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THERMOGRAPHICAL APPLICATIONS FOR THE MACHINE TOOLS MAINTENANCE

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Abstract: *The importance of the maintenance function, and therefore also of maintenance management, has grown continuously. Reducing machine tool downtime and assuring quality have become increasingly important as the demand for higher production rates and closer tolerances continues to grow. Infrared thermography (IRT) is a non-invasive tool to detect and analyze thermal anomalies. The experimental researches concerning the machine tools predictive maintenance with the aid of infrared thermography were developed in laboratory conditions, in an unloaded condition, on an engine lathe. Determinations of the thermal field were oriented on the main drive and some important maintenance conclusions were find especially for the vee-belt drive and the main shaft.*

Key words: *infrared thermography, machine tools, preventive maintenance.*

1. INTRODUCTION

The unexpected production interruption is intolerable in today's business environment, in which little time or money is available for taking chances. Sophisticated production processes, just-in-time delivery, and increased productivity demands require using every tool available to prevent disrupting production schedules [4, 7].

Throughout the years, the importance of the maintenance function, and therefore also of maintenance management, has grown. The widespread mechanization and automatisation has reduced the number of production personnel and has increased the capital employed in production equipment and civil structures. As a result, the fraction of employees working in the maintenance area has grown, as well as the fraction of maintenance spending on the total operational costs. In very big factories, rafineries, it is not uncommon that the maintenance and operations departments are the largest and that each comprises about 30% of total manpower: next to energy costs, maintenance spending can be the largest part of the operational budget [5].

2. MAINTENANCE PROBLEMS ON THE MACHINE TOOLS

2.1. General maintenance policies

For a good maintenance program it should know what to measure and then be able to accurately interpret the result. Unfortunately, maintenance programs come under the category of unwanted necessities. The costs of such programs have to be balanced against the consequences of catastrophic downtime [8, 9].

There are three common maintenance philosophies.

- *Run until it breaks*. This is only practical if the penalties of unscheduled downtime are acceptable.
- *Fixed-schedule maintenance.* Machines are inspected at fixed intervals, and that usually includes regular replacement of certain parts. This philosophy has the potential flaw of over or under maintaining the equipment.
- *On-condition maintenance*. This type of maintenance has been around since about 1980 when microchips made low-cost portable test instruments practical. This is a two-step process. First a performance base for all equipment has to be established. Then maintenance is carried out based on how various components are expected to perform [10].

Preventive maintenance or on-condition monitoring programs can range from using a simple meter to give a single vibration reading to detailed analysis of a number of variables. A key is to detect shifts in performance [1].

Spindle performance is one of the first elements checked in any machine tool maintenance program. One difficult problem to resolve is the root cause of failure. For example, suppose a spindle is failing frequently. It may be the spindle design that is at fault, or it could have something to do with the machine tool's alignment or a fault in the machine's base. The spindle is the element that is usually checked first. But often there are other root causes of the problem such as a bad drive motor, structural problems within the machine, or even resonance from an adjacent machine [1].

2.2. Machine tools maintenance problems

Reducing machine tool downtime and assuring quality have become increasingly important as the demand for higher production rates and closer tolerances continues to grow. To assure maximum performance from machine tools, manufacturers are increasingly employing predictive maintenance (PDM) programs. The objective of PDM and similar programs – such as Machine Tool Variability Management System (MTVMS), Reliability and Maintainability (R&M), Failure Mode and Effective Analysis (FMEA) and Total Productive Maintenance (TPM) – is to predict when a machine tool will fail or go out of tolerance in order to reduce unplanned downtime, particularly at critical times during production. This objective is achieved by monitoring machine tools and collecting data with a combination of instruments, such as calibration, vibration analysis and infrared thermography equipment. A historic comparison of the data is made and used to predict both when a machine tool will require service and the scope of services that will be necessary. Therefore, repairs and other maintenance can be scheduled for time periods which will least interfere with production [11].

