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SOME PROCESS OF DETECTION OF CUTTING TOOL WEAR IN HIGH SPEED MILLING

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ABSTRACT

Milling is one of the main methods in manufacturing. Therefore, the detection of tool wear is essential to improve manufacturing quality and to increase productivity. The main objective of this work is to establish a relationship between acquired signals variation and the tool wear. To achieve our goal, an experimental setup was carried out using a horizontal high speed milling machine. The cutting forces were measured by means of dynamometer during milling operation. However, the tool wear was measured in an off-line manner using a binocular microscope. In this paper, we analyzed cutting force signatures during milling operation throughout the tool life. This analysis was based on both temporal and frequency signal processing techniques in order to extract the relevant indicators of cutting tool state. Results have shown that the variance values and the first harmonic amplitudes variation were linked to the flank wear evolution. These parameters were among the best which provided relevant information about the tool wear.

INTRODUCTION

A successful on-line monitoring system for machining operations has the potential to reduce cost, guarantee consistency of product quality, improve productivity and provide a safer environment for the operator. Milling research areas can be divided into four broad areas: force modeling; surface texture modeling; control strategies; tool wear / tool failure [1] [2][5].

Wear of a cutting tool in milling is a complicated process that requires a reliable technique for monitoring and control of the cutter performance.

All approaches, proposed for the tool wear monitoring area; we usually measured several parameters, such as forces, vibrations, acoustic emission, and they are directly correlated with tool wear. These parameters are measured on-line during the machining process [7] [3].

Several researches were focused on the detection of tool breakage. The effect of tool breakage is usually revealed from an abrupt change in the processed measurements, which is in excess of a threshold value. In this context, Tansel et al [8] used EA signal to detect the tool breakage. We can see in figure 1-a the EA signal corresponding to the fresh new cutting tool and in figure 1-b the EA signal where a significant impulse is produced at broken moment of tool. Otherwise, Romero-Troncoso René de Jesus et al. [6] exploited the current driver monitoring (figure 2) to examine the tool failure.

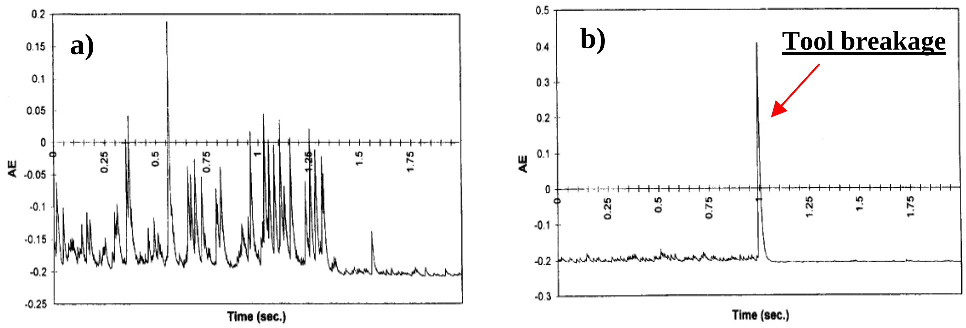

Figure 1 - Detection of tool breakage by EA signal [8]

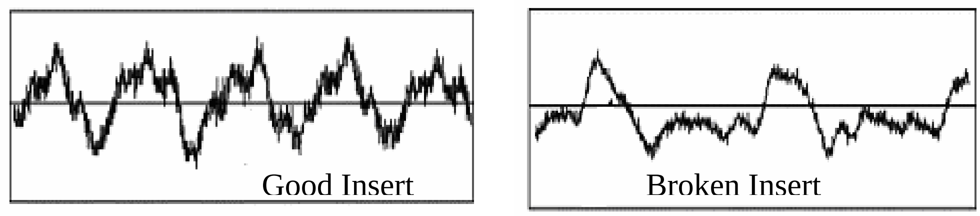

Figure 2 - Detection of tool Breakage by current driver [6]

The cutting force signal is considered to be the most suitable signal for tool failure detection in milling operations. This is because the cutting force signal in milling can offer a clear feature for the detection of tool failure.

