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Original Research Article

Effect of magnetic field on damping ability of magnetorheological damper during hard turning

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ABSTRACT

Tool vibration is a frequent problem in the manufacturing industry where metal cutting operation takes place. It affects the surface finish of the work piece, tool life, and produce irritating noise. In order to restrain tool vibration in metal cutting, it is necessary to develop and analyze suitable methods which increases stability and also improves the cutting performance. Magnetorheological damper has received great attention due to their ability to reversibly change from a free flowing, linear, viscous liquid to a semi-solid when exposed to magnetic field in just few milliseconds and also found to be effective on suppressing tool vibration. The present investigation aims at studying the effect of magnetic field on the damping abilities of the magnetorheological (MR) damper during hard turning operation. MR damper was characterized and the effect of magnetic field on damping ability of MR damper and cutting performances like tool vibration, cutting force, cutting temperature, tool wear and surface roughness were analyzed. From the result, it was observed that direction of magnetic field parameter on magnetorheological damper reduces tool vibration effectively and brought forth better cutting performance.

1. Introduction

In turning operations the cutting tool is subjected to a dynamic excitation due to the deformation of work material during the cutting operation. The relative dynamic motion between the cutting tool and the workpiece will affect the result of the machining, in particular the surface finish. The identification of tool vibration as a limitation for machining was initially found by Taylor [1]. The regeneration of waves on the workpiece was identified as a potential cause of chatter in turning, by Arnold [2]. Tool vibration related problems are of great interest in turning operations [3,4]. Tool vibration is a result of the dynamic interaction between the tool and the

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workpiece that is present during the machining process causing instability in the cutting process. In machining, tool vibration have to be reduced because excess vibration will increase the tool wear which will in turn reduce the tool life and also produce poor surface finish in the machined workpiece [5]. Since the tool life and the surface finish of the workpiece is of greater prominence and concern in the manufacturing industry, greater attention has been given to reduce amplitude of tool vibration. The vibration that is produced during the machining process can be sub-divided into a few categories. Amongst the different chatters, self-excited vibration is actually of greater concern. The dynamic interaction between the cutter and the workpiece during a turning process causes self-excited vibration. Self-excited vibration begins to vibrate of their own accord spontaneously; the amplitude will increase until some nonlinear effect limits any further increase [6]. They are generally classified into primary and secondary chatter [7]. Primary chatter is not of greater importance and they are caused because of the friction between tool-workpiece, thermo-mechanical effect or by mode of coupling. The secondary chatter is caused by the regenerative wavy surface on the workpiece and is the most destructive among all the other vibrations [8]. Modulation effects in waviness usually caused by the tool vibrating radially relative to the component or axially is mainly due to the self excited vibration between the tool and the work piece. Self-excited vibrations are characterized by the presence of a mechanism whereby a system will vibrate at its own natural or critical frequency, essentially independent of the frequency of any external stimulus.

Magnetorheological fluids belong to a class of controllable non-Newtonian fluids. When MR fluids are exposed to magnetic field they change from a free flowing linear viscous liquid to a semi-solid state in just few milliseconds [9]. Lord Corporation [10] developed MR fluid shock absorbers for automobiles and it was observed that such shock absorbers can vary levels of chatter, shock and motions instantly. Investigations on boring tool holder with MR damper has been performed by Sathianarayanan et al. [11] and it has been observed that the damper application reduces the chatter and improves the stability of the boring operation. Chatter could be suppressed more effectively by adjusting the damping and natural frequency of the system using MR fluid dampers [12]. Also surface finish and cutting performance has been improved effectively by considering MR damper during hard turning [13]. The intensity of the magnetic field produced will determine the viscosity of the MR damper [14] and they are capable of replicating this process for infinite number of times. Sam Paul and Varadarajan [15] studied the effect of MR damper on the amplitude of tool vibration and they observed that MR damper reduces tool vibration effectively by adjusting the controlling parameters like the shape of the plunger, viscosity of the oil and particle size.

In the present investigation, an attempt was made to study the effect of magnetic field on the damping ability of magnetorheological damper during hard turning operation. When an electric field is applied to the MR fluids, the fluid becomes a semisolid and this transition is reversible and can be achieved in a few milliseconds. Cutting experiments were conducted to arrive at a set of electrical and material parameters that can develop better damping force during turning of AISI 4340 steel of 46 HRC using hard metal insert with sculptured rake face which in turn reduces the amplitude of tool vibration effectively and brought forth better cutting performances.

2. Development of magnetorheological fluid damper

A magnetorheological fluid (MR fluid) is a type of smart fluid, where iron particles usually in the size of micron or nano are suspended uniformly in a base fluid of certain viscosity. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a viscoelastic solid. Magnetorheological dampers are a specific type of semi active suspension components that uses electric current to generate the magnetic field. The present investigation aims at characterization of the MR damper and the changes that are developed in the damping ability of MR fluid damper when there is a change in the direction of magnetic field.

2.1. *Fabrication of magnetorheological damper*

Magnetorheological (MR) damper consists of a conical plunger (Fig. 1) which moves inside the cylinder (Fig. 2) containing MR fluid. Other end of the plunger will match with the thread cut on the hole of the tool holder. MR fluid will be magnetized by passing current through the coil. A coil is wound around the outer surface of the cylinder, where current will be applied. When the coil is energized, MR fluid is activated and offers resistance to the motion of the plunger, thereby damping the tool vibration. In the initial stage of the present study, the effect of material on the damping ability of MR damper was investigated. Accordingly two different materials namely OHNS steel and stainless steel 410 were selected based on their properties.

Fig. 1 – Piston with piston head.