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Lateral vibration control of a drill by using MR elastomer

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Abstract

The drilling tool, during drilling operation is subjected to different forces. Unbalanced lateral forces in the drill, due to inaccurate tool geometry, bent in spindle causes lateral vibrations in the tool. These lateral vibrations reduces the tool life, disturbs tool geometry by increasing tool wear and also reduces the accuracy of machining which leads to large amount of rejection. In this paper, to control these vibrations, drill is supported on MRE (Magneto Rheological Elastomer) which is prepared in laboratory with silicon based rubber mixed with iron particles. Magnetic field is applied over MRE to change the stiffness. This change in stiffness holds the drill at its mean position and vibrations in the drill are absorbed by magnetized MRE material. The tool vibrations, during drilling operation are measured with and without applying magnetic field over MRE. These results were compared and presented. It is found that there is significant reduction in lateral vibrations in drill after application magnetic field.

Key Words: *Drill Vibrations, Magneto Rheological Elastomer, Magnetic Field*

1. Introduction

Drilling is one of the most commonly used machining processes in various industries such as automotive, aircraft and aerospace, dies/molds, home appliance, medical and electronic equipment industries. Due to the increasing competitiveness in the market, cycle times of the drilling processes must be decreased. Moreover, tight geometric tolerance requirements in designs demand that the precision of drilled hole must be increased in production [1].During drilling operation, the drill is subjected to vibrations because of unbalanced cutting forces. The quality of drilled hole is greatly influenced by these vibrations.

1.1 Lateral vibrations in drill

Three kinds of vibration are possible in a drilling process: torsional, longitudinal, and transverse. Since torsional and longitudinal vibrations do not significantly affect the hole surface quality, this analysis focuses on the transverse vibration, especially the forced vibration case. Cutting forces can be decomposed into three components, Px, Py and Pz as shown in figure 1. The Py's are the indenting forces in feed motion and contribute to the thrust. The Pz's are a couple, which needs a torque to overcome it. In the ideal case, the forces of Px acting on the drill are of equal magnitude but opposite directions along the same line, thus canceling each other. But when the drill is asymmetrical, because of poor drill point grinding or drill wear/ breakage, the two Px forces tend to be unbalanced. The unbalanced force causes a sinusoidal vibration with a frequency identical to the spindle speed. The deflection of the drill or lateral displacement caused by this vibration tends to overcut on one side and undercut the other. Depending on the vibration pattern, the drilled holes may be oversized, have irregular geometry and shape, or have poor surface finish [2].

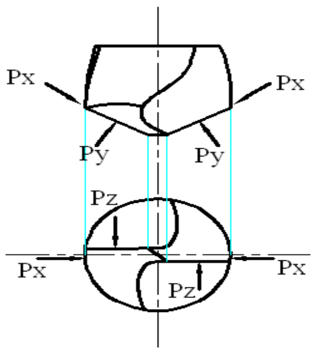

Figure 1: Cutting forces on drill.

This paper deals with the application of Magneto Rheological elastomer to control these drill vibrations. The MRE is one of the smart materials being used for vibration control in various applications. MRE has proposed applications such as adaptive tuned vibration absorber, stiffness tuned mounts and suspension. On application of magnetic field the stiffness of MRE is varied and this property enables MRE to use as vibration absorber. The other smart materials like MR fluid, ER fluid, piezoelectric materials, Shape Memory Alloys etc. are being used in applications of vibration control.

Lei [3] first proposed the concept of utilizing ER fluids for chatter control. Two different design schemes were proposed including a cutting tool filled with ER fluids that can directly change the stiffness or damping of the tool and a flexible machine tool spindle with an ER squeeze film damper. Segalman and Redmond [4] utilized ER fluids to actively control the impedance of boring bars to suppress chatter. This approach is similar to a conventional chatter avoidance method, which adjusts the spindle speed so that the cutting process stays inside the stability region Chiu and Chan [5] published the design of a piezoelectric controlled boring bar. The forced displacement of the boring bar was actively corrected by piezoelectric actuation acting on the bar holder. Wang and Fei [6] has published paper on the application of ER fluids in boring bars for chatter suppression.

To control the drill vibrations, drill shank is supported on MRE in tail stock of centre lathe and magnetic field is applied to change the stiffness of MRE. As the magnetic field varies there is change in the stiffness of the MRE material, MRE material holds the drill at its mean position. Vibrations in the drill are absorbed by magnetized MRE material. Vibrations are measured with and without applying magnetic field over MRE to see the effectiveness of MRE in vibration control of the drilling tool.

