Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2017, 4(9): 711-716

Research Article ISSN: 2394 - 658X

An Investigation of Dynamic Characteristics of Milling Cutter for Better Health Condition Monitoring

V Sudheer Kumar, Ch Nagaraju and M Balaji

Department of Mechanical Engineering, V R Siddhartha Engineering College, Vijayawada, India
vskumar.1999@gmail.com

ABSTRACT

Increasing competitiveness, gaining greater productivity and better quality have been attained by increasing the performance of machine tools and of machining process. Machining processes such as milling, drilling, turning etc. which are characterized by interrupted cutting are often susceptible to problems involving vibration of the machine-tool and work piece fixation system because of the proximity between their natural frequency harmonics and the frequency of tool entry on the work piece. The vibrations analysis has long been used for the detection and identification of the cutter condition. The purpose of this work is to investigate the healthiness of the milling cutter with vibration analysis by using FFT analyzer. Experimentation is carried on the column and knee type of horizontal milling machine by placing the accelerometer with magnetic attachment at three positions of machine viz. Cutter end, Motor driven end and Motor nondriven end. It is observed that the velocity amplitude is significantly varied compared with the displacement and acceleration amplitudes. Amplitudes at the cutter end signify the health monitoring of cutter compared with the remaining positions like Motor driven end and Motor nondriven end because the amplitudes at the remaining two ends are significantly unconcluded. Subcritical at the cutter end position with low frequency range of top ten peak amplitudes represents the faultiness of the milling cutter. From the experimental results, it was concluded that the cutter end position is the best location to identify the health condition of the milling cutter.

Keywords: *Machining, Milling, Vibration analysis, FFT Analyzer, Health Condition Monitoring*

INTRODUCTION

Vibration and noise in metal cutting are ubiquitous problems in the workshop. Today the industry aims at smaller tolerances in surface finish. Harder regulations in terms of the noise levels in the operator environment are also central. One step towards a solution to the noise and vibration problems is to investigate what kind of vibrations that is present in a machining operation. The vibrations in a milling operation have been put under scrutiny in this work. To prevent unwanted vibration; many researchers have conducted in depth studies. Because of this, chatter stability is now reasonably predicted and has been practically applied in many shop floors. However, few people have addressed the influence of the dynamic characteristics of the spindle rotational direction even though the vibration directly influences the relative motion between the cutter and work piece, which essentially realizes a material removal process.

A milling operation is inherently an intermittent material removal process where cutter engagement and disengagement is repeated until the end of the material removal process. During the process, the cutter receives multiple impacts and mechanical and thermal vibrations which eventually damage the cutting edge. In the present manufacturing industry, milling process plays an important role, therefore many efforts have been made to improve the efficiency of milling. The main limitation of milling is caused by the vibration of machine tool and work piece. As the speed of milling is increased, it is very important to control vibration of the tool. This present study is focused on the healthiness of the cutter.

Prickett and Johns [1] developed a detection system for on-line milling cutter tooth breakage which is based upon the utilization of existing machine tool controller signals as a means of monitoring the milling cutting process. Kalvoda *et al* [2] investigated the end cutter tool fault monitoring in milling based on dynamic force in the frequency domain and time-frequency domain using a new data analysis technique, the Hilbert–Huang transform (HHT). Huang *et al* [3] investigated the effect of cutting conditions on dynamic cutting factor and system process damping in a dynamic milling process. By considering variation of edge ploughing force, a frequency domain method is presented to identify the dynamic cutting factor through measured vibration in a milling process. The average process damping is shown to increase rapidly at lower cutting speed, but remain constant as the cutting speed beyond a critical value. Babu *et al* [4] studied tool condition by analysing surface roughness and vibration of cutter with the use of response surface methodology. The response surface methodology was used to find out significant parameters that are affecting surface roughness and amplitude of cutter vibration.

