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Chatter Suppression in Boring Process Using Passive Damper

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***Abstract*—**During machining process, chatter is an unavoidable phenomenon. Boring bars possess the cantilever shape and due to this, it is subjected to chatter. The adverse effect of chatter includes the increase in temperature which will leads to excess tool wear. To overcome these problems, in this investigation, Cartridge brass (Cu – 70% and Zn – 30%) is passively fixed on the boring bar and also clearance is provided in order to reduce the displacement, tool wear and cutting temperature. A conventional all geared lathe is attached with vibrometer and pyrometer is used to measure the displacement and temperature. The influence of input parameters such as cutting speed, depth of cut and clearance on temperature, tool wear and displacement are investigated for various cutting conditions. From the result, the optimum conditions to obtain better damping in boring process for chatter reduction is identified.

***Keywords*—**Boring, chatter, mass damping, passive damping.

I. Introduction

REGENERATIVE and non-regenerative are the types of self-excited vibration. Out of this the regenerative type of vibrations are formed due to the interaction of the cutting force and the surface irregularities that are formed during the previous passes of the tools in the work-piece [1]. In boring process, the vibration is a well-defined problem, due to its long and slender boring bars which are essential to perform the internal machining of work-piece [2]. Vibration that occurs in tool or work piece leads to higher surface roughness in machined work piece, reduced tool life, and also results in chatter which are highly unfavorable [3]. Thus, the vibration in machining is mainly due to the deficiency of dynamic stiffness of various components in the machine tool. They can be alienated into free, forced and self-excited vibrations. Even though the system is fully balanced, the existence of vibration may also due to the intermittent forces that arise due to chip thickness. That means that they are always present. Therefore, to prevent damage, the vibration level must be controlled. The most common self-excited vibration is regenerative chatter.

Chatter can be attenuated by either active or passive methods of damping. The active methods of damping needs separate hardware segments to identify and control the chatter and it also expensive than passive damping. In passive method of damping, even though many kinds are available researchers were given more importance to the mass damping [4].

The damping capability of cutting tools can be improved with the help of dampers and the dampers that are used for this purpose should be in small size and facilitates easy mounting [5]. The deeper holes can be bored using the tools equipped with impact dampers when compared with the commercially available boring tools [6]. In boring process, the boring bar is the weakest link in the system due to its cantilever shape, so that it will more prone to vibration. In the past effect has also been taken to improve the damping by tuning the tool holder and also by slightly modifying the clamping system [7]. Boring bar modeled by considering the Euler-Bernoulli equation and first mode is reported in literature. Researchers were generally focused on the behavior of boring bars with a passive dynamic vibration absorber (DVA) for chatter suppression [8]. When the tool passes over the undulations produced during previous cut, then the chip thickness and the force on the cutting tool vary due to the phase difference between the wave left by the previous pass and the wave left by the current ones. This phenomenon can greatly amplify vibrations, become dominant and build up chatter [9]–[12].

Various damping materials like Copper, Phosphor Bronze, Gun metal, Cast Iron, Brass, EN8, Aluminium, and polymers were reported in literature. In addition to DVA's, attempts were made in the past to control the chatter by utilizing the electro-rheological and frictional dampers [13], [14]. Some attempts were carried out in the past using the tunable vibration bars which will counteract the chatter that arises during machining and also with the incorporation of magneto-rheological dampers (active mode of damping) [15]–[17]. Based on the boring mechanism, it is very clear that the boring operation encounters sever chatter problems due to its meager nature of bar, so that it leads to instability of the boring bar [18]–[25]. Hence, in this present work in order to suppress the chatter that arises during the boring process, the boring bar is equipped with cartridge brass as damper with clearance and it is investigated for its displacement, temperature and tool wear and compared with the undamped bar.

II. Material Selection

A. Damping Material

Based on the literature survey and by considering the other factors such as availability, manufacturability and cost, Cartridge brass is selected as damping material for this work due to its higher density. The property of the selected damping material is given in Table I.