3. THEMOGRAPHY – A MODERN WAY TO ANALYZE THE MACHINES CONDITION

In mechanical devices such as motors and gearboxes, thermal anomalies are normally indicators of insufficient lubrication, misalignment, worn components, or mechanical loading issues. With its origins in aerospace, the use of Infrared Thermography (IRT) as a non-invasive tool to detect and analyze thermal anomalies is spreading rapidly throughout many industries.

Thermal imaging cameras collect and convert the infrared radiation that objects emit (wavelengths between 0.7 and 1 000 microns) or reflect into images that you can see on a computer screen or viewer. Precise heat measurements allow to monitor thermal performance, identify and evaluate the relative severity of heat-related problems.

By deploying thermography over a specific timeframe to monitor equipment, it's possible to predict failures to a greater degree, or at the least, conduct preventive maintenance to head off costly shutdowns. Due to its non-contact, non-destructive capabilities, the use of thermography is advantageous over other methods because of its ability to assess a wide array of equipment, such as electrical circuitry, motors, pumps, fans, gearboxes, and compressors, while they are operating under normal conditions. Thermography is fast and cheap when compared to a costly breakdown and loss of production.

Among IRT techniques that come to play are:

- comparative thermography;
- absolute thermography – this technique is used when it is vital that you know as precisely as possible the true temperature of the device you're monitoring.

Comparative thermography can be further broken down into the following:

- comparative quantitative thermography – this is the most effective method in evaluating a machine or component by comparing their approximate temperatures to identical units, reference values, or baselines;
- comparative qualitative thermography – this compares infrared patterns of one component to an identical or similar component running under the same or as close to operating conditions as possible without assigning temperature values to the patterns.

An effective IRT program is only as good as the results, which plant management and maintenance personnel should easily understand. All of which, of course, is dependent on the qualifications of the thermographer, who not only "takes the picture", but also interprets the findings [2, 3].

Infrared Thermography (IRT) is a third of the triad of procedures used in predictive maintenance – the other two being vibration analysis and oil analysis.

A missed opportunity occurs if thermography is not used in conjunction with vibration and oil analysis to assess the internal condition of a piece of equipment. Used individually, these techniques can be very effective, but together, as a triad, they represent a powerful analytical tool that helps your maintenance department move from PM (preventive maintenance) to RCM (Reliability Centered Maintenance).

Quantitative thermography compares a piece of equipment's temperature to an earlier determined baseline of that or similar equipment, which can be used to determine how severely a piece of equipment may have been damaged.

Qualitative thermography compares the infrared pattern of one component to an identical or similar component under similar conditions, which can identify a problem, but cannot provide a level of severity. In instances where the information being gathered is not necessarily needed to diagnose a problem or for recommending a specific correction, then qualitative thermography may be sufficient [6].

4. EXPERIMENTAL RESULTS

The experimental researches concerning the machine tools predictive maintenance with the aid of infrared thermography were developed in laboratory conditions, in an unloaded condition, on an engine lathe SNB 400.

Determinations of the thermal field were oriented on the main drive, which contains important heat sources: the electric motor, the vee-belt drive, and the transmission gearbox with bearings and ball bearings. The thermo graphical images were taken off after an unloaded running time of two hours, with an 830-RPM spindle rotational speed. The next images were recorded after other 30 minutes running time at the same speed, to monitor the evolution of the temperature distributions on the front side of the headstock.

The thermo graphic camera Therma Cam PM 350 and the corresponding software for thermogram interpretation were used.

Some of the recorded thermograms, witch contain significant data for the appreciation of the running consition of the main drive are presented and explained below.

Thermograms of the front side of the headstock (Fig. 1 and Fig. 2) have in the middle the front bearing of the spindle, in which cylindrical smooth shift is clamped. So is very easy to notice the cap, which covers the ball bearings and the adjacent area from the transmission gearbox. Through the processing of the thermogram data it was established the minimum temperature (18.6°C), the maximum temperature (33.2°C) and many others, marked on the figure. The temperature distribution in this thermogram shows an important heating of the upper side of the front bearing of the spindle.

