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TOOL CONDITION MONITORING USING VIBRATION ANALYSIS

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ABSTRACT

Cutting tools can be used when they do not reach tool life criteria and can produce parts with desired surface finish and dimensional accuracy. When the cutting edge of the tool reaches one of the tool life criterion, the tool should be replaced by a new one or sending it for regrinding. Tool condition monitoring is carried out by analyzing Amplitude-Time signals using a vibration analyzer. During cutting operations, the cutting tool experiences various stresses such as normal, shear and also thermal shocks. These stresses cause wear and breakage of cutting edge. Tool wear is defined as a gradual loss of tool material at contact zones of work piece and tool material, resulting the cutting tool reaches its life limit. Spindle speed, feed and depth of cut are three machining parameters. Different experiments are conducted by varying one parameter and keeping other two parameters constant so that maximum value of each parameter was obtained This research is based on ISO3685 and investigates their flank wear patterns of HSS tools during machining of EN24. Amplitude time spectrum is analyzed using Matlab and the data is converted into frequency spectra an signals above 5 KHz is filtered to remove noises using a Butterworth filter and the signal is then converted to amplitude-time spectra. The rms of signals is found out to carry out failure diagnosis.

KEYWORDS: Tool-Wear Monitoring in Metal Cutting Operations–A Review of Methods. International Journal of Machine Tools and Manufacture

INTRODUCTION

In practical situation, the time at which a tool ceases to produce work pieces with desired size, surface quality and acceptable dimensional tolerances, usually determines the end of tool life. The main objective of tool life testing and wear investigation is to determine experimentally how wear affect the useful life of cutting tool. In most cases the tool wears gradually and the work done by the tool becomes less satisfactory. Various damage and wear of the cutting tool can be developed during cutting process. There are several different causes and mechanisms of tool wear. Friction on the rake face and on the flank of the tool occurs under a close contact of freshly created surface of the work piece material. The temperatures in the contact zone are high and may reach the melting temperature of the one of the materials in this zone, most often that of the work piece material.

Turning operation is carried out to create rotational parts by removing unwanted materials. Usually a single point cutting tool is used for turning. The work piece is attached to the rotating spindle of the machine and allowed to rotate at high speeds. The cutting tool is fed into the rotating work piece and cuts away material in the form of small chips to create desired shape.

L9 Taguchi orthogonal array is designed using software Minitab 17. The Taguchi method is a well known technique that provides a systematic and efficient methodology for the process of optimization and is a powerful tool for the design of a high quality system. EN24 is used as work piece for the experiment.EN24 is mainly used for the manufacture of shafts, gears bolts, heavy duty axles.EN24 is capable of retaining good impact values at low temperatures and hence its specified for hard offshore applications.

Tool condition monitoring is carried out by analyzing Amplitude-Time signals using a vibration analyzer. High pass filtering is done on the signal and the pattern above 5 khz is collected. A Butterworth filter is used for filtering the frequency data. The frequency data is converted into amplitude-time spectrum with the help of a Matlab program. The rms value of the amplitude-time spectrum is carried out and values are analyzed.

OBJECTIVES

The objective of the present investigation is as follows:

- To obtain amplitude-time vibration signals.
- To obtain the tool life.
- To obtain the rms value of filtered amplitude-time spectrum.

VIBRATION ANALYSIS

A vibration analyzer is used for analyzing the vibrations. The probe f the vibration analyzer is kept on the tool and FFT is used. Amplitude time spectrum is used for analyzing the condition of tool.

FIELDPAQ VIBRATION ANALYZER

Fieldpaq vibration analyzer system is a new standard for advanced sound and vibration test in the field. The analyzer supports 3 channel non-synchronized analysis, which can be used with a tri-axial accelerometer in the field. Fieldpaq supports a compact flash card storage system and USB interface for storage of large data. The high resolution colour TFT display of the fieldpaq provides a clearer view of data.

Figure 1: Field paq Vibration Analyzer

Figure 2: Experiment Carried Out on Nagmati Lathe

Process Parameters

Table 1

Sl. No	Spindle Speed	Feed Rate	Depth of Cut
1	215	0.191	0.6
2	325	0.220	0.7
3	500	0.318	0.8

Here spindle speed, feed rate and depth of cut are chosen as factors influencing tool life. Each factor is varied to three different levels and experiments are performed according to data obtained from Taguchi Orthogonal Array.

