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Investigation of vibration in boring operation to improve Machining process to get required surface finish

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ABSTRACT

Boring is a most commonly used lathe machine operation to enlarge the small holes of any structures. When a cantilever and long boring tool is used, it is subjected to optimum static deflections or self-excited vibrations, which reduces the accuracy and surface wrap up of the boring operation. It also causes the tool to wear out and become damaged. Boring frequently necessitates the use of a long and slender boring tool to machine inside a hole, and vibrations become strongly correlated with one of the boring tool's fundamental bending modes. There are several methods for reducing vibrations; however, implementing the most efficient and stable methods necessitates extensive knowledge of the dynamic characteristics of the tooling system. Moreover, the functionality between the boring tool as well as the clamping house has a significant impact on the clamped boring tool's dynamic properties. This paper examines the behavior of a boring tool under various overhang lengths that are frequently used in the machining process.
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1. Introduction

Engineers are currently faced with a number of important tasks, including increasing the competitiveness and technological level of cutting tools and metalworking equipment, as well as lowering the cost of metalworking operations such as turning, milling, and boring. One of the most effective ways to reduce production costs is to increase the productivity of metalworking, particularly boring operations, which can be accomplished by increasing cutting speed and using cutting tools with more advanced designs. Automation is the primary focus in the development of modern engineering production, which places high demands on machining tools in order to increase productivity. Automation inside the manufacturing processing chain improves not only the cutting conditions but also the varies of drive regulation, power, as well as speed of machine moving parts, and also the capability of taking on them as shown in Fig. 1.

The boring tool is subjected to dynamic excitation during a boring operation as a result of the material deformation process throughout a cutting operation. This will cause the boring tool to deflect over time. A condition of resonance is encountered when the frequency of the excitation happens to coincide with one of the free vibration of the boring tool.

Because the vibrations are at their peak under these conditions, calculating the natural frequencies is critical in the study of vibrations. Bending vibration is a common type of vibration in boring tools caused by cutting forces. The force is applied to the cutting tool and is generated by the chip forming operation during a cutting operation. The ability to support transverse shear as well as internal stiffness is a feature of most believable structural systems.

When the l/d (overhang length/boring tool diameter) ratio is greater during the deep boring process, excessive vibrations are induced at the tip of the boring tool, affecting the surface finish and thus the quality of the products. Furthermore, it shortens the life of the cutting tool. As a result, vibration of the boring tool is reduced by using carbon fibre composite layer upon layer as a passive damper with different fibre orientations. We intend to develop a new technique to reduction of vibration in boring operation also we will study the analytic behavior of boring tool under different cutting conditions. We also focus to analyses the effect of carbon fiber lapping with different angle of layer and optimize vibration and the vibration response of laminated tool by experimental result.

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Fig. 1. Photograph Standard and Laminated Boring Tool.

In this study, a finite element analysis of boring tool with and without the damper, with different layer configuration will be carried out. The experimental set-up will be designed to study the effect of various cutting parameters on the boring tool. It is proposed that the configurations of the polymer-based composite should be selected such that it gives maximum damping effect. The results obtained by finite element analysis will be validated with experimental analysis. To reduce vibration, the damping ratio of the boring tool must be increased. In this paper, the boring tool is layered with carbon fibre with 450 Fiber Orientations to obtain the optimum damping effect. Experimentation with various cutting parameters is carried out to evaluate the impact of carbon fibre on acceleration amplitude.

2. Literature review

Y.Beauchamp and M. Thomas [1] "Statistical investigation of cutting tool modal parameters in dry turning." It is critical to select optimised cutting parameters when controlling the quality required for surface finishes. Unfortunately, surface roughness is not solely determined by feed rate, tool nose radius, or cutting speed. Excessive tool vibrations, friction of the cut surface against the tool cutting point, and particle embedding of the materials being machined can all ruff the surface.

