

TOOL WEAR MONITORING TECHNIQUES AND INTEGRATION POSSIBILITIES WITH THE AUTOMATIC TOOL READJUSTEMENT FUNCTION

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Abstract— The paper aims to present the major tool monitoring techniques used in manufacturing industry. Tool monitoring in the actual competitive market is of significant importance in maintaining a cost effective production and obtaining the required quality of the finished product. The paper will also analyze the integration of tool monitoring techniques from the perspective of implementing the ATR (Automated Tool Readjustment) for the TMA 55 AI flexible manufacturing cell at the University of Oradea, Mechatronics Department.

Keywords—tool monitoring, flexibility, tool readjustment, tool management.

I. DURABILITY AND CAUSES TOOL WEAR

Tool wear is a complex physic-chemical process in which the surface layers of the tool material are destroyed [1]

The main types of tool wear are:

Breaking or crushing a part of the cutting edge - is due to the occurrence of a forces that overwhelm the cutting edge. This type of damage occurs when processing material has a high hardness.

Cracks caused by thermal stresses occur especially at low toughness material, and is due to uneven heating or cutting part of its temperature variations.

Serrated rupture of the cutting tool edge appears in case of temperature variations of the cutting edge or in the case high cutting pressure. Serrated breaks may also be due to variations in the depth the cut, and are caused by vibrations or in some cases are caused by interrupted or inconsistent supply with coolant.

Monitoring of tool wear has a particularly important role widen flexible manufacturing systems. High productivity as well as production systems where the human operator's role to monitor directly the production system can be significantly reduced if implemented methods perform only monitoring tools and methods to

determine or avoid damage cutting tools. An essential principle of flexible manufacturing systems is that of obtaining a consistent quality of products. In light of this principle tool wear monitoring and ensuring their proper management plays an important role. Also ensure proper operation tools in flexible manufacturing systems can be achieved only if there is a system for monitoring wear. Tool wear monitoring methods are grouped into two broad categories namely direct monitoring tool or indirect monitoring (monitoring of parameters directly related to cutting tool wear). The main direct methods for determining wear toolmaker related video monitoring through real-time systems. Indirect methods refer to monitoring certain parameters that influence the tool wear but namely: torque, advance the current drawn by the motor, vibration monitoring, etc.

II. MAIN CAUSES OF TOOL WEAR

Tool wear by abrasion is due to the contact between the chip and the rake face, and contact between the cut surface and sliding faces. When the cutting process allowable stresses are exceeded, there is separation of particles from the tool, which is involved in the cutting process, producing surface scratching. In some cases these particles are embedded in the cutting material sliding across the contact areas, resulting in wear grooves [1].

Tool wear due to the appearance deposits on the cutting edge occurs on the rake face of the tool due to the action of external mechanical forces and friction forces in processing materials with toughness and plasticity properties.

Diffusion wear occurs due to the change of the material structure and composition tool caused by the cutting temperature. Diffusion occurs because the molecules get great mobility, being able to move in tool-chip contact points where this contact is so fully and the temperature is at maximum level.

This phenomenon is accentuated when materials have a high thermal conductivity because the heat produced is induced in the layers furthest from the contact area.

III. TOOL MONITORING TECHNIQUES.

A. Determinations of tool wear by monitoring using torque and advance rate.

This type of methods for determining tool wear is based on monitoring forces in the cutting process. These methods are based on the fact that cutting forces increase with increased wear [2].

Measurement of axial force and torque were related to surface roughness of holes and especially the effect it has tools wear over roughness in the drilling [3].

On the same principle of ware monitoring by measuring torque and advance rate combined with other parameters, complex systems are being developed which take in account several factors involved in cutting processes.

For exact determination of the tool ware multi parameter systems are used, systems that simultaneously monitors torque, spindle speed, advance rate and tensions in the machine. The measurement for tensions is realized on two directions using strain gauges [4].

B. Determinations of tool wear by monitoring vibration and sound emissions.

Vibration monitoring is a well known and use diagnostic tool in machine tool maintenance, but this method is poses some challenges when used in tool monitoring. This is determined by the high sensitivity of the method and the nature of the cutting progresses which inherent determine a high level of vibrations.

The most commonly used vibration measuring system is based on accelerometers mounted in the close proximity of the tool (in close proximity of the spindle) [5]. The accelerometers are suitable for such conditions and don't have restrictions related to the condition of the area (temperature, humidity level etc.). The signal from the accelerometers is of very low level posing significant challenges in acquiring the signal. Measures have to be taken to reduce the perturbations in the signal acquired from the accelerometers.

Other disadvantages of the method are presented in several studies, namely the high dependency of the signal related to the tool material, the material being cut and to the mechanical structure of the machine tool.