The important difference between the lower side and the upper side of the bearing is due to some factors, mainly related to the design, consisting in the different thermal resistance on the two ways of thermal flow. The thermal resistance is lower in the lower side of the bearing and the thermal energy is easily dissipated to the bed, which is a design element with a high heat capacity.

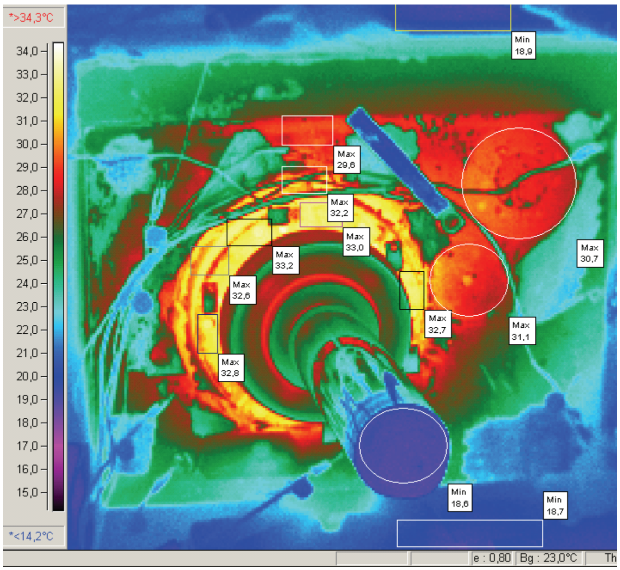

Fig. 1. Front side headstock.

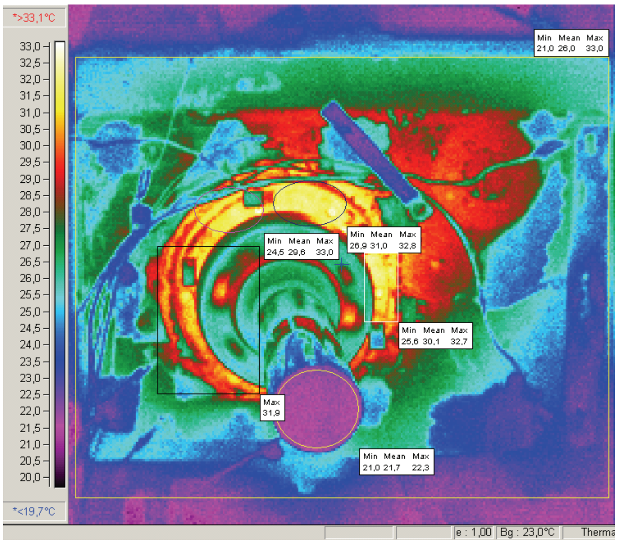

Fig. 2. Front side headstock.

The lubrication and the cooling of the transmission gearbox may be considered the second factor which should compensate the designed thermal asymmetry: in this case the too low flow of the oil in the front bearing lubrication circuit of the main spindle is reflected by an insufficient heat evacuation produced in this bearing.

The thermogram of the transmission gearbox after another 30 minutes ofrunning has not revealed significant changes of the thermal field, which proves that after two working/running hours, the machine is stabilized from the point of view of thermal flow.

The lateral image of the headstock (Fig. 3) points out an important overheating of the front roller bearing of the main spindle, compared to the back roller bearing.

This important temperature difference in the unloaded running between the two bearings of the main spindle; this difference was also pointed out through measures made with the thermocouples mounted in the two bearings; the above mentioned difference is mainly due to the pre-tension of roller bearings belonging to the front bearing, which leads to the friction growing between the rolling elements and the ball bearing rings.