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TABLE I
PROPERTIES OF THE DAMPER

Material	Density (kg/m^3)	Thermal Conductivity (W/m K)	Young's modulus (N/mm^2)
Cartridge Brass	8530	120	11 x 10^3

B. Boring Bar and Tool

EN31 boring bar is selected for this work due to its high strength, hardness, and abrasion resistance characteristics. The properties of the commercially available EN31 boring bar are given in Table II and the boring bar is shown in Fig. 1.

Fig. 1 EN31 Boring Bar

TABLE II
PROPERTIES OF EN31 BORING BAR

Young's modulus, E (N/mm^2)	Density (kg/m^3)	Cross sectional area, A (m^2)	Length of the bar, L (m)
215 x 10^3	7850	3.14159 x 10^{-4}	0.2

C. Experimental Setup

The experiments were performed in an all geared lathe to machine the grey cast iron work piece of 60 mm inner diameter and 50 mm in length. It is incorporated with pyrometer and vibration response unit in order to measure the cutting temperature and displacement respectively during boring process as shown in Fig. 2.

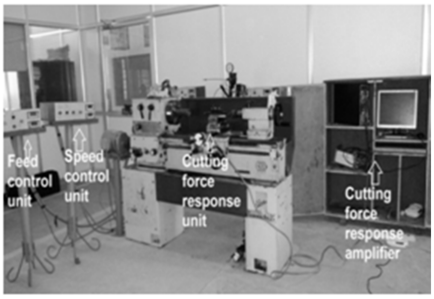

Fig. 2 Experimental Setup

From the literature it can be understood that the effectiveness of boring process depends on the many parameters such as speed, feed, depth of cut, type of damping provided, damping material used, overhanging length, position of the dampers etc. This research is mainly focused to reduce the chatter and to investigate the effect of damping provided in the boring process. Clearance is considered as one of the factor to achieve this objective. Because the clearance will provides more impact or impulsive force over the bar during chatter. Thus, this force will help to attain the stability during machining. Hence, in this work various level of speed, depth of cut and clearance is selected as the process parameters. Feed (0.08 mm/rev) and position of damper (64 mm) are kept as constant. Experiments were carried out with various combinations of the cutting parameters in full factorial method. Finally, 36 observations were obtained with and without dampers. The various levels of the parameters selected are shown in Table III.

TABLE III
LEVELS OF PROCESS PARAMETERS

S. No.	Factors	Levels		
		1	2	3
1	Speed (rpm)	300	400	500
2	Depth of cut (mm)	0.2	0.4	0.6
3	Clearance (mm)	0.4	0.6	0.8

III. CUTTING RESPONSES OF BORING BAR

A. Displacement of the Boring Bar

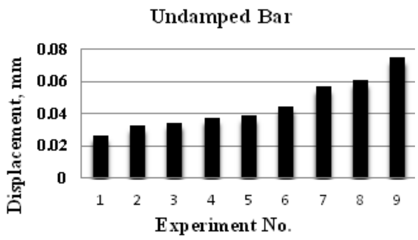

Fig. 3 Displacement of undamped boring bar

Fig. 3 shows the relationship between the cutting parameters (cutting speed and depth of cut) and displacement of the undamped boring bar. The minimum and maximum displacement obtained is 0.023 and 0.075 mm at 300 and 500 rpm respectively. Also it is observed that the displacement is increasing for the succeeding experiments. This higher value of displacement shows us the chatter level during the operation. A lower value of displacement (0.023 mm) is observed at lower level of speed and depth of cut.

