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Online vibration suppression in lathe machine

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ABSTRACT

Purpose: The main objective of the project is to reduce the vibration of the tool and to increase the accuracy of the component. The efficiency of the tool and precise machining can be increased by this project.

Design/methodology/approach: In this project sensors and vibration exciter are used.

Findings: In order to suppress the vibration, sensors are placed on top of the tool and vibration exciter is placed at the bottom of the tool. The sensors will sense the vibration of the tool and the vibration exciter will generate opposite vibration force to suppress the vibration of the tool. By doing this we can acquire good surface finish of the components.

Practical implications: The better surface finishes, increased tool life are obtained as the result of online vibration suppression, this methodology provides the simple and flexible control of vibration over conventional complex methods and the system adopt itself for variation in process parameters more over it is economically feasible.

Keywords: Vibration; Vibration suppression; Lathe machine; CNC; Machine tool

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MANUFACTURING AND PROCESSING

1. Introduction

In turning operations, vibrations are a common problem as they affect productivity and performance of the machine tool. Due to the occurring vibrations, the geometrical accuracy as well as the surface quality is reduced. Furthermore severe acoustic noise is emitted and the tool life also reduced. It is well known that vibration problems are correlated to the dynamic stiffness of the machine tool structure and the work material. The vibration problems can be reduced to some amount by proper machine design which stiffens the machine structure. This is most often correlated with an increase of mass which is in contradiction to the demand for small and light structures. Smart actuators and intelligent structures receive a considerable interest in the fields of machining, in order to realize new or more efficient functions than passive structures. In these fields, there are needs for actuators that offer high mechanical energy density (product of stroke and force divided by the volume), a low power consumption, a resistance to severe environment as well as other cases by case needs: High resolution (micro-machining), fast response (active control of structures shape, active damping of vibration) [1-3].

By the development of the electronic technology it is possible to sense and response to the vibration. The vibration exciters and accelerometer are available in wide range of frequency to reduce the vibration of the tool. By providing equal and opposite vibration force the vibration of tool will be controlled. The vibration is sensed by accelerometer; accordingly the vibration exciter will provide the opposite vibration.

2. Proposed methodology

In this project the main objective is to reduce the vibration of the tool and to increase the accuracy of the component. While machining the component the tool will get vibrated in order to reduce the vibration of the tool and to get good finishing of the component we are using accelerometer and vibration motor. Accelerometer is kept at the top of the tool and vibration motor is kept at the bottom of the tool.

Accelerometer will sense the vibration of the tool and the vibration motor will produce equal and opposite vibration to reduce the vibration of the tool. The portion of the tool which is nearer to work piece will vibrate more when compared to the portion of the tool which is nearer to the tool post. Therefore the vibration motor will be kept accordingly to reduce the vibration of the tool.

3. Literature review

Eric T. Falangas, J.A. Dworak, and Shozo Koshigoe [4] has laid emphasis on Controlling Plate Vibrations Using Piezoelectric Actuators. Active damping method using piezo electric actuators is shown in Figure 1.This study focuses on control design methods that can be used for driving piezoelectric actuators (PZTs). The PZTs are bonded on the plate structure to remove vibration energy from the plate. The goal of this study is to demonstrate vibration damping on a metal plate by means of an experiment.

The purpose of the experiment was to demonstrate the capability of using distributed sensors, actuators, and real-time active digital controls for attenuating vibrations in plate structures. PZTs were selected for providing the local moments on the plate because of their low weight, volume, and cost and their capability to respond at high frequencies (3 to 5 kHz). Models of PZTs bonded or embedded in beams or plates have been developed. Accelerometers were used for sensing the motion at various parts of the plate. Accelerometers rather than PZTs or PVDFs were chosen for sensors because of availability. These are small, about one square centimetre in size, and also made out of piezo-electric material. The accelerometers were collocated with the PZTs.

