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Study of Vibration in Milling Process

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ABSTRACT

Milling operates on the principle of rotary motion. A milling cutter is spun about an axis while a workpiece is advanced through it in such a way that the blades of the cutter are able to shave chips of material with each pass. Milling processes are designed such that the cutter makes many individual cuts on the material in a single run; this may be accomplished by using a cutter with many teeth, spinning the cutter at high speed, or advancing the material through the cutter slowly. Most often it is some combination of the three.

Introduction

The basic function of milling machines is to produce flat surfaces in any orientation as well as surfaces of revolution, helical surfaces and contoured surfaces of various configurations. Such functions are accomplished by slowly feeding the workpiece into the equispaced multiedge circular cutting tool rotating at moderately high speed as indicated in Fig.1. Upmilling needs stronger holding of the job and downmilling needs backlash free screw-nut systems for feeding.

Milling machines of various type are widely used for the following purposes using proper cutting tools called milling cutters :

• Flat surface in vertical, horizontal and inclined planes
• Making slots or ribs of various sections
• Slitting or parting
• Often producing surfaces of revolution
• Making helical grooves like flutes of the drills
• Long thread milling on large lead screws, power screws, worms etc and short thread milling for small size fastening screws, bolts etc.
• 2-D contouring like cam profiles, clutches etc and 3-D contouring like die or mould cavities
• Cutting teeth in piece or batch production of spur gears, straight toothed bevel gears, worm wheels, sprockets, clutches etc.
• Producing some salient features like grooves, flutes, gushing and profiles in various cutting tools, e.g., drills, taps, reamers, hobs, gear shaping cutters etc.

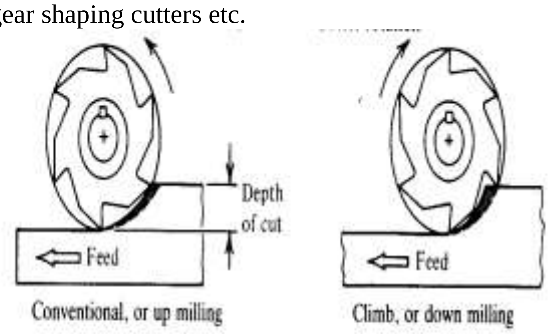

Fig.1. Schematic views of conventional up and down milling

Increasing competitiveness and gaining a greater productivity and a better quality has been determined by increasing the performance of machine tools, of cutting tools and of designing and machining process. Given that these conditions the appearance of vibration is inevitable in the cutting process dynamic especially in the milling process. The vibrations analysis has long been used for the detection and identification of the machine tool condition. Also, the predictive maintenance is directed towards recognizing the earliest significant changes in machinery condition. Because of this, particular interest is the dynamic models of cutting in tridimensional conditions to provide stability information necessary to optimize existing processes work on the current market [Antonialli et al, 2010], [Engin et al, 2001]. This research is a part of a larger project of developing a dynamic three-dimensional cutting model by integrating the moments generated by cutting process [Cahuc et al, 2009], [Zapciu et al, 2009]. In a first step we are interested in analyzing the dynamic behavior of the mill tool and to obtain a complete method of monitoring the evolution of cutter teeth during the cutting process. By using modern acquisition systems and signal processing we are focused on the analysis of the contact tool/chip/workpiece so we can analyze the quality of work at any time of the cutter teeth.

Experimental Setup

As material passes through the cutting area of a milling machine, the blades of the cutter take swarfs of material at regular intervals. This non-continuous cutting operation means that no surface cut by a milling machine will ever be completely smooth; at a very close level (microscopic for very fine feed rates), it will always contain regular ridges. These ridges are known as revolution marks, because rather than being caused by the individual teeth of the cutter, they are caused by irregularities present in the cutter and milling machine; these irregularities amount to the cutter being at effectively different heights above the workpiece at each point in its rotation. The height and occurrence of these ridges can be calculated from the diameter of the cutter and the feed. These revolution ridges create the roughness associated with surface finish.

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Gang milling refers to the use of two or more milling cutters mounted on the same arbor (that is, ganged) in a horizontal-milling setup. All of the cutters may perform the same type of operation, or each cutter may perform a different type of operation. For example, if several workpieces need a slot, a flat surface, and an angular groove, a good method to cut these (within a non-CNC context) would be gang milling. All the completed workpieces would be the same, and milling time per piece would be minimized.

Gang milling was especially important before the CNC era, because for duplicate part production, it was a substantial efficiency improvement over manual-milling one feature at an operation, then changing machines (or changing setup of the same machine) to cut the next op. Today, CNC mills with automatic tool change and 4- or 5-axis control obviate gang-milling practice to a large extent.

To achieve this research an experimental device is designed to obtain the dynamic information provided by the system: machine/tool/workpiece. The experiment were performed on a 3 axis CNC vertical machining center with 11 kW of power in the spindle motor and a maximum speed rotation of 8000 rpm. Wait for our goal the recording data of vibrations and cutting forces signals in the same time with rotational speed is absolutely necessary. A Kistler 9257B stationary dynamometer Quartz 3-Component, a National Instruments NI USB-6216 analogical/digital data acquisition board and Fastview software were used for three axis cutting force measurements. A three-dimensional PCB piezoelectric accelerometer fixed on the workpiece and a B&K unidirectional piezoelectric accelerometer placed on the spindle in radial direction, a National Instruments NI USB-9162 analogical/digital board and Fastview software were used for vibrations measurement.