A multi-response optimization technique was used to identify optimum cutting parameters for less surface roughness and amplitude of cutter vibration. Koo *et al* [5] proposed a point in time at which tool change should take place and a program to monitor tool condition for microscale milling processes. The independent variables were the spindle speed, axial depth of cut, and feed per tooth. A point of tool change time for the microscale milling process was proposed by analysing the characteristics of cutting force signals and acoustic emission signals acquired during the experiments. Saedon *et al* [6] presented a study for the development the first and second order tool life models of micro milling hardened tool steel AISI D2 62 HRC. The developed models were in terms of cutting speed, feed per tooth and depth of cut, using response surface methodology. Cutting tests were performed within specified ranges of parameters using 0.5 mm TiAlN microtools under dry condition. Soshi *et al* [7] introduced the concept of flexible rotational rigidity control using a high performance Permanent Magnet Synchronous Motor (PMSM) which is used as a direct spindle drive. With the PMSM spindle, the spindle rotational characteristics can be adjusted for optimizing the cutting process in order to prevent tools from unwanted premature damage. The experimental results show that the PMSM spindle characteristics behave differently depending on the controller setting, and the spindle motor drive system rotational characteristics greatly affect the cutting process, which confirms the importance of the flexible motor control concept. Dini and Tognazzi [8] studied the application of cutting force measurement method, consisting of acquiring the cutting torque signal in end milling by means of a commercial low-cost rotating dynamometer, usually applied in other machining operations. On-line threshold-based monitoring strategies were also proposed, and significant indicators were considered for tool condition monitoring in milling. Madhu sudhan *et al* [9] deals with the diagnosis of the face milling tool based on machine learning approach using histogram features and K Star algorithm technique. Mandel [10] studied different methods and proposed to use for tool condition monitoring, mainly applicability of tool condition monitoring methods used in conventional milling. Amit Kumar Jain *et al* [11] studied the effectiveness of tool condition monitoring strategy depends on accuracy in failure prediction of cutting tool. Wang *et al* [12] has proposed different evaluation and support vector machine condition monitoring. Korake et al [13] concentrated on grapes environmental condition monitoring using wireless sensor network. Agrawal *et al* [14] has studied the effect of cutting parameters on material hardness and condition monitoring of turning machine.

The present work depicts the healthiness of milling cutter by analysing the dynamic behaviour which is analysed by spectrum analyser. Very low frequency ranges the displacement spectrum is used. In this study, the velocity amplitude spectrum was taken due to the operating frequency range. The studies mainly focused on axial position amplitudes as compared to the horizontal and vertical position amplitudes.

EXPERIMENTAL PROCEDURE

For experimental setup, the column and knee type of Horizontal milling machine is kept in running at 800 rpm condition and place the Piezoelectric Accelerometer with magnetic attachment on different positions of machine like Cutter End 1(a), Motor Driven End 1(b), Motor Non-Driven End 1(c), and machine model (1d).

For each position three different directions are analysed namely Horizontal, Vertical and Axial. The FFT analyzer has a capability to measure velocities of 200 mm/sec with a resolution of 0.1 mm/sec and frequency range of 10-1 KHz. The data regarding the set up and the position of the sensor is fed into the computer and then it was transferred to the FFT analyser. The collected data from the FFT analyser is again transferred to the computer for generating the wave forms.

Spectrum Analysis

Spectrum analysis separates the total vibration into discrete frequencies so that the source(s) of a given problem may be easily identified. Spectrum analysis involves passing the raw time domain data through a mathematical calculation called the “Fast Fourier Transform” or FFT. The FFT algorithm converts the original signal from the time domain into the frequency domain. The result is that a complex signal is separated out into different contributing frequencies (units of frequency are cycles per unit of time, e.g., Hertz = cycles/second).

It is important that the same signal is analysed over different frequency ranges for a complete understanding of the problem. Experience and good data acquisition skills and tools are essential for making sure that all relevant frequency ranges are verified. A common mistake analyst make is to analyse all data over a single frequency range.

(a) Cutter End

(b) Motor Driven End

(c) Motor Non Driven End

(d) Column and Knee type of Horizontal milling machine

Fig. 1 Different positions of machine and Milling Machine

Resolution implies the ability to distinguish between closely spaced frequencies. Too little resolution causes the analyst to assume that a single frequency or source of interest exists - when several frequencies and therefore, several sources may actually be present, but very close together in the frequency domain. Flexibility in being able to display a lot of data simultaneously allows for effective diagnostics. For example, the Metso data analysis and acquisition system has very advanced data presentation tools.

