SELF-MANAGEMENT OF MACHINES IN SMART FACTORIES VIA ADVANCED ALGORITHMS

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ABSTRACT: In the context of actual production, more and more adapted to the principles of Industry 4.0, the machines have to interact with other machines and with persons, and transmit in real time information that is processed and used to manage the production chains. The most important challenge is to make the machines working whit low or without human intervention. To this aim, it is necessary to find features that can be used for self-assessment of the machine condition and evaluation of the production processes in terms of finished and intermediate products. In this paper we present the strategy to acquire data from a CNC milling machine via a piezoelectric accelerometer and use this data to ensure the machine's autonomous functioning by involving an advanced algorithm. The machine condition and production evolution is transmitted to other machines and devices in order to take, also autonomous, decisions about their functioning.

KEY WORDS: Industry 4.0, production chain, self-management, monitoring, decision tree.

1. INTRODUCTION

The actual production system moves fast to a new concept, Industry 4.0. First proposed in Germany [1], the concept attained a rapid grow and now it is present in most developed countries [2,3] as well as in the countries with emerging economies [4].
This new industrial trend changes the way we see the management of companies [5,6,7]. The production chains are monitored and decision traced basing od more accurate information [8,9]. This concept can be even found in the household, controlling devices from distance via the Internet of Things being now a reality [10]. A similar approach is present in urban management [11].
In our prior research we have used optical and piezoelectric sensors to assess the machine condition [12,13,14] for the technical point of view. In this paper we extend the research and focus on involving sensors to recognize, beside the condition of the machine and the tools, the production advancements in terms of manufactured parts, intermediate parts and rejects. It also the aim of the developed algorithm to count the hours registered by the machine for the process, the hours need for maintenance respectively the hours the machine rest due to lack of material or request of products.

2. THE EXPERIMENTAL STAND

To study the monitoring mode of the CNC machine type EMCO Concept Mill 155 we used a Kistler 8772 accelerometer placed on the machine's desk. It transmits the data to an analog-digital conversion module NI 9234 which turn transmits the data to a laptop. It has the LabVIEW software and the Measurement & Automation application installed.

Figure 1. CNC machine and the vibration measurement system.

The stand configuration, described in detail in [15], is shown in figure 1, where noted: 1-milling machine, 2-vise, 3-accelerometer, 4-analog-to-digital conversion module, 5-laptop.

3. THE ACQUIERD DATA AND THE LIMITS PROPOSED FOR CLASSIFICATION

The acquired signal is the acceleration of the vise. Figure 2 schematically illustrates how the vibration signals are obtained when processing a product on the CNC machine. It includes three passes in the same operating mode and with the respective machine the cutting tool with the same wear state.
The accelerometer indicates the time the machine rests T_{STAT} by framing the amplitude of the A_{STAT} vibration (marked by a green dashed line in figure 3). These amplitudes are due to anthropogenic or natural micro-seismicity [16].
Also, the accelerometer can indicate the T_{MG} idling time by fitting in the amplitudes $\pm A_{MG}$ (marked with purple line in figure 3) and exceeding the amplitudes $\pm A_{STAT}$. The amplitudes at idle have the origin of the machine operation and are due to the eccentricity of the rotating parts, the mounting imperfections, etc.
A third condition is given by the actual processing of the piece under normal conditions, in which case the measured amplitudes increase. The T_{OPER} operating time can be determined for the period when the amplitude falls within the A_{OPER} limit (marked with an orange line in figure 3) but exceeds the A_{STAT} amplitude.
If the operating amplitude exceeds the values prescribed for proper operation, that is A_{OPER}, it means that a malfunction in the machine, tool wear or material non-compliance has occurred. Depending on previous experience, alert and stop limits for the car can be defined and the maintenance team's intervention must be advertised. By processing the signal and analyzing the frequency spectrum, more information can be obtained about the incident (type of failure or degree of tool wear, part destruction, etc.). As a result of this information, the quality assurance department can be alerted.

