FEA BASED MODELING OF MAGNETO RHEOLOGICAL DAMPER TO CONTROL VIBRATIONS DURING CONTOUR MILLING

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ABSTRACT

In determining the vibrations and deflections occurring during end milling process, the modeling and structural behavior plays an important role. The geometry of an end mill tool is complex. To overcome the complexity of the analysis, a simple beam model is considered. In this work the modeling of structure of an end mill is carried out and by the application of Finite Element Methods. The Static analysis has been performed in order to determine the deflection and suppress the vibration of end mill cutter so that the work piece will not have waviness on the surface, leading to minimization of chatter encountered during machining. The effect of dynamic response of the end mill tool is studied with and without the application of MR damper. Metal cutting operation involves interaction of cutting forces of the tool with the regenerative forces of the material of work piece during metal cutting. To control the end mill tool vibration and suppress the chatter, the method incorporates the unique features of a magnetic-rheological fluid, utilizes the damper input current to modify the magnetic field inside the coil of the damper and increase the variable stiffness and produce damping effect. In this work, the identification of chatter is done by means of the magnetic-rheological fluid. The different metal cutting parameters are considered in experimental work and results are compared with and without the application of magnetic-rheological damping effect. The results show the enhancement of quality of the machined surface, reduction of deflection of the end mill tool and decrease in the chatter marks on work piece by producing magnetic-rheological damping to the end mill tool. The damper input current is varied from 0 to 2 Amps, which modifies the rheological damping effect to the end mill at different machining parameters and the results are validated with finite element analysis software ANSYS 11.0. It is inferred that experimental results are in good agreement with results in ANSYS. It is seen that ANSYS can predict the value of deflection very accurately with a variation of 3% to 5% of the actual value, indicating the validity that ANSYS for the analysis of both H.S.Steel and Carbide cutter in case of four flute end milling under different machining conditions. The effectiveness of the MR damper is used in an end milling operation and it is successfully established in the project.

1. INTRODUCTION

The most important and common machining operation in the production industry is the end milling operations. It is used for various operations like face milling, plain milling, angular milling, form milling, profile milling, etc. According to a study the dynamic position of the cutting tool affects the parameters like surface roughness, chip removal rate etc. The roughness depends mainly on depth of cut and feed rate. As the radial and axial depth of cut increases, there is an increasing in the cutting force and the vibration of the tool. Due to the vibration of the tool, chatters occur in the surface of the work piece. The chatter may affect machining parameters, tool wear, waviness-poor surface quality, inaccuracy, reduction in metal removal rate. To overcome the issue of chatter during the milling operations, a study was conducted to understand the machine, cutting tool and work piece. The issue of vibration can be solved by making the cutting tool as rigid as possible. Therefore MR damper was used in order to analyze the effect on cutting tool in conventional milling operations. Experimental work has been done with different machining parameters are measured from the milling tool with and without the applications of the MR damper. The main objective of this work is to minimize the surface roughness with the inputs of depth of cut to the work piece and voltage to the MR damper connected to the cutting tool.

1.1 MILLING OPERATION

Milling is the process of machining flat, curved, or Milling machines are basically classified as vertical or irregular surfaces by feeding the workpiece against a rotating horizontal. These machines are also classified as knee-type, cutter containing a number of cutting edges. The milling ram-type, manufacturing or bed type, and planer-type. Most machine consists basically of a motor driven spindle, which milling machines have self-contained electric drive motors, mounts and revolves the milling cutter, and a reciprocating coolant system, variable spindle speeds, and power-operated adjustable worktable, which mounts and feeds the workpiece.

1.2 HSS END MILL CUTTER

High speed steel is a type of steel that is commonly used as a cutting tool material. It is often used in power saw blades. The new high-carbon steel tools are better than the older tools used extensively through the 1940s because they can withstand higher temperatures without losing their temper (hardness). This property allows HSS to cut faster than high carbon steel, hence its name, high speed steel. At room temperature, under their commonly recommended heat treatment, HSS grades typically exhibit high hardness (above Rockwell 60) and abrasion resistance (typically associated with tungsten and vanadium, often used in HSS) compared to conventional carbon and tool steels.

1.3 TIALN COATED CARBIDE END MILL CUTTER

Carbide inserts are the most common because they are good for high performance milling operations. High speed steel is commonly used for tooling that is not commonly used for high production processes. Ceramics inserts are often used in high-speed machining with high production. Diamond inserts are commonly used in products requiring tight tolerances, usually consisting of high surface quality. Although most TiAlN and ALTiN coatings are industrially synthesized using alloy targets with specific percentages of aluminum and titanium, it is possible to produce TiAlN coatings with pure Al and Ti targets using a cathodic deposition technique.