2. Preparation of MR elastomer

There are numerous factors which can affect the manner in which the MRE will behave; for example, the elastomer matrix will have its own material properties of elastic modulus, density, etc. Therefore, material selection for the elastomer matrix is very important for the viscoelastic behavior of the MRE and similarly the material selected for the micron sized magnetisable particles will have its own affect on the overall MRE behavior. The damping and stiffness properties of aligned MREs depend on the mutual directions of load, magnetic field and the particle alignment in the composite [7].

From available dimensions of drill shank and tail stock spindle, circular aluminum mould dimensions are calculated. The calculated volume of mould is 61.85 ml. The elastomer used for experimentation is prepared by taking 50 ml (volume) of Sylar TIVI 11 silicon base rubber, 10 ml of Iron particle of 5μ (microns) size and 1.2 ml curing agent. All these constituents are taken in beaker and stirred so that semisolid mixture is obtained. When viscosity of mixture becomes exactly double then it is poured in the 61.85 ml aluminum mould. The mould is then kept in magnetic field for 24 hours for curing. For magnetic field two pole stator of D.C. motor is used and magnetic field is applied by providing constant field current of 0.25 ampere. The general arrangement for MR elastomer preparation is shown in Figure2 and Figure3 shows cured MR elastomer with aluminum mould.

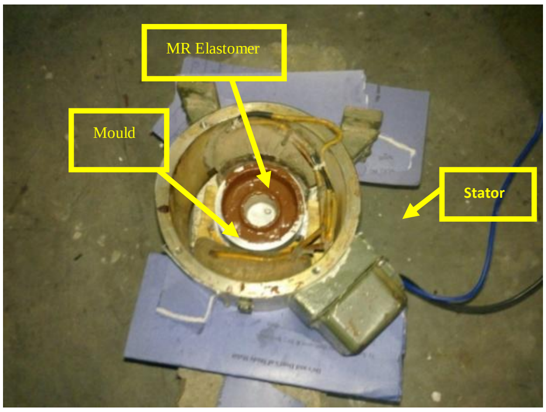

Figure 2: Photograph showing curing arrangement of MR elastomer in magnetic field.

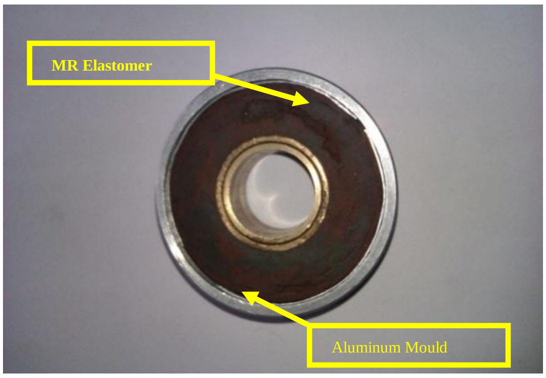

Figure 3: Photograph of mould and elastomer.

3. Experimental

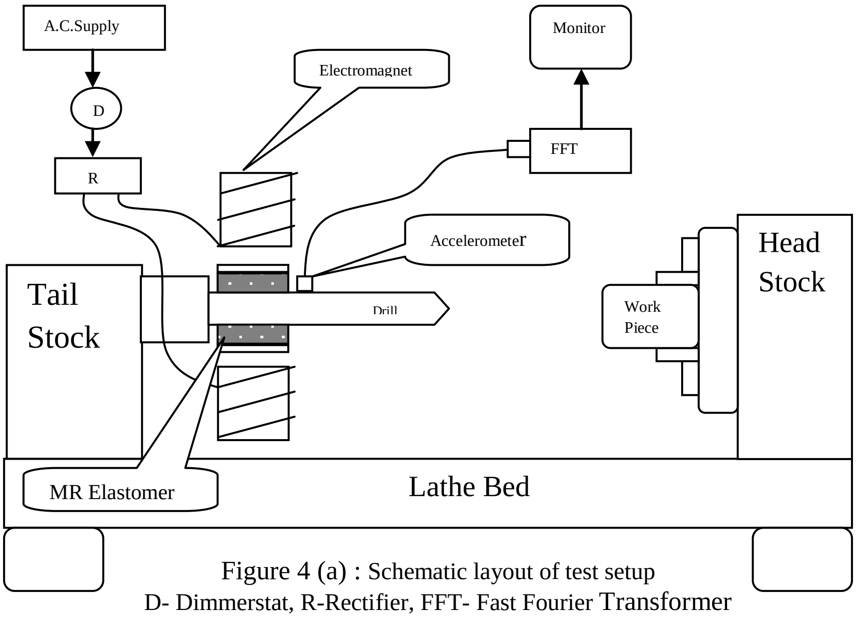

Figure 4 (a) : Schematic layout of test setup
D- Dimmerstat, R-Rectifier, FFT- Fast Fourier Transformer

