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DETECTION OF THE DEVELOPMENT OF CHATTER IN END MILLING OPERATIONS BY USING INDEX BASED REASONING (IBR)

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ABSTRACT

Many techniques have been developed for detection of chatter in milling operations. However, their practical applications have not been common since expensive dynamometers and serious computation power is needed. Index Based Reasoning (IBR) was proposed in this study for chatter detection. IBR allow the engineers to program microcontrollers easily for diagnostic applications. In this paper, IBR was used for detection of chatter in milling operations. In addition to chatter, the system may be developed further to monitor the tool wear and diagnostic of machine tool. The proposed method detected the chatter when we test it on the experimental data.

INTRODUCTION

The theoretical and experimental studies on the development of chatter in machining operations started around 1950s and two important books on the topic were published between 1065 and 1970 [1,2]. However, still there are not widely installed commercial systems in the shop floors. Contributions of many researchers are needed to find reliable low cost methods for future commercial applications. In this paper, Index Based Reasoning (IBR) method is proposed as a very low cost computational component of chatter detection system [3]. IBR may be easily programmed by the engineers for different type of machining operations may even be embedded easily inside the fixtures since it needs only microcontrollers.

The chatter related studies could be considered two groups. First group aimed to detect later predict chatter [4-15]. All the studies concluded that the main indicator of the chatter is the excessive vibrations developing at the very close proximity of the dominant frequency of the weakest element of the machine tool- workpiece system. Researchers have used Fast Fourier Transformation (FFT) [4], time series analysis [9], neural networks [10], Kalman filters [5], and customized models [11] for detection or prediction of chatter. The second group studies, aimed either compensation or suppression of chatter by carefully controlling the cutting conditions [15-19].

The Index Based Reasoner (IBR) [3] was proposed to adjust the flight characteristics of small unmanned air vehicles (UAV) by interpreting the large number of sensory signals with multiple classifiers which use simple programs based on look up tables. IBR may consist of a single node or multiple layers with several smart nodes on each of them depending on the desired sophistication. The condition of the subassemblies is represented with Health Index (HI) values. Information is processed layer by layer by using the smart nodes. The HI of larger subassemblies is estimated as the information moves through the layers. n this study only single IBR node was used for detection of chatter.

In the following sections, the proposed chatter detection system, experimental setup, and results are presented.

THE PROPOSED CHATTER DETECTION SYSTEM

The IBR was introduced [3] to simplify the development of structural health monitoring (SHM) systems by using one or very high number of nodes depending on the complexity of the structure. The existing IBRs were prepared by using the well known diagnostic methods. Instead of a single monitoring unit with many inputs, a distributed system performs a similar job by sending index values among the IBRs. Arranging the IBRs in layers and using three or less inputs for easy programming of the classifiers are recommended. The simplest IBR classifier determines the Health Index (HI) value after the sensory inputs are mapped with a previously programmed look up table. A general purpose IBR use an encoder to calculate the most significant characteristics of the signal before it is given to the classifier. An Index History Evaluator (IHE) is used to avoid the fluctuations of the index value with noise. Both of the IBRs are presented in Fig.1.

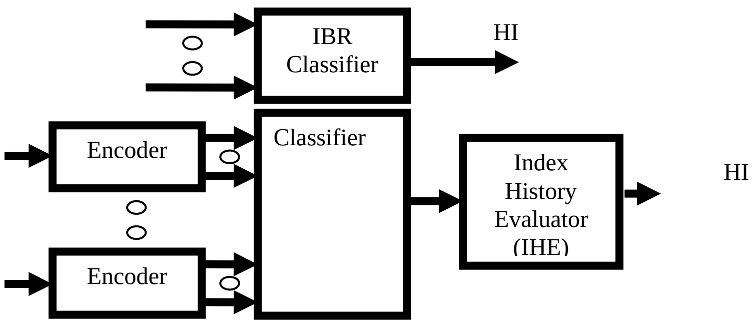

Fig 1. The basic (top) and general purpose (bottom) Index Based Reasoner (IBR)

The IBR system has been developed using Matlab's Simulink in order to take advantage of specific blocks and built in functions that are available. The diagram of the IBR based chatter detection system is presented in Fig.2.

The IBR calculates the spectrum of the signal by using Fast Fourier Transformation (FFT). The amplitude and the frequency of the highest spike of the magnitude plot are identified. The IBR uses a 2-D look up table to estimate the Health Index (HI) of the machining operation. The chatter is detected when the values of the HI reach to certain value.