Multiple signals can be easily overlaid for quick comparison and source identification. This allows simultaneous determination of vibration severity and contributing sources can be analysed at different locations. Tachometer signals from various rolls, felts, etc. allow for precise source identification. It is presented in the frequency domain so that vibration frequencies may be compared to it.

RESULTS AND DISCUSSION

Experiments were conducted on milling machine with arbor diameter of 25mm for knowing the condition of the plane milling cutter at a speed of 800rpm. As compared to time Vs Amplitude signal (Figure 2(a),2(b)), the Frequency Vs Amplitude (Figures (3(a),3(b)), (4(a),4(b)), and (5(a),5(b)) were giving the good results for discussion for the analysis. Due to this present study mainly focused on Frequency Vs Amplitude only.

Motor Non-Driven End

From the observation of signature analysis for the Motor Non Driven End (Figures 3(a), 3(b)) it is found that there is amplitude 4.33 mm/sec for the healthy cutter and 6.24 mm/sec for the faulty cutter with certain usage. Further it is observed that there is no significant subcritical with the faulty cutter. Additionally, the frequency range is also not significant. This is because the generated vibrations are absorbed over the travel from the cutter end and in the mean travel these vibrations are absorbed with foundation. The peak values of Amplitudes are mainly may be due to the bearing defects as well as defects in rotating parts.