As a result, the applied forces on the tool, which can be thought of as the sum of steady forces, harmonic forces, and arbitrary forces, act on the cutting tool and make a contribution to the modification of the tool's vibration response by affecting its stiffness and elasticity. These variations in stiffness and damping are caused by parameters that are difficult to predict in practise. Furthermore, the effects of cutting parameters on the cutting tool, which contribute to variation in the tool's modal parameters, are more useful for controlling tool vibration. The purpose of this research is to collect and analyse cutting-force, tool-vibration, and tool-modal-parameter data collected by lathe dry turning of mild carbon steel samples at various speeds, feeds, depths of cut, tool nose radius, tool hanging lengths, and work piece diameter and lengths. A full factorial experimental design was used, which takes into account the two-level interactions between the independent variables. In this study, they looked at the effect of all cutting parameters on tool stiffness and damping, and they came up with an empirical forecasting the behaviour of tool stiffness variation.

"Novel applications of composite structures to robots, machine tools, and automobiles," Dai Gil Lee, Chang Sup Lee, Hak Gu Lee, Hui Yun Hwang, and Jong Woon Kim [2]. Fiber reinforced composite materials outperform many traditional metals in terms of strength and modulus. Because of their low specific gravities, these composite materials have much higher strength-weight ratios and modulus-weight ratios than metallic materials. The special details of each design will be met by composite materials. The materials used, the volume fraction of fibre and matrix, the fabrication method, the number of hidden layers in a specific direction, the thickness of individual layers, the type of layer, and the layer stacking sequence are all available design parameters. The most important drawback of all composite materials is their high material costs. Fiber reinforced reinforced composites are now primarily used in the strength design of aircraft, spacecraft, and vehicles.

R.F.Kristensen, K.L.Nielsen, and L.P.Mikkelsen [3] gave a paper titled "Numerical studies of shear damped composite beams using a constrained damping layer." In the current analysis, the rubber was added on one side of the beam and could be either free or constricted by a stiff outer layer, referred to as constricted setup. When the rubber layer was constrained, it was forced to follow the surrounding material, resulting in large shear deformations. For the current load case, shear deformation of the rubber was greater than axial as well as bending deformation, and thus shear deformation provided the greatest amount of damping. It has been discovered that for an uniform thickness of the constraining layer, the amount of shear decreases while the amount of material with high damping properties increases. Analysis showed that these two effects almost cancel each other out, and that the amount of damping is thus insensitive to variations in rubber thickness. The thickness and stiffness of the constraining layer, on the other hand, cause large variations in damping, and configurations with high damping are found for a thick constricting layer with reasonable stiffness. The beam and constraining layer materials should be much stiffer than the rubber, so that the impact of the rubber stiffness can be ignored. The current work also considers the impact of incorrectly positioned cuts in the constraining layer, which commonly occurs when applying loads and supports to the beam. The significance of a constant constraining layer was discovered to be significant, as major drops in damping were found for layer discontinuity.

Significant research has been conducted to determine how to avoid vibrations during the machining process. Authors [4] initiated such research in the early twentieth century, and then in the 1940 s, Authors [5] studied cutting tool vibrations based on experimental turning operations. Later, researchers [6–10] made numerous attempts to identify the chatter issue in terms of machining productivity. Vibrations from the machine are transferred to the workpiece via the tool and fixtures, led to significantly lower surface quality. Because an adaptable cutting tool is used in this procedure, the vibration problem is worsening. Various authors focused their efforts on experimental and analytical studies of the boring bar dynamic. To find the impact of mode coupling on generating additional during a machining process, the writers [11] studied the stability of a cantilever boring bar, depicted by a simple two-degree-of-freedom mass-spring-damper system.

