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Vibration Minimization Using Electrorheological Damper During Hard Boring.

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Abstract

Hard boring has gained substantial response in metal machining since it has substituted the cycle of traditional process such as boring, heat treatment and finish grinding associated with hard parts. This current research goals at evolving an electrorheological fluid damper for reducing vibrations of tools and endorsing improved machining results during hard boring. The electrorheological fluid performs like a spring having nonlinear vibration features tackled by configuration of electrorheological fluid, the electric parameters of electric field and the shape of plunger. Boring investigations are conducted to attain a set of electrical compositional and shape constraints which will reduce tool vibrations and endorse improved cutting performance throughout boring of steel EN24 of 49 HRC with minimum fluid application. It is perceived that utilization of electrorheological fluid damper decreases tool vibrations and increases boring performance efficiently. In this research it is observed that implementation of electrorheological fluid damper can decrease amount of vibration amplitude up to 81.81%. In future commercialization of this technique will beneficial for machining industries.

Index Terms: Hard boring, Tool vibration, Electrorheological fluid, Electrorheological damper, Surface finish, Tool wear

I. INTRODUCTION

Vibration is undesired but it is a common phenomenon during machining of work piece. These are harmful both to the work piece as well as the system itself. In this research we have conducted experiments to minimize the effect of vibrations during the hard boring process. For high hardness of cylindrical parts, the conventional method is to machine the work piece to near required size then it is hardened as per requirement and then ground to the final size. This is a time-consuming process which can be escaped if toughened work piece is straight away machined to its ultimate measurement. This process is probable by hard turning that substitutes the conventional practice of turning, heat treatment and finish grinding and for gaining of hardware resistant metal parts [1]. Similarly hard boring might yield in low process cost and time, along with good surface quality and less amount of wastage. Hard boring includes huge quantity of cutting fluids. Maintenance of cutting fluid requires huge overheads and it is hazardous to environment. Dry machining is a key aspect to solve this issue as it doesn't necessitate any cutting fluid. Although dry machining needs rigid machine tools and firm cutting which are very expensive to install and maintain

There are number of techniques to reduce the vibrations like isolating, damping, eliminating, absorbing etc. This research shows a state of art technique by using the Electrorheological Fluid for reduction of vibrations. Here a little amount of cutting fluid has been utilized (2 ml/min) this reduces the problems which would have occurred due to the use of large quantity of cutting fluids which is usually practiced in wet machining. Varadarajan et al. [2] noticed that throughout the minimum use of the fluid the overall result was much better compared to the dry turning and traditional turning. Surface finish and tool wear in hard machining are vital parameters to assess the efficiency of machining operations. Tool wears lead to down time of machine, rejection of product and personal problems. Extreme cutting temperature, growth in tool vibration and high cutting force are symptoms of liberal tool wear [3]. While the process of machining desired surface finish is a vital criterion, of the product to achieve required function. The aspect which has maximum impact on the machined surface which may decline the superiority of the surface is the existence of tool vibrations [4, 5]. Due to tool vibrations, there is damage of surface finish as well as cutting tool. Tool vibration produces unpleasant and irritating noise. These extreme tool vibrations while machining will cause poor surface finish increasing the tool wear [6].

II. RELATED WORK

Spencer et al. [7] experimented the Magneto Rheological (MR) damper methods that lessen the tool vibrations while machining, he was one of the first scientist to do this. He noticed that it is highly efficient compared to the traditional viscous damper. Wang and Fei [8] experimented to subdue chatter in boring bar using the non-linear vibration characteristics of ER fluid and established online chatter recognition and control system. The uncertainty that occurs during the metal cutting process is tool vibration that is produced from interaction amongst the dynamics of machine tool and the metal cutting process [9]. Shi [10] et al. has established technique of controlled layer damper for destruction of vibration in thin-walled component milling. Lu et al. [11] have premeditated polishing characteristics of minute grinding wheel based on Fe3O4 ER fluid. Apte et al. [12] have studied effect of electrorheological damper on vibrations during hard turning. Gavin [13] have displayed design method of high force electrorheological damper. The literature survey indicates the utilization of MR and ER damper has verified to be effectual if it is applied appropriately. Implementation of damper in proper manner will result in improved damping action. The present exploration goals to develop an ER damper that implements for hard boring with minimum fluid utilization by conquering tool vibration hence enhancing machining efficiency with decrease in cutting force, tool wear and enhancement in the surface finish etc. Once ER fluids come in contact of an electric field, the fluid gets converted to semisolid with non-linear vibration features that performs as viscoelastic spring. This is completed in few milliseconds and is a reversible change. Cutting experimentations are completed to attain at set of electrical attributes that would decrease the tool vibrations and therefore promote improved cutting results throughout machining of steel EN24 of 49HRC with minimum cutting fluid submission utilizing hard metal insert. The ER fluid damper developed appears to lower tool vibrations to enhance machining performance.

