USING MONITORING SYSTEMS IN MACHINE-TOOLS FOR REDUCTION OF SET-UP TIME

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Abstract. *The reduction of the set-up time in CNC machine-tools is an aim to be reached, because it provides the growth of flexibility and of productivity of the machine-tools. This issue proposes the development of an automatic presetting system using a monitoring system with an acoustic emission sensor. Most of the users of CNC machine-tools in Brazil do not use any kind of presetting system because of its costs. The acoustic emission monitoring systems have some advantages that can make possible its use for the implementation of an automatic presetting system: low cost, non intrusivity, sensitivity of the system to acquire the signal of the contact between two surfaces, tool and workpiece or tool and a reference point. The results achieved show that monitoring acoustic emission can also provides a control of other occurences in the process, like: detection of collision between tool and workpiece or between tool and parts of the machine and determination of a pattern of signal for the process*

Keywords*: set-up reduction, process automation, acoustic emission, process monitoring*

1. Introduction

The increasing use of the most modern CNC machines, with resources that permit the use of higher speeds for the displacement of the axis, brought a reality to manufacturing process: reduction of milling time, use of higher cutting speed, tools with geometries and materials that permit higher removal of chip, amongst others.

It is a reality that aims, mainly, to satisfy the flexible scenery of manufacturing, in which prevails the production of small and medium size batches, the use of group technology, the use of group tooling, etc. Several brazilian authors have proposed solutions to same questions that arise in this scenery: Baptista (2001), worked with optimization of milling process, aiming to get maximized cutting speed that could offer cost and production compatible to the needs of manufacturing flexible systems; Correia Filho (1996), identified the advantages and disadvantages of using standard tools for a certain family of pieces; Coelho *et al*. (2001), presented a rising of the researches that are being developed in Brazil on the field of high speed cut milling.

Related to the equipments, the development is shown in the constructive aspects, which favor structural innovations on machines (Mason, 2001; Metternich, 2002); alterations on movement transmission systems (Simon, 2001); and the changes axis spindles, which permit working with higher cutting speeds (Layne, 2001; Schleinkoker, 2001). These progresses that the machines are suffering can be observed clearly on Fig. 1.

However, the question of safety on using the equipments CNC still deserves attention. It is common that machines come to the customers without having any resources that help them to identify a series of problems that occurs both during the operation of material removal and (mainly) on the moments that occur displacements on emptiness for positioning of pieces and/or tools. There are few works that look for solutions to this kind of problem, and most of them are directed to the use in grinding machines. Felipe *et al*. (1998), proposed the use of monitoring system with acoustic emission (AE), to identify occurrences of collisions in CNC grinding machines; Souza (2002) proposed the use of monitoring system with acoustic emission (AE) through intelligent function (IF) to monitoring a turning process; Hara (2000), also tried to treat the subject in the senses of avoiding collision on operation of grinding with the use of acoustic emission (AE).

Another problem that must be focused aiming industrial process automation is the low use of tool presetting systems in CNC machines. Simon (2003), identified that just a small part of the users of CNC machines, in special those using milling centers, employed the resources which permit the accomplishment of presetting before assembling the tools on turrets or magazines of machine tools. These users prefer to accomplish this sort of setting with tools already assembled on the machine in an activity that takes a lot of time; the tools setting is accomplished manually by the user. The use of auxiliary functions on tools presetting using signals of monitoring systems must be also object of research and development.

The viability of the implementation and the use of automatic presetting through the monitoring systems on machine tools, specially in milling centers, will make possible the acchievement of a better performance and an increase in quality, as well as cost reduction, in milling operation. This happens because the monitoring system works as it were a kind of dedicated precise and careful operator who observes from the beginning until the end of machining cycle. The milling operations possess functions that can be monitored and automated by monitoring systems, which are able to decide corrective actions.