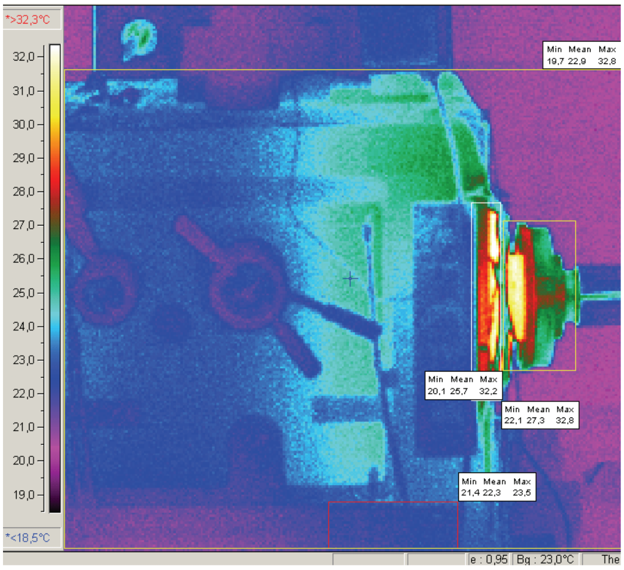

Fig. 3. Lateral image of the headstock.

This pre-tension should be set-up to o minimum acceptable value for the normal working conditions of the main spindle.

The thermo graphical image of the vee-belts drive between the electric motor and the transmission gear box (Fig. 4) shows an important asymmetry of the thermal behavior of the vee-belts group: one of these belts is much more overheated then the others and it reaches the temperature of 66.3°C. The pulley from the electric motor shift presents as well a temperature of 70.2°C in the hottest vee-belt channel area.

This temperature difference is due to the different qualities of the belts: the hottest belt was a new one, changed a short time prior to the examination.

The stress occurring in this belt was higher than in the other belts, the friction with the pulley has grown and consequently the temperature has considerably raised.

The long term loaded function inexorably leads in these conditions to the early wear and to the weakening of the overheated belt, namely to the requirement of the repair intervention.

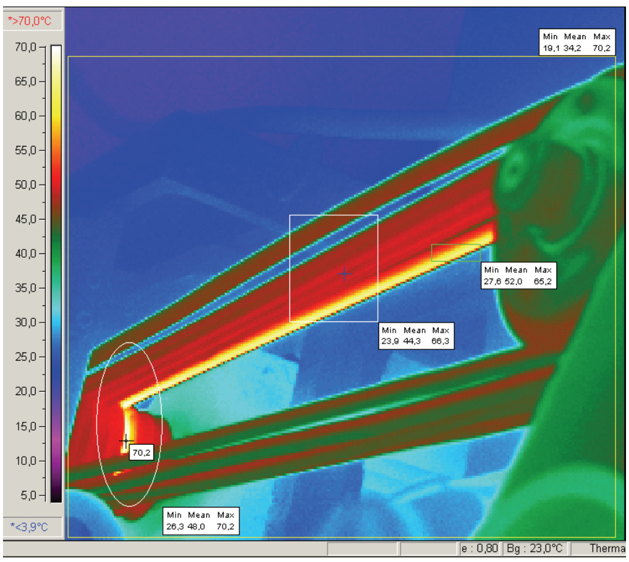

Fig. 4. The vee-belts drive.

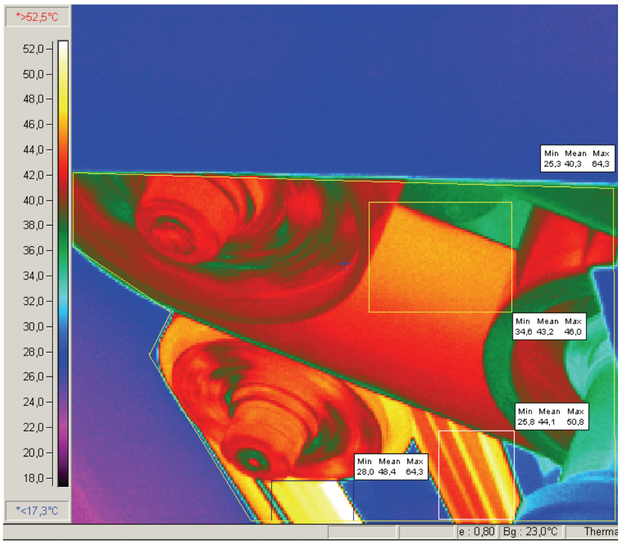

Fig. 5. The open belt drive.

