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Reduction Of Vibration In Boring Tool By Using Carbon Fiber Laminate

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ABSTRACT

In boring process, tool vibration is an important parameter which results in progressive tool wear, poor surface finish and cutting tool damage. This tool vibration was reduced by passive, semi-active and active techniques which are used by various researchers in the past. In this paper, various techniques employed to prevent tool vibration in boring operation are reviewed, analyzed and presented. It was inferred that the control of tool vibration was effective by utilizing appropriate damping mechanism in the boring process. Also, from the overall review of the literature, it was observed that as the tool wear started to progress, the tool vibration gets increased which leads to failure of the tool. In this paper, scope of developing a damper where tool vibration can be suppressed by varying the damping ability based on requirement was established.

INTRODUCTION

Conventional techniques of the vibration suppression such as active damping technique consist of a closed circuit. This closed circuit includes control panel, feedback system and servomotor. To drive the servomotor, external power supply is required. Hence it is expensive method and cannot be used in all circumstances. While passive damping technique is relatively low cost method and simple to apply hence it can be easily implemented to boring tool.

process during a cutting operation. This will introduce a time varying deflection of the boring tool. If the frequency of the excitation coincides with one of the natural frequencies of the boring tool, a condition of resonance is encountered. Under such circumstances the vibrations are at a maximum, thus the calculation of the natural frequencies is of major importance in the study of vibrations. Bending vibration is major type of vibration in the boring tool caused by the forces from the cutting process. The force is applied at the cutting tool and the force originates from the chip deformation process during a cutting operation. Most realistic structural systems are characterized by the ability to support transverse shear as well as having internal stiffness.

Present Methods of Reduction of Vibrations:

Attempts have been tried to reduce the vibration by increasing the dynamic stiffness of machine parts. One method to increase the dynamic stiffness of a boring tool is, to use two materials for manufacturing of the boring tool. Fix segment of the boring tool is made from material having high modulus of elasticity which increases the stiffness, while free segment is made up from light weight which reduces effective mass of the tool. Hence, fundamental frequency well separated from the excitation frequency which helps to reduce the vibrations. But it is difficult to prepare such tool.

The vibration of the boring bar can be reduced by using laminated tool holder. Laminated tool holder provides higher dynamic stiffness for the holder–boring tool assembly. There are no significant restrictions on the holder design or material. This type of the tool Holder supports boring tool and effectively act as a dynamic absorber for clamped boring tool. Another method to reduce boring tool vibration is to use impact dampers. The impact damper is located on exterior surface of the boring tool. The results of the above damper depend on free mass and clearance. Above damper cannot be used in all circumstances. Hence applying carbon fiber lamination is an appropriate solution.

Use of fiber-reinforced composites is increased as alternatives for conventional passive damping methods, primarily because of their significant properties like high specific strength, specific stiffness and tailorable properties. The viscoelastic character of composites made them suitable for high-performance structural applications like aerospace, marine, automobile, etc.

Fiber reinforced polymeric composite materials composed of two very high modulus fibers and high damping polymeric matrix material. This material has both high static stiffness and damping. The principal roles of the polymeric matrix in the composite material are to transfer load between the fibers. The polymer also increases the material damping capacity of composite structures, which results in much better dynamic performances for moving parts. The specific stiffness of high modulus carbon fiber epoxy is about 10 times higher than those of conventional metals like steel, aluminum, etc

OBJECTIVES

1. To develop an experimental set-up with required instrumentation.
2. To study the dynamic behavior of boring tool under different cutting conditions.
3. To analyses the effect of polymer based composite layers on boring tool vibrations and to decide the Configurations, which achieves maximum damping.
4. To analyses the vibration response of laminated tool by FEM.
5. To validate the FEA results with experimental results.

Construction of the Damped Boring Tool

The carbide tip steel boring tool of diameter 16 mm is used for the boring of mild steel work piece of 80 mm diameter. Because of dynamic stiffness and natural frequency of high-speed steel, boring with high slenderness ratio is very difficult as it induces vibrations in boring operation. It is difficult to perform a boring operation at low feed rate, low speed and high depth of cut due to poor properties of the boring tool. Therefore, in this project work the boring tool of diameter 19 mm is constructed by using carbon fiber as a passive damper. The unidirectional carbon fiber is wrapped to the high-speed steel boring tool to increase the damping with the help of epoxy resin as an adhesive agent. The unidirectional carbon fiber is cut into 100 and 450 pieces and they are wrapped around the boring tool to get different combinations of the boring tool by using different fiber orientation. The schematic diagram of the boring tool is shown in the Figure.