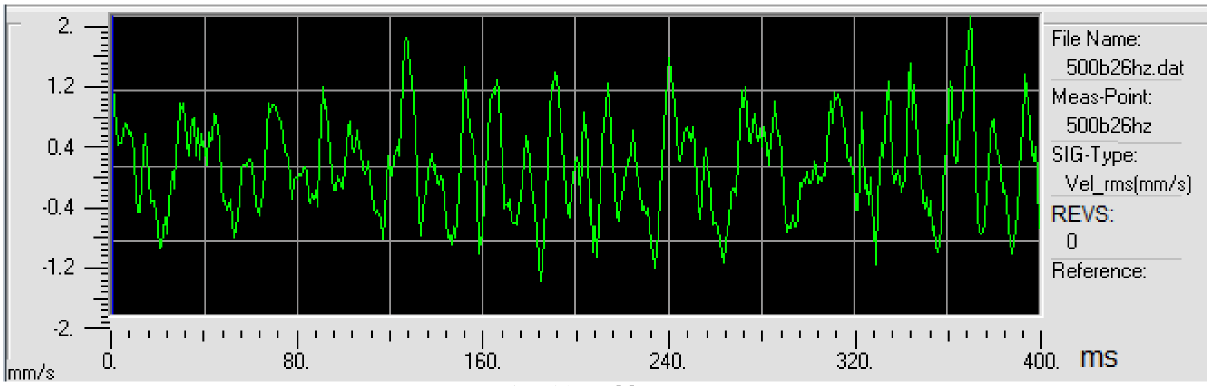

Fig. 2(a) Healthy cutter

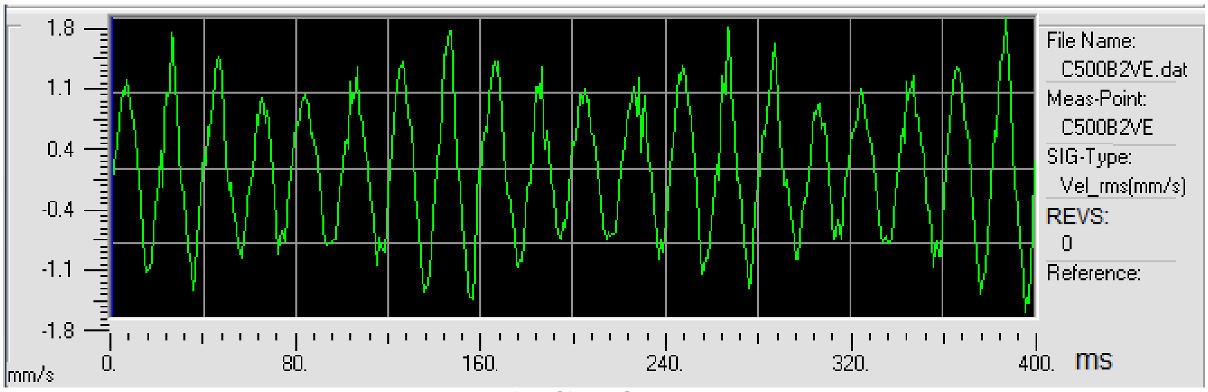

Fig. 2(b): Faulty cutter

Fig. 2 Time Vs Amplitude for the Motor Driven End

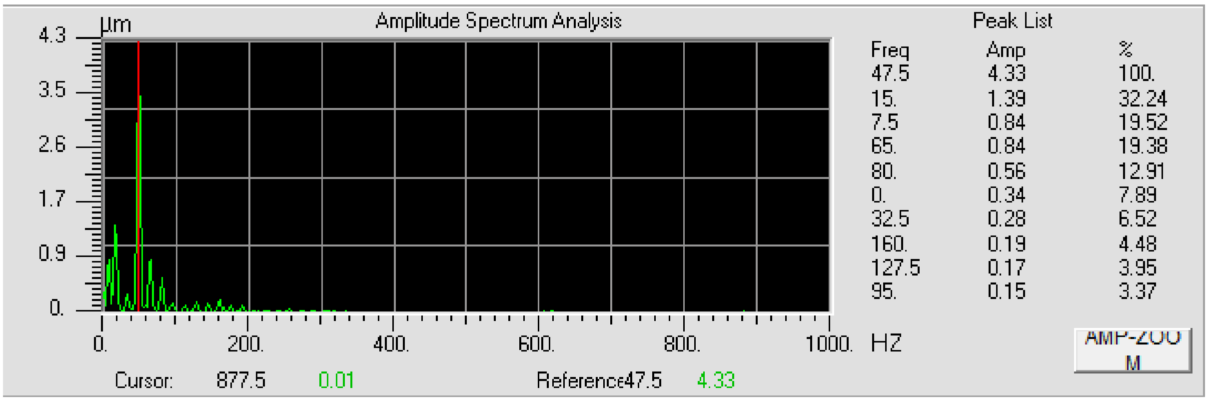

Fig. 3(a) Healthy Cutter

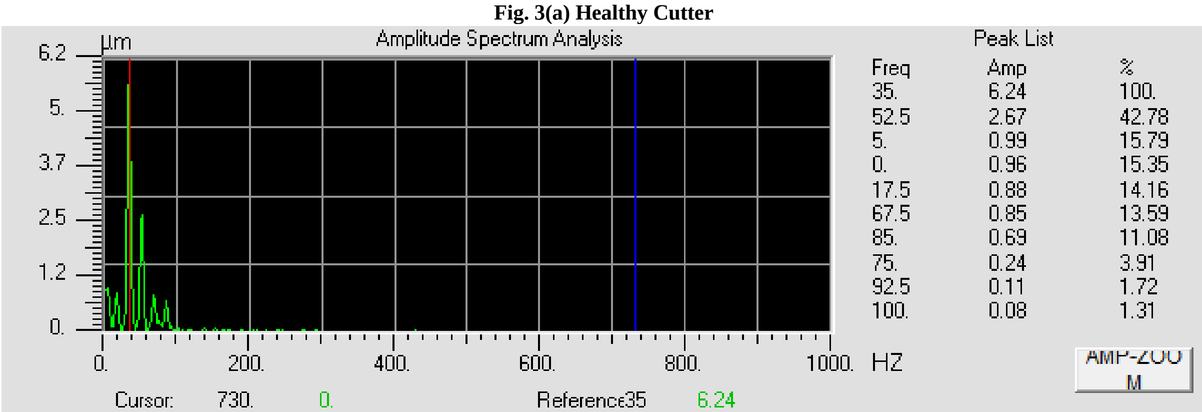

Fig: 3(b) Faulty Cutter

Fig. 3 Frequency Vs Amplitude for the Motor Non Driven End

Motor Driven End

At the Motor Driven End the signatures (Figures 4(a), 4(b)) shows significant findings with the healthy cutter vs Faulty cutter. The peak amplitude for the healthy cutter is 0.92 mm/sec as compared with the 1.04 mm/sec for faulty cutter. This may be due to the dominance in the noise. The main significant difference with the velocity signature is the formation subcritical in the selected range of frequency. This shows that the formations of subcritical are the indication of faultiness of the cutter. Immediately the cutter has to be replaced with new cutter or otherwise ground the cutting edges for the appropriate tool signatures. As compared to the motor non driven end in the motor driven end subcritical are more. In order to analyse the healthiness of the cutter motor driven end signatures are enough as compared to the motor non driven end. Another observation from the signatures was the top ten peak amplitudes were scattered in the frequency range 25- 615Hz.

