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A study of Magneto-Rheological Fluid (MRF) Boring Bar For Chatter Stability

Srilatha[1], Shalaja[2], Shiva Kumar[3]
[1]*Professor, Department of Mechanical, Faculty of HITS ,Hyderabad ,India.*
[2]*Professor, Department of Mechanical, Faculty of HITS, Hyderabad,India.*
[3]*Asso. Professor, Department of Mechanical, Faculty of HITS, Hyderabad India.*

ABSTRACT - *Chatter is a concern in boring process, due to the low dynamic stiffness of long cantilever boring bars. Chatter suppression in machining permits higher productivity and better surface finishes. The MR fluid, which changes stiffness and undergoes a phase transformation when subjected to an external magnetic field, is applied to adjust the stiffness of the boring bar and suppress chatter. The stiffness and energy dissipation properties of the MR fluid boring bar can be adjusted by varying the strength of the applied magnetic field. The focus of this research work is to design and develop the magneto-rheological fluid (MRF) boring bar and test the same for chatter stability during boring process.*

Key words: *Chatter, MR Fluid Boring Bar, Dynamic Stiffness, Boring Process, Surface Finish*

I. INTRODUCTION

The vibration of tools used in machining operations plays a key role in hindering the productivity of those processes. Excessive vibrations accelerate tool wear, cause poor surface finish, and may damage spindle bearings. Chatter is a self-excited vibration phenomenon common in machining. In deep hole boring, the long, cantilevered boring bars have inherently low stiffness. This makes them prone to chatter, even at very small cutting depths. Chatter during the boring process directly influences the dimensional accuracy, surface quality, and material removal rate. Suppressing the chatter effectively in deep hole boring is important.

Research in boring chatter suppression has been conducted during the past several decades. A variety of passive vibration absorbers have been proposed in the literature for boring bars [1]. The passive damping methods require the attachment of a mass– spring–damper system to the boring bar with an identical frequency which needs to be damped. Godfrey used a carbide tool shank with a built-in passive damper to improve the performance of boring bars [2]. Miguelez *et al*. [3] considered the parameters of passive dynamic absorbers into the chatter stability model, and the absorber parameters were determined by optimizing the chatter stability. Yang *et al*. [4] presented an optimal tuning method for multiple tuned mass dampers to increase chatter stability. The parameters of the dampers are tuned to maximize the minimum negative real part of the frequency response function (FRF) at the tool-work piece interface. However, it is difficult to damp several modes with tuned dampers when the space is limited as in the case of boring bars. Furthermore, the natural frequency of the system may differ in each application, and tuned, passive dampers need to be remanufactured for each mode.

The active methods allow damping of several modes simultaneously by adjusting the control parameters of the actuators. Tanaka *et al*. [5] installed eight piezo-actuators into a boring bar for active damping. An accelerometer was used to measure the boring bar vibration at the tool tip, and a velocity feedback controller is implemented to actively damp the vibrations. Redmond *et al*. [6] installed four piezo actuators inside a boring bar with acceleration feedback control for active damping. Pratt and Nayfeh [7] installed two Terfenol-D actuators outside the boring bar and used a dynamic compensator in the control system to make the actuators behave like an active vibration absorber. A survey of the active damping of spindle vibrations is presented by Abele *et al*. [8]. A set of piezo-actuators has been installed behind the outer rings of the spindle bearings for active damping with various control strategies

between the delivered force and the commanded current, and hence, their output must be linearized before they can effectively be used in active damping.

In this study, a semi-active chatter control method is proposed using a MR fluid-controlled chatter suppressing boring bar. The MR fluid-controlled boring bar is first detailed along with the setup. Next, the surface roughness measurements are made of Bronze material with/without Magneto-rheological effect.

