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Experimental Investigation and Finite Element Analysis of Boring Tool vibration by using passive damper

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Abstract — *Boring is a commonly used operation to enlarge the existing holes of machine structures. When boring tool is slender and long, it is subjected to excessive static deflections or a self-excited chatter vibration which reduces the accuracy and surface finish of the hole. It also causes accelerated wear and chipping of the tool. Internal turning frequently requires a long and slender boring tool in order to machine inside a cavity, and the vibrations generally become highly correlated with one of the fundamental bending modes of the boring tool. use of passive Damper of different orientation reduces vibration level in Boring tool & tool holder &work piece to be enlarging hole improving surface finish. Furthermore, the interface between the boring tool and the clamping house has a significant influence on the dynamic properties of the clamped boring tool. This report focuses on the behavior of a boring tool that arises under different overhang lengths which are commonly used in the manufacturing industry.*

Keywords- *Vibration, Passive Damper, Surface finish, Natural Frequency, Boring Tool*

I. 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.

In a boring operation, the boring tool is subjected to dynamic excitation, due to the material deformation 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. 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. 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 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 property. 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.

II. LITERATURE REVIEW

Dai Gil Lee et al.(2003) presented paper on chatter is a self-excited vibration that occurs in metal cutting if, either the chip width is too large with respect to the dynamic stiffness of the system [1] Kanase Sandip, Patil Jaydeep (2013) This paper presents the improvement of surface finish of boring operation using passive damper[2] V.Prasannavenkadesan, et al. (2015) presented paper on investigation, Cartridge brass (Cu –70% and Zn – 30%) is passively fixed on the boring bar also clearance provided to reduce displacement,tool wear[3]. Pranali Khatake,P.T. Nitnaware(2013)This paper introduced a vibration mitigation for boring bar with enhanced damping capability minimizing loss in static stiffness by implementation of passive damper[4].shrikant waydande et al.presented paper on performance of Boring Tool under vibratory condition with and without Passive Damper by varying machining Parameters[5] M. Senthil kumar et al.(2011) investigates the efficiency of particle damping in control of vibrations in a boring bar using copper and lead particles of various sizes[6]. Gaurav Saindane June-July, 2014 paper introduces an experimental investigation of vibration damping in boring using passive damper, newly designed tool has been compared to a conventional tool [7]. Shrikant Waydande April 2014, Presents the study of implemented passive damping design using VE composite materials for boring bars has resulted in efficient tools that can be used to perform at high material removal rates in stable conditions [8] Pooja J. Waghmare et al reveals that passive damping techniques by using Magneto-Rheological fluid (MR) and damping particles like copper, lead, silicon, rubber etc. can suppress the vibrations during boring operation to the desired amount[9]. Tojo Thomas, S.B.Tiwari (2015) Author presented paper on study and design of passive damper for boring operation of a convergent-divergent nozzl [10].

III.PROBLEM STATEMENT

During deep boring process, usually when l/d (overhang length/boring tool diameter) ratio is higher, the excessive vibrations are induced at tip of boring tool which hampers the surface finish consequently quality of the products. Moreover it reduces life of cutting tool. Hence, vibration of boring tool is reduced by means of applying carbon fibre composite layers as a passive damper with different orientations of fibre.

IV. METHODOLOGY

The stiffness and damping of the boring tool should be increased in order to reduce the vibration. In this project, to achieve the maximum damping effect, the boring tool is laminated with carbon fibre with different fibre orientations. Four different boring tools were laminated with different carbon fibre orientations and these are as follows;

i. 10°Fibre Orientation
ii. Cross 10° Fibre Orientation
iii. 45° Fibre Orientation
iv. Cross 45° Fibre Orientation

To assess the effect of carbon fibre on the acceleration amplitude, experimentation is carried out with different cutting parameters.