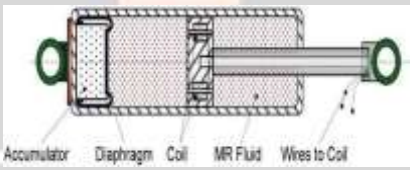
1.4 MILLING PROCESS

The experiment is to test the effectiveness of the magneto-rheological damper for end milling. The principle, usage range, and applications of each instrument used in the experiment are detailed below. A multi-meter is a console device used for service work with high precision. The two probes are insulated wires with pointed tips. The voltmeter is used to test the circuit and the results are displayed on a digital screen. A ball bearing is the component that uses a ball to help keep the surfaces moving in the bearing separated. The purpose of ball bearings is to reduce rotational friction and axial loads. The damper usually sits at the eye end of the pedal. During machining, use a 6 mm inner diameter ball bearing to hold the end mill shank at the eye end of the damper, and the inner groove rotates with the machine tool spindle. This experiment will study how magneto-rheological substances change when subjected to pressure.

EXPERIMENTAL SETUP

2. MAGNETO – RHEOLOGICAL DAMPER

The MR damper is a semi-active device that contains magneto-rheological fluid. The fluid helps to control the movement of the damper, and it can be seen in the figure. MR Fluid consists of sunflower oil, and ferrous particles. When voltage is applied to the coil of the damper, tiny magnetic dipoles are scattered in the fluid in the form of ferrous particles. These dipoles align along the magnetic flux lines, creating a damper. The MR fluid state changes from a liquid to a semi-solid state which will absorb the vibration of a cutting tool. We can control the damping rate of the damper by changing the voltage applied to the coil. MR Fluid is composed of sunflower oil, and iron particles.



MR DAMPER

3. MODELING AND FINITE ELEMENT ANALYSIS OF AN END MILL CUTTER

The static characteristics of tool can be obtained by using finite element analysis. In determining the vibrations and deflections occurs during end milling process, the modeling and structural behavior plays an important role. The geometry of an end mill is a complex to represent this, simple model of a beam is considered in the analysis. In this section modeling of structure of an end mill is carried out in SOLIDWORKS modeling software package and analysis has been using finite element method software ANSYS 11.0. The static analysis has been performed in order to evaluate the deflection of the cutter for 2 and 4 flutes of HSS and carbide end mill cutter. The effect of response of the end mill is studied with and without the application of MR damper. High cutting forces, tool breakage, part-tool deflections and chatter vibrations are the common reasons for reduced productivity and quality in many milling operations. The metal cutting forces recorded from milling tool dynamometer was used to determine structural deformations. Another very important limitation in milling is the self-exited chatter vibrations and overhangs length which causes poor surface finish and tool life results in reduced productivity. Deflection of end mills may cause precision less milled parts. These deflection needs to be check in order to evaluate potential compensation of the errors on machine tools. This section discusses the static analysis of two-flute and four-flute end mill tools. A cantilever model of the beam is assumed for the static analysis of the cutters under cutting load. Therefore, the primary objective of static analysis of the cutter is to determine the maximum deflection at the tool tip during end milling process. The deflection of the end mill tool is an important factor affecting the accuracy of machining dimensions and on the selection of metal cutting parameters. Although the deflection affects adversely the accuracy of the work piece, the flexibility of cutter is required in attenuating the overload in a transient situation during machining. In order to perform static analysis for models of the two-flute and four-flute cutters. Two models have been developed in SOLIDWORKS modeling software to determine the maximum deflection for two and four flutes end mills.

4. FINITE ELEMENT MODELING AND STATIC ANALYSIS OF END MILL CUTTER.

In the static analysis the end of the shank of the milling cutter is fixed in all degrees of freedom with cantilever model is used in the present work. Modeling and analysis of end mill cutter is done using FEA software ANSYS 11. The analysis software helps in determining the deflection of the end mill due to the metal cutting forces recorded during machining. Several iterations for solving the analytic procedure has been carried out for the material properties like Young's modulus and density of carbide and HSS tool, they are 605 and 200 GPa with densities 13500 Kg/m3 and 8600 Kg/m3 , For both the materials of the tool poison ratio was taken as 0.3. When the cutting forces are applied at the tool tip it will acts as a cantilever load which helps in determining the amount of deflection and compare the results with analytical solution. The maximum deflections occurred and the results are compared with and without the application of the MR-Damper by using ANSYS simulation of end mill with HSS tool with two and four flutes.