Figure 3: Experiment Set Up

The probe of the vibration analyzer is kept on the top of the tool and vibrations are recorded using the instrument. Readings are taken for various cutting conditions. Amplitude time spectrum is analyzed using Matlab and the data is converted into frequency spectra an signals above 5 KHz is filtered to remove noises and the signal is then converted to amplitude-time spectra. The rms of signals is found ou t to carry out failure diagnosis.

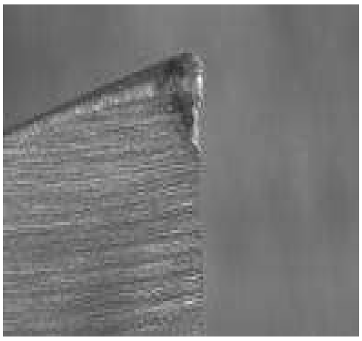

Figure 4: Medium Flank Wear on Tool

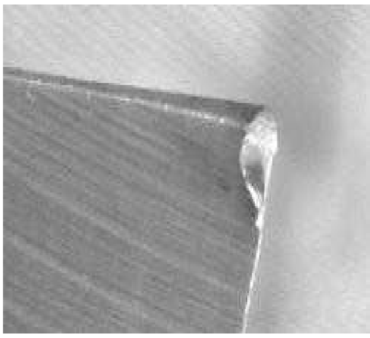

Figure 5: Severe Flank Wear on Tool

Work Piece Material

The test materials are of EN24 alloy steel. To prevent undesirable vibrations the length (L)/diameter (D) ratio must be smaller than 10. The tools are made up of HSS.

Table 2: Comparison of Harness Values

Materials	Hardness
Mild Steel	142 BHN
EN8	222 BHN
EN24	248 BHN

Table 3: Chemical Composition of EN24

Sl. No	Metal	Range
1	Carbon	0.36 -0.44%
2	Silicon	0.10-0.35%
3	Manganeese	0.45-0.70%
4	Sulphur	0.040%
5	Phosphorous	0.035%
6	Chromium	1.00-1.40%
7	Molybdenum	0.20-0.35%
8	Nickel	1.30-1.70%

Design of Experiment

Taguchi's designs aimed at greater understanding of variation than did many of the traditional designs. L9 Taguchi Orthogonal Array for Experiments

Table 4

Sl. No	Spindle Speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	215	0.191	0.8
2	215	0.220	0.7
3	215	0.318	0.6
4	325	0.191	0.7
5	325	0.220	0.6
6	325	0.318	0.8
7	500	0.191	0.6
8	500	0.220	0.8
9	500	0.318	0.7
10	215	0.191	0.8