Another system for vibration monitoring is the non contact vibration measurement systems. These systems use a laser to accurately determine the vibration practically canceling any possibility of perturbations from the electrical systems of the machine tools.

At the University of Oradea is used a portable digital vibrometer PDV 100 system realized by Polytech.



Fig. 1. Portable digital vibrometer PVD 100.

The system is characterized by a non contact measurement, velocity measurement from 0 to 22 kHz, digital signal processing, analog and digital signal outputs, variable working distance from 0.2 m up to 30 m [6].

From a theoretical perspective determination of tool wear by acoustic measurements should produce the same results as vibration measurement [2] mainly due to the fact that a vibration occurring in contact with the work piece with the cutting tool is at least partially transferred to the environment as acoustic waves. In practice this is not true because disturbances affecting the two types of measurements are different [2].

C. Determination of tool wear by monitoring ultrasonic vibrations.

Using ultrasonic vibration monitoring to determine tool wear has a number of advantages over other methods of monitoring tool ware such as the monitoring of vibration. Acoustic emissions that occur during the cutting process are attenuated by the mechanical structure or machine tools or are disturbed by noise or other emissions and measurement can be compromised by restrictions regarding positioning of sensors relative to the tool and work piece.

Low frequency signals which are used in ultrasonic vibrations analysis are not affected by attenuation or significant distortions. For this reason transducers can be located at a greater distance from the tool and work piece. In this type of analysis is the common practice to compare multiple amplitudes signals in ultrasonic frequencies spectrum. The ultrasonic spectrum used for tool ware monitoring, tool failure (tool brake) is between 20 - 80 kHz [7].

Comparative studies between monitoring tool wear by monitoring feed rate and axial forces and monitoring ultrasonic vibration have been realized. The study determined that ultrasonic vibration monitoring is a more reliable method to determine the tool wear, especially useful for detecting the risk of breaking cutting tools [8].

C. Determination of tool wear by monitoring the spindle current.

From the principle point of view monitoring tool wear by monitoring the spindle current is similar with the method of monitoring the motor torque because both methods offer information's referring to the dynamics of the cutting process [2].

Regarding the precision, the method using torque measurement is superior mainly because of the proximity of the sensor to the tool.

The spindle current measurement method is commonly used to the ease of it implementation, the majority of CNC control systems have this function implemented.

At the University of Oradea GE-FANUC 310i model type CNC equipment is used to upgrade the TMA AL 500 work center, which is a 3 axis machine to a 5 axis machine. In this context the complex functions specific to the flexible cell or to flexible manufacturing system are implemented.

The FANUC 310i model A5 with which the machine is equipped included a parameter monitoring function that includes a series of options for monitoring the tools.

In Fig. 2 is presented the main screen of the wave diagnostic function of the FANUC 310i CNC.

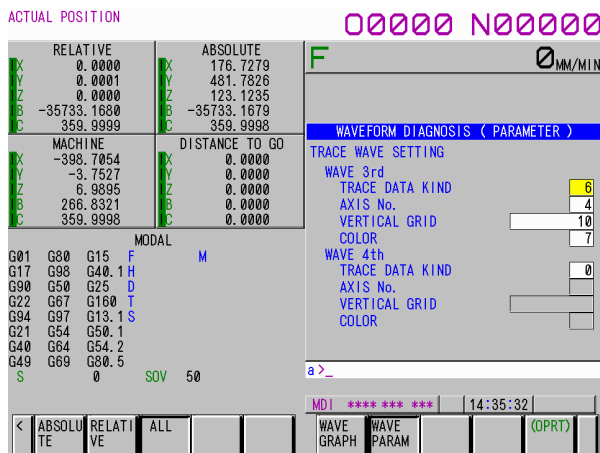


Fig. 2. Waveform diagnostics screen.

The function allows the monitoring of the following parameters of the machine.

- (1) Servo-related data
 - Positional deviation amount
 - Pulse amount after distribution
 - Torque amount
 - Pulse amount after acceleration/deceleration
 - Current command value
 - Heat simulation data
 - Composite speed of all axes

- (2) Spindle-related data
 - Speed of each spindle
 - Load meter value

- Spindle-converted positional deviation difference

(3) Machine signal

- ON/OFF state of the external I/O signal specified by a signal address [9].

The system can generate a diagram which includes the selected signals (shown in Fig. 3) and will generate a file containing the acquisitioned parameters (Table I).

