A Review on Vibration attenuation of Boring Bar by using Passive Dampers

Shrikant Waydande1, Prof. D. A. Mahajan2, Prof. (Dr.) S. Y. Gajjal3
1ME student, Design Engineering NBN Sinhgad school of Engineering, Pune
2Assistant Professor, 3Professor, Department of Mechanical Engineering, NBN Sinhgad school of Engineering, Pune,

Abstract- The boring operation is a very critical manufacturing process which created surface roughness, tool wear, noise and vibration related problems. A deep internal boring operation in a workpiece is a classic example of chatter-prone machining. This review focuses on study of new damping composite materials for boring tool and introduces new advance viscoelastic materials for vibration attenuation purpose. This study also focuses on various damping techniques such as active damping and passive damping system and also an optimal selection of the parameters of a passive vibration dampers. This review introduces mechanics of boring process which affect tool wear, noise, surface roughness and hence influence on important factors such as productivity, production costs, etc. The main objective of the study is attenuation of vibration in boring bar by using passive dampers. This study will enhance the design of boring bar with Visco-Elastic materials with reference to different machining parameters such as length to diameter ratio (L/D), Speed, feed, Depth of cut etc. The computed results on Experimental Modal Analysis, Machining Test and Surface Roughness will be compared to a conventional tool.

Keywords— Boring bar, Vibration Attenuation, Composite Materials, Passive Damping, EMA Analysis.

I. INTRODUCTION

Today in the manufacturing industry, the vibrations concerned with metal cutting, such as turning, milling and boring operations. Turning operations, and especially boring operations, are facing tough vibration related problems. To reduce the problem of vibration extra care must be taken in the production planning and preparation regarding the machining of a workpiece in order to obtain a desired shape and tolerance. Thus, the vibration problem in metal cutting has a considerable influence on important factors such as productivity, production costs, etc. A boring operation (Refer figure 1) is a metal cutting operation that bores deep and precise holes in the workpiece. The actual cutting is performed at the cutting tool mounted at the tip of the boring bar. During a cutting operation the boring bar is fed in the feed direction at a specific cutting depth and a specific rotational speed of the workpiece. The vibration of the boring bar is influenced by three parameters, feed rate, cutting depth and cutting speed. The vibration in the boring bar are in the cutting speed and the cutting depth direction.

During an internal turning operation the cutting tool and the boring bar are subjected to cutting forces due to the relative motion between the tool and workpiece in the cutting speed direction and in the feed direction. A desire of being able to perform a cutting operation into pre-drilled holes in a workpiece limits the diameter or cross sectional size of the boring bar. Usually a boring bar is comparatively long and slender, and is therefore more sensitive to excitation forces. In boring operations the cutting tool is placed on a boring bar. Since the boring bar is the weakest link in the boring bar - clamping system of the lathe, this is where the vibrations will be of major concern. The boring bar motion may vary with time. The dynamic motion originates from the deformation process of the work material. The motion of the boring bar or vibrations will affect the result of the machining, and the surface finish in particular. The tool life is also likely to be influenced by the vibrations. Machine tools are notoriously subject to three types of vibration: free, forced, and self-excited Free vibrations take place when the stable system is displaced from its equilibrium by an impulse-like excitation; the system vibrates and eventually returns to the starting position according to its structural properties. Forced vibrations are all those occurring due to dynamic forces applied to a stable system. Generally there are four types of sources that might generate such forces: Alternating cutting forces, such as those induced by in homogeneities in the workpiece material, break-off of built-up edge or changes in the chip cross section, interrupted cutting processes, such as milling, internal sources, such as unbalances in the rotating units, external disturbances transmitted through the machine tool foundation. Self-excited vibration or chatter is a complex phenomenon and is commonly the least desirable type of vibration as the machine tool structure enters an unstable state. Chatter depends on the design of the machine tool as a whole, on the workpiece material and geometry and on machining regimes; its occurrence is due to insufficient damping in the machine tool structure. There are several ways to minimize the vibration in machining like active damping system and passive damping system etc. Passive vibration damper are manufactured by using various types of damping materials in such way that they can reduce machining vibrations effectively.
The visco-elastic substance that can be worked into machine tools in various ways.

A passive vibration control approach has been used to design a boring bar for internal turning operations with enhanced damping capability. The design allowed a ten times enhancement of the damping ratio losing only a fraction of the static stiffness. The novel 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 over a relatively wide range of cutting conditions.