A schematic layout of test rig is as shown in figure 4(a). The drill with 25mm shank diameter is fitted in tail stock spindle and supported on MR elastomer at centre as shown in figure 4(b). The elastomer is covered with aluminum mould and supported by wooden block as shown in Figure 4(b) so that its horizontal movement is arrested. The magnetic field is applied to elastomer by using stator of D.C. Motor and field strength is varied by varying field current of stator from 0 to 0.25 Ampere through dimmerstat arrangement. The test specimen of plain carbon steel (MS) and Aluminum are selected as shown in figure 5.These specimens have diameter 45mm, length 50mm and blind hole of 10mm diameter.

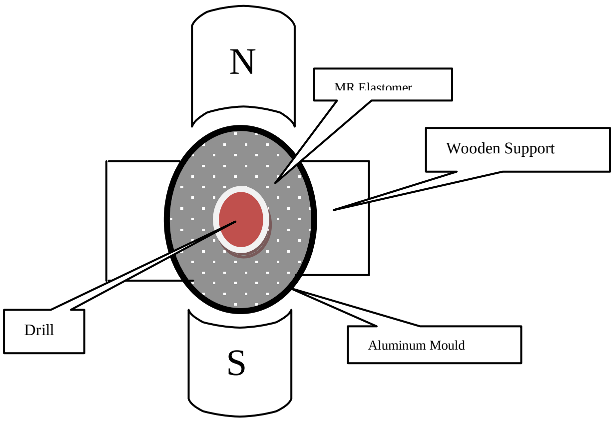

Figure 4(b): Arrangement showing Drill supported on MR elastomer in Magnetic Field.

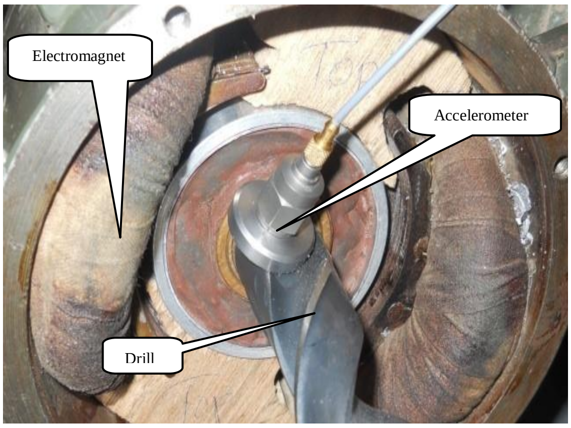

Figure 4 (c): Photograph for showing arrangement of drill, Electromagnet and accelerometer.

Figure 5: Test Specimen

The instruments used in the experiment include Dela-Tron IEPE accelerometer (Type 4514) with 10 mV/g, 1-10 KHz frequency range and ± 500g peak measuring range, B&K FFT analyzer (Type 3050-B-040), model LAN-XI 51.2 KHz with 4 Channel Input module, data acquisition and analysis software (B&K PULSE 14.1.1). The detail experimental procedure is as below; an accelerometer is mounted on drill near shank as shown in figure 4(c) to receive vibration signals in lateral direction. Initially the strength of applied magnetic field is brought zero by varying field current through dimmerstat, lathe spindle speed is set to 600 rpm. Test specimen is adjusted in chuck and blind hole is drilled up to 25mm depth with constant feed rate and vibration signals are transferred to FFT analyzer. The FFT of analog signals and vibration spectrum in time domain are obtained with the help of PULSE 14.1.1 analysis software. The vibration level in RMS (mm/s^2) is recorded. Remaining depth of 25mm is drilled by keeping same feed rate and spindle rpm but applying full magnetic field over MR elastomer by varying field current and vibration level is recorded. The same procedure is repeated by changing test specimen. The vibration responses in time domain are compared to see the effectiveness MR elastomer in vibration control.