At the cutter end the signatures (Fig 5(a), 5(b)) shows more subcritical in the lower frequency values. As compared to the motor driven end the sub critical amplitudes fall in the lower range of frequency. This is the best indication of faultiness of the cutter. Though the subcritical are the common feature of the cutter end and motor driven end, the lower frequency range is the significant difference between two positions. The top ten peak amplitudes fall in the range 35-612.5Hz. The falling of subcritical in the lower frequency range is the best indication of faultiness in the cutter. Out of the three above positions specified cutter end position is the position to know the good performance of the cutter.

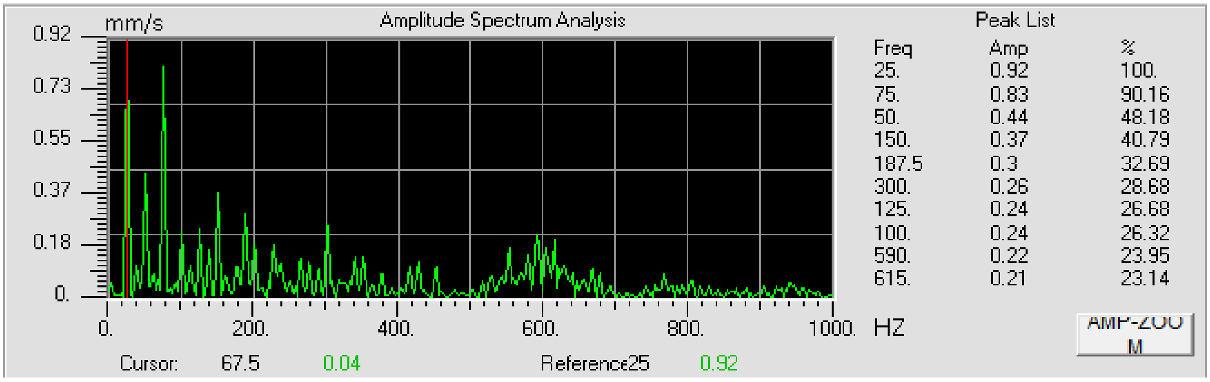

Fig. 4(a) Healthy Cutter

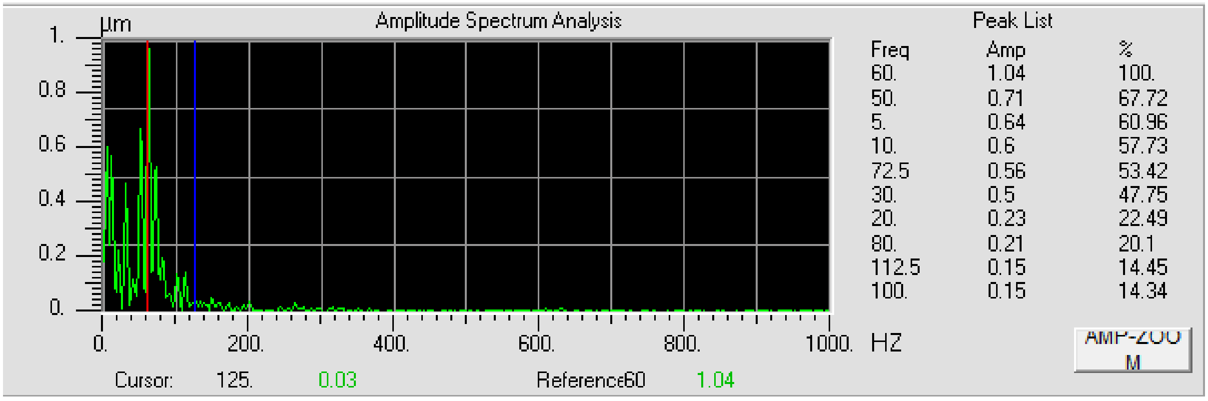

Fig. 4(b) Faulty cutter

Fig. 4 Frequency Vs Amplitude for the Motor Driven End

Cutter End

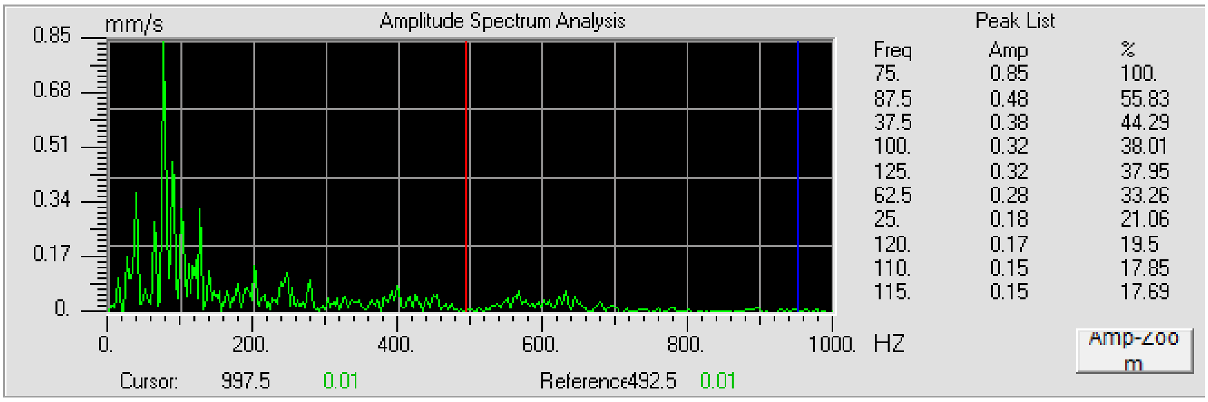

Fig. 5(a) Healthy Cutter

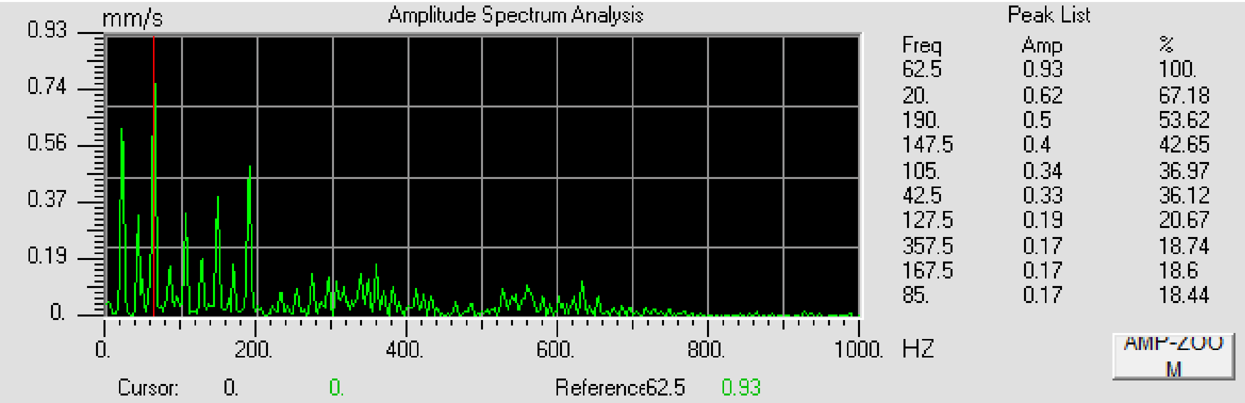

Fig. 5(b) Faulty cutter

Fig. 5 Frequency Vs Amplitude for the Cutter End

CONCLUSIONS

Experimental setup on milling machine, which runs at speed, feed and at depth of cut. In healthy and unhealthy milling cutter conditions, the vibrations are observed using FFT Analyser. Comparing healthy and unhealthy milling cutter conditions, the vibrations are high in unhealthy cutter conditions. From the observation of signature analysis for the Motor Non Driven End it is observed that there is no significant subcritical with the faulty cutter. At the Motor Driven end, it is observed that the dominance in the noise. As compared to the motor non driven end in the motor driven end subcritical are more. Amplitudes at the cutter end signify