Effect of Ultrasonic Sound Signal on Machinability Control during Turning Operation of Mild Steel

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***Abstract*—Turning is a form of machining which is used to create rotational parts by removing unwanted material. In turning process, sometimes machined surface quality is damaged because of formation of chatter. Chatter causes unwanted excessive vibratory motion in between the tool and the work-piece causing adverse effects on the product quality. 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 in machining processes because of resonance effect in between the system responses and cutting process responses.**

The main purpose of this research is to send an extra signal in the cutting processes to eliminate the resonance formation so that chatter formation can be controlled. An attempt was made to send ultrasonic sound signal in the cutting processes and to investigate the effect of ultrasonic sound waves signal during turning operation on the machinability responses such as tool wear, surface roughness, and chip behavior. The ultrasonic sound wave that has been used in this set up is 40 KH_Z. There are two ultrasound modules has been used from where that sound wave has been generated. The results show clear improvement in the machinability responses during the turning process which include significant reduction in the tool wear, improvement in surface quality, and decrease in the serration behavior of chips.

***Index Terms*—turning operation, ultrasonic sound wave, surface roughness, tool wear, chip morphology.**

I. Introduction

The quality of machined components is evaluated in respect of how closely they adhere to set product specifications for length, width, diameter, surface finish, and reflective properties. Dimensional accuracy, tool wear and quality of surface finish are three factors that manufacturers must be able to control at the machining operations to ensure better performance and service life of engineering component. In the leading edge of manufacturing, manufacturers are facing the challenges of higher productivity, quality and overall economy in the field of manufacturing by machining. To meet the above challenges in a global environment, there is an increasing demand for high material removal rate (MRR) and also longer life and stability of the cutting tool .Tool wear and surface roughness prediction plays an important role in machining industry for gaining higher productivity, product quality, manufacturing process planning and also in computer aided process planning.

Average principal flank wear (VB) of cutting tools is often selected as the tool life criterion as it determines the diametric accuracy of machining, its stability and reliability. The productivity of a machining system and machining cost, as well as quality, the integrity of the machined surface and profit strongly depend on tool wear and tool life. Sudden failure of cutting tools leads to loss of productivity, rejection of parts and consequential economic losses. Flank wear occurs on the relief face of the tool and is mainly attributed to the rubbing action of the tool on the machined surface during turning operation During turning operation the average principal flank wear (VB) predominantly occurs in cutting tool, so the life of a particular tool used in the machining process depends upon the amount of average principal flank wear. The surface finish of the machined component primarily depends upon the amount of average principal flank wear (VB). An increase in the amount of average principal flank wear (VB) leads to reduction in nose radius of the cutting insert which in turn reduces the surface quality along the job axis. The maximum utilization of cutting tool is one of the ways for an industry to reduce its manufacturing cost. Hence tool wear has to be controlled and should be kept within the desired limits for any marching process [1]. Kwon *et al.* (2004) proposed a model providing a relationship between surface roughness and tool wear. They concluded that this model can serve for a better utilization of tool in a way that tools can be employed to the fullest extent until they do not achieve the required surface quality [2]. The work of Davim and Figueira (2007), concerning the machinability evaluation of cold-work tool steel (D2) using statistical techniques, presented that the most influential factors for surface roughness are feed rate and cutting time, with

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percentage of contributions of 29.6% and 32.0%, respectively [3]. Gaitonde *et al.* (2009) predicted that the combination of low feed rate, less machining time, and high cutting speed is necessary for minimizing the surface roughness. The maximum tool wear occurs at a cutting speed of 150 m/min for all values of feed rate. For a specified value of cutting speed or feed rate, the tool wear increases with increase in machining time [4]. Prasad *et al.* (2009) investigated that surface roughness values increased with increase in speed, depth of cut was not influencing much on roughness values, but the roughness values were varying nonlinearly with increase variation of feed. Strong interaction among all input process parameters was observed [5]. 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 [6]. For continuous turning the maximum tool wear land width (VBmax) shows a near linear increase with cutting distance after initial rapid wear [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]. 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 [9]. The effect of introducing magnetic field in case of tool wear reduction and surface roughness in milling process has already been observed [10]. 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 [11]-[12].

This paper aims to develop the machinability responses by creating a circuit which has been generated continuous ultrasonic sound wave which is 40KHZ. By using this generated ultrasonic sound wave turning operation have done in different cutting conditions. There are two ultrasound modules for creating this sound beside the tool holder. The goal is to investigate 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 Set Up

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 30 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 0.95 mm/ sec, depth of cut 0.75 mm, rotational cutting speed 530 rpm.

Figure 1. Experimental Set-up

Figure 2. Tool holder

Figure 3. Insert with dimension

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.