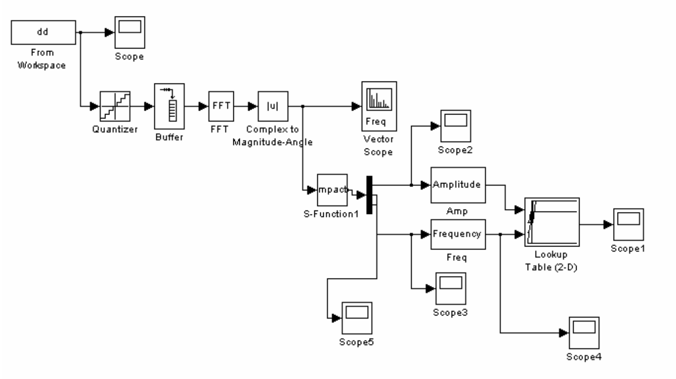

Fig. 2. Block diagram of a simulated IBR for chatter monitoring

EXPERIMENTAL SETUP

Experiments were performed at the Gebze Institute of Technology (GIT). An aluminum plate with 5 mm thickness and 138.2 mm lenght was machined with a five axis Deckel Maho DMU 60 P high speed CNC milling machine. The spindle speed was 1,592 rpm while the feed rate of the table was 647 mm/min. The horizontal depth of cut into the material (in the x direction) is 1mm while the vertical depth of cut into the workpiece started at 0.5 mm and increased to 7 mm. The cutting forces in 3-axises and the torque were measured by using a Kistler 9123C1111 type rotational dynamometer and a 5223 multi-channel signal conditioner. All of the data was collected via a National Instrument PCMCI 6036E DAQ Board with a BNC 2110 connection box. The sampling rate was 5K/sec.

The experimental setup and the geometry of the workpiece are presented in Figure 3. The feed direction is in line with the Y axis while Z direction is chosen to be in the Z-axis. It was observed that when the tool reached the middle of the workpiece length, it began to vibrate severely and generated loud noises. When the vertical depth of cut reached 5-6 mm, the unsteady cutting conditions diminished.

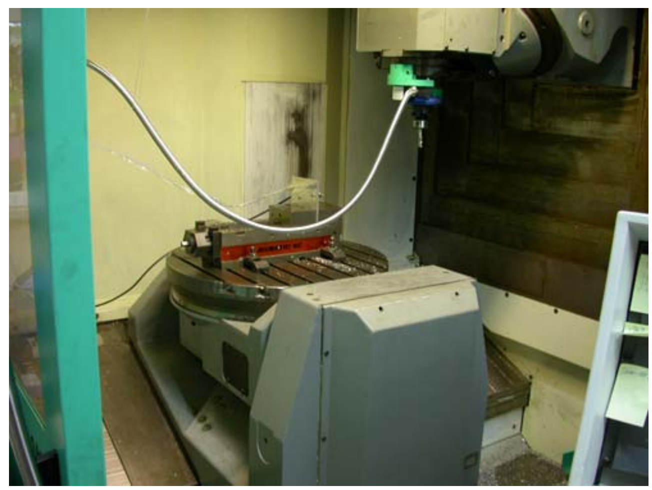

Fig. 3. Experimental Setup

RESULTS AND DISCUSSION

The chatter marks created by the severe vibrations are presented in Fig. 5. The variation of the torque and the cutting forces are presented in Fig.6 and Fig.7 respectively. The chatter mainly occurred between 6^{th} and 8th seconds.