This experiment which is designed for hard boring by utilizing minimum fluid can also be further implemented to improve boring performance for normal boring operations.

III. METHODOLOGY

The methodology of the experiment is carried out in different steps.

A. *Selection of work material.*

The material used for work piece is steel EN24 that is hardened to 49 HRC by heat treatment. This material has a wide variety of applications. In present investigation four work pieces of Ø 50mm outer diameter and Ø30mm inner diameter, 150mm length are used for boring. The chemical configuration of steel EN24 material in mass percent is 0.45%C, 0.70%Mn, 1.80%Ni, 1.40%Cr, 0.35Mo, 0.35%Si. The tolerance for boring is H7 $35^{+0.030}_{+0.000}$

B. *Selection of tool.*

The tool holder has specification R 174-29-2525M. Boring tool with specification 135 1212 P30 2R.

C. *Design and manufacturing of ER damper.*

ER fluids are manageable fluids that can be controlled. The property of these fluids is that they are capable to transform from liquid to semisolid and vice versa within milliseconds, when exposed to electric field. On application of electric field, the adjacent particles polarize and intermingle to form chains allied to electric field. This mechanism is shown in figure 1.

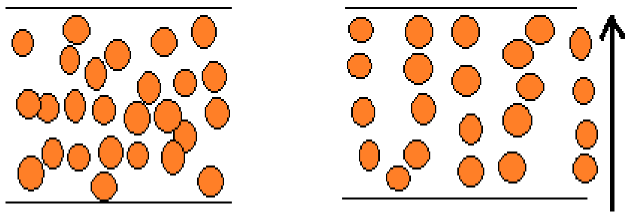

Figure 1 a Figure 1 b

Prior to application of electric field. and structure of ER material after application of electric field.

Due to change in phase fluid gets convert from liquid to semisolid state. The ER fluid viscosity rises with the strength of electric field and when electric field disappears ER fluid again turns back to its liquid state. This transformation takes place within milliseconds. Photograph of ER damper is presented in figure 3. It consists of a plunger that passes through the cup containing ER fluid. ER effect is achieved by applying current through ER fluid. Threads are made at both sides of plunger, similarly the attachment made to hold plunger rigidly with tool. When ER fluid comes in contact with high voltage and low current it offers opposition to movement of plunger due to which tool vibrations gets damped. The damping action achieve on following aspects

i) viscosity of fluid medium ii) size of particles included in ER fluid iii) voltage strength applied to fluid iv) type of voltage and current applied to fluid (D.C.)
For preparation of ER fluid alumina and titanium dioxide nano particles are used. Nano particles are mixed with various carrier oils like silicone oil, transformer oil, mineral oil, castor oil to form different types of suspensions. All suspensions are tested using Rheometer (Anton Paar). The suspension which has shown highest dielectric strength, better viscosity and less sedimentation is chosen to use in ER damper. In present work suspension of alumina nano particles mixed in silicone oil as carrier fluid has shown highest dielectric strength, better viscosity and less sedimentation hence it is chosen to use in ER damper.

Experimental Setup and work

In this research cutting experiments are implemented on the Kirloskar turn master lathe. A 6-run experiment is designed and conducted based on Taguchi technique. Boring operations are performed on four different specimens. D.C. voltage from 1KV to 5KV is applied during experimentation to illustrate the effect on tool vibrations using ER damper. The Design matrix is presented in table 1. The performance of ER damper during boring operations for different specimens with respect to different parameters like the vibration, cutting force, surface finish, and tool wear are represented in figure 4, 5, 6 and 7 respectively. Figure 2 shows the setup of the experiment and figure 3 represents the ER Damper.