The speed of rotation is achieved through a laser sensor tachometer. The signals were processed with Fastview program, application developed with Digitline Company. Before starting the dynamic analysis of the tool in cutting process, the characterization of the machine is necessary in order to identify the dynamics of the assembly spindle – bearings.

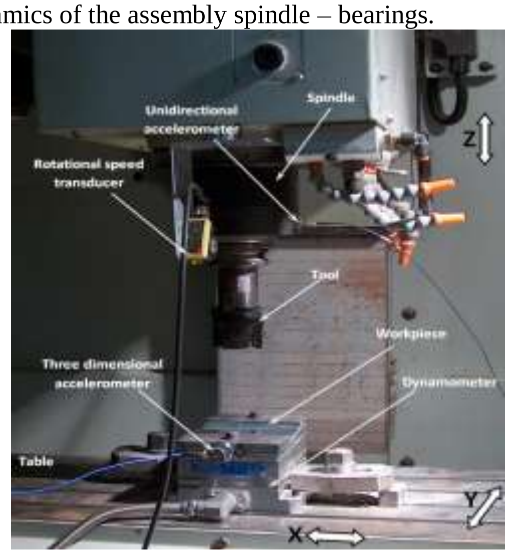

Fig. 2. Experimental setup

Features of the research object

A vertical milling centre VMC FADAL 4020HT (made in USA) has beenchosen as an object of the research. It seems to be a modern milling machine (Fig. 4), in case of which an investigation of implementation of vibration control strategies is fully reasonable. Though it satisfies conditions, they concern:

dynamic properties of the carrying system. A feature of modern machine tools is rigid carrying system whose influence on dynamics of the cutting process ismeagre;

- dynamic properties of the main driving system. Small inertia of the system is required, which puts in principal position structures with short kinematic chains and motor installed directly on the spindle (so called: electrospindles).

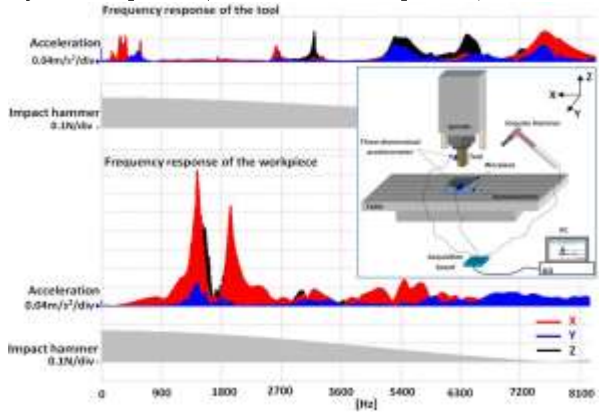

Fig.3. Hammer impact test setup for the tool and workpiece.

Leading producers of machine tools offer such solutions as above. In case of the VMC FADAL, its main driving system is composed of: contemporary vector asynchronous motor with optimal phase regulation, two-speed belt transmission and short, rigid spindle; production process, in which, due to a danger of the *chatter* occurrence, some problems with technological criteria (e.g. surface quality, tool life, productivity) being satisfied, are observed. The phenomena may occur during the milling by using long tools (end mills, ball end mills) and drilling deep holes (at drill diameter being increased). Any, more simple rules of the counteraction (e.g. diversification of edges' pitch) cannot be considered in this case;

Fig. 4. Vertical milling centre FADAL

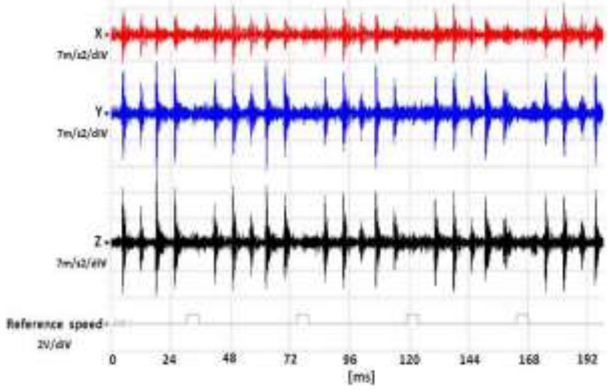

Fig.5. Vibration cutting signal for x, y and z direction for 0.5 mm depth of cut

Results And Analysis

The study is focused on dynamic behavior analysis of the mill cutter during the cutting process with 0.5 mm and 1 mm depth of cut. Before applying the enveloping method requires the identification of dynamic frequencies that occur in the cutting process.

Conclusion

The aim of this paper, which was depended upon assessment of abilities of two strategies of tool-workpiece *chatter* vibration surveillance, has been performed. The strategies described in the paper for control of vibration are observed during real machining operations. The first strategy, which is based on matching the spindle speed to optimal phase shift between two subsequent passes of tool edges, is limited for applications. The efficiency of one can be observed only for short time of machining process (~0.5 sec), when the *chatter* vibration is undeveloped. The developed chatter vibration can not be suppressed using this strategy. The

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