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MODERN MONITORING OPPORTUNITIES IN SHOPFLOOR

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Abstract: *Growing efficiency in shop floor depends rather to managing decisions than machining improvements. Immediate reliable information from shop floor can be achieved by monitoring with wireless sensor network (WSN). Precondition for these applications is availability of reliable monitoring models. Regarding this challenge vibration measurements were made in different working modes and also in fault situation. Values in fault situation and different working modes were compared and differences between them were stated.*
Key words: *manufacturing, sensors, machinery, monitoring.*

1. INTRODUCTION

Volumes of production have been diminished continuously after economical crash in the world. Now there is a situation where producing capacity is bigger than the need to use it. As a result competition between manufacturers has grown. Manufacturers have to produce with less cost, but remain the same quality or even improve it to be competitive. Seems like conflict: improved quality but lower cost. In this situation monitoring can be useful tool. Monitoring helps to less refuse, improve working quality, avoid unplanned pauses and manage production in more efficient way. It gives strong base to manufacturers to survive and turn enterprise to yield a profit in changed producing environment.

In modern world it is essential to employ wireless sensors for monitoring. Monitoring with wireless sensors is more flexible. Installing a monitoring system based on wireless sensor nodes is relatively cheap, faster to attach and it has more attaching opportunities. Attaching embedded computers with a wireless communication interface which form a wireless sensor network onto machinery for monitoring machinery condition keeps the price of the solution reasonable but provides extra safety to existing process. The installation cost of cable in industrial plant can vary greatly based on the type of plant and physical configurations. Studies have shown that average cable installation cost is between 10$ and 100$ per foot (Tiwaria and Lewis, 2004), but in a nuclear plant even 2000$ per foot.

Control of shop floor plants is usually automated in higher level. Building up more sophisticated working processes, using wear resistant tool materials, raising speeds and powers permit the production of more complicated parts and also shorten the time of machining. In last year's material processing times have shortened. In the same time unplanned pauses and producing faults still take the same time. It means the time for material processing in percentage is smaller and pauses are relatively longer. It shows effectively that the bottleneck is rather in managing level than in machining. Improved tool materials and faster processing speeds alone give only a little effect in whole process in company. Initial is to shorten pauses and avoid reoperation to achieve considerable result. Monitoring is the tool to analyse routine of work and detect changes in shop floor without delay. Detecting unsuitable working modes earlier saves time, material, customer relations not to mention environment.

The aim of this paper is to point to show options for active machinery monitoring in shop floor.

2. PREVIOUS RESEARCHES

Monitoring with wireless sensors is also one idea of e-manufacturing. It includes the ability to monitor the plant floor assets, predict the variation of product quality and performance loss of any equipment for dynamic rescheduling of production and maintenance operations (Koç et al, 2003).

Research in the field of wireless sensor networks (also called smart dust) was started as a research project in 1997 by University of California computer science professor Kris Pister. A smart dust mote is a tiny computer equipped with a processor, some memory, a wireless communication interface, an autonomous power supply and a set of sensors appropriate for the task at hand. In order to prolong battery life the motes can communicate with each other and activate themselves only if it is required by the application to.

More than ten years of research in the field of smart dust applications has been done. WSN can be used not only for shop floor monitoring, but it has many other potential fields as civil engineering, health monitoring and surgery, military applications, agriculture and environmental monitoring etc (Haenggi, 2006).

Product life cycle monitoring has been research topic (Vichare et al, 2007), where temperature was experiment object. Also machining process has been monitored. For instance linear correlation was found between surface finish and vibrations resulting for tool wear in end-milling (Wright et al, 2008). Temperature, current pulse and force measuring experiments have showed positive results in CNC-milling machine (Shin et al, 2006).

Many studies have been done in this area, but in real life wireless monitoring is used infrequently in shop floors. In United States Company Dust Networks and GE Energy in UK provide smart dust particles also for industrial applications, but in plants they are used only for condition monitoring. Condition monitoring is one component of predictive maintenance. But it does not predict failure, it only helps predicting the time of failure. It means machining modes and regimes are not monitored.

3. EXPERIMENTAL WORK

3.1 Vibration tests

Vibration of the unit was measured with solid-state MEMS accelerometer LIS3LV02DQ. The sensor was interfaced to a computer during the experiments via the low-voltage SPI bus. 640 samples/s were measured and 30 s measuring period was chosen.