II. MAGNETO-RHEOLOGICAL BORING BAR

The boring bar assembly in Fig.1&2 consists of the MR fluid, a cylinder, a non-magnetic sleeve, an electromagnet, and a boring bar with two shoulders, marked as S_1 and S_2. To fabricate this boring bar assembly, the electromagnet is first embedded between the two shoulders of the boring bar and coated with ethoxyline resin. The non-magnetic sleeve and cylinder are then assembled. The MR fluid is poured into the annular cavity and then sealed in by a cap and O-rings. The thickness of the MR fluid layer in the annular cavity is about 1.0mm. The diameter of the boring bar is 20mm, the ratio of length and diameter is 6, and the length of the fixed portion is 160mm.

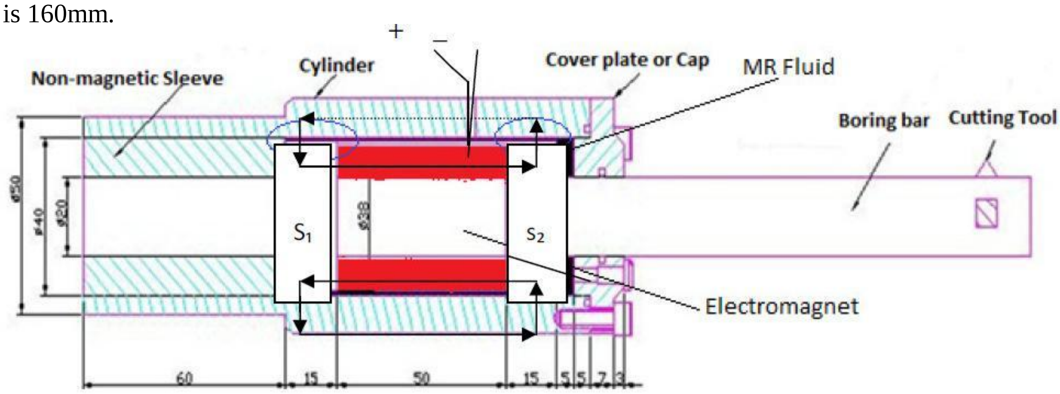
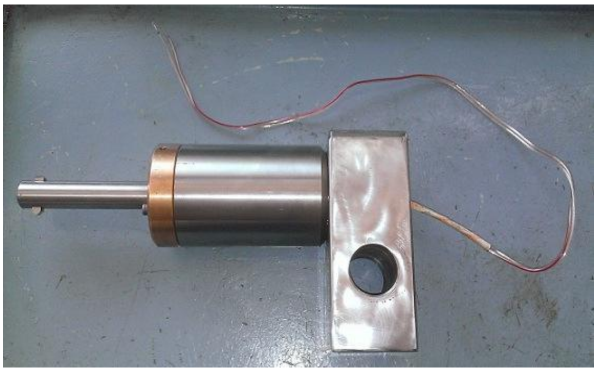


Figure 1 Diagram of Magneto-rheological Fluid Boring Bar

The electromagnet of the magnetic system consists of 200 turns, 24AWG coil wire and was energized by 0.5-2.0A DC as shown in Fig.3. The direction of magnetic flux lines is shown in Fig.1 by the arrow lines. The geometry of the boring bar components was designed with the goals that the magnetic lines of flux are perpendicular to the thin layer of MR fluid in shaft shoulders S_1 and S_2, and most magnetic lines of flux can go through two shoulders, thus enabling better actuation of the MR fluid.



III. EXPERIMENTAL SETUP

It consists of a Magneto-rheological fluid (MRF) boring bar installed on a lathe machine as shown in Fig.4. A regulated power supply shown in Fig.5 was used to supply variable current to the boring bar at constant voltage. A surface roughness tester shown in Fig.6 was used to measure the surface roughness values of Bronze test specimens (Fig.7).