Several models of cutting force have been established. In our study we have used the following model. [7]

$$F_r = K_s\, a\, S_t \sin(wt) + a\, C_w\, V_b \qquad (1)$$

$$F_a = R_1 K_s\, a\, S_t \sin(wt) + R_2\, a\, C_w\, V_b \qquad (2)$$

$$F_{RR} = (F_r^2 + F_a^2)^{1/2} \qquad (3)$$

Nomenclature:

a	Depth of cut (mm)	R_1, R_2	Force ratio constants
Cw	The edge force constant (N/mm^2)	S_t	Feed rate per tooth (mm/tooth)
F_a	Axial force (N)	V_b	The flank wear width (mm)
Fr	Radial force (N)	K_t	The crater wear depth (mm)
F_{RR}	Resultant force (N)	V_f	Feed speed (m/min)
K_s	Specific cutting pressure of work piece material (N/mm^2)	V_c	Cutting speed (m/min)
		S_s	Spindle speed

EXPERIMENTAL SETUP

An experimental setup was carried out on a horizontal high speed milling machine (Meteor 10). The cutting force was measured by piezo-type tool dynamometer (Kistler 9255B) and measured force was amplified using a charge amplifier (Kistler 5011). The dynamometer was used to measure the cutting forces in three mutually perpendicular directions, X, Y and Z axis. During the milling, the Z axis cutting force component contained little information but X and Y axis cutting forces permeated modeling of the process. The dynamometer was clamped between the work-piece and the table (or pallet), as shown in figure 3. In our study we have used cutter milling type: RT130408R-31 with 25 mm diameter and workpiece material type: 40CMD8+S.

Cutting conditions:

S_s = 2291 rpm
V_f = 343 m/min
V_c = 180 m/min
S_t = 0.25 mm/tooth
a = 2 mm

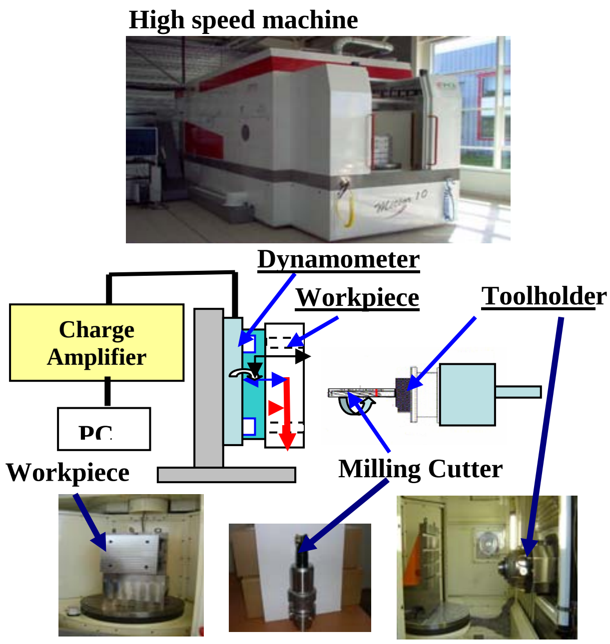

Figure 3 - Schematics diagram of experimental setup

For better undertaking of our study, we eliminated the parts of the signal corresponding to the clamp holes passing and tool entry (figure 4).

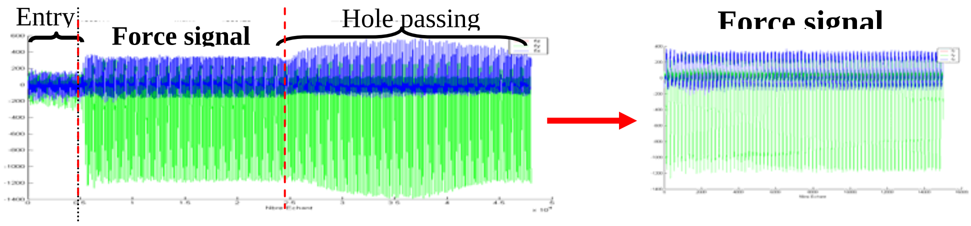

Figure 4 : Cutting force signals acquired according the three axis

RESULTS AND DISCUSSION

Thirty-nine recordings were collected during our experimental test which enabled us to follow the evolution of tool wear during machining time, (figure 5, 6).

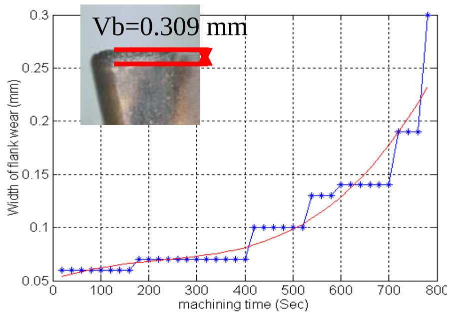

Figure 5 - Flank Wear evolution

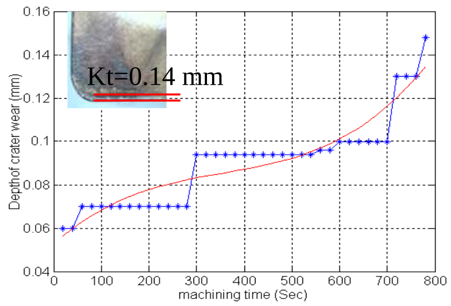

Figure 6 - Crater Wear evolution

The temporal analysis of cutting force signal is presented in the figure 7. Using the statistical parameters: mean (figure 7-a, RMS (figure 7-b) and variance (figure 7-c), it can be seen that the variance values (figure 7-c) provided more relevant information on the evolution of the milling cutter wear than the other parameters [4] [9].