All measurements were made on a CNC turning lathe 16A20F3RM132. The acceleration sensor was bolted to CNC turning lathe carriage for tests 1-5 and to tool holder for test 6. Different spindle speeds and feeds were used to compare accelerations in various working modes and also in fault situation. Tests inputs and maximum range values can be seen in table 1.

test no	spindle speed (rev/min)	feed (mm/ rev)	fai-lure	linear velocity (m/min)	max range value
1	600	0.3		180	161
2	2400	0.3	x	723	385
3	600	0.3	x	180	200
4	2000	0.2	x	603	200

Tab. 1. Vibration tests parameters

Comparison of tests 1 and 3 illustrates the difference between normal operation and failure during operation. Maximum range value was 24% higher in fault situation than in normal operation mode. This distinction allows fault identification. Comparison of tests 2 and 3 illustrates rapidly growing vibration in breaking situation in higher spindle and linear speeds. With higher spindle speeds the failure pattern is more distinct. In test 3 an 4 absolute range values are the same, but pattern is stronger in test 4 (fig. 1).

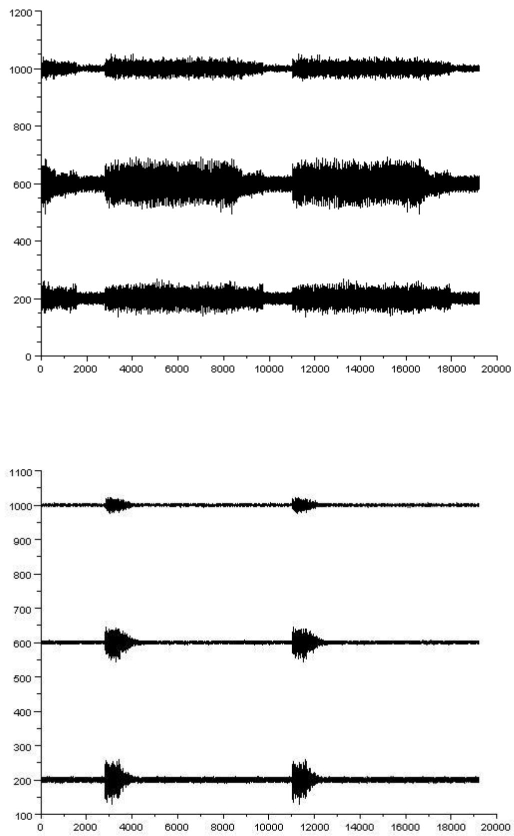

Fig. 1. Comparison of tests 3 and 4 acceleration outputs.

3.2 Acoustic test

Acoustic signal of the unit was measured with SM58 microphone and the analogue signal was converted to digital using Roland Edirol UA-25EX audio signal processor. The digitized signal was recorded in a PC. All measurements were made on the CNC turning lathe 16A20F3RM132. The microphone was positioned near the cutting area. The acoustic signal was sampled at a sampling rate of 22050 Hz and recorded to a wav file in the PC. Data was sampled during a turning work cycle (starting up engines, turning, turning fault and turning off engine).

Table 2 shows different value of the signal in feed engine working mode, regular turning mode and in the occurrence of a fault. These 3 modes are easily identifiable from each other, difference between them is 50% or more. It makes rational to use acoustic signal in monitoring process.

working mode	spindle only	regular machining	fault situation
range value	1,6	2,4	3,7

Tab. 2. Acoustic signal range values in different regimes

4. FURTHER RESEARCHES

Further research is required to develop and implement practical solutions. At first, manufacturing equipment must be categorized from the monitoring perspective to develop and employ fixed configurations of monitoring equipment on different machines. Secondly, the optimal sensor placement must be determined for every type of machine in order to acquire the parameters of interest. According to sensor types and placement, monitoring models have to be worked out. In order to determine tool wearing pattern, experiments must be conducted also with different tool wear levels.

5. CONCLUSION

Experiments showed that different modes of operation of manufacturing equipment can be determined using basic sensors and signal processing methods. Acoustic and vibration measurements allow distinguishing idle operation, normal operation and faulting situation. Further research is needed to make it widely usable in plants.

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