experimental study of using a permanent magnet in turning of a shaft made of mild steel. The goal is to obtain improved machinability in terms of tool life, surface finish and chip behavior. The results show significant improvement of tool life and surface roughness and better chip characteristics leading to reduced cost of machining operation.

II. EXPERIMENTAL SETUP

This experimental study was conducted on a precision lathe (Gate INC. Model- L-1/180) under dry cutting conditions. Fig. 1 shows the photographic view of the experimental set-up. Mild steel has been chosen as work materials with the dimensions of 20 mm diameter and 200 mm length. The insert used was coated tungsten carbide insert. The tool holder along with the insert geometry is shown in Fig.2 and Fig.3 respectively. In the experiment the parameters selected for cutting conditions are feed 1 mm/sec (automatic), depth of cut 0.5 mm, rotational cutting speed 500 rpm.

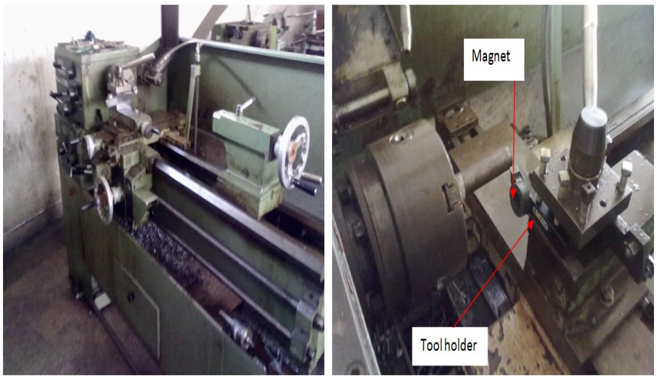


Fig. 1 Experimental setup (center lathe)

Fig. 2 Tool holder with insert

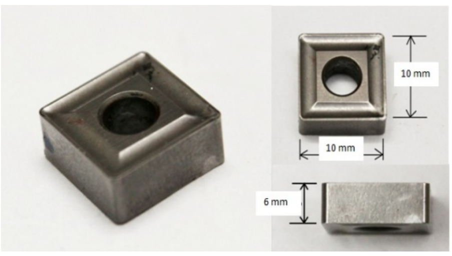
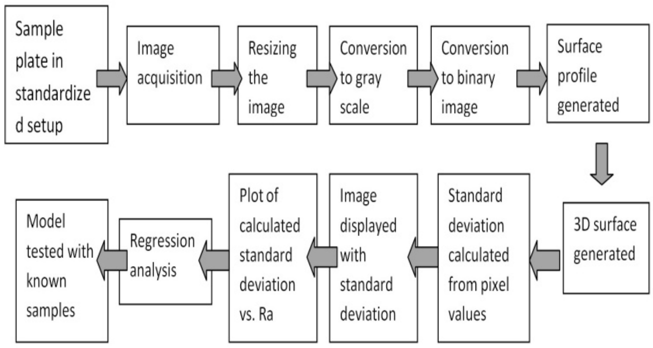
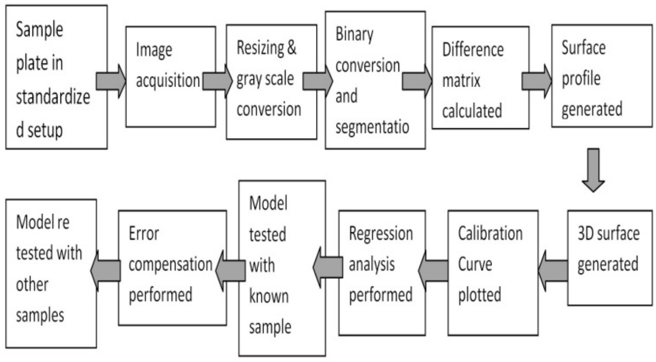


Fig. 3 Insert with dimensions

Machinability factors were measured by measuring and analysis of three parameters namely tool wear, surface roughness and chip morphology. Tool wear was measured by using metallurgical microscope as shown in Fig.4. The pictures of the wear surface were taken by using a built in camera in the microscope. Surface roughness was measured by an image processing technique developed by Anayet U Patwari and Arif et al. [14-15]. The process flow diagram of the steps to determine a linear regression calibration curve for shaped plates, using digital image processing, is as follows