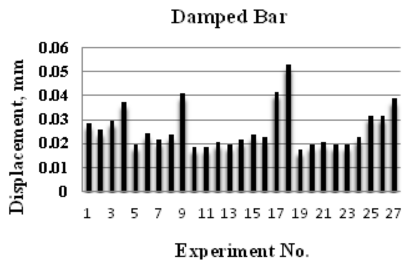

Fig. 4 Displacement of damped boring bar

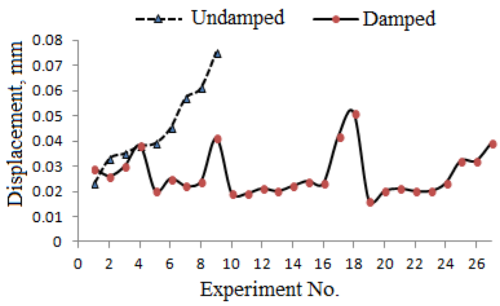

Fig. 5 Displacement of damped and undamped bar

Fig. 4 shows the relationship between the cutting parameters (cutting speed, depth of cut and clearance) and displacement of the damped boring bar. Fig. 5 shows the comparison of the displacement of damped and undamped boring bar. E1to E27 indicates the 27 experimental conditions in boring operations. A low value of the displacement of the tool 0.016 mm was obtained in 300 rpm cutting speed, 0.2 mm depth of cut and the clearance of 0.8 mm. A high value of the displacement of the tool 0.051 mm was obtained in 500 rpm cutting speed, 0.6 mm depth of cut and the clearance of 0.4 mm. Thus, the large level of clearance helps to provide better damping in order to attenuate the chatter. Thus in the both cases (damped and undamped system) the lower level of speed (300 rpm) provides better result in terms of displacement.

The introduction of the brass damper in the boring tool decreases the displacement of the boring tool thereby increases the stability of the boring tool. It was observed that the equipment of brass as a damping material leads to 30.4 % of decrease in the displacement of the boring tool, when compared with the minimum displacement of the boring tool that was obtained without damper. This reduction in the displacement clearly shows that the chatter level is controlled with the help of damper provided with the clearance.

B. Response of Cutting Temperature

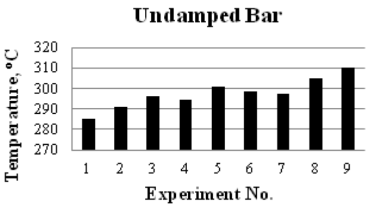

Fig. 6 Temperature of undamped boring bar

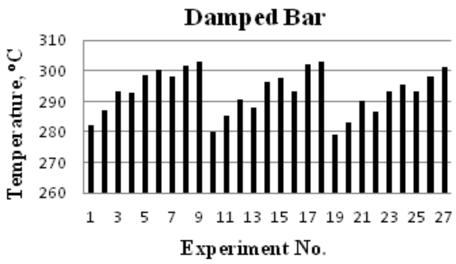

Fig. 7 Temperature of damped boring bar

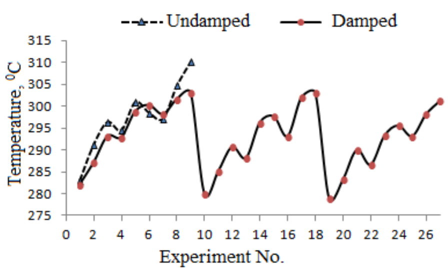

Fig. 8 Temperature response of damped and undamped boring bar

Figs. 6 and 7 show the relationship between the cutting parameters (cutting speed, depth of cut and clearance) and cutting temperature in ˚C of the undamped and damped boring bar. Fig. 8 shows the comparison of temperature response of the damped and undamped bar.

A lower value of 283˚C is obtained for the undamped process. But, a better value of the cutting temperature as 279˚C was obtained in 300 rpm cutting speed, 0.2 mm depth of cut and the clearance of 0.8 mm for the damped boring bar. It was observed that the introduction of damper leads to 1.4% of decrease in the cutting temperature, when compared with the minimum temperature of the boring tool that was obtained without equipping damper. In both the damped and undamped system the lower level of temperature is obtained at lower level of speed (300 rpm). Thus in the case of cutting temperature also, the higher level of clearance provides the better effect.