(a) (b) (c)

Fig -1 (a) 2 Flutes **Fig -2** (b) 4 Flutes mesh model **Fig -3** (c) Deformed and non-deformed of an end mill cutter

4. RESULTS AND DISCUSSION

HSS TOOL

HSS 0V **HSS 6V**

HSS 12V

CARBIDE TOOL

CARBIDE 12V

From this picture, we are showing the surface finish of the workpiece with the help of damper we could arrest the vibration of the end milling cutter.

6. CONCLUSIONS

From the above experimental observations, we could see the decay of vibrations at each voltage levels. And the finished jobs prove the damping of vibration by showing better surface roughness values at each voltage levels. Thus, the vibrations in this milling machine is damped using the MRF damper. The same type of damper structure cannot be used for other machines, so the futuristic vision of this project could be done by integrating this type of damper in the various machines. The damper can be altered in geometry for fitness inside the machine or while manufacturing the machine itself, the damper type mechanism could be installed in it for use in future to preserve its life and also to provide better surface roughness. Hence the result of this project satisfies the need of better surface roughness. The result clearly indicates that the presence of magneto rheological fluid can reduce surface roughness effectively. This smooth surface limits the risk of crack and reduces tool wear effectively through the reduction in cutting force and tool vibration parameters. From the experimental results it was observed that the magneto rheological fluid reduces tool wear when compared to a condition in which the tool holder was not provided with a magneto rheological fluid system.

7. REFERENCES

- Guillem Quintana, Joaquim Ciurana Chatter in machining processes: A review Int. J. Machine and Manufacture., **51**, 363–376 (2011)
- Chunmei and Weina Liu Semi-active Fuzzy Control for Machine Tool Vibration. Int. Conference on Mechanics, Materials and Structural Engineering (ICMMSE 2016)
- Hakeemuddin Ahmed, N. Seetharamaiah, M. Manzoor Hussain Effect of MR Fluid Damping during Milling of CFRP Laminates. Int. J. Engineering Research and Application. 37–41 (2016)
- Davood Sajedi Pour, Saeed Behbahani Semi-active fuzzy control of machine tool chatter vibration using smart MR dampers., **83**:421–428 (2016)

- A.K.M Nurul Amin, Anayet U. Patwari1, M.S. Sharulhazrin, and I. Hafizuddin (2010) Investigation of Effect of Chatter Amplitude on Surface Roughness duringEnd Milling of Medium Carbon Steel. Proceedings of the Int. C. Industrial Engineering and Operations Management Dhaka, Bangladesh, January 9 – 10 (2010).

- A. Parus, B. Powalka, K. Marchelek, S. Domek, M. Hoffmann Active vibration control in milling flexible workpiece, J. Vib. Control. **19**. 1103–1120. (2013)

- G. Urbikain, L.N.L. deLacalle, A. Fernández Regenerative vibration avoidance due to tool tangential dynamics in interrupted turning operations J. Sound Vib **333** 3996– 4006. (2014)

- M. Wiercigroch, M. BudakE, Sources of nonlinearities, chatter generation and suppression in metal cutting, Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. **356**, 663–693 (2001)
- J. Munoa, X. Beudaert, Z. Dombovari, Y. Altintas, E. Budak, C. Brecher, G. Stepan, Chatter suppression techniques in metal cutting, CIR PAnn. Manuf. Technol. **65** 785–808 (2016)

- G. Urbikain, F.-J. Campa, J. Zulaika, D. L. López, M.- Alonso, V. Collado Preventingchatter vibrations in heavy-duty turning operations in large horizontal lathes, J. SoundVib. **340**, 317–330 (2015)

- M. Siddhpua, R. Paurobally, A review of chatter vibration research in turning, Int. J. Mach. Tools Manuf. **61** 27–47 (2012)

- Sadak Ali Khan, A. Suresh, N. Seetha Ramaiah Principles, Characteristics and Applications of Magneto Rheological Fluid Damper in Flow and Shear Mode 1547– 1556 (2014)

- Zekeriyaparlak Tahsin, Ismail, Calli, Optimal design of MR damper via finite element analysis of fluid dynamic and magnetic field Journal Intelligent Mechatronics **22**,890–903 (2012)

- S. Elizabeth Premalatha, R. Chokkalingam, M. Mahendran Magneto Mechanical Properties of Iron Based MR Fluids American Journal of Polymer Science **2**(**4**): 50– 55 (2012)

- Haifeng Ma, Jianhua Wu, Liuqing Yang, Zhenhua Xiong Active chatter suppression with displacement-only measurement in turning process Journal of Sound and Vibration. **401** 255–267 (2017)