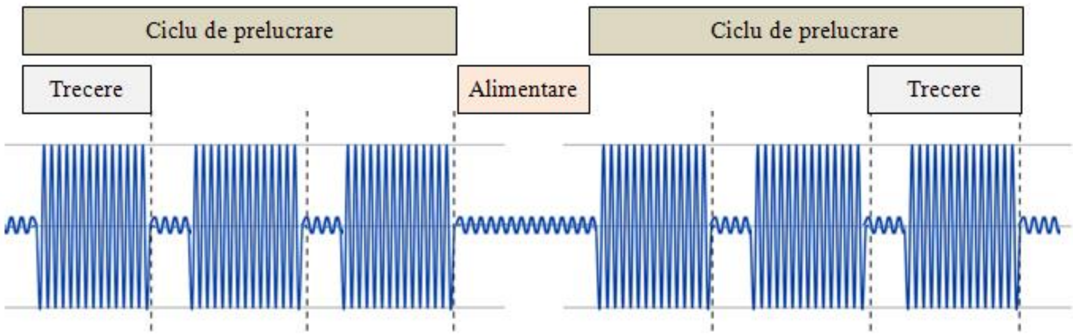

Figure 2. The acquired acceleration of the vise when the machine works in normal parameters.

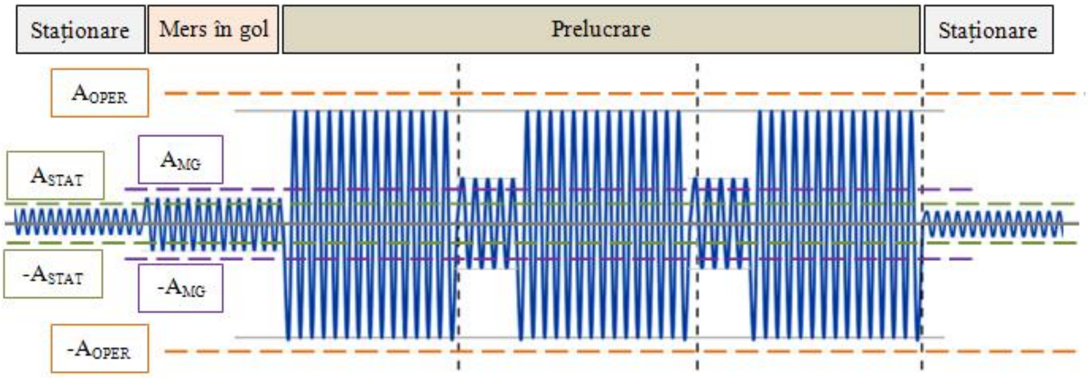

Figure 3. The imposed acceleration limits for different stages of normal functioning.