Figure 2. Experimental Setup

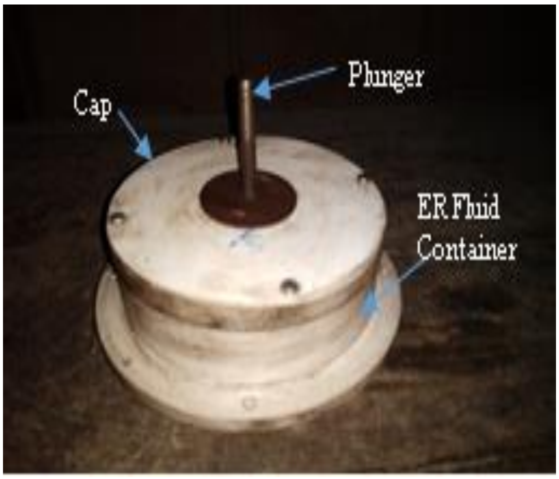

Figure 3 Electrorheological Damper

Experiments are conducted using inverted conical shaped plunger and are repeated on four specimens to increase accuracy of results. The average results of these four specimens are expressed in table 2. Percentage improvement in results is given in table 3. Cutting force is measured using standard electronic tool dynamometer. The external diameter of work piece is measured by micrometer. The measurement of surface roughness is done by stylus type surface roughness tester. Vibrometer is utilized to measure vibration amplitude which is fixed at top of tool holder and the measurement of tool wear is done by the digital vernier caliper. Optimum cutting velocity is kept 84 m per min, cut depth of 1mm and feed rate 0.12mm per min. Design matrix is presented in table 1 where S1, S2, S3, S4 are four sample specimens. E0 (without damper), E1 (20mA, 1KV), E2 (30mA, 2KV), E3 (40mA, 3KV), E4 (50mA, 4KV) and E5 (60mA, 5KV) are different strengths of electric fields.

Table 1. Design matrix for six run experiments

Sr. No	Parameters	No. of specimens			
	D.C. Electric field strength	Specimen 1	2	3	4
1	E0 (Without Damper)	S1	S2	S3	S4
2	E1 (1KV,20mA)	S1	S2	S3	S4
3	E2 (2KV,30mA)	S1	S2	S3	S4
4	E3 (3KV,40mA)	S1	S2	S3	S4
5	E4 (4KV,50mA)	S1	S2	S3	S4
6	E5 (5KV, 60mA)	S1	S2	S3	S4

IV. RESULTS AND DISCUSSION

Boring experiments are implemented with same specified input parameters with and without damper and are expressed in figure 4 to 7. The comparative consequence of input attributes on tool vibration amplitude is illustrated in figure 4. Tool vibration amplitude gets reduced as voltage gets increased. The comparative presentation of input parameters on cutting force is illustrated in figure 5. Cutting force gets reduced as voltage gets increased. Likewise, the performance of input attributes on surface finish and tool wear is presented by figure 6 and figure 7 respectively. It is observed that tool wear gets reduced due to use of ER damper and surface finish shows improvement due to use of ER damper. The experimental results are analyzed to gain lower value of tool vibrations amplitude, cutting force, surface roughness and tool wear.

Average evaluation of cutting performance of boring operation for the two conditions with and without damper is illustrated in table 2. Comparative percentage evaluation of cutting performance of boring operation for these conditions is illustrated in table 3. It is observed that implementation of ER damper can decrease value of vibration amplitude up to 81.81%, reduction in cutting force up to 23.24% and reduction in tool wear up to 58.4% during boring operation. Also, implementation of ER damper shows improvement in surface finish up to 51.35% during boring operation.