Figs. 9 and 10 show the relationship between the cutting parameters and tool wear in mm for the damped and undamped system respectively. The lower level of tool wear as 0.16 mm is observed with the undamped system. By using the damper, a very low value of the tool wear of 0.07 mm was obtained in 300 rpm cutting speed, 0.2 mm depth of cut and with the clearance of 0.8 mm.

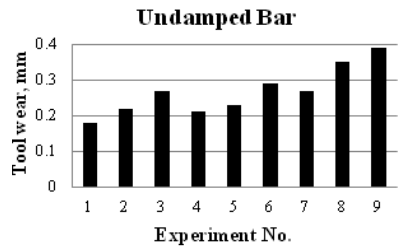

Fig. 9 Tool wear of undamped boring bar

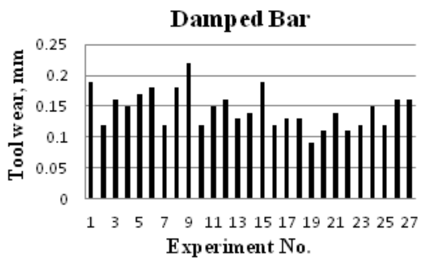

Fig. 10 Tool wear of undamped boring bar

C. Response of Tool Wear

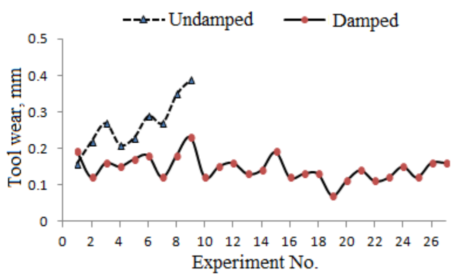

Fig. 11 Tool wear for undamped and damped boring bar

Fig. 11 shows the comparison of tool wear response for the damped and undamped boring bar. Through this, it can be seen that, the maximum value of tool wear as 0.23 mm was obtained in cutting speed of 500 rpm, depth of cut of 0.6 mm and clearance of 0.4 mm. Hence, the damped system provides a 56% reduction in tool wear. The damped and undamped boring bar attains the lower value of temperature at lower speed (300 rpm). Hence, a higher level of clearance is required even in the case of temperature.

IV. Conclusion

Based on experimental results, the observations which were made in this work are concluded and summarized.

1) The brass damper equipped with the boring tool exhibited lower values of the displacement, cutting temperature, and tool wear of 0.016 mm, 279 °C and 0.07 mm respectively.
2) A 30.43% decrease of the displacement of the tool was achieved by using brass as a damping material in the boring tool when compared with the boring tool not equipped with the damping materials.
3) A 1.4 % decrease of the cutting temperature of the tool was achieved by introduction of damper in the boring tool when compared with the undamped boring tool.
4) A 56.00% decrease of the Tool wear was achieved by brass as damping material in the boring tool when compared with the undamped boring tool.
5) The low level of speed and depth of cut with high level of clearance is found as the optimum level to suppress the chatter effectively.
6) The damper provided acts a UDL over the certain length which will improves the stability of the bar due to its continuous impaction over the bar during the occurrence of the chatter.

Hence, from this investigation it is concluded that the boring bar equipped with brass as damper provides better responses (in terms of displacement, tool wear, and temperature) when compared with the undamped boring bar. Generally, the clearance level provided to the damper lay a major role in the cutting responses. For all the cutting responses, the larger clearance value (0.8mm) provides minimum displacement, temperature and tool wear. The clearance in the damper arrangement improves the stability of the boring tool due to the generation of more impulsive force and thus it dissipates the chatter.

V. Scope for Future Work

1) This work can be extended to predict the chip-morphology under different machining conditions using the FEM simulation.
2) The cutting forces can be measured and correlate them with the chip formation and surface roughness.
3) The ANN models can also be used to predict the above responses.
4) Modal and Harmonic analysis can be performed to analyze about the frequency levels of the system during operating conditions.
5) The damping materials can be made from polymers or composites and then incorporate them in the system.
6) In this work, damping is provided from only one direction, hence in the future work damping can be provided form multiple direction and analyses can be performed to obtain the system response.

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