Figure 4 MRF Boring Bar installed on Lathe

Figure 5 Regulated Power Supply

Figure 7 Bronze Test Specimens

IV. RESULR & DISCUSSIONS

The experiments were conducted on Bronze material at two spindle speeds i.e. 775 rpm and 1020 rpm with two MR Fluids i.e. MRF-I (40% magnetisable particles by volume) and MRF-II (36% magnetisable particles by volume). The least Surface roughness value for MRF-I at 775 rpm and 1020 rpm was recorded at current of 1.5A and the highest values at 0A (Table.1). The highest Surface roughness value for MRF-

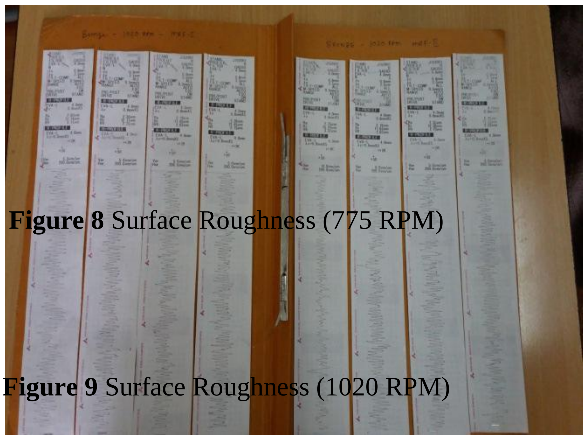


Figure 8 Surface Roughness (775 RPM)

Figure 9 Surface Roughness (1020 RPM)

Table 1 Surface roughness values

BRONZE	775 RPM		1020 RPM	
CURREN(A)	**MRF-I**	**MRF-II**	**MRF-I**	**MRF-II**
0	2.39	2.35	2.6	2.75
1	2.19	2.14	2.35	2.19
1.5	1.96	2.43	2.19	2.35
2	2.33	2.9	2.36	2.16

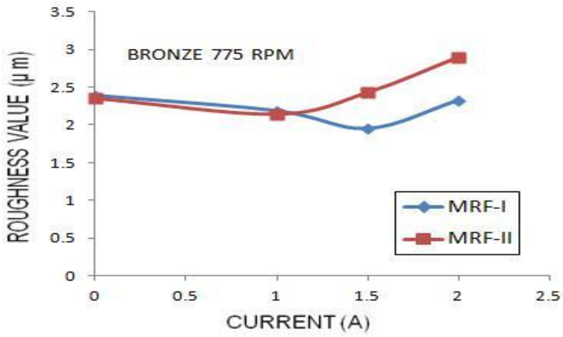


Figure 10 Surface roughness v/s input current at 775 RPM

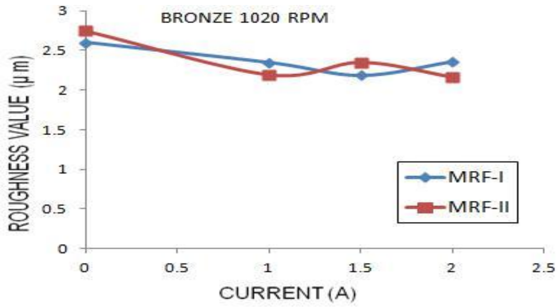


Figure 11 Surface roughness v/s input current at 1020 RPM

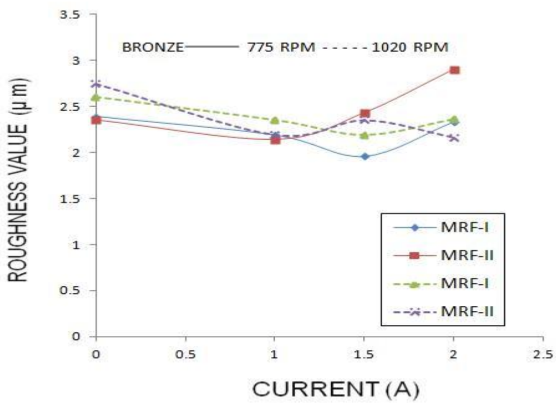


Figure 12 Surface roughness v/s input current

V. CONCLUSIONS

Two different MR fluids with 40% and 36% of magnetisible particles are proposed. A Magneto-rheological Fluid Boring Bar is fabricated and experiments were conducted using the same. The least Surface roughness value of 1.96µm and the highest Surface roughness value of 2.9µm are obtained. It is observed that the optimum Surface roughness value of 2.25µm is obtained at an input current of 1.3A for both MRF-I and MRF-II at both the speeds.

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