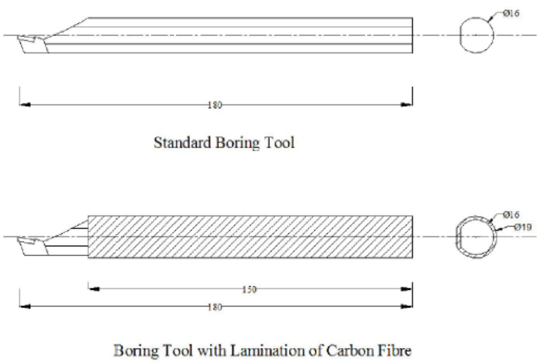

Fig. 1: Schematic of a Standard and Laminated Boring Tool

Steel has less stiffness as compared to the composite material. Hence to improve longitudinal and bending stiffness, lamination of carbon fiber with different orientation (100, Cross 10, 450, Cross 450) was done on the shank of the Boring Tool. Adhesive used for lamination of a carbon fiber is the epoxy resin. Epoxy resin is not only act as an adhesive but also it improves the stiffness of the structure.

Fig. 2: Photograph Standard and Laminated Boring Tool

Once the epoxy resin is applied over the carbon fiber and boring tool, the wrapping has to be done quickly because epoxy resin starts getting thick once it is mixed with a hardener and exposed to air. After wrapping carbon fiber around the shank of the boring tool it was kept aside for 2 days to become hard. The hardening process continuous for 16 days but it will not largely affect the properties of carbon fiber. To put the accelerometer over the boring tool for measuring the data, after hardening of the carbon fiber, small piece of laminated material was removed and that metal part was polished to remove the adhesive.

Table 1: Mechanical Properties of Boring Tool Used in the Analysis

Part of Boring tool	Material	Material Properties		
		Young's Modulus (MPa)	Density (Kg/m^3)	Poisson's Ratio
Shank	High Speed Steel	2.84 E5	7850	0.3
Tip	Cemented Carbide	6.25 E5	1495	0.22
Lamination	Carbon Fibre	3.5 E5	1800	0.4

FINITE ELEMENT ANALYSIS

Boundary Conditions

From the values obtained from experimental analysis, the force acting on the boring tool is calculated. This force is further used to do harmonic analysis of the boring tool.

I. Force Acting on Boring Tool:

Tangential cutting force is given by [12]

$$F_t = \frac{1677 \times f^{0.8} \times D^{0.96} \times L^{0.05}}{r^{0.07} \times S^{0.08}}$$

Where,

S = cutting speed (m/min) = 113.09 (mm/min)

f = feed rate (mm/rev) = 0.05 mm/rev

D = depth of cut (mm) = 0.1 mm

r = tool nose radius (mm) = 0.4 mm

L = tool length (mm) = 96 mm

$$F_t = \frac{1677 \times 0.05^{0.8} \times 0.1^{0.96} \times 96^{0.05}}{0.4^{0.07} \times 113.09^{0.08}}$$

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F_t= 15.36 N

Radial cutting force is given by [12]

$F_r = 0.308 \times F_t$

$F_r = 0.308 \times 15.36$

$F_r = 4.73$ N

Resultant force is given by

$$F_e = \sqrt{F_t^{\,2} + F_r^{\,2}} = 16.07 \text{ N}$$

The Harmonic Analysis of model was carried out for over hanged length of 96 mm, 112 mm and 128 mm respectively. The model was fixed in all degrees of freedom except overhang length. The model was analyzed for 12 different magnitudes of radial and tangential loads.

Table 6.2: Different Load Cases of Boring Tool

Load Case Without Lamination	Frequency (Hz)	Tangential Load F_t (N)	Radial Load F_r (N)	Equivalent Force F_e (N)
1	1113.28	15.36038972	4.731000034	16.07245885
2	1020.51	26.74399185	8.237149488	27.98377622
3	839.84	25.98542976	8.003512367	27.1900491
4	795.9	14.92471021	4.596810745	15.61658234
5	613.73	26.15950376	8.057127157	15.72119638
6	664.06	15.02468947	4.627604356	27.37219273
Load Case With Lamination	Frequency (Hz)	Tangential Load F_t (N)	Radial Load F_r (N)	Equivalent Force F_e (N)
7	927.73	15.36038972	4.731000034	16.07245885
8	1000.98	26.74399185	8.237149488	27.98377622
9	781.25	25.98542976	8.003512367	27.1900491
10	771.48	14.92471021	4.596810745	15.61658234
11	600.59	26.15950376	8.057127157	15.72119638
12	644.53	15.02468947	4.627604356	27.37219273

The above forces were calculated at different cutting conditions to see the effect of the boring tool when the tool is under the finite element analysis.

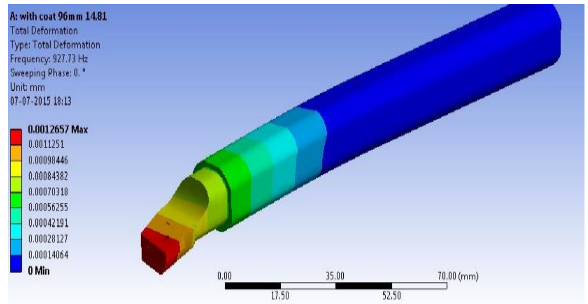

Fig. 4: Total Deformation of the Boring Tool

EXPERIMENTAL SET-UP

The vibration analysis of the boring tool with and without lamination has been carried out on the lathe machine in workshop. The capacity of the lathe machine is 2.0 KW and a maximum machining diameter of 150 mm. The experiment was performed on a mild steel work pieces having 80 mm inner diameter as an internal boring operation using boring tool. Fig. 5 shows the configuration of the standard boring tool used in the boring operation of mild steel.