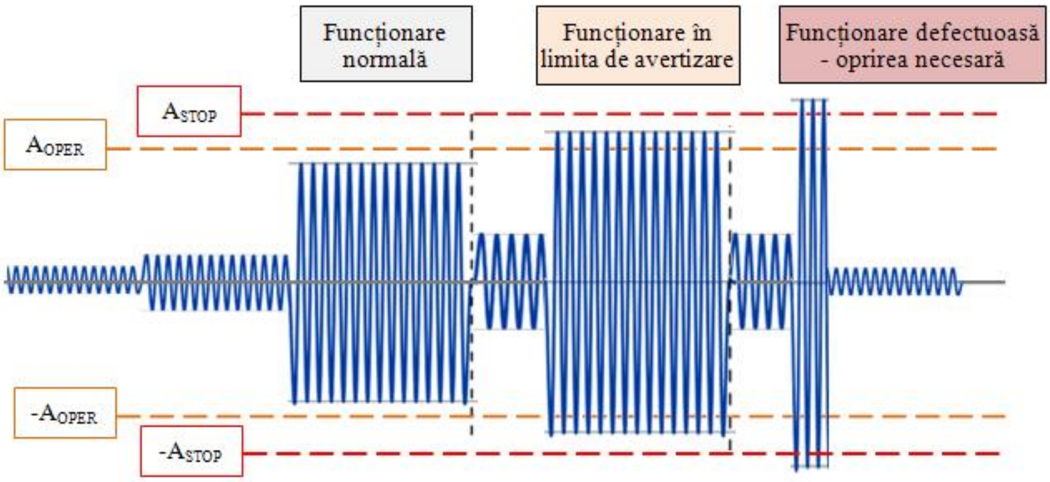

Figure 4. The imposed acceleration limits for different stages of abnormal funtioning.

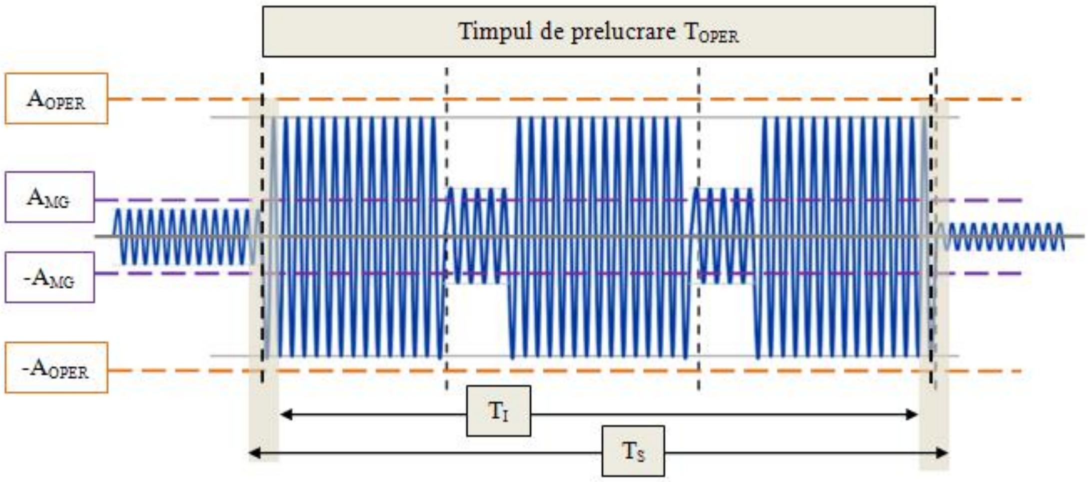

Figure 5. The imposed time limits to mark the manufacturing of one finished part.

A simple example of classification of abnormal machine operation is illustrated in Figure 4. Here are defined two areas of operation of the machine: (i) a limit of the amplitude of the A_{AVERT} vibration for minor defects at which the machine can continue to operate but must be strictly supervised and intervened at the first opportunity to remedy the situation; (ii) a limit of the amplitude of the A_{STOP} vibration, when the car stops and immediately intervenes to remedy the situation.

In case of continuous production monitoring, a signal similar to that illustrated in figure 2 is

obtained, and the central control unit receives information about the duration of the processing process. As long as the measured acceleration does not exceed the A_{STAT} value the machine is stopped and the T_{STAT} parking time is recorded. When the A_{STAT} value is exceeded but with the A_{MG} limitation, the machine goes empty. These times can be counted individually or cumulatively to set the total stay time for a calendar month.
If the A_{MG} value is exceeded, it means that the machine is processing the part. A representation of the signal with emphasis on processing time is shown in Figure 5. It is observed that a minimum required time noted T_I and a maximum required time noted T_S are defined. The classification between these operating time limits T_{OPER} indicates the execution of a part; otherwise it is assumed that the piece is unfinished or rejected. By adding the individual operating times, it is possible to determine the period in which the machine has worked for a given time interval, and the number of cycles performed that encompasses both the time and the amplitude within the preset limits indicates the number of finished parts.