The open belt drive between the transmission gear box and the main spindle, presented in the next thermogram (Fig. 5) shows a moderate heating of the belt, at the temperature of 46°C, as well as the thermal field uniformity in the belt, this resulting in the normal running/working of the drive.

The vee-belt drive, presented above, occurs in the lower side of the image, pointing out much higher temperature differences compared to the open belt drive.

5. CONCLUSION

The exploration of the working condition of the main drive of an engine lathe using the infrared thermography has emphasised the important mechanical heat sources: belt drives and the bearings of the main spindle. The thermograms achieved for the unloaded running pointed out high temperature differences due to the malfunction of the vee-belt drive and of the main spindle bearings.

The machine tools maintenance strategies may be classified in three general principles: no preventive maintenance, periodical scheduled maintenance and intervention from case to case.

The preventive maintenance through monitoring programs for the functional state of the machine tool enables the detecting of the change (reduction) of the performances. Through good monitoring programs it is possible to avoid catastrophic expensive failures.

The parameters to be analysed for the running/working monitoring are: vibrations, oil quality, temperatures distributions and the current in the power circuits.

The infrared thermography offers a rapid and affordable mean for the analysis of thermal anomalies, generated by heat sources, which may determine the occurrence of certain failures of mechanical, hydraulic or electrical part.

The data processing of the thermograms recorded on the loaded running of an engine lathe pointed out the unequal heating of the main spindle front bearing and of the vee-belt drive.

The inadequate function of some sub-assemblies, emphasized through the infrared thermography, can be easily rectified through ball bearings set-up or through the replacement of some cheap parts (belts) during the preventive maintenance.

REFERENCES

[1] Aronson, B. R. (2002). *What to Measure for Proper Maintenance*, Manufacturing Engineering, vol. 129, no. 4.

[2] Basta, J. (2004). *Infrared thermography – its role in maintenance and loss prevention*, `http://www.thefabricator.com`.

[3] Bevevino, E., *How Infrared Thermography Fits Into Your Maintenance*, Program, `http://www.chem.info`.

[4] Bevevino, E. (2006). *See red!*, MRO Today, February/March 2006, Issue.

[5] Dekker, R. (1996). *Applications of maintenance optimization models: a review and analysis*, Reliability Engineering and System Safety, **51**, pp. 229–240.

[6] Meola, C., Giorleo, G., Nele, L., Squillace, A., Carlomagno, G. M. (2002). *Infrared thermography in the quality assurance of manufacturing systems*, Nondestructive Testing and Evaluation, vol. 18, no. 2, pp. 83–90(8).

[7] Paris, A., Târcolea, C. (2004). *Taguchi Applications on Manufacturing Systems*, Edit. Academiei Române, International Conference on Manufacturing Systems – ICMaS 2004, pp. 459–462.

[8] Târcolea, C., Paris, A. (1980). *Metode matematice aplicate în întreţinere şi reparaţii*, Al II-lea simpozion naţional de ingineria sistemelor şi cibernetică industrială, “Politehnica” University, Bucharest.

[9] Târcolea, C., Paris, A. (1980). *Model de prognoză a necesităţilor de întreţinere şi reparaţii*, Al II-lea simpozion naţional de ingineria sistemelor şi cibernetică industrială, “Politehnica” University, Bucharest.

[10] Târcolea, C., Paris, A., Zaharia, R., Duculescu, G. (1982). *Contribuţii la studiul mentenabilităţii maşinilor*, A IV-a Conferinţă Naţională de Maşini-unelte, Bucharest.

[11] Wang, Ch., Thomas, B. (1987). *Predictive maintenance and machine tool calibration techniques*, Modern Machine Shop**.**

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