M.H. Miguelez, L. Rubio, J.A. Loya, J. Fernandez-Saez [2] focused on the behavior of boring bars with a passive dynamic vibration absorber (DVA) for chatter suppression. The boring bar was modeled as a cantilever Euler–Bernoulli beam and only its first mode of vibration was considered. The stability of the two-degree-of-freedom model was analyzed constructing the stability diagram, dependent on the bar characteristics and on the absorber parameters (mass, stiffness, damping, and position). Two analytical approaches for tuning the absorber parameters were compared. The selection criterion consisted on the maximization of the minimum values of the stability-lobes diagram. Subsequent analysis performed in this work, allowed formulating of new analytical expressions for the tuning frequency improving the behavior of the system against chatter. This work is focused on the design improvement of passive dynamic absorbers (DVA) for chatter suppression in boring operations. The boring bar, being the main structure, was modeled as a Euler–Bernoulli beam, accounting only the first vibration mode. Moreover, subsequent local analysis performed in this work, allowed the establishment of simple analytical expressions for the tuning frequency improving the behavior of the system against chatter. The method could be easily implemented in the design procedure of passive absorbers in boring operations. The procedure was successfully applied in a practical example illustrative of a real case of boring operation in industry.

Viktor P. Astakhov [3] presents the origin of the aforementioned contradicting results. It argues that, when the optimal cutting temperature is considered, the influence of the aforementioned parameters on tool wear becomes clear and straightforward. The obtained results reveal the true influence of the cutting feed, diameter of the workpiece, and diameter of the hole being bored on the tool wear rate. It was also found that the depth of cut does not have a significant influence on the tool wear rate. The obtained results provide methodological help in the experimental assessment and proper reporting of the tool wear rates studied under different cutting conditions. The notion of optimal cutting temperature resulting in the formulation of the first metal cutting law is very useful in the analysis of the influence of various parameters of the cutting process on tool wear, as it makes such an analysis simple and straightforward.

II. LITERATURE REVIEW

Lorenzo Daghini, Andreas Archenti, and Cornel Mihai Nicolescu [1] paper explains that a novel design for boring bar with enhanced damping capability. The principle followed in the design phase was to enhance the damping capability minimizing the loss in static stiffness through implementation of composite material interfaces. The newly designed tool has been compared to a conventional tool. The evaluation criteria were the dynamic characteristics, frequency and damping ratio, of the machining system, as well as the surface roughness of the machined workpieces. The use of composite material in the design of damped tool has been demonstrated effective. Furthermore, the autoregressive moving average (ARMA) models presented in this paper take into consideration the interaction between the elastic structure of the machine tool and the cutting process and can therefore be used to characterize the machining system in operational conditions.
There are least five independent factors that determine the influence of the cutting feed on tool wear. Among them, the length of the tool path and the cutting temperature are of prime importance. As a result, the influence of the cutting feed on the tool wear rate is different at different cutting speeds. The diameter of the workpiece has a strong influence on the cutting temperature and, thus, on the tool wear rate and the roughness of the machined surface. This is because this diameter affects the static and dynamic rigidity of the machining system, curvature of the surface being cut, and interaction of the thermal and deformation waves in the layer being removed. Apart from being of particular practical significance, the obtained experimental results should be considered as methodological help in the experimental assessment and proper reporting of the tool wear rates studied under different cutting conditions.

F. Atabey, I. Lazoglu, Y. Altintas [4] explain the mechanics of boring operations. The distribution of chip thickness along the cutting edge is modeled as a function of tool inclination angle, nose radius, depth of cut and feed rate. The cutting mechanics of the process is modeled using both mechanicistic and orthogonal to oblique cutting transformation approaches. The forces are separated into tangential and friction directions. The friction force is further projected into the radial and feed directions. The cutting forces are correlated to chip area using mechanicistic cutting force coefficients which are expressed as a function of chip-tool edge contact length, chip area and cutting speed. For tools which have uniform rake face, the cutting coefficients are predicted using shear stress, shear angle and friction coefficient of the material. Both approaches are experimentally verified and the cutting forces in three Cartesian directions are predicted satisfactorily. A comprehensive model of single point boring operations has been presented. The chip geometry removed by curved boring inserts is modeled as a function of tool geometry, feedrate and radial depth of cut. Due to irregular distribution of chip load around the insert’s cutting edge, the amplitudes and directions of distributed cutting forces change as a function of tool geometry and cutting conditions. As a result, the cutting forces in boring have a linear dependency with the chip area, but non-linear dependency with the feedrate and radial depth of cut. The cutting coefficients are evaluated mechanistically by conducting cutting tests at different feeds, speeds and depth of cuts with inserts having irregular rake face geometry. The cutting coefficients are estimated by correlating the chip geometry and forces using regression analysis. The cutting coefficients for inserts having smooth rake faces are modeled using orthogonal to oblique transformation method. The models are experimentally proven for single point boring bars used in industry.

The models allow the process engineers to investigate the influence of insert geometry, feed, speed and radial depth of cut, boring forces, torque and power. The model is an essential foundation to study the forced and chatter vibrations in boring operations with single point boring bars and multi-insert boring heads.