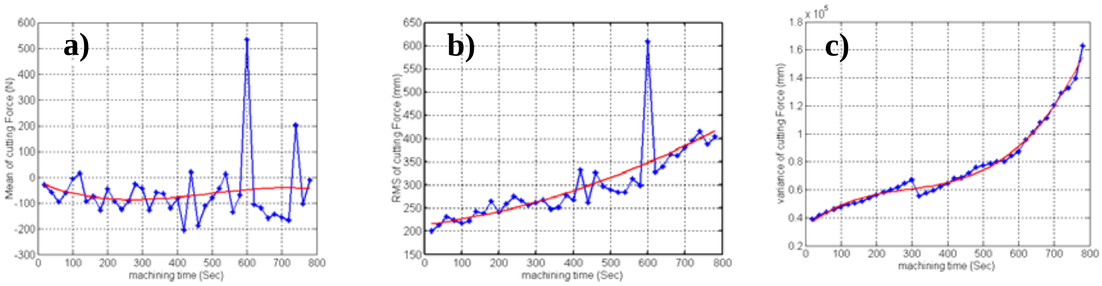

Figure 7 - Evolution of time features, a) Mean, b) RMS, c) Variance

In this study we followed the ten first harmonics of the three cutting forces (radial, axial and resultant) during the machining process. In Figure 6, it can be seen that the magnitudes of certain cutting harmonics increased significantly with flank wear while other harmonics are unaffected. Furthermore, we have remarked that the first harmonic of the axial force was the most sensitive to the variation of tool wear.

Consequently, any changes in the cutting conditions or on the tool performance leaded to changes in the amounts of flank wear and then leaded to changes in the significant cutting forces harmonics.

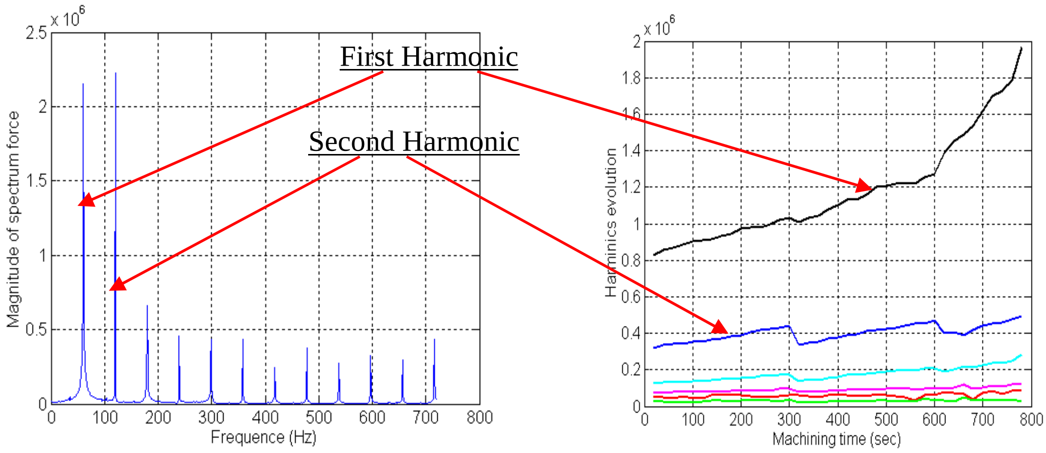

Figure 8 - Evolution of harmonics during machining time

CONCLUSIONS

This study investigated the use of several signal measurements to improve the on-line tool-breakage detection and monitoring of coated tool in milling. All approaches (EA, current driver, cutting forces) showed successful results on tool-breakage detection. We have focused our effort to estimate tool life using cutting forces analysis. It was shown that the state of tool wear observed by the microscope was related to results obtained by cutting force analysis.

Variance and the first harmonic evolutions presented the significant results: they increased significantly with flank wear. A threshold level can be drawn up to estimate the tool life.

However, in this preliminary study, we used only one type of tool and materials, under constant machining conditions. In a future work, we wish generalize our study using various types of tools and materials.

The mean aim of the analysis of the relevant parameters (variance, RMS, Kurtosis, spectrum harmonics, flank wear) will be to implement an automatic monitoring system of tool wear based on neural networks.

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