[12] developed an analytical form of tool motion to anticipate boring bar chatter during a machining operation. They also determined experimentally the stability imit of the width of the cut and compared it to predicted values. They [13] created a new vibrant boring force model that accounts for chip cross-sectional area under dynamic conditions. The authors [14] compared the Euler–Bernoulli beam model to the time-series approach in identifying the vibration characteristics of boring bars. Using a combination dynamic tooling system model based on the finite element beams and empirical models, researchers [15,16] probed the process damping stability in internal finish turning. They claimed that the proportion of boring bar eaves to bar external diameter, as well as the material of the boring bar, were the primary determinants of the experimental damping values. Another strategy for improving the dynamic behaviour of the boring bar is to examine the effect of the clamping condition [17] and the geometrical of the cutting insert on the cutting conditions [18–21].

2.1. Discussion

Studying the state of arts system it is found that the methods are not as much efficient for lowering vibrations, this creates a scope to come up with an advance method for lowering the vibrations Using the most efficient and dependable methodologies, on the other hand, necessitates a thorough understanding of the dynamic properties of the tooling system.

3. Boring tool specification

A carbide tip steel boring tool with a diameter of 16 mm is used to bore a mild steel work piece with a diameter of 100 mm. Boring with a high slenderness ratio is difficult due to the dynamic stiffness and natural frequency of high-speed steel, which causes vibrations during the boring operation. Due to the poor properties of the boring tool, it is difficult to perform a boring operation at a low feed rate, low speed, and high depth of cut.

Steel has a lower stiffness than composite materials. As a result, carbon fibre lamination with 450 orientations was performed on the Boring Tool's shank to improve longitudinal and bending stiffness. The epoxy resin is the adhesive used for carbon fibre lamination. Epoxy resin not only serves as an adhesive, but it also increases the stiffness of the structure.

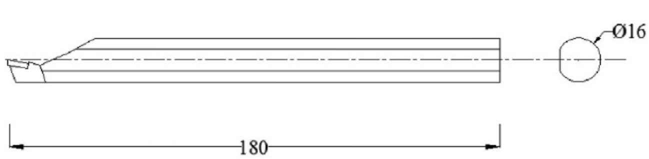

Fig. 2. Configuration of the Standard Boring Tool.

Table 1
Specifications of the Boring Tool.

Tool Used	S16Q SCLCR 09 T3 WIDAX
Tool material	Steel
Tool length (mm)	180
Tool diameter (mm)	16
Tool nose radius (mm)	0.4

Fig. 3. Experimental Set-up.

4. Experimental setup

On the lathe machine in the college workshop, the vibration analysis of the boring tool both with lamination was performed. The lathe machine has a capacity of 2.2 KW and a highest machining diameter of 120 mm. The experiment was carried out on mild steel work pieces with an inner diameter of 80 mm using an S16Q SCLCR 09 T3 WIDAX boring tool as an inner boring operation.

Fig. 2 shows the configuration of the ideal boring tool used in the boring operation of mild steel.

The specifications of the boring tool used in the cutting test are given in Table 1.

The vibration acceleration magnitude as well as displacement of the boring tool were evaluated using the F.F.T. analyzer with various combinations of cutting parameters. An FTT accelerometer was adhered to the edge of the boring tool with adhesive material in order to obtain efficient results of the tool tip under different conditions. The F.F.T. analyzer is linked to a laptop via a USB cable to obtain a pictorial depiction of the experiment output. Fig. 3 depicts the entire experimental setup.

5. Result

Result of Harmonic Analysis.

	Acceleration Amplitude (m/s^2)		
Overhang Length (mm)	Standard Tool	Cross 45^0 Fiber Orientation	% Reduction in Acceleration Amplitude
96	102.6	88	14.23
112	225.54	69.88	69.01658
128	296.21	74.78	74.7544

6. Conclusion

This paper deals with a problem that has a considerable importance for mechanical engineering and it examines the behaviour of a boring tool under various overhang lengths that are commonly used in the machining process. The results analysis shows that Using laminated boring tool substantial reduction in acceleration amplitude is discovered in comparison to standard boring tool. The carbon fiber with cross 450 fiber orientation shows maximum damping effectiveness compared to other orientations. At highest overhang length, reduction in acceleration amplitude obtained up to 70% when cross 450 fiber orientation is used.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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