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An overview of data acquisition system for cutting force measuring and optimization in milling

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Abstract: This paper presents an approach, for the systematic design of condition monitoring system for machine tool and machining operations. The research is based on utilising the genetic optimization method for the on-line optimization of the cutting parameters and to design a programme for the signal processing and for the detection of fault conditions for milling processes. Cutting parameters and the measured cutting forces are selected in this work as an application of the proposed approach.

Keywords: Optimization, Acquisition, Ball-End Milling, Cutting Process

1. INTRODUCTION

One of the most significant developments in the manufacturing environment is the increasing use of tool and process monitoring systems. Many different sensor types, coupled with signal processing technologies are now available, and many sophisticated signal and information processing techniques have been invented and presented in research papers. However, only a few have found their way to industrial application. The aim of this paper is to present the cutting force measurement system for the ball-end milling. The system is based on LabVIEW software, the data acquisition system and the measuring devices (sensors) for the cutting force measuring. The system collects the variables of the cutting process by means of sensors and makes transformation of those data into numerical values. Generally used measuring devices for cutting force measuring are piezoelectric dynamometer. Delivered signals are distorted due to their self dynamic behaviour. Their dynamic characteristics are identified under normal machining operation. The proposed method is based on the interrupted cutting of a specially designed workpiece that provides a strong broadband excitation. The three components of the exciting force and the acceleration of the gravity centre of the dynamometer cover plate are measured simultaneously. The measured values are delivered to the computer programe through the data acquisition system.

The data obtained from the acquisition system, are a basis for the optimization of the machining process - cutting parameters.

2. CUTTING FORCE MEASURING

The present world market competition has attracted the manufacturer's attention on automation of manufacturing systems for condition monitoring of machine tools and processes for the improving of the quality of products, eliminating inspection, and manufacturing productivity [1].

Successful condition monitoring system depends, to a vast extent, on the ability of the system to identify any abnormalities and respond, on-line, with an appropriate action. A condition monitoring system, as shown in Figure 1 consists of sensors, signal processing stages, and decision making systems to interpret the sensory information and to decide on the essential corrective action.

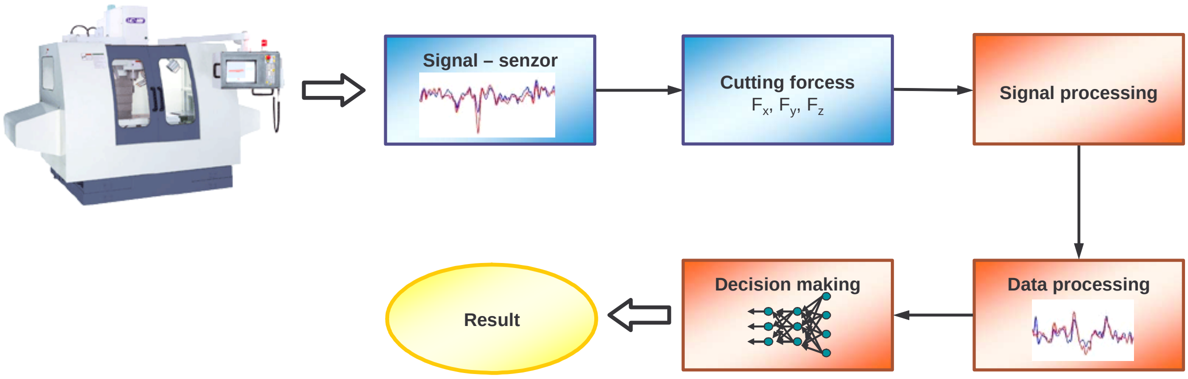

Figure 1. Monitoring system

The purpose of this paper is to presents the system for the cutting force measuring in milling. The force generated during machining process is an important parameter, which reflects the machining conditions. The most frequent approach taken to milling process monitoring is to attach sensors to the machine and then monitor the signals obtained from these sensors.

With a cutting force acquisition system, the cutting process can be monitored easily. The data acquisition system frequently commences with experiments using a table force dynamometer which quantifies the actual force exerted on the milling tool during the cutting process. Using different cutting tools and different cutting conditions, the tool which generates the smaller force is expected to be the more effective in cutting. With this system, different tools of different mechanical properties can be tried out on the same workpiece, enabling a suitable cutting tool to be chosen. The objectives of this paper are to design a system for the cutting forces measuring in milling. The results show that the methodology outlined in this paper can be used to reduce the cost and complexity of the condition monitoring system and the number of sensors required for fault identification of milling cutters without compromising the system's ability to detect cutter faults. The approach, however, can be used for other operations and faults with minimal modification.

3. SYSTEM FOR THE CUTTING FORCE MEASUREMENT

The system for the cutting force measurement presents the data acquisition system, LabVIEW software, and the results measured cutting forces. The data acquisition system used in this experimental model consists of dynamometer, fixture module, hardware and software module.