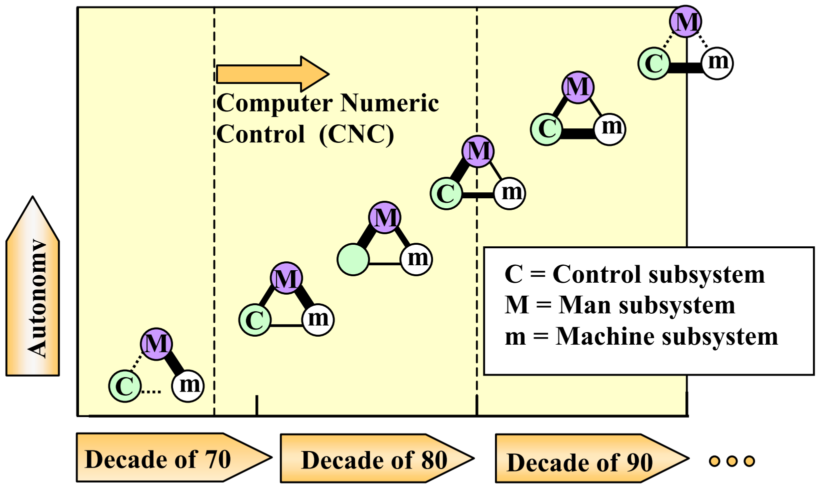

Figure 1. Evolution of automatization on milling process (Felipe *et al.*, 1998)

One of the most used and studied monitoring methods on machine tools, is that using the acoustic emission (AE) analyze. One of the main advantages of this monitoring method is not being intrusive to the process, since the system capture the acoustic emission (AE) signal generated in a milling process, through a sensor fixed on any point of the machine tools structures. Another advantage is that this system can be applied on the monitoring of several phenomena that occur during the milling process; in the case of monitoring in a milling center, this sensor can be used to identify, collisions, contacts, tools wearing, amongst other phenomena caused by the process, using just a sensor fixed on a point of the machine tool which permits the acquisition the signals generated by these phenomena.

The use of acoustic emission (AE) techniques can make possible the implementation and automation of several milling operations, once the acoustic emission signals are excellent to evaluate the existing contacts amongst surfaces in movement, what occurs very often in a milling process with CNC machines.

2. Monitoring System

The working principle of a monitoring and milling process control systems is to promote the substitution of function that the man still carries out on producing milled goods. The CNC machines already carry out several functions previously accomplished by man, as approaching, spacing and tool positioning, fixing of speed and cut speed, tool indexation, etc. Some functions, still remain under the responsibility of the operator, as establishment of the moment to change the tool, piece inspection and the own change of to these are some activities that a monitoring as milling process control system try to accomplish (Byrne *et al.*, 1995).

The current tendency on milling is directed to the increase of the rate removal of materials with a high grade of automation and the reduction of human intervention; this requires process and monitoring systems also reliable. Amongst the most command monitored values are mechanical vibration, the acoustic emission, electrical current consumed by spindle and the temperature process which are associated with the results of the process in questions (surface finishing, dimensional or geometric tolerances and microstructures integrity).

3. Components of a Control and a Monitoring Systems

Figure 2 shows the components of a complete system of control monitoring: sensor, signals conditioner, mathematical models and strategy of action and control (Dornfeld, 1994).

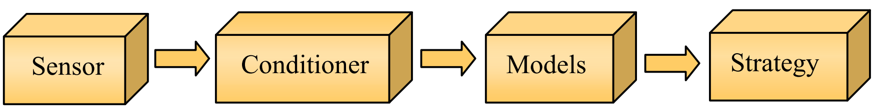

Figure 2. Components of a Control and a Monitoring System

The sensor has the function of acquiring the signals that is interested in the process and carry it to a conditioning process (amplification, attenuation, filtering, etc); once the signals are conditioned, it is possible to compare its behaviour to a mathematical model previously established to be able to the size the strategies for action and control to be used.

4. Proposal for Set-Up Otimization in CNC Machines With the Use of Monitoing Systems

As it was seen in the beginning of this work, Simon (2003) identified the absence of the use of an external presetting of tools, as one of the aim causes the no use of CNC machines and Brazilian Industrial Park (Tab. 1).

The tools are assembled on the tool turrets of the machines and definitions of the setting condition are made manually, by approaching the tool until a reference position and the manual record of the axis of position on the numerical control (NC).

Table 1. CNC machine tools installed in the Brazilian Industrial Park X Total CNC machine tools that DO NOT supported by equipment of presetting tools of the Brazilian Industrial Park (Simon, 2003).

Group of CNC machines	Total of machines	Total of machines that DO NOT use presetter systems
Lathe	8,408	5,658
Machining Center	5,978	1,295
Boring machines	279	170
Milling machines	1,375	544
Total CNC machines in Brazilian Industrial Park	16,040	7,667
Total CNC machines that **DO NOT** use preseter	8,373	

Despite this activity seems to be simple, it consumes a high time and reduces the availability of the machines. Depending on the quantity of tools that are being used and the quantity of changes that is carried out, the final results are an evident reduction on the indexes of flexibility and productivity of the machines, compromising the production programs. A CNC machine, which usually already has high cost of operation, may have increases due this low utilization. The Table 2, compare a process which use a tool presetting with a process that doesn't use it. It can be seen clearly the inactive time of the machine in the process in which tool presetting is not used.