the health monitoring of cutter compared with the remaining positions like Motor driven end and Motor non driven end. Subcritical at the cutter end position with low frequency range represents the faultiness of the milling cutter. The subcritical at the motor non-driven end are infeasible. Amplitudes at the remaining two ends are significantly analysed. From the experimental results, it was concluded that the cutter end position is the best location to identify the health condition of the milling cutter.

REFERENCES

[1] PW Prickett and C Johns, The Development of an On-Line Milling Cutter Tooth Breakage Detection System, *Proceedings of the institute of Mechanical Engineers Part B: Journal of Manufacture*, **2001,** 215 (B), 147-160.

[2] T Kalvoda, Hwang and Vrabec, Cutter Tool Fault Detection Using a New Spectral Analysis Method, *Journal of Engineering Manufacture*, **2010**, 224, 1784-1791.

[3] CY Huang and Junz Wang, Effects of Cutting Conditions on Dynamic Cutting Factor and Process Damping in Milling, *International Journal of Machine Tools & Manufacture*, **2011**, 51, 320–330.

[4] GHV Prasad Babu, BSN Murthy, K Venkatarao and Ch Ratnam, Multi-Response Optimization in Orthogonal Turn Milling by Analysing Tool Vibration and Surface Roughness Using Response Surface Methodology, *Journal of Engineering Manufacture*, **2016,** DOI: 10.1177/0954405415624349, IMech E **2016**, 1–10.

[4] Joon-Young Koo, Jeong-Suk Kim and Su-Hoon Jang, Point of Tool Change Time and Monitoring Program for Microscale Milling Process, *Journal of Engineering Manufacture*, **2013,** 227(7), 929–942.

[5] JB Saedon, SL Soo, DK Aspinwall, A Barnaclec and NH Saada, Prediction and Optimization of Tool Life in Micro milling AISI D2 (62 HRC) Hardened Steel, *Procedia Engineering*, **2012,** 41, 1674 – 1683.