L. Rubio, J.A. Loya, M.H. Miguel, J. Fernandez-Saez [5] in their paper focused on the optimal selection of the parameters of a passive dynamic vibration absorber (DVA) attached to a boring bar. The boring bar was modeled as an Euler–Bernoulli cantilever beam and the stability of the system was analyzed in terms of the bar and the absorber characteristics. To obtain the optimum parameters of the absorber, a classical method for unconstrained optimization problems has been used. The selection criterion consisted of the maximization of the minimum values of the stability lobe diagram. Empirically fitted expressions for the frequency and damping ratio of the DVA (which permit to obtain its stiffness and damping) are proposed. These expressions are fully applicable when the damping ratio of the boring bar is non-null as it is in practical operations. The computed results show a clear improvement in the stability performance regarding other methodologies previously used. This paper deals with the chatter stability of a boring bar with an attached passive dynamical vibration absorber. The boring bar is modeled as an Euler–Bernoulli cantilever beam, and the absorber is considered attached by a spring and a damper at a certain section of the beam. The stability problem has been properly solved and the stability lobe diagram constructed. To determine the optimum values of the absorber parameters, the criterion was to maximize the minimum values of the stability lobe diagram. The method could be easily implemented in the design procedure of passive absorbers in boring operations, and note that it is fully applicable when the damping ratio of the boring bar is non-null as it occurs in practical operations.

Rongping Fan, Guang Meng, Jun Yang, Caichun He [6] explain the application of visco-elastic materials in railway vehicles. Three types of viscoelastic damping materials, bitumen-based damping material, water-based damping coating and butyl rubber damping material, were developed to reduce the vibration and noise within railway vehicles. Two sleeper carriages were furnished with the new materials in different patterns of constrained-layer and free-layer damping treatment. The measurements of vibration and noise were carried out in three running carriages. It is found that the reduction effect of damping treatments depends on the running speed. The unweighted root-mean-square acceleration is reduced by 0.08–0.79 and 0.06–0.49 m/s² for the carriage treated by bitumen-based as well as water-based damping material and water-based damping material, respectively.
The first two materials reduce vibration in a wider frequency range of 63–1000 Hz than the last. It turns out that the damping treatments of the first two reduce the interior noise level by 5–8 dBA within the carriage, and the last damping material by 1–6 dBA. However, the specific loudness analysis of noises shows that the noise components between 125 and 250 Hz are dominant for the overall loudness, although the low-frequency noise is noticeably decreased by the damping materials. The measure of loudness is shown to be more accurate to assess reduction effect of the damping material on the acoustic comfort. The method of application of constrained-layer and free-layer damping treatments to luxury sleeper carriages has been developed. Running experiments show that three new damping materials can reduce the internal vibration and noise and provide a more comfortable travelling environment relative to motion and sound for the passengers. The reduction effect of the internal vibration and noise has been shown to depend strongly on train speed and the measurement location selected. The use of proper sound measure such as loudness rather than A-weighting can evaluate and assess more accurately the efficiency of different damping materials to reduce the internal noise.

III. BORING OPERATION

In machining, boring is the process of enlarging a hole that has already been drilled or cast, by means of a single-point cutting tool or of a boring head containing several such tools. The boring operation is also sometimes referred as internal turning operation and which requires due care to attain a desired manufacturing requirements. The dimensions of the workpiece hole generally determine the length and limit of the diameter or cross sectional size of the boring bar. In boring, the long, cantilevered boring bars have inherently low stiffness and become the weakest link in the boring bar-clamping system of the lathe. If the static/dynamic rigidity of these cantilever elements is inadequate, they directly limit the attainable accuracy, due to the easy deflection of the boring bar, even under low magnitude cutting forces, indirectly limit accuracy, the high-frequency micro-vibrations produce noticeable wear in the cutting inserts during each cutting cycle which results in tapered surfaces instead of the required cylindrical ones and limit machining regimes through the generation of self-excited vibrations even at relatively low cutting regimes when the length-to-diameter (L/D) ratio of the boring bar exceeds 4:1.

A Mechanics of Boring Operation

B Vibration Damping System

What is damping? Damping is the energy dissipation properties of a material or system under cyclic stress. Active damping and passive damping:

Active damping system

The objective of active vibration control is to reduce the vibration of a mechanical system by automatic modification of the system’s structural response. The principle of active control of vibration in machining is to analyze in real time the signal emitted during machining, recognize instability (chatter) and compensate for it. For this purpose different techniques can be used. One way is to predict the arising of chatter and consequently change the cutting parameters before the full instability occurs. The signals are processed and sent eventually to the actuators located in the tool clamp, which compensates by providing dynamic forces to the boring bar. The apparent advantage of the active vibration control approach is the perfect adaptability to the changes in the cutting conditions; all the above mentioned techniques are based on online adaptation to the ongoing process to ensure stability. The drawback of this approach is the required computation resources and hardware: the system has to process the acquired signal for chatter recognition in real time, and the amount of data can be large. In addition to this, the presence of cables between the control system and the tools could compromise the machining operation.
IV. PASSIVE DAMPING SYSTEM