3. THE CLASSIFICATION AND DECISSION TREE

The aim being to obtain a self-organized production line, an algorithm is needed that allows the central control unit to make autonomous decisions. Figure 6 shows the classification and decision tree that consists the base of the ALMA algorithm developed for a self-managed machine.

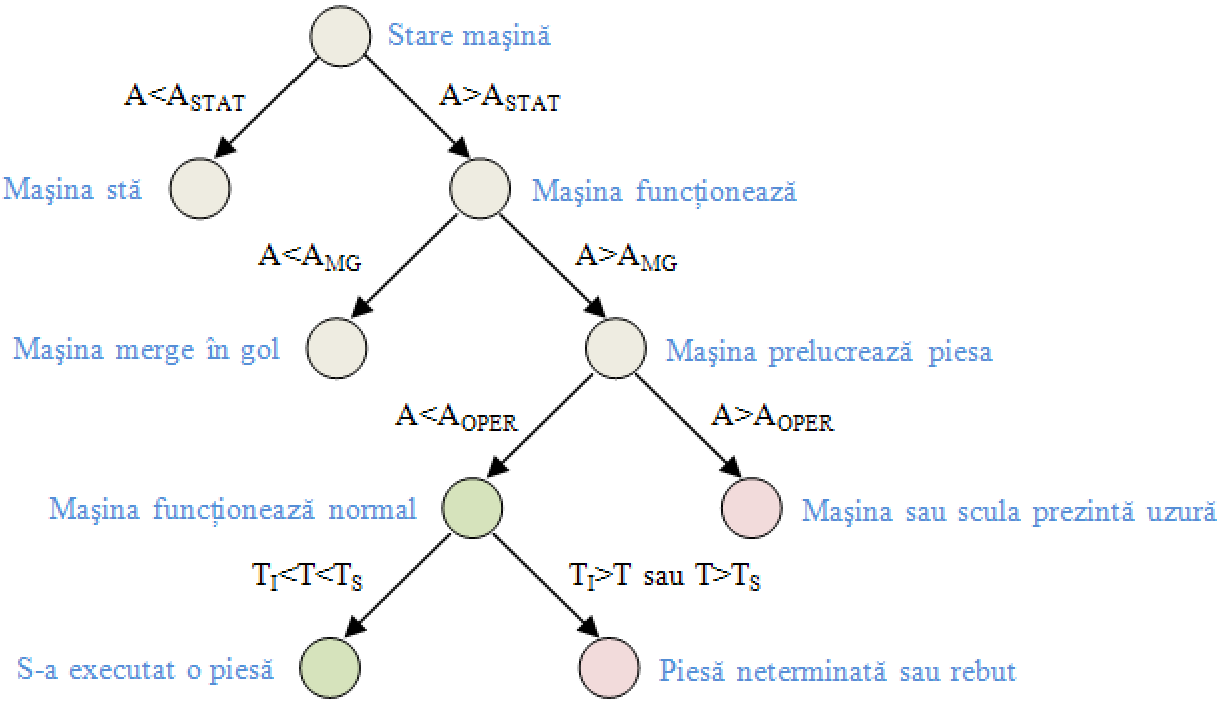

Figure 6. The decision tree as base of the algorithm that organizes the workflow

By applying the ALMA algorithm, the degree of autonomy of the operation of the manufacturing flow can be greatly increased, by its completion being possible even the manufacture without human decision, the human intervention being necessary only to the quality control of the parts, the maintenance and the supply of the classic machines with semi-manufactured and respectively parts finished.

4. CONCLUSION

The paper presents a strategy to design a self-managed machine as part of an intelligent production chain.

We used an accelerometer to monitor the production flow, the signal being classified in respect to several limits imposed for the different machine condition stages. By analyzing the time flow, the algorithm can also count the number of finished parts, the number of intermediate parts and the number of rejected parts.

By involving the algorithm, the machine is able to ask for maintenance, supplementary intermediate parts or control the regime of the other equipment that is part of the production chain.

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