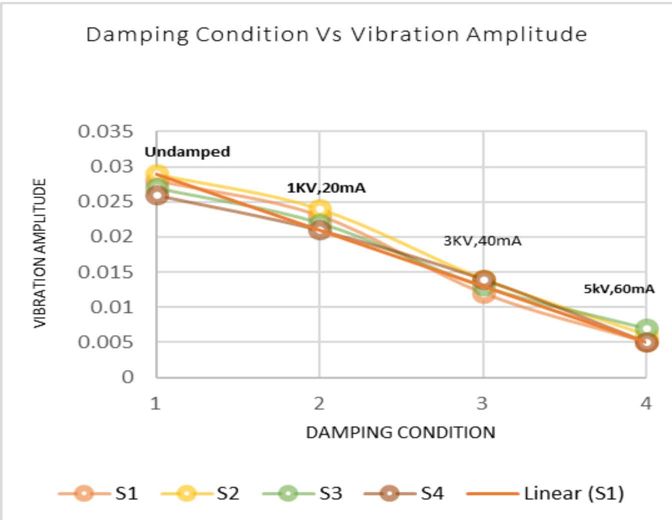

Figure 4 Consequences of Damping Condition on Vibration Amplitude.

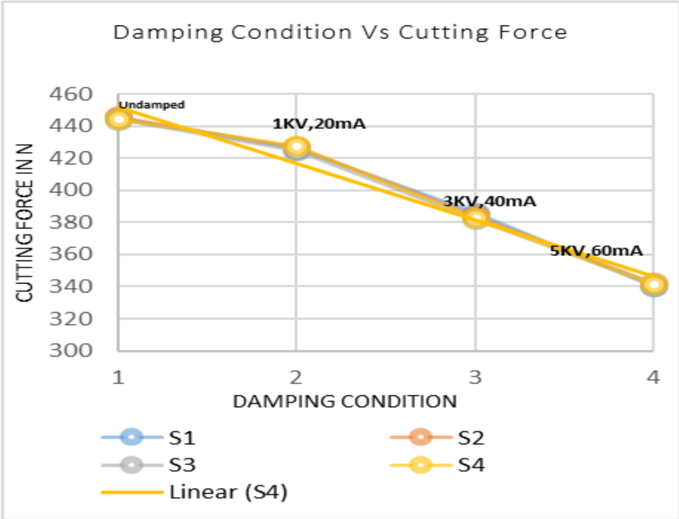

Figure 5 Consequences of Damping Condition on Cutting Force.

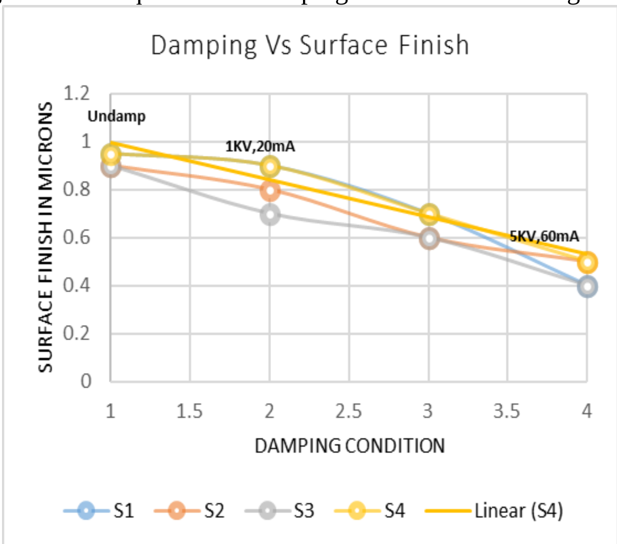

Figure 6. Consequences of Damping Condition on Surface Finish.

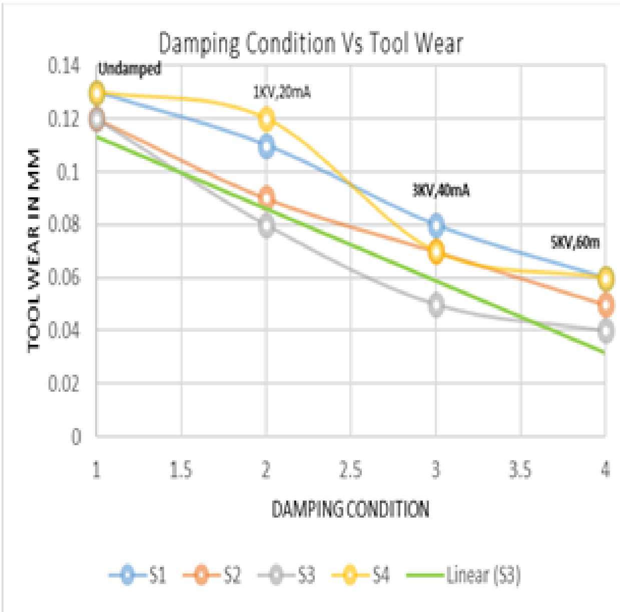

Figure 7 Consequences of Damping Condition on Tool Wear.