The principle of vibration passive control is to convert the mechanical energy into some other forms, for instance heat. A common way to achieve passive damping is by using viscoelastic (VE) composite materials to dissipate the energy that causes vibration. The use VE composite materials for damping purposes is quite common, this technique has been used in other fields of application, such as automotive and aeronautics. VE composite materials are used for damping enhancement generically in three different ways: as free-layer dampers (FLD), as constrained-layer dampers (CLD) and in tuned viscoelastic dampers (TVD). The latter has been successfully adapted for designing tooling systems. The basic principle of TVD technique is to add a mass residing on a spring and a viscous damper at the point of maximum displacement. This additional single degree of freedom (SDOF) system must have the natural frequency close to that of the boring bar in order to transfer the vibrational energy to the TVD. If the damper is properly designed it will dissipate the mechanical energy. When implementing such a solution it is of vital importance for the design to properly locate the pre-stressed VE composite layers in the structure to optimally exploit the property of VE material to give largest deformation in shear.

Material used for Passive Damping system

Composite materials such as Visco-Elastic materials are used for passive damping system. Examples of passive damping materials include viscoelastic materials (VEMs), viscous fluids, magnets, smart materials (piezoceramics, electrophotolcal fluids, magnetohoreological fluids, mangetorestrictives, shape memory alloys), high damping alloys, and particle damping. These systems use the potential energy generated by the structural response to provide the control force. The most common of these is viscoelastic materials. VEMs dissipate mechanical energy into heat when they undergo cyclic stress due to polymer chain interactions.

V. DESIGN AND IMPLEMENTATION OF PASSIVE DAMPING SYSTEM IN BORING BAR TOOL

The Turning tool used in this work has a diameter 25 mm with milled facets for clamping on conventional VDI adapter with screws. The damped tool has been produced by placing damping rings on the tool shaft (see Fig. 3(a)). These rings are made of VE composite material composed of a 0.26 mm thick aluminium foil and a 0.12 mm thick visco elastic material layer.

Figure3: Mechanical components of the tool: (a) damping ring shape; (b) channels for the glue flow; (c) specially shaped ring for allowing the coolant flow through the tool; (d) section of the damping structure; (e) the protective discs are designed to not touch the external collet

Three protective steel rings, to prevent the deformation of the damping rings, are also placed on the shaft. Two of the protective rings are positioned at the extremities of the damping structure while the third is in the middle (see Fig. 3(d)) The damping assembly has been glued on the tool, where small channels have been milled in order to let the adhesive cover the area homogeneously (see Fig. 3(b)). To protect the damping assembly from the coolant, a specially shaped ring has been fitted to the bottom of the tool where channels have been milled to direct the coolant flow through the tool (see Fig. 3(c)). The connecting screw is provided with a coolant Channel as well. A collet with an external diameter of 42 mm is glued on top of the whole structure. This design allows for the clamping to be completely isolated from the tool, i.e. all the energy generated during the cutting process flows through the damping material (see Fig. 3(e) ). The complete tool assembly is shown in Fig. 4
The surface finish produced by the conventional tool is of much lower quality if compared to the one produced by the damped tool, as also can be concluded from the model identification procedure.

B. Machining tests

The tools have been tested clamped in the same clamping configurations as modal analysis. Round workpieces made of TOOLOX® 44 and SS2541, respectively, with a diameter of 150 mm and a length of 170 mm were machined. The operation was internal turning and the starting inner diameter was 48 mm. The machining operations were carried out at three different depths of cut \(a\), 1 mm, 2 mm, 3 mm, keeping constant cutting speed \(v\) at 120 m/min and feed \(f\) at 0.15 mm/rev.

C. Surface roughness

The surface finish produced by the conventional tool is of much lower quality if compared to the one produced by the damped tool, as also can be concluded from the model identification procedure.

Result shows the surface profile taken after machining at \(a = 1\) mm; the conventional tool is not able to perform in stable conditions and therefore the surface profile is disturbed by the chatter marks and the average surface roughness for the different depth of cut settings and tools. At \(a = 3\) mm, due to severe chatter condition, the machining could not be accomplished with the conventional tool.

VII. Conclusion

This review 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 over a relatively wide range of cutting conditions. The design is validated by both EMA and machining tests. The results show a ten times damping ratio enhancement compared to the conventional tool with a relatively low loss of static stiffness. The damped tool was able to perform stably at higher removal rates with a better surface finish than the conventional tool. This study enhance the future scope to develop optimum design of boring bar with passive damping system by using various types of composite materials to attenuate vibrations in machining.

REFERENCES