V. 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.

VI. CONSTRUCTION OF THE 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 steel tool, 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 boring tool to increase the damping with the help of epoxy resin as an adhesive agent. The unidirectional carbon fiber is cut into 10° and 45° 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.

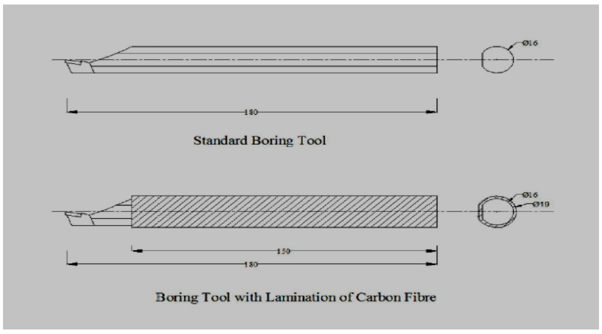

Fig. 1 Schematic of a Standard and Laminated Boring Tool

Steel has less stiffness as compared to the composite material. Hence to improve longitudinal and bending stiffness, lamination of carbon fiber with different orientation (10°, Cross 10°, 45°, Cross 45°) 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

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. Accelerometer placed 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. The laminated boring tools prepared for the experimentation are shown in Fig. 3.

Fig. 3 Boring Tools Prepared for Experimentation.

Table 1.Mechanical properties of boring tool used in analysis

		Material Properties		
Part of Boring tool	Material	Young's Modules (MPa)	Density (Kg/m³)	Poissons Ratio
Shank	Mild Steel	$2.1X10^5$	7860	0.3
Tip	Carbide	$6.25X10^5$	1495	0.22
Lamination	Carbon Fibre	$3.5 X10^5$	1800	0.4

VII. EXPERIMENTAL SET-UP

The vibration analysis of the boring tool with and without lamination has been carried out on the lathe machine in college workshop. The capacity of the lathe machine is 2.2 KW and a maximum machining diameter of 120 mm. The experiment was performed on a mild steel work pieces having 80 mm inner diameter as an internal boring operation using S16Q SCLCR 09T3 WIDAX boring tool. Table.2 shows the configuration of the standard boring tool used in the boring operation of mild steel. 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. 4

Table 2.Specification of Boring Tool

Tool Used	S16QSCLCR09T3WIDAX
Tool Material	Steel
Tool Length(mm)	180
Tool Diameter (mm)	16
Tool NoseRadius(mm)	0.4

Fig. 4 Experimental Set-up

Table 3 Parameters Used In Experimentation

Parameter	Level 1	Level 2	Level 3
Feed Rate F (mm/rev)	0.05	0.1	0.15
Depth of Cut D (mm)	0.1	0.2	0.3
Length Of Tool L (mm)	96	112	128
Tool Nose Radius r (mm)	0.4	0.4	0.4
Spindle Speed S (rpm)	280	450	710

Force Acting on Boring Tool:

I.Tangential cutting force is given by

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

Where,

S = Cutting speed (m/min) = 280 (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

$F_t = \frac{1677 * f^{0.8} * D^{0.96} * L^{0.05}}{r^{0.07} * s^{0.08}} = \frac{1677 * 0.05^{0.8} * 0.1^{0.96} * 96^{0.05}}{0.4^{0.07} * 280^{0.08}}$

F_t=14.28 N

II.Radial cutting force is given by

$F_r = 0.308 * Ft = 0.308 * 14.28 = 4.76\ N$

Resultant force is given by

$F_e = \sqrt{Ft^2 + Fr^2}$=14.942 N

Similarly Ft,Fr,Fe values are calculated for different level changing feed rate, depth of cut and speed of tool, Analysis of Boring tool carried for maximum force. The Analysis of model was carried out for over hanged length of 128 mm. The model was fixed in all degrees of freedom except overhang length. The model was analyzed for different magnitudes of radial and tangential loads.

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.