Table 2. Reduction of preparation in milling center through a tool preseting (Simon, 2003)

Operation	Tool Setting	Tool DO NOT setting
Put the tool in the tool turret	20 s	20 s
Move until the surface of the piece, calculate the correction, move the tool back to the previous position	------	120 s
Enter with the tool correction	30 s	30 s
Carry out the milling	Equal	Equal
Check de dimension	-----	30 s
Necessary time to prepare a tool	50 s	210 s
Reduction of the time through the presetting	160 s (2,66 min)	

The proposal presented here is the use of a contact monitoring systems between the tool and a device of presetting automatic by the use of acoustic emission (AE) to reduce the initial setting time of the tools. An acoustic emission (AE) sensor may clearly identify the contact between a tool and a reference position in the machine, executing out an automatic movement, scheduled with an advanced speed equal or bigger than the defined by the milling process. As soon as the contact begins, the signal is sent to the numeric control (NC) of the machine to interrupt the movement and to identify the position of the axles in order to keep them automatically in the memory of the numeric control (NC).

5. Results Up to Present Time

The present work used the experimental assembling shown in Fig. 3. The signal acquired by the acoustic emission sensor at the machine tool is conditioned through the acoustic emission equipment SENSIS BM12, which makes the direct communication with the numeric control (NC) of machine tool or store and analyze the data acquired from a microcomputer with an A/D board and a monitoring software (LabView).

The exchange of the data between the monitoring system and the CNC of the machine tool is made through input/output external channel that the numeric control (NC) of machine tool possesses; than, through electrical pulse is possible to enable or disable the input/output external channel making possible the communication and the implementation of this kind of monitoring for intervention in the process. As for as intercommunication between the software and the hardware of the machine tool, the machine tool used the CNC (SIEMENS 810D) has controls and functions that makes possible recognize and manipulate external variables.

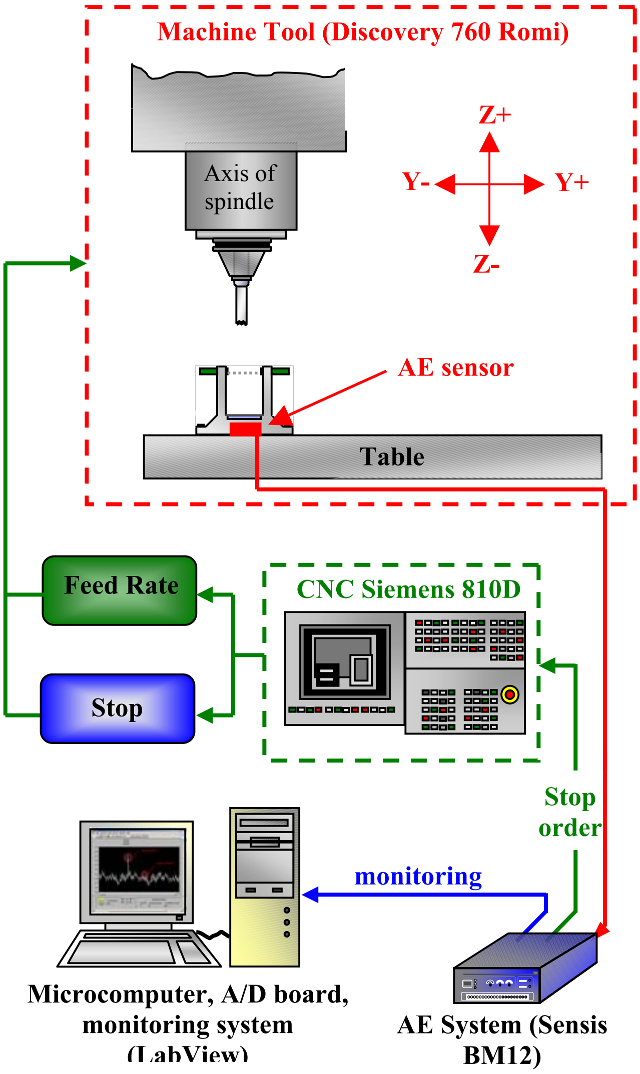

Figure 3. Experimental assembly of bench test

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To detect contact of tool, a presetting device that best adapts to a milling center was developed (Fig. 4). It is known that there are many kinds of automatic presetting systems to tools (external and internal) used nowadays by milling companies, but the cost of this type of equipment is very high, making not possible to most of companies possess this kind of instrument. The presetting and monitoring system that is being studied by the acoustic emission (AE) is a low cost type, and with just a sensor is possible its use not only as a presetting device, but also to detect: tool wearing, tool breakage, collisions, amongst other important variables to improve the quantity process and final product.

