SOME APPLICATIONS OF THERMOGRAPHY AND LASER MEASUREMENTS FOR DAMAGE PREDICTION AND DIAGNOSTICS OF A CNC MACHINE

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ABSTRACT
Infrared Thermography it's a non-destructive testing technology that can be applied to determine the superficial temperature of the objects. In most of the cases it is really expensive and can cause many problems when a machine stops because of a damaged part. With the use of thermography the damage can be predicted, its growth can be monitored and maintenance can be programmed avoiding the unexpected shutdown of the machinery. The paper presents an experimental approach for the analysis of the machines from a workshop using thermo-graphic investigations and interferometer encoders which provide the ultimate accuracy in linear position. This paper shows that from combination of these two methods we can gain a detailed picture of how each characteristic of a machine's performance is varying over time. Maintenance work can be predicted and contingency plans can be established in advance.

Keywords: thermography, laser interferometers, maintenance, diagnose

1. INTRODUCTION
The demands of modern industry to meet ever tighter tolerances, and the requirements of international quality standards, mean that the performance of manufacturing machinery has never been more important [7]. In order to meet these demands, measurement systems that assess, monitor and improve machine performance, are used. Actual manufacturing machines must follow a repeatable and accurate behaviour. Unfortunately, thermal deformations up to 150 microns can be found e.g. in milling machines working at medium load. This phenomenon is found also (in other scale but with similar relevance) at the industrial robots, in coordinate measuring machines (CMM's) or in precision machining equipment. More than

50% of the machining errors even in the case of modern machine-tools are due to the thermal phenomena [8]. In fact the errors having static, dynamic causes or resulting from wear have been in greater proportion already studied and obtained [8]. Since 1988 the ML10 laser measurement system represented the ultimate in calibration for machine tools, co-ordinate measuring machines (CMMs) and other position and motion critical systems. Laser interferometry is a well-established method for measuring distances with great accuracy. Laser measurement machine performance measurement systems use remote interferometers for all measurement modes (not just linear) and a precision laser source to deliver exceptional precision and accuracy [7]**.** Every corpse from our environment that has a temperature of over 0˚k (-273˚C) emits thermal energy under the form of infrared radiation (IR). [1]. Thermal vision infrared cameras measure this radiation using special sensors; it converts it and shows it as thermal images. This is a non-destructive, non-contact method used for detecting the faults during the production process, without the interruption of the technological process [3].

2. EXPERIMENTAL EQUIPMENT

2.1. Flir Thermacam E45

The necessity of generating thermal maps that can be interpreted in different domains of science conducted to an increase of the interest of the companies into developing special equipments which will expand the human visual field and the infrared radiation domain. So, thanks to new technologies, thermal cameras were manufactured, cameras that allow the visualization of the infrared radiation, emitted or reflected by biological and technical systems, the final result being the visualization of the temperatures from the measured object. The structure of the used detectors for non-contact termography, thermovision works in the infrared range of the electromagnetic spectrum. In Figure no. 1 we can see an example of a Thermal camera, the Flir Thermacam E45 with a range between -20˚C to 250˚C (900˚C Optional), with a display of 50Hz, emissivity range from 0.1 to1.0. Precision of ±2˚C and ±2%, with a spectrum between 7.5 and 13 µm the reproduced image is jpeg format, 16k colors, 160x120 pixels. IR camera construction is similar to a digital video camera [6]. The main components are the lens that focuses IR onto a detector, plus electronics and software for processing and displaying the signals and images. Instead of a charge coupled device that video and digital cameras still use, the IR camera detector is a focal plane array (FPA) of micrometer size pixels made of various materials sensitive to IR wavelengths.

Figure 1. Flir ThermaCam E45[6]

2.2. Laser interferometer ML10

Laser interferometry is a well-established method for measuring distances with great accuracy. Renishaw's machine performance measurement systems use remote interferometers for all measurement modes (not just linear) and a precision stabilized laser source to deliver exceptional precision and accuracy. The ML 10 laser measurement system is used for the comprehensive accuracy assessment of machine tools, CMMs and other positioning systems [7]. System accuracy of 1,1 ppm is maintained throughout its operating range of 0-40 C (32-104˚F), a standard level of performance that no other competitive system can match [7]. The software is extremely flexible in enabling the capture, storage and presentation of data from electronic levels and digital indicators. The captured data can then be analysed in accordance with national and international standards. The ML10 laser head is the core unit of the measurement system. It contains a Helium Neon (HeNe) laser tube producing stabilised laser light at 633nm. The Class II laser power rating means that it can be used without the need of special safety equipment [7]. The single frequency laser contains sophisticated electronics for stabilisation and to interpolate and count the interference fringes. This provides true nanometre resolution measurements at federates in excess of 1m/s. Renishaw ML 10 system can be used for calibrating axes up to 80m in length. The accuracy of a laser distance measurement system is primarily dependant on how well it can compensate for the effects of air reaction changes on the wavelength of the laser. Without this compensation, accuracy of any system is significantly compromised [7]. The EC10 compensation unit continually monitors the surrounding environment by collecting data from highly accurate sensors measuring the ambient air temperature, pressure and humidity. From this data, the unit calculates the true laser wavelength using Edlen's equation. This compensated wavelength is combined with the fringe count from the ML 10 laser to give compensated distance measurements with guaranteed accuracy.Highly durable, the aluminum optics housing, including threads, are all hard-anodized, corrosion proof and shock resistant. With half the weight of steel optics housing, machine loading is reduced and they acclimatize 10 times quicker than steel optics. In the next picture it is shown the experimental set-up for linear measurements using the ML10 laser interferometer from Renishaw.

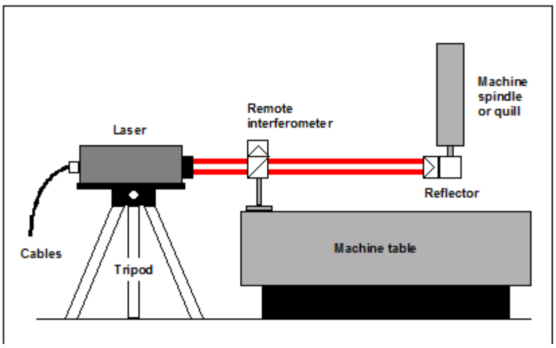

Figure 2. Linear measurement [7]

3. EXPERIMENTAL MEASUREMENTS

Measurements were made on a