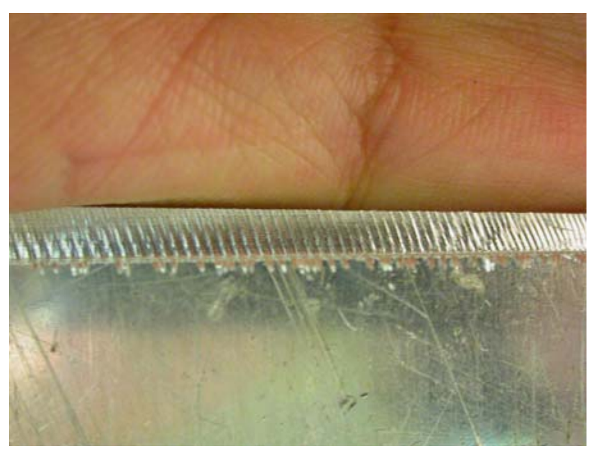

Figure 4. Picture of Chatter

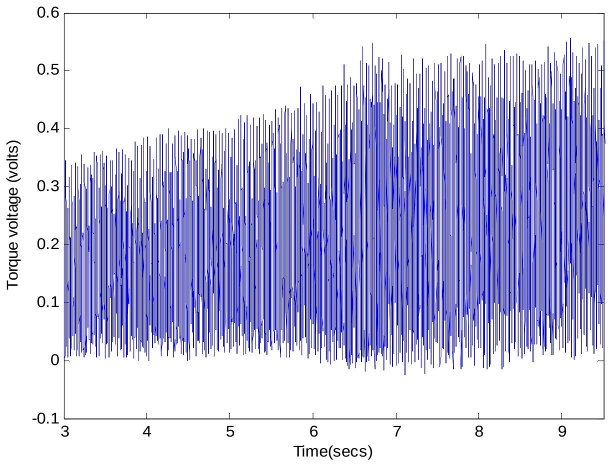

Fig 5. Cutting torque time series containing excessive vibrations

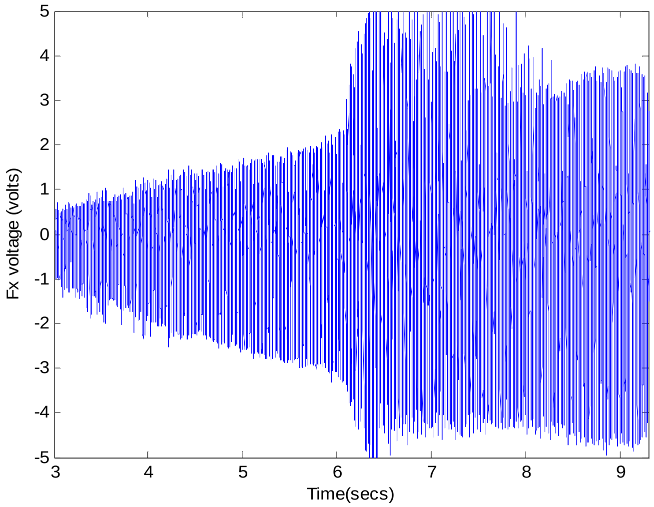

Fig 6. Cutting force time series containing excessive vibrations

The variation of the Health is presented in the Fig. 7. The tool vabrations were within the acceptable range at the beginning. The HI values ath the beginning was 0. Since we machined a thin plate, the vibrations increased with the depth of cut. Between the 6.25th and 7.5th seconds, the health index increased to 3 and indicated chatter. From 7.5th to 8.25th second, the HI fluctuated between 2 and 3 which indicated that chatter was momentarily suspended probably by the tool which was loosing the contact with the workpeice time to time. After 8.25 seconds, the HI stabilized at 2 corresponding to large force vibrations which were not growing excessively with the instability of the system.

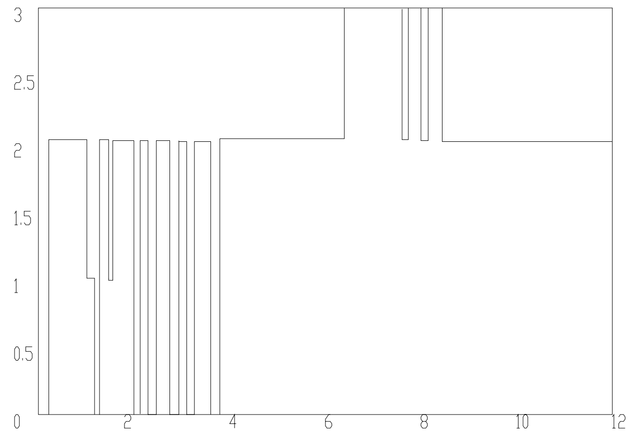

Fig 7. Health index values that capture excessive chatter

CONCLUSION

Use of IBR was proposed for detection of chatter in milling operations. The IBR simulator was established by using the MATLAB. The main advantage of the IBR is letting the engineers to develop the system by assigning numbers to different levels of the sensory signals. Objective is to program microcontrollers from this program. Once, the IBR is developed it may be emulated either using MATLAB or its own simulator.

The feasibility of the proposed method was investigated on the data of end milling operation. The HI indicated chatter by raising the value of the HI when the vibrations reach to severe levels.

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