Just for a comparision of the reliability of the proposed system, an electric sensor to detect the contact between tool and presetting device was installed. This sensor uses radio-frequency (RF) to transmit the contact moment to the computer. Also for a comparision, there was acquired the electric pulse generated by a trigger pulled by the AE signal.

The trigger can be adjusted to send to the machine a pulse of command everytime the AE reaches a pre-defined level. This is to avoid any confusion between the interference of noise on the AE signal and the effective contact monitored.

The operation of the presetting device, as said previously, will be through acoustic emission. Therefore when the tool touches the presetting device (with the spindle stopped or rotating) the acoustic emission sensor will detect the contact and to inform to the command of the machine tool. For a larger safety in the presetting process, the device possesses a safety mechanism (internal absorption system), to absorb possible displacements after the tool contact in the device related with the inertia effect of the mechanical system, avoiding some problems as for example tool breakage.

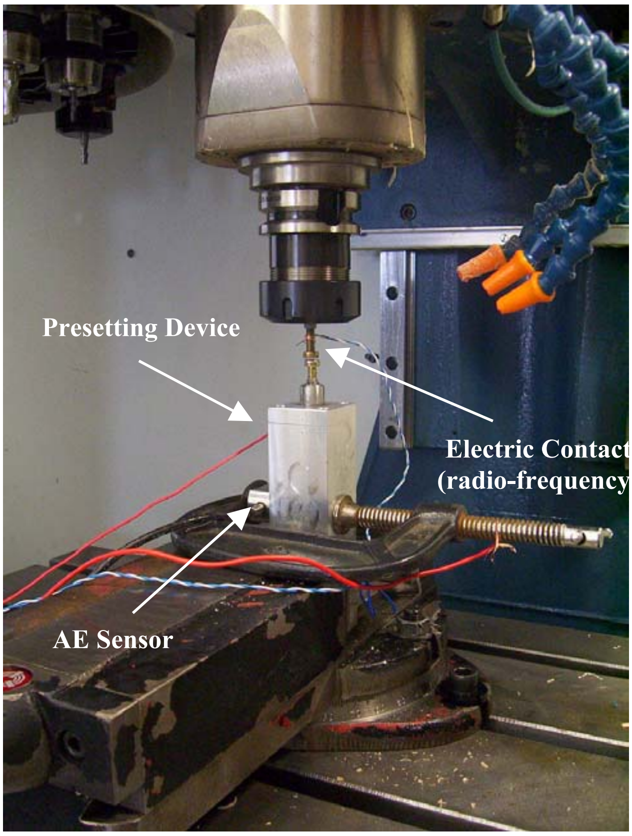

Figure 4. Presetting device through acoustic emission (AE)

To analyze the performance of the automatic tool presetting device proposed, there were made preliminaries tests to determine essential parameters for the automatic tool presetting process, as for example: contact detection of the tool with the presetting device, processing speed of the tool contact information in the device and intercommunication with the machine tool.

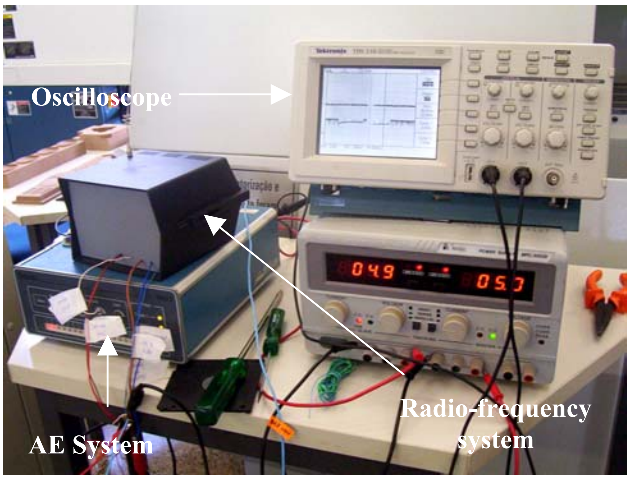

Figure 5. Bench Test

For the accomplishment of the tests a bench test was set up to observe the behavior of the acoustic emission signal in relation to simulation of a sub-routine of the tool presetting (Fig. 5). For the assembly and execution of the tests there were followed these steps: fixation of the device in the machine tool; fixation of the acoustic emission sensor in the device; fixation of an electric contact through radio-frequency (device-tool) for detection at the beginning of de tool contact with the device; development of a sub-routine for simulation of automatic presetting; acquire of data; analysis of data.