4. Result and Discussion

The time vibration spectrums of drilling operation were obtained a for both test specimens, with and without applying magnetic field over MRE. The figure 6(a) and (b) shows the time spectrum for Plain carbon steel (MS) while figure 7(a) and (b) for aluminum. The vibration level in acceleration (mm/s^2) is recorded for both specimens. The acceleration peaks were observed around 0.2S, 0.3S, and 0.4S(S- seconds) on time spectrum for both specimens when the specimens were drilled without magnetic field. These peaks are corresponds to spindle rpm of the lathe machine and when magnetic field is applied the peaks were suppressed considerably. The percentage reduction in vibration level for both materials, having different machineability is calculated and presented in table 1. The significant amount of percentage reduction in vibration level is found for both materials after applying magnetic field.

Material of Test Specimen	Acceleration in RMS(mm/s^2)		
	Without Magnetic Field	With Magnetic Field	Percentage reduction in Vibration Level
Plain Carbon Steel(Mild Steel)	27.3	21.2	22.34%
Aluminum	41.9	32.3	22.91%

Table 1: Vibration level of drill for different operating conditions.

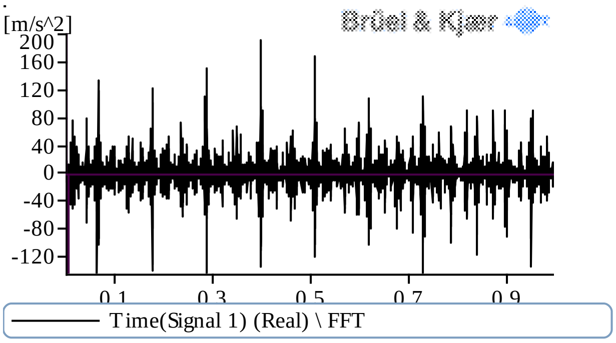

Figure 6(a): Time spectrum for plain carbon steel by without applying magnetic field.

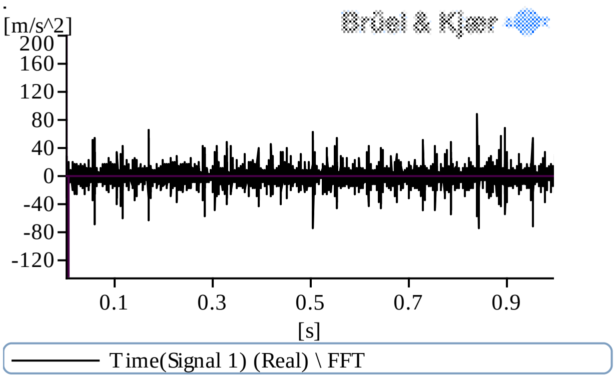

Figure 6(b): Time spectrum for plain carbon steel by applying magnetic field.

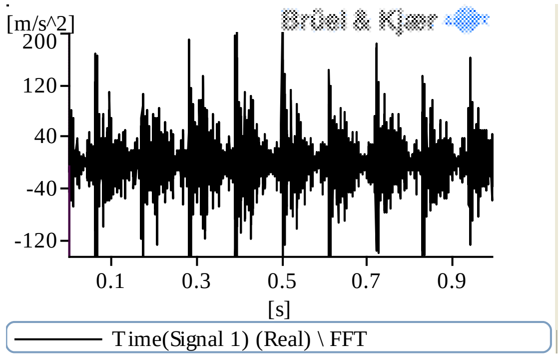

Figure 7(a): Time spectrum for Aluminum by without applying magnetic field.

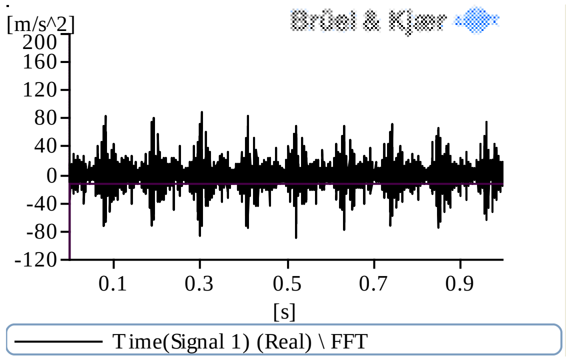

Figure7 (b): Time spectrum for Aluminum by applying magnetic field.

5. Conclusion

In this work the effectiveness of MR elastomer in vibration control of drill on centre lathe is investigated experimentally. It is observed that the prepared MR elastomer is able to absorb about 22% of drill vibrations when magnetic field is applied over MRE during drilling operation for specific cutting parameters however it is necessary to check the vibration absorbing capacity of MR elastomer at different parameters like tool geometry, spindle speeds, feed and specimens with different materials. As there is significant amount of drop in vibration level this work has great deal with application of MR elastomer as a semi-active vibration absorber to control the vibrations of tools during machining operations.

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