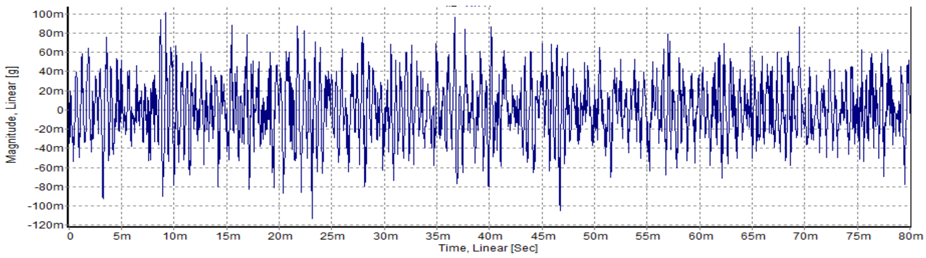

Figure 6: Amplitude-Time Spectrum of Initial Wear Condition

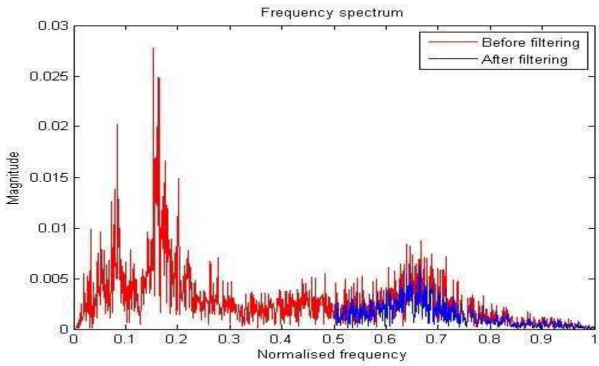

Figure 7: Filtering of Signals above 5 KHZ Using Filter

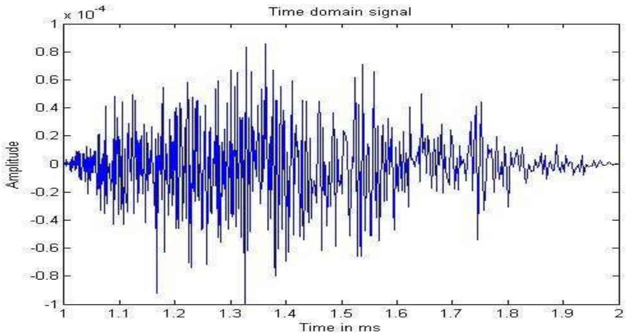

Figure 8: Amplitude Time Spectra of Filtered Signal

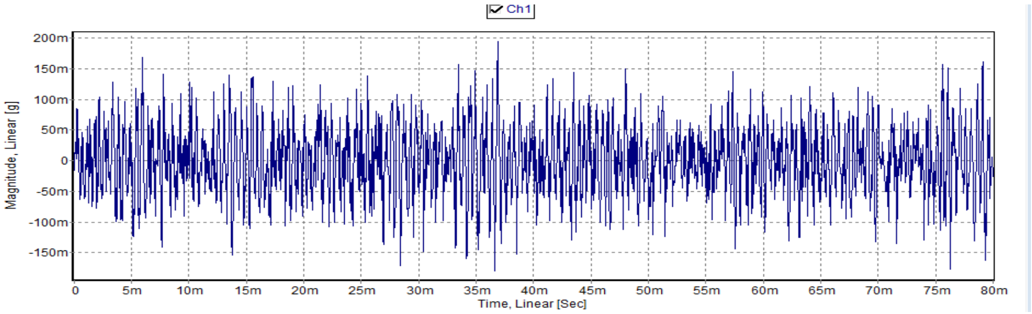

Figure 9: Amplitude-Time Spectrum of Medium Wear Condition (0.3 mm Flank Wear)