Table 2. Average observed readings of 1 to 4 specimens

Sr. No.	Parameters	Amplitude of vibrations in mm	Cutting force in N	Tool wear in mm for 1 mm cut	Surface finish in µm
1	Undamped	0.0275	444.8	0.125	0.925
2	1KV 20mA,	0.0225	426.3	0.100	0.823
3	2KV,30mA	0.0178	405.05	0.0837	0.737
4	3KV, 40mA	0.0132	383.8	0.0675	0.650
5	4KV, 50mA	0.0095	362.45	0.0610	0.560
6	5KV, 60mA	0.0057	341.1	0.0525	0.450

Table 3. Comparative results in percentage form

Sr No	Parameters	Without damper	With damper	**Percentage Improvement**
1	Vibration amplitude in mm	0.0275	0.005	**81.81**
2	Cutting force in N	444.8	341.1	**23.24**
3	Tool wear in mm	0.125	0.052	**58.4**
4	Surface finish in µm	0.925	0.45	**51.35**

From average of all readings of four sample specimens it is observed that D.C. supply voltage of 5KV and 60 mA shows highest damping capacity as strength of electric field is maximum due to supply voltage. Greater is the strength of electric field due to higher supply voltage, better damping capability. But an applied voltage must be less than break down voltage of used suspension. Also, high voltage might create rise in temperatures and may cause some safety issues. During hard boring operation there is chance of higher cutting forces which decreases performance of cutting tool.

The utmost noticeable element of cutting force is the central cutting force which is towards the downward direction. The system that resists the movement of tool in downward direction provides superior damping. This damping will decrease the difficulty of machine tool structure and offer good damping action and increase the entire energy to execute machining operation. Due to damping of tool on work piece the irregularities of surface decrease and improvement in surface finish is observed which reduces possibility of crack instigation. The life of the tool grows with the increase of dynamic rigidity of the cutting tool due to the growth in stiffness of tool rather than the tool working under vibrating conditions. An ER fluid made of silicone oil and alumina nano particles shows improved machining performance. A better surface finish is obtained by the fluid with greater viscosity which offers more resistance to the movement of plunger. In observations of the present investigation are alumina particles in silicone oil gives decrease in tool wear and good machining performance with power consumption of 300 watts.

At 5KV there is good distribution of ER particles to provide improved opposition to movement of plunger leading to a reduction in tool wear and enhancement in surface finish.

V. CONCLUSION

In this research experiments are conducted on four sample specimens with and without ER damper which is designed and verified for the effect of tool vibration amplitude, tool wear, surface finish and cutting force during hard boring by applying minimal fluid. The performance of boring thus achieved using ER damper is matched with the boring performance of traditional minimal fluid utilization without ER damper. Maximum power requirement of ER damper in present investigation is 300Watts.

The important conclusions drawn are:

1. From average of readings on four sample specimens it is observed that an ER fluid damper is able to enhance surface finish, suppress tool vibration amplitudes, decrease in tool wear and cutting force also stimulate overall cutting performance effectually while hard boring.

2. To gain improved machining results like reduction in tool vibration amplitude, tool wear, cutting force and improvement in surface finish the ER fluid suspension of alumina nano particles in silicone oil charged with direct current.

3. In future this technique can be established into a device that might offer adaptable damping to the cutting tool to attain the finest machining performance as desired with great accuracy and gives assurance for capitalization.

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REFERENCES

[1] Byrne G, Dornfeld D, Denkena B. Advancing Cutting Technology. CIRP Annals-Manufacturing Technology. 2003;2(52):483-507.