The pictures of the surface profile 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.* [13]-[14].The flow diagram of the process used by Anayet U. Patwari *et al.* [13]-[14] in order to generate the 3D contours and determine the Ra of machined surfaces is as follows as shown in Fig.4:

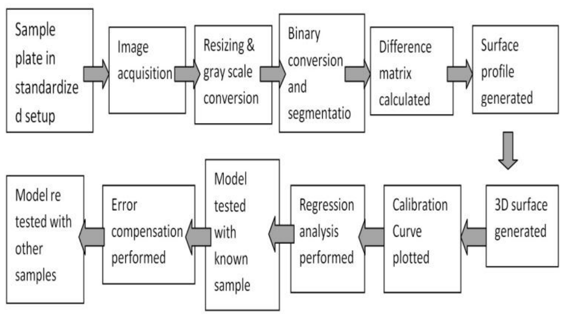

Figure 4. Generation of 3D contour and surface roughness measurement technique.

III. Results Discussion

The pictures of the tool, surface of the work piece and the chip were taken by using a built in camera in the microscope. The picture of tool was then processed by associated software with microscope. The tool wear length was measured in millimeter for each of the pictures using software. Tool wear measured by using metallurgical microscope (company-KRUSS, Model MMB 2300) as shown in the Fig. 5:

Figure 5. KRUSS metallurgical microscope for measuring tool wears

(a) Without sound wave (b) With Sound wave

Figure 6-Samples of the pictures taken by microscope at cutting length 1800 mm at (a) Without sound wave signal and (b) With sound wave signal respectively.

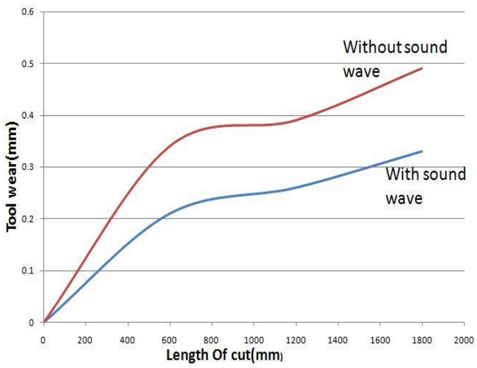

Figure 7. Tool wear vs length of cut graph

Samples of the photographs taken by microscope at cutting length 1800 mm for sound wave machining and without sound wave machining are shown in Fig.6. It has been clearly observed that tool wear is very much significant and high in non sound wave machining compared sound wave machining.

The tool wear variation along with the different length of cut is shown in Fig.7. The maximum tool wear reaches 0.34 mm at length of cut 600 mm for without sound wave signal whereas for sound wave tool wear reaches 0.33 mm at a length of cut 1800 mm. So, it is shown that there is a significant improvement of the tool wear when ultrasonic sound wave signal have been used.

(a) without sound wave (b) with sound wave

Figure 8. Surface of the work-piece after machining at (a) without sound wave signal (b) with sound wave signal.

The pictures of the finished surfaces of the work piece in both cutting conditions were taken by the microscope. Samples of these pictures are shown in Fig. 8. These were processed by an image processing technique developed by Anayet U Patwari *et al.* [13]-[14] to find out the average surface roughness. The processed images were further evaluated to generate contour plot and roughness profile of the surfaces of the job piece both in without sound wave and with sound wave cutting condition. The average value of the roughness was obtained directly from this analysis. It has been observed that with sound wave signal the machined surface significantly improved.

(a) without sound wave (b) with sound wave

Figure 9. Serration nature of the chip.

(a) without sound wave (b) with sound wave

Figure 10. Continuity of chip.

Chip collected in each cutting environment showed different continuity. Chip produced in non sound waves condition were generally discontinuous and loosely packed. Whereas the chip produced in sound wave cutting were continuous and closely packed as shown in Fig. 10. The chips formed during turning were mainly investigated and it has been found that at some specific cutting conditions chip formation presents extreme cases of secondary and primary chip serration. Each chip was mounted using a mixture of resin and hardener to make mounting.

The next step is to grind the mounting surface in order to reveal the chip to the surface. Various grade of abrasive paper are used. In order to remove the scratches on the surfaces, the mounting is then polished using alumina solution starting from grain size 6.0 μ, followed by 1.0 μ, 0.3 μ and 0.01μ. As a safety precaution, before polishing; the mounting is viewed under the microscope to ensure that the chip is visible on the surface. Finally, nitol is applied to the surface to reveal the grain boundaries of the ferrite and pearlite. Then the mounting is ready to be viewed under the microscope to capture the structure of the chip.

Then picture was taken by microscope to investigate the serration of the chip which is given in the Fig. 9. It has been observed that the chip serration nature in case of sound wave machining has been reduced and the serrated teeth height become less compared to non sound wave machining. From the nature of chip serration it can be predicted that sound wave signal reduces the vibration during machining processes compared to without sound signal waves.

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 ultrasonic sound wave with the tool holder. The tool wear, surface roughness in the machined surface significantly improved in ultrasonic sound wave conditions compared to normal dry cutting conditions. The chip type has also been changed during the ultrasonic sound wave cutting compared to without sound wave cutting.

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