VIII.FINITE ELEMENT ANALYSIS

1.Geometry

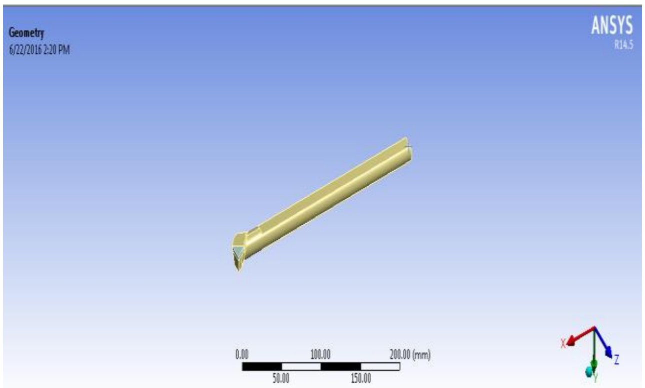

Fig.5 Geometry

Above fig shows Boring tool geometry of length 180 mm and Diameter 16 mm modeled in Ansys 14.5

2.Meshing

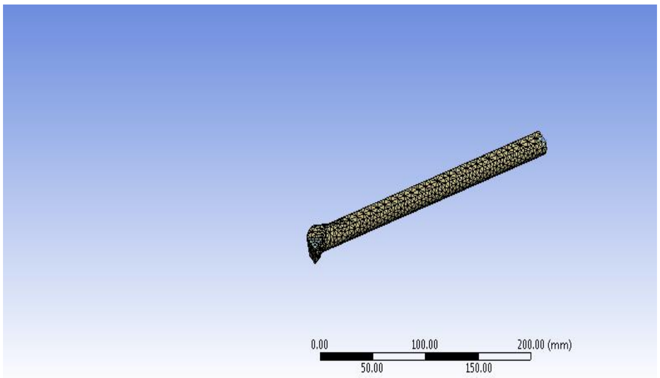

Fig. 6 Meshing

Fig shows meshed model with nodes 6714 and elements 3418, with meshing element tetrahedral type

3.Boundary Condition

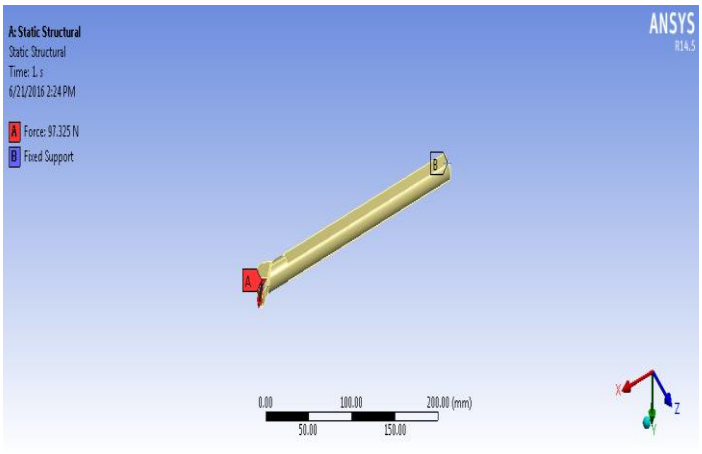

Fig.7 Boundary Condition

One end of Boring Tool is fixed in tool holder and another end with tip of tool is free. Total overhanged length of tool is 128 mm.

4.Stress

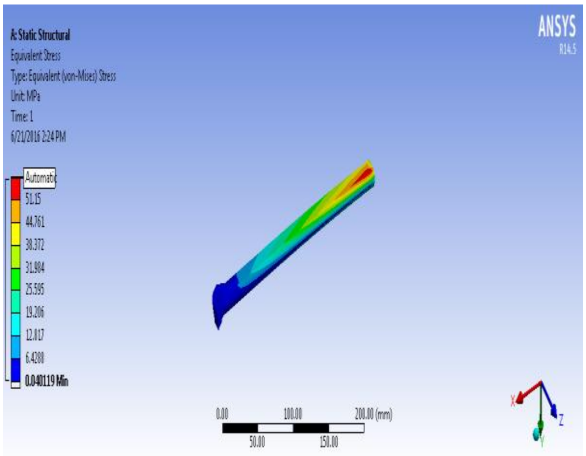

Fig.8 Boring Tool Stress Analysis

Fig Shows stress analysis of boring tool having maximum stress is 51.15MPa occur in fixed area (Red colour) and minimum stress is 0.040119 MPa occur at tip of tool (Blue colour)