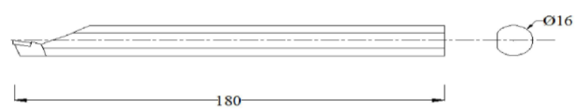

Fig.5 Configuration of the Standard Boring Tool

The specifications of the boring tool used in the cutting test are given in Table 3

Tool Used	Specification
Tool material	Steel
Tool length (mm)	180
Tool diameter (mm)	16
Tool nose radius (mm)	0.4

Table 3: Specifications of the Boring Tool

The F.F.T. analyzer has been used to obtain the vibration acceleration amplitude and the displacement of the boring tool under different combinations of cutting parameters. An accelerometer has been mounted with the help of adhesive at the tip of the boring tool in order to get efficient results of the tip of the tool under different conditions. The F.F.T. analyzer is connected to a laptop by using USB cable in order to get a graphical representation of the output of the experiments. The entire experimental set-up has been shown in fig. 3.4

Fig. 6: Experimental Set-up

RESULTS

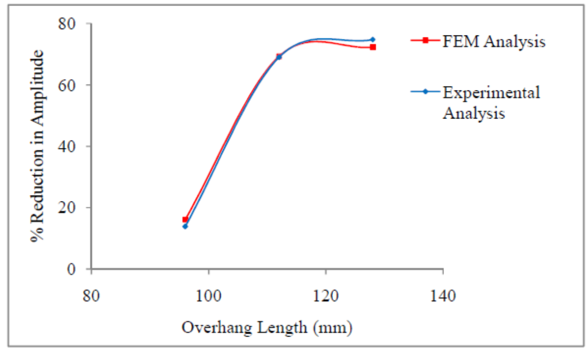

Fig. 7: Percent Reduction in Acceleration Amplitude at 0.1 mm Depth of Cut

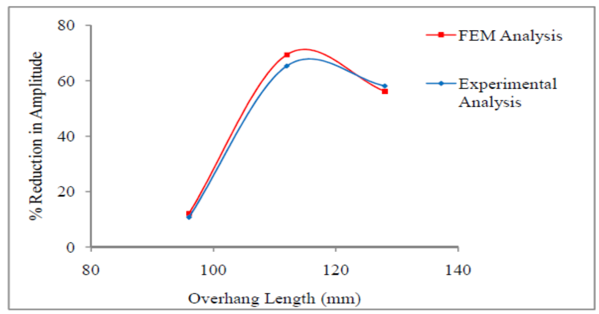

Fig. 8: Percent Reduction in Acceleration Amplitude at 0.3 mm Depth of Cut

Fig. 7 and Fig. 8 show the percent reduction in acceleration amplitude obtained from experimental and FEM analysis. The percent reduction in the acceleration amplitude at 0.1 mm depth of cut is 75 % while at 0.3 mm depth of cut is 68 %. The total deformation in the boring tool is shown in the figure for a particular load case.

RESULTS AND DISCUSSION

In order to study the effect of different fiber orientation on the damping of the boring tool, four tools were prepared. First the pilot experiments were performed to investigate the performance of each boring tool. At first by keeping spindle speed and feed rate constant i.e. 710 R.P.M. and 0.05 mm/rev respectively, 9 readings were taken by using combination of overhang tool length (96 mm, 112 mm, 128 mm) and depth of cut (0.1 mm, 0.2 mm, 0.3 mm). From the pilot experiments, it is found that the tool with cross 10- degree lamination and cross 45-degree lamination gives the better results over the other two tools.

Effect of Overhang Length on Acceleration Amplitude

The effect of tool overhang length on the acceleration amplitude with a different fiber orientation is presented in following figures. Three overhang lengths have been plotted against the percent reduction in the acceleration amplitude by keeping all cutting conditions constant except depth of cut.

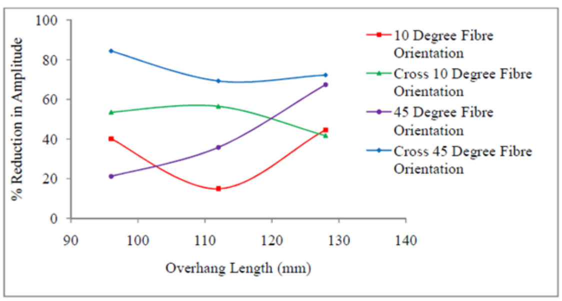

Fig. 9 : Effect of Overhang Length of Tool on Different Fibre Orientation at 0.1 mm Depth of Cut

CONCLUSIONS

In order to study the effect of different fiber orientation on the damping of the boring tool, full factorial experimental analysis has been performed. And to validate the results, finite element analysis was done. For standard tool and laminated tool, readings were taken under the same cutting conditions to check the damping effectiveness of each tool. In this work it is observed that, when the depth of cut, feed rate and overhang length of the boring tool was increased then, the magnitude of acceleration amplitude was also increased. And when spindle speed was increased, the magnitude of acceleration amplitude was decreased.

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