The flow diagram of the process used by Anayet U. Patwari et al. [14-15] in order to generate the 3-D contours and determine the Ra of machined surfaces is as follows:



The mathematical definition of average surface roughness, Ra, was utilized. Ra is equivalent to half of the mean difference in heights between the asperities and troughs of a rough surface. The equation is as follows:

$$R_a = \frac{y_a + y_b + \dots + y_n}{n} = \frac{1}{n}\sum_{i=1}^{n} y_i = \frac{1}{l}\int_0^l \left| y \right| dx$$

III. RESULT DISCUSSION

Tool wear was measured by using metallurgical microscope (company-KRUSS, model MMB 2300) shown in Fig. 4. The pictures of the wear surface were taken by using a built-in camera in the microscope. One sample set of the pictures is shown in Fig. 5. The pictures were then processed by associated software with the microscope. The maximum wear length (VBmax) was measured in millimetre for each of the picture using the software. In the observation it was found that the tool wear was relatively less in case of magnetic cutting condition compared to non magnetic cutting. The comparison of tool wear at different length of cutting is shown in Table 1 and Fig. 6.

Fig. 4 KRUSS Metallurgical microscope used for measuring tool wears

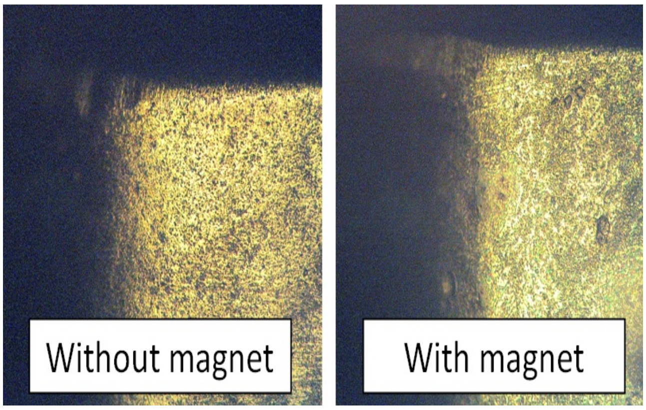


Fig. 5 samples of pictures taken by the microscope at cutting length 1000mm at without magnet and with magnet condition

TABLE I
TOOL WEAR AT DIFFERENT CUTTING CONDITION

Length of cut (mm)	Tool wear without magnet (mm)	Tool wear with magnet (mm)
0	0	0
200	0	0
400	0.057	0.024
500	0.281	0.051
600	0.323	0.135
700	0.374	0.267
800	0.393	0.286
1000	0.412	0.305

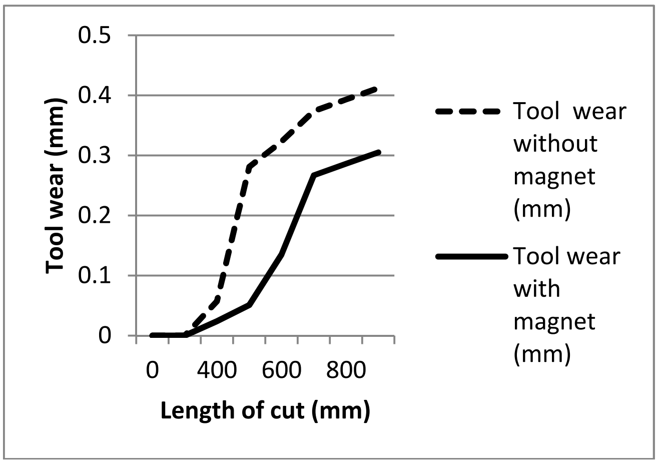
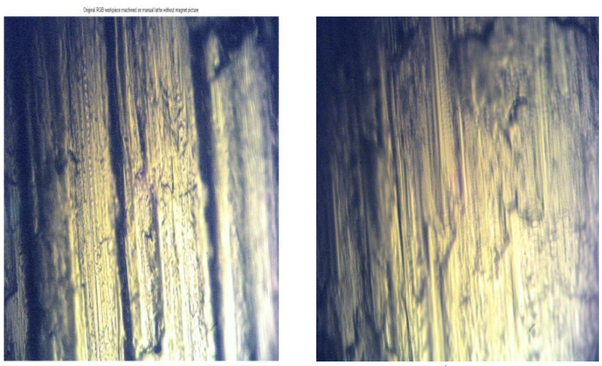


Fig. 6 Graph showing the tool wears along with the increase of length of cut at without magnet and with magnet cutting conditions

The tool wear reaches the 0.03 mm at 550 mm length of cut during machining without magnet whereas the length of cut is almost 1000 mm for magnetic cut to reach the same tool wear.