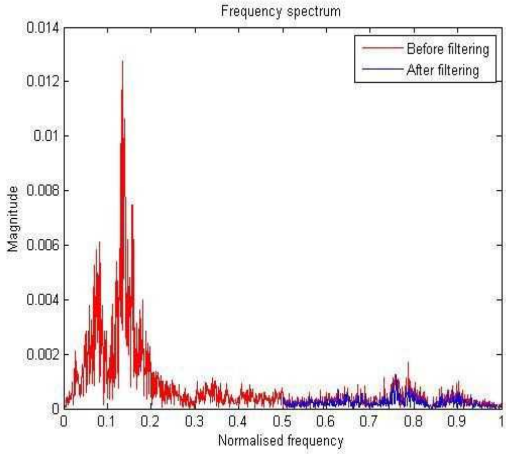

Figure 10: Filtering Signals above 5 Khz Using Filter

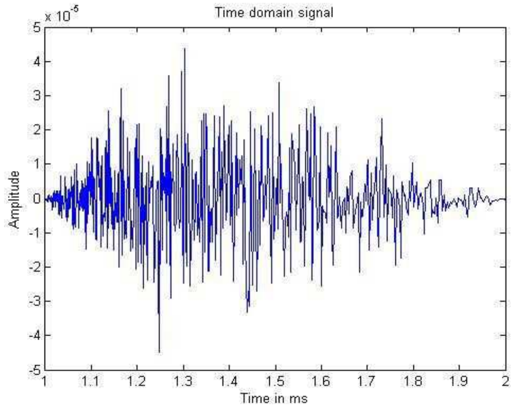

Figure 11: Amplitude Time Spectra of Filtered Signal

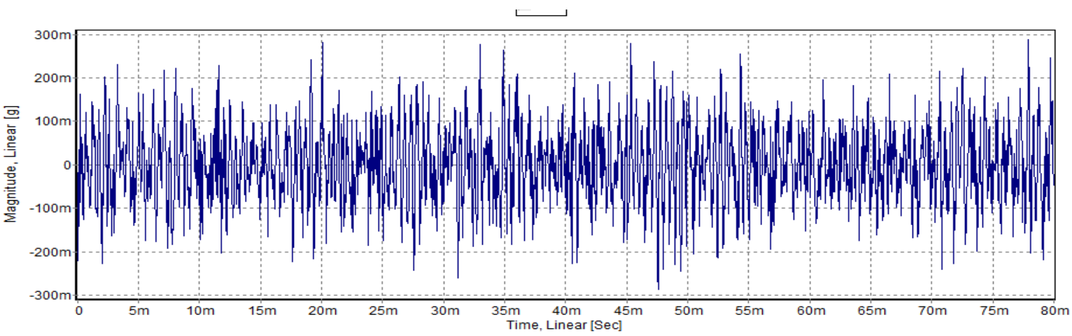

Figure 12: Amplitude-Time Spectrum of Severe Wear Condition (above 0.6 mm Flank Wear)

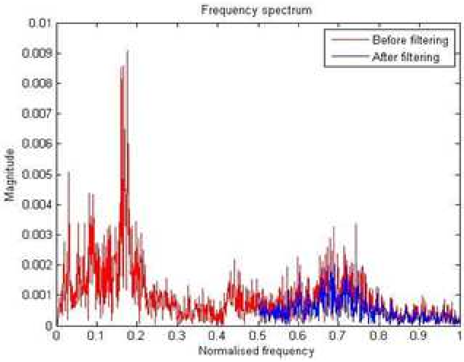

Figure 13: Filtering of Signals above 5 Khz Using Filter

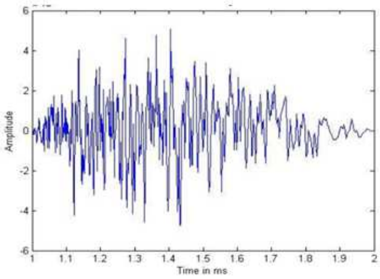

Figure 14: Amplitude Time Spectra of Filtered Signal

RESULTS AND DISCUSSIONS

The safe limit of acceleration amplitude rms is found out.

Table 5

Exp No	Speed (RPM)	Feed Rate (mm/rev)	Depth of Cut (mm)	Cutting Speed (m/min)	Safe Limit of rms Acceleration Amplitude (x 10 $^{-5}$)m^2/s
1	215	0.191	0.8	19	2.7
2	215	0.220	0.7	19	2.9
3	215	0.318	0.6	19	3.0
4	325	0.191	0.7	28	3.2
5	325	0.220	0.6	28	3.4
6	325	0.318	0.8	28	3.7
7	500	0.191	0.6	43	4.6
8	500	0.220	0.8	43	4.8

For various spindle speeds the safe limits of operational ranges are obtained. So the operation can be stopped if lower limits of these values are obtained and tool can be replaced.

Table 6

Sl. No	Spindle Speed (rpm)	Safe Limit of rms Acceleration Amplitude (x 10 $^{-5}$)m^2/s
1	215	2.7 – 3.0
2	325	3.2 – 3.7
3	500	4.6 – 4.8

CONCLUSIONS

Tool life of HSS turning tools is modeled. The criterion used for tool life prediction is based on ISO 3685.

- Amplitude - time spectrum can be used to analyze condition of tool.
- Flank wear during failure was observed above 0.6 mm in all cases.
- Tool condition monitoring is carried out by analyzing Amplitude-Time signals using a vibration analyzer. High pass filtering is done on the signal and the pattern above 5 khz is done using a Butterworth filter is used for filtering the frequency data.
- The rms value of the amplitude-time spectrum of filtered signal is carried out
- The safe limit for the machining operations various cutting conditions are listed. So when the above limits are attained the machining operations can be stopped.

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