5.Deformation

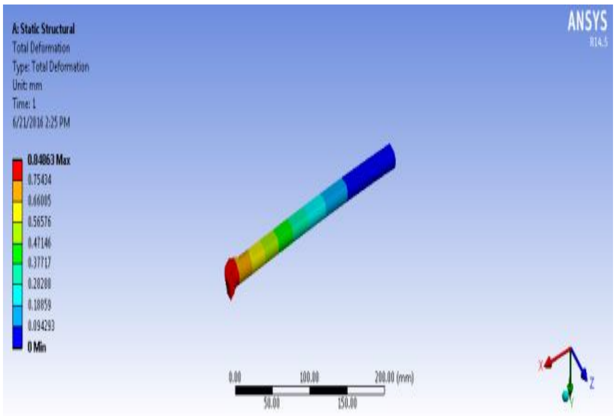

Fig. 9 Deformation

Fig Shows maximum deformation of boring tool, applying maximum resultant force 97.3279 N at tip of tool. After analysis maximum deformation is 0.84863 mm at tip of Boring tool (Red colour) and minimum deformation is zero at fixed end (Blue colour).

IX .RESULTS

Table 4. Different Load Cases of Boring Tool

Load Case Without Lamination	Frequency (Hz)	Tangential Load Ft (N)	Radial Load Fr (N)	Equivalent Force Fe (N)
1	613.73	14.28	4.400	14.942
2	664.06	27.7847	8.557	29.07
3	1020.41	41.0149	12.63	42.9162
Level 2				
4	795.9	24.1319	7.432	25.2505
5	1090.51	46.9464	14.45	49.1227
6	1113.28	69.2834	21.33	72.4952
Level 3				
7	839.84	32.3982	9.978	33.9001
8	1110.58	63.0246	19.41	65.9462
9	2225.32	93.0160	28.64	97.3279
Load Case With Lamination	Frequency (Hz)	Tangential Load Ft (N)	Radial Load Fr (N)	Equivalent Force fe (N)
Level 1				
1	600.59	14.28	4.400	14.942
2	614.81	27.7847	8.557	29.07
3	781.25	41.0149	12.63	42.9162
Level 2				
4	644.53	24.1319	7.432	25.2505
5	927.73	46.9464	14.45	49.1227
6	997.11	69.2834	21.33	72.4952
Level 3				
7	771.48	32.3982	9.978	33.9001
8	1000.98	63.0246	19.41	65.9462
9	1586.21	93.0160	28.64	97.3279

X.RESULTS AND DISCUSSION

In order to study the effect of lamination carbon fiber on the damping of the boring tool, two tools were prepared (laminated and unlaminated) for experimentation by changing parameters feed rate, depth of cut, tool length tool, speed we found following result.

1.For laminated tool frequency is increased with increase of speed, feed, depth of cut, length of tool, at max force
Ft=93.0160 N,
Fr =28.64 N,
Fe=97.3279 N
frequency is 2225.32Hz

2.By using carbon fiber laminated tool as passive damping, frequency is reduced to 1586.21 Hz.

XI.CONCLUSION

As frequency is reduced from 2225.32 Hz to 1586.21 Hz Vibration in Boring tool is reduced by using Passive damper carbon fiber laminated tool. Use of carbon fiber laminated Boring tool gives reduced frequency so reduced Noise level during cutting operation.

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