The pictures of the finished surfaces of the work piece in both cutting conditions were taken by the microscope. Samples of these pictures are given in Fig. 7. These were processed by an image processing technique developed by Anayet U Patwari [14-15] for further evaluation to generate contour plot and roughness profile of the surfaces of the job piece both in non magnetic and magnetic cutting condition. The average value of the roughness was obtained directly from this analysis.

The contour plot obtained in the analysis is shown in Fig.8 (a,b). It has been observed from the contour plot of the surface area that the surface roughness of the machined surface during magnetic cutting is more polished than that of non-magnetic cutting. The surface profile is more uniform in magnetic cutting as shown in Fig.7 and Fig.8.



a b

Fig. 7 Surface of the work piece after machining a) without magnet; b) with magnet

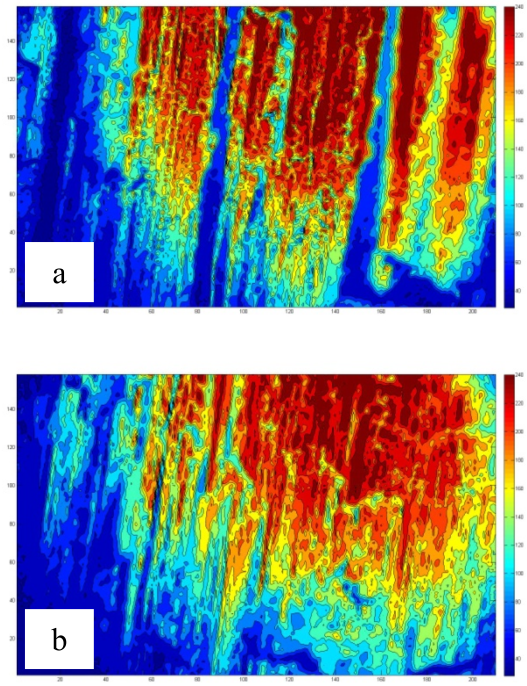


Fig. 8 Contour plot of surface roughness (a) without magnet; b) with magnet

Chips produced both in magnetic and non magnetic cutting conditions were collected and analysed. It was found that the chip produced in non magnetic cutting was discontinuous compared to magnetic cutting. This comparison is illustrated in Fig.9.

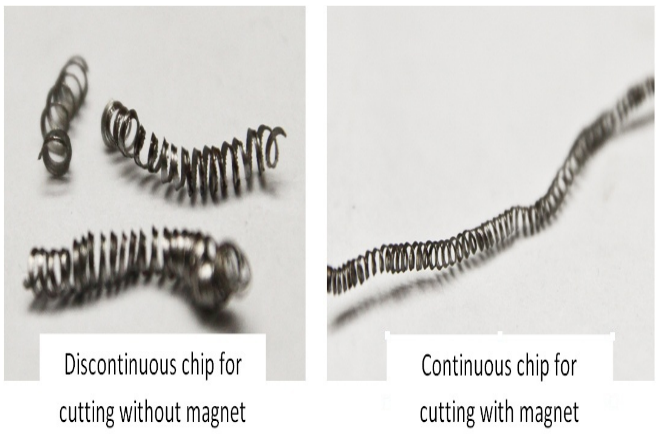


Fig.9. Graph showing chip characteristics at without magnet and with magnet cutting condition

IV. Conclusions

It has been observed in the study that there has been a significant improvement in machinability of mild steel during turning operation when cutting was done by applying magnet with the tool holder. The tool wear, surface roughness in the machined surface significantly improved in magnetic cutting conditions. The chip type has also been changed during the magnetic cutting compared to non magnetic cutting.

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