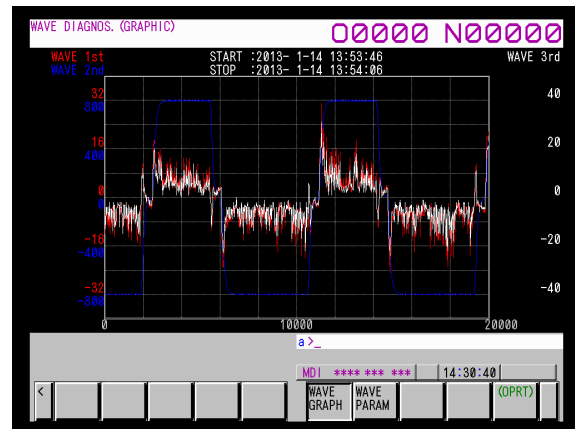


Fig. 3. Waveform diagnostics diagram

TABLE I
DATA ACQUISITION PARAMETER FILE GENERATED BY THE WAVE FORM DIAGNOSTIC FUNCTION OF THE FANUC 310i CNC. - SAMPLE PART

%
T1CWAVE DIAGNOS
T69D20130114.135346
T92D20130114.135406
T90D20
T91D4
T68P2D4
T68P3D4
T68P4D4
T62D-4
T63D-800
T64D-4
T62D-4
T63D-800
T64D-4
T62D-12
T63D-797
T64D-13
T62D-5
T63D-805

In Table II the main parameters available for monitoring by using the wave diagnostic function of the FANUC 310i CNC and there identification is presented [9].

TABLE II
PARAMETER IDENTIFICATION FOR THE DATA FILES ENCODING [9]

Identifier word(T)	Meaning
T0/T1	Header
T60	Servo positional deviation
T61	Servo pulses after distribution
T62	Servo torque
T63	Actual servo speed
T64	Servo current command value
T68	Measurement item
T69	Date and time

T80	Spindle speed
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From the Table II can be observed that the file presented in Table I includes information for T62- Servo torque parameter, T63- Actual servo speed and T64 Servo current command value.

The data file generated by the system can be used in MATLAB to generate and analyze the information referring to the monitorized parameters. (Fig. 4 -T62, Servo torque)

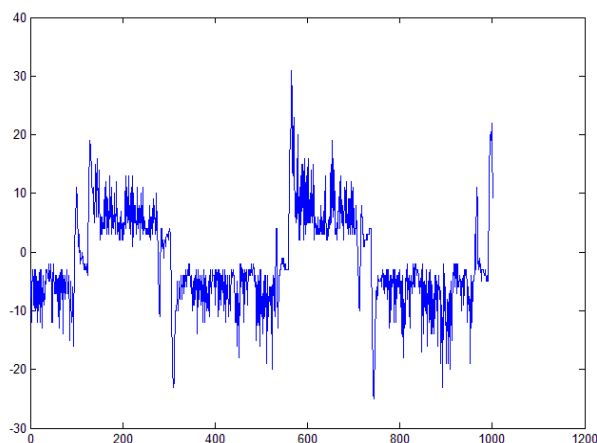


Fig. 4. Servo torque parameter diagram obtained using MATLAB from the file generated by the wave form diagnostic function.

IV. CONCLUSIONS ON INTEGRATION OF TOOL MONITORING TECHNIQUES IN THE TOOL MANAGEMENT SYSTEM OF FMS.

Tool management strategies have the main aim to increase the efficiency of the tool usage within a FSM without affecting the quality of the finished product. Several possibilities for tool management have been developed, and within the same FSM several different strategies are possible.

Regardless of the strategy for tool management all the systems are based on implementing the ATR (Automatic tool readjustment) function in one of its forms. The ATR function can be realized either by using tool storage for each machine in the FSM, tool storage equipped with an ASRS (Automated storage and retrieval system) or by using a general tool storage for the entire system, case in which the system must be equipped with a monorail robot which has access to the tool storage and to each individual machine. Each of the two main methods presented has its advantages and disadvantages but the main issues related to the strategy involved in realizing the ATR function are related to maximizing the tool usage, reducing or canceling the waiting time for the replacement tool at the machine and ensuring that all required tools are found in the system and available when needed. The last mentioned problem is of high importance in the actual manufacturing industry because of the high complexity and implicit cost of some

specialized tools. In this context having replacement tools can be a financial challenge, seriously affecting the cost of manufacturing and the competitiveness of the companies.

Modern approaches to tool management are concentrating towards the "tool sharing concept". This concept is based on the optimization of the number of tools in the system, especially for the complex and custom design tools. Tool monitoring techniques are implemented to extend the usage of the tools up to the limit where the quality is affected even if the tool life is overshoot. By implementing systems that combine the tool monitoring technique with the flexibility of the ATR function significant cost reduction can be achieved by reducing the number of tools needed in the system and by efficiently using the available tools.

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