[6] Masakazu Soshi, Shinji Ishii, Kazuo Yamazaki, A Study on the Effect of Rotational Dynamic Characteristics of a Machine Tool Spindle Drive on Milling Processes, Procedia CIRP, **2012**, 319 – 324.

[7] G Dini and F Tognazzi, Tool Condition Monitoring in End Milling Using a Torque-Based Sensorized Tool Holder, *Journal of Engineering Manufacture*, **2006,** 221, 11-23.

[8] CK Madhusudana, Hemanth Kumar and S Narendranath, Condition Monitoring of Face Milling Tool Using K Star Algorithm and Histogram Features of Vibration Signal, *International Journal of Engineering Science and Technology*, **2016,** 19, 1543-1551.

[9] Soumen Mandal, Applicability of Tool Condition Monitoring Methods used for Conventional Milling in Micro Milling, *Journal of Industrial Engineering*, **2014,** 8 pages.

[10] Amit Kumar Jain and Bhupesh Kumar Lad, Data Driven Model Prognostics of High Speed Milling Machine, *International Journal of Performability Engineering*, **2016,** 12 (1), 3-12.

[12] Guo F Wang, Qing L Xie, Yan C Zhang, Tool Condition Monitoring System Based on Support Vector Machine and Differential Evaluation Optimization, *Proceeding of the Institution of Mechanical Engineering, Part B: Journal of Engineering Manufacture*. **2016**, DOI: 10.1177/0954405415619871

[11] PM Korake and MK Bhanarkar, Humidity and Temperature Measurement WSN Node for Grapes Environmental Condition Monitoring, *European Journal of Advance Engineering and Technology*, **2015,** 2(5), 72-76.

[12] Saurabh Agrawal, MK Gaur and DK Kasdekar, Optimal Machining Conditions for Turning of Hard Porcelain using Response Surface Methodology, *European Journal of Advance Engineering and Technology*, **2015,** 2(5), 44-51.