[2] Alaxender A, Varadarajan AS, Philip PK. Hard turning with minimum cutting fluid: a viable green alternative on the shop floor. InProc. of the 18th AIMTDR 1998 (pp. 152-155).

[3] Paul PS, Varadarajan AS. A multi-sensor fusion model based on artificial neural network to predict tool wear during hard turning. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 2012 May;226(5):853-60.

[4] Ghani AK, Choudhury IA. Study of tool life, surface roughness and vibration in machining nodular cast iron with ceramic tool. Journal of Materials Processing Technology. 2002 Sep 20;127(1):17-22.

[5] Arizmendi M, Campa FJ, Fernández J, de Lacalle LL, Gil A, Bilbao E, Veiga F, Lamikiz A. Model for surface topography prediction in peripheral milling considering tool vibration. CIRP annals. 2009 Jan 1;58(1):93-6.

[6] Altintas Y, Ber AA. Manufacturing automation: metal cutting mechanics, machine tool vibrations, and CNC design. Appl. Mech. Rev. 2001 Sep 1;54(5): B84-.

[7] Spencer Jr B, Dyke SJ, Sain MK, Carlson J. Phenomenological model for magnetorheological dampers. Journal of engineering mechanics. 1997 Mar;123(3):230-8.

[8] Wang M, Fei R. Chatter suppression based on nonlinear vibration characteristic of electrorheological fluids. International Journal of Machine Tools and Manufacture. 1999 Dec 1;39(12):1925-34.

[9] Paul PS, Varadarajan AS. Effect of magneto rheological damper on tool vibration during hard turning. Frontiers of Mechanical Engineering. 2012 Dec 1;7(4):410-6.

[10] Shi J, Song Q, Liu Z, Wan Y. Formulating a numerically low-cost method of a constrained layer damper for vibration suppression in thin-walled component milling and experimental validation. International Journal of Mechanical Sciences. 2017 Aug 1; 128:294-311.

[11] Lu JB, Yan QS, Tian H, Kong LY. Polishing properties of tiny grinding wheel based on Fe3O4 electrorheological fluid.

[12] Aditi Apte, Chetan S. Jarali, S. Raja, S.S. Kulkarni, "Vibration minimization using electrorheological damper during hard turning", International Journal of Mechanical Engineering and Technology (IJMET) Volume 12, Issue 2, February 2021, pp. 1-9.

[13] Gavin HP. Design method for high-force electrorheological dampers. Smart Materials and structures. 1998 Oct 1;7(5):664. Journal of Materials Processing Technology. 2009 Jun 21;209(11):4954-7.

[14] Krishna, V. Murali. "Heat Transfer Enhancement by using CuO-Water Nanofluid in a Concentric Tube Heat Exchanger-an Experimental Study." International Journal of Mechanical Engineering (IJME) 6.1 (2017): 11-20.

[15] Matrawy, K. K. "Modeling and Performance Evaluation of an Indirect Solar Desalination System." International Journal of Mechanical Engineering (IJME) 6.4 (2017): 1-14.

[16] Rishipal, Swarna Torgal, M. P. Kamath, and A. S. Joshi. "Simple Technique for Fabrication of Toroidal Surface with a Bender and Cylindrical Polishing Machine." International Journal of Mechanical Engineering (IJME) 6.4 (2017): 15-26.

[17] KUSHWAHA, DIGVIJAY, et al. "EVALUATION AND OPTIMIZATION OF CUTTING PARAMETERS, FOR TURNING OF EN-8 STEEL: A TAGUCHI APPROACH." International Journal of Mechanical Engineering (IJME) 6.4 (2017) 35-44

[18] LUHULIMA, RICHARD B. "AN INVESTIGATION INTO THE RESISTANCE OF DISPLACEMENT TRIMARAN: A COMPARATIVE ANALYSIS BETWEEN EXPERIMENTAL AND CFD APPROACHES." International Journal of Mechanical Engineering (IJME) 6.5 (2017) 9-18

[19] Shamin, M. K. "MORPHOLOGICAL AND STRUCTURAL STUDY OF FRICTION STIR WELDED THIN AA6061-T6 SHEETS." International Journal of Mechanical Engineering 6.5 (2017): 19-24.

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