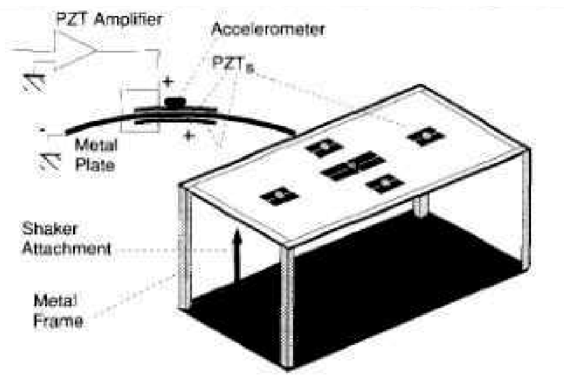

Fig. 1. Active damping using piezo-electric crystals

Seung-Hi Lee, Member, IEEE, Chung Choo Chung, Member, IEEE, and Choong Woo Lee has laid emphasis on Active High-Frequency Vibration Rejection in Hard Disk Drives [5]. So far, several techniques have been applied to deal with the resonance mode. Measuring the disturbances with accelerometers, one can design feed forward control to reject the effect of external vibrations. In accelerometers attached on the disk drive frame (or PCB) was used to measure the rotational component of external vibrations. Strain sensors attached on the surface of the suspension were used to measure suspension vibration. A strain-type sensor was attached to the actuator such that the flexible modes are detected while the rigid body mode is not sensed. A strain-feedback controller was proposed to overcome the mechanical limiting the servo bandwidth. This paper presents an AVR control technique to reject actuator arm resonance modes using a PZT sensor attached to the actuator arm to detect high-frequency off-track actuator vibration. In the proposed AVR (active vibration rejection) scheme, the VCM (voice coil motor) is used as an actuator, while the piezoelectric sensor is used as a sensor (Fig. 2).

The vibration control signal is synchronized with the slow state feedback control input such that the two control signals are summed and applied to the VCM. No control command is to be applied to the PZT. The sampling rate of position error signal is not affected by the implementation of the proposed scheme.

Fig. 2. Compound actuator with PZT MA used for vibration sensing

4. Overall system model and components used

The part drawings and the assembly drawing were generated with the help of Pro/E modelling software and paint shown in Figures 3 and 4 The part description is given below.

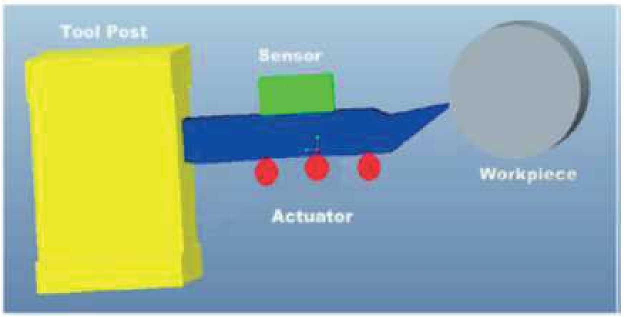

Fig. 3. Pro/E model setup

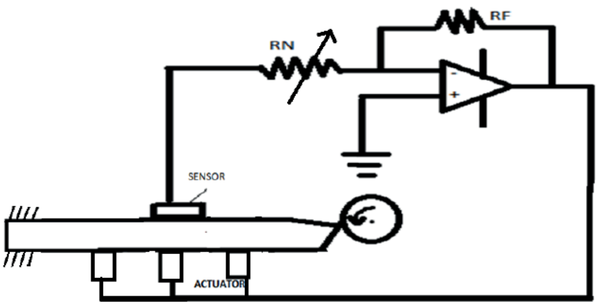

Fig. 4. Detailed description of the setup

4.1. Potentiometer

A potentiometer measuring instrument is essentially a voltage divider used for measuring electric potential (voltage). It informally a pot, is a three-terminal resistor with a sliding contact that forms an adjustable voltage divider If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.