A significant amount of research has been based around the measurement of cutting forces [2-5]. Force measurements are commonly taken using a table mounted dynamometer during machining. These dynamometers measure the cutting force in three mutually perpendicular directions notationally the X, Y and Z axis. The dynamometer is clamped between the workpiece and the table or pallet.

The dynamometer system is composed of a dynamometer (Kister Model 9255), a multi-channel charge amplifier (Kister Model 5001) and their connecting cable. When the tool is cutting the workpiece, the force will be applied to the dynamometer through the tool. The piezoelectric quartz in the dynamometer will be strained and an electric charge will be generated. The electric charge is then transmitted to the multi-channel charge amplifier through the connecting cable. The charge is then amplified using the multi-channel charge amplifier. In the multi-channel charge amplifier, different parameters can be adjusted so that the required resolution can be achieved.

Essentially, at the output of the amplifier, the voltage will correspond to the force depending on the parameters set in the charge amplifier. The interface hardware module consists of a connecting plan block, analogue signal conditioning modules and a 16 channel A/D interface board (PC-MIO-16E-4). In the A/D board, the analogue signal will be transformed into a digital signal so that the LabVIEW software is able to read and receive the data. The voltages will then be converted into forces in X, Y and Z directions using the LabVIEW program. The LabVIEW data acquisition module is based on a PC computer, and is a general-purpose programming system with an extensive library of functions and subroutines for any programming task. It also contains an application specific library for data acquisition, serial instrument control, data analysis, data presentation, and data storage [6].

4. SIGNAL ANALYSIS

The kind of signal analysis methods used is of some importance. Sometimes it looks as if some researchers think that if the measured signal is acceptable then it would be possible with a clever diagnostic tool to solve everything. Unfortunately this is not the case. The diagnosis always needs to be based on reliable and meaningful information and this is where signal analysis can help by providing effective features as a basis for diagnosis.

The role of signal analysis could be described as a tool which tries to pick up the meaningful information out of the mass of information. In many cases the dilemma is that the more sophisticated methods need a lot of raw signals and it takes time to collect this raw material and it also takes time to perform the calculations. Consequently, many of the most sophisticated methods are not suitable, e.g. for tool breakage monitoring. In addition, the results with a sophisticated analysis function are influenced by the cutting process, i.e. workpiece material, type of tool, feeding and cutting speed which makes the diagnosis more demanding. On the other hand, very simplistic methods are fast to use and often not that sensitive to changes in cutting conditions.

5. FUTURE DEVELOPMENTS

The continuing development of efficient manufacturing systems requires a greater degree of process optimisation. Tool wear and tool breakage problems constantly disrupt these processes. On-line tool condition monitoring strategies utilising multi-signal inputs to monitor and diagnose tool condition are being researched and should be encouraged.

The use of artificial intelligence, in particular neural networks, seems to be the way forward in the handling of both a multi-signal and a multi-model strategy. The earlier research into cutting process monitoring is still valid but now many of the methods can be combined into one comprehensive strategy. To do so it is important that established researchers who are familiar with the nature of the cutting process and those who operate within the area of intelligent systems engineering come together and meet with industrial machine tool users and manufacturers to develop a strategy for the advancement in this area.

Overall there seems to be the possibility that the next generation of monitoring tools can be engineered to fit into the control strategies used in the design of advanced machine tools. As such, truly intelligent monitoring systems will be capable of working with the machine to continuously optimise the cutting process. In this area the most promising approaches would seem to be those which will utilise, and indeed share, the signals used to control the elements of the machine tool as the basis of process monitoring. Work in this field is continuing to provide more reliable, robust and responsive tool condition monitoring systems which are needed in modern manufacturing systems. They are much needed, and must be developed if truly automated manufacturing is to develop further.

6. CONCLUSION

The increase in awareness regarding the need to optimise manufacturing process efficiency has led to a great deal of research aimed at machine tool condition monitoring. This paper also considers the application of condition monitoring techniques to the detection of cutting tool wear and breakage during the milling process. Established approaches to the problem are considered and their application to the next generation of monitoring systems is discussed. A many approaches are identified as being key to the industrial application of operational tool monitoring systems.

Multiple sensor systems, which use a wide range of sensors with an increasing level of intelligence, are seen as providing long-term benefits, particularly in the field of tool wear monitoring. Such systems are being developed by a number of researchers in this area. The second approach integrates the control signals used by the machine controller into a process monitoring system which is capable of detecting tool breakage.

Initial findings mainly under laboratory conditions; indicate that these approaches can be of major benefit. It is finally argued that a combination of these approaches will ultimately lead to robust systems which can operate in an industrial environment.

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