The first results were obtained with a programed Z axis speed of 3m/min, and showed that the detection system is very reliable. A comparison between acoustic emission signal and radio-frequency signals (response to the mechanical contact) showed a small difference on the response time of these tool methods (Fig. 6).

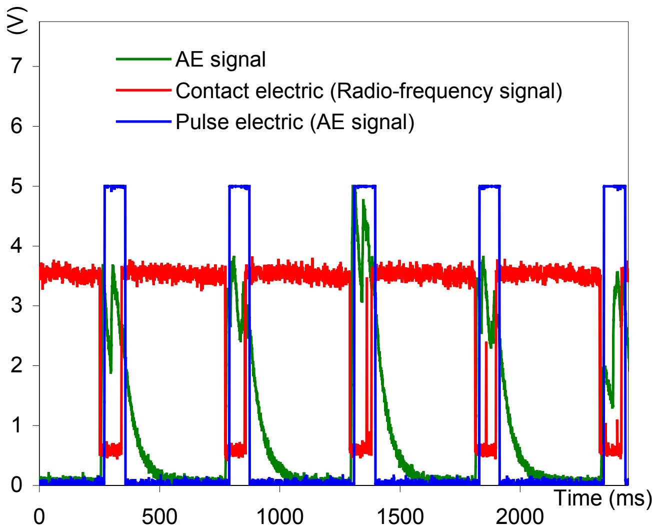

Figure 6. Comparison between acoustic emission signal, radio-frequency signal and acoustic emission pulse (trigger signal)

The RF signal decreases when the contact occurs; the AE signal increases when the contact occurs; and the AE pulse (trigger) appears only when the AE signal increases. The acoustic emission signal presented a delay of 2 milliseconds in relation to the radio-frequency signal. Already the acoustic emission pulse (trigger signal) presents a delay of 6 to 8 milliseconds, but it can be reduced by the regulation of the trigger level. It can be seen clearly in Fig. 7.

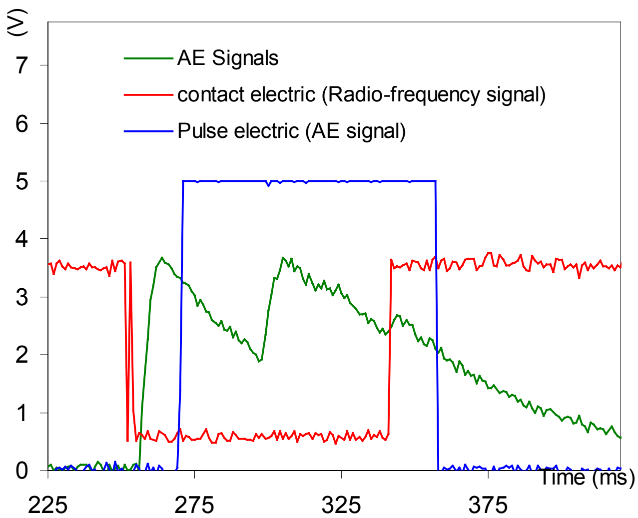

Figure 7. Details of the delay between acoustic emission signal, radio-frequency signals and acoustic emission pulse (trigger signal)

6. Conclusion

The system proposed is still being implemented indeed. Until the present moment it was possible: to develop a preliminary device for the accomplishment of the tests: to characterize the behavior of the acoustic emission signal during the tool contact with the presetting device; to evaluate the time response in relation to detection contact and of the acoustic emission signal processing for the system.

In relation to the response time of the contact detection and of the signal processing, these values can still be reduced with a better study of the acoustic emission sensor location and the development of a final device for more specific tests. Although the electric signal presented a faster response, its use is limited only to detect the presetting contact, and the AE sensor can be used for more monitoring functions.

The complete establishment of the proposed system must pass by the interaction between the machine tool and the monitoring system, and claims by the establishment of a series of addition controls to the CNC software.

With the effective implementation of this resources it is expected that the activities of tools positioning in CNC machine can be accelerated and promote the reduction of set-up time even to the case of companies do not use the resources of external presetters (great part of Brazilian companies).

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