Potentiometers operated by a mechanism can be used as position transducers. Potentiometers are rarely used to directly control significant power (more than a watt), since the power dissipated in the potentiometer would be comparable to the power in the controlled load.

The resistive element of inexpensive potentiometers is often made of graphite. Other materials used include resistance wire, carbon particles in plastic, and a ceramic/metal mixture called cermets. Conductive track potentiometers use conductive polymer resistor pastes that contain hard-wearing resins and polymers, solvents, and lubricant, in addition to the carbon that provides the conductive 7 properties.

4.2. Operational amplifier

An operational amplifier (op-amp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals.

4.3. Vibration sensor (accelerometer)

An accelerometer is a device that measures proper acceleration. Single- and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration as a vector quantity, and can be used to sense orientation coordinate acceleration vibration, shock, and falling in a resistive medium (a case where the proper acceleration changes, since it starts at zero, then increases Micro machined accelerometers are increasingly present in portable electronic devices and video game controllers, to detect the position of the device or provide for game input.

4.4. Vibration motor

Vibration motor is a compact size coreless DC motor used to inform the users of receiving the signal by vibrating. The vibration motor is the magnet coreless DC motor is permanent. Moreover, the noise and the power consumption that the motor produce while using are low. The rotor is the non-stationary part of a rotary electric motor. The wires and magnetic field of the motor are arranged so that a torque is developed about the rotor's axis. The stator is the stationary part of a rotary electric motor. It could be worked as the magnet field and interact with the armature to create motion. Another function of the stator is it could act as the armature. A commutator is a rotary electrical switch in certain types of electric motors or electrical generators that periodically reverses the current direction between the rotor and the external circuit. The armature is a set of thin metal plates stacked together, with thin copper wire coiled around each of the three poles. The main function of the armature is to convert the magnetic energy into the kinetic energy. In motor's shaft, the brushes conduct the current between stator and coils.

5. Working of the project

5.1. Problem identification

Some of the key problems, which were identified for the initiation of this project, are:

a) Now a day in every machine structure (especially in lathe) the vibration is controlled by means of providing the damping effect.
b) The damping effect itself not sufficient to control the vibration for accurate operation.
c) The accuracy the component is not sufficient to meet the needs.

5.2. Objectives

The primary objectives, upon which, the project is based are to control the vibration induced in lathe machine tool and there by increases the accuracy and surface finish of the machined components.

5.3. Brief working

The project consists several components they are accelerometer-to sense the vibration of the tool, vibration motor-to produce opposite vibration in order to reduce the vibration of the tool, trimmer potentiometer, resistor, operational amplifier.

In lathe as the work piece is rotating member and the tool is the fixed member. The tool is fixed in the tool post which is used to machine the work piece. It is holded by chuck. While machining the component the tool will get vibrated in order to reduce the vibration of the tool and to get good finishing of the component we are using accelerometer and vibration motor. Accelerometer is kept at the top of the tool and vibration motor is kept at the bottom of the tool.

Accelerometer will sense the vibration of the tools and that signal will send as input to the variable resistor and then the signal will send to operational amplifier IC 741 through the pin no 2 which is an inverting terminal and pin no 3 which is non inverting terminal is connected to ground. Vibration amplitude over its length in cantilever structure is shown in Figure 5.

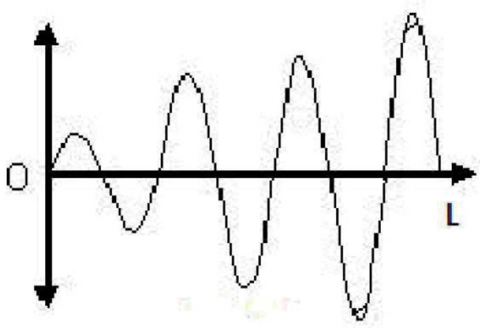

Fig. 5. Vibration amplitude over its length in cantilever structure

Operational amplifier will amplify the signal and produces the output voltage. The output voltage of the operational Amplifier is feedback by using feedback resistor in order to match the required signal.

Then the output signal from op-amp is send as input to all the vibration motor of various eccentric mass which is kept at the bottom of the tool. The vibration motor will produce equal and opposite vibration in order to reduce the vibration of the tool and thereby increasing accuracy of the component.

The portion of the tool which is nearer to work piece will vibrate more when compared to the portion of the tool which is nearer to the tool post. Therefore the vibration motor with various eccentric mass will be kept accordingly. The input requirement for the each motor will vary according to that the operational amplifier will vary its gain and give that signal as the input to the vibration motor and the motor will generate opposite vibration to reduce the vibration of the tool effectively. The active control of vibration of machine tool is shown in Figure 6.

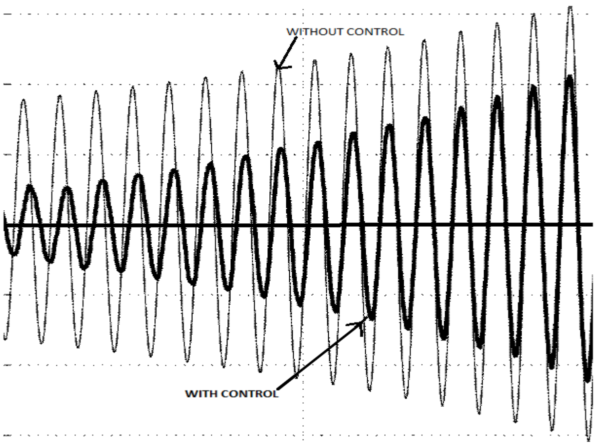

Fig. 6. The active control of vibration

5.4. Photographic view of the setup

The experimental setup photographic view is shown in Figures 7 and 8.

Fig. 7. The Experimental setup

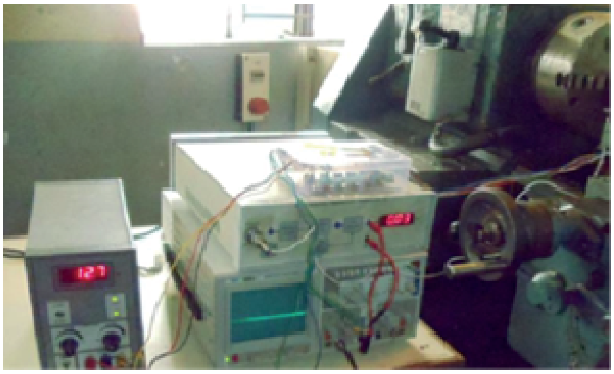

Fig. 8. The Experimental setup

6. Design calculation

Cutting parameters for finishing for different materials:
Cutting speed ranges from (20-450) m/min;
Feed rate ranges from (0.07-0.3) mm/rev;
Spindle speed = speed/circumference;
Depth of cut = 0.125-0.2 mm;
Induced vibration force = 3-5 N;
Sensor output=10 mv/g;
Output frequency range = 0.3 Hz-15 Hz;
Output voltage range = 0-5.8 V;
Op-amp dead time = 0.3 ns;
Gain factor= Rf / Ri = desired and varied by pot;
Placing point = no such standards choose closely to origin of vibration.

7. Results and discussion

- The amplitude of vibration is significantly reduced.
- Due to the hysterisis effect of piezo-sensor the expected outcome is affected.
- The cantilever structure length is high in conventional lathe as compared to CNC lathe it increases the amplitude of vibration.
- With the high mechanical power density of actuator we effectively reduce vibration in CNC.

8. Conclusions

Thus, the better surface finishes, increased tool life are obtained as the result of online vibration suppression, this methodology provides the simple and flexible control of vibration over conventional complex methods and the system adopt itself for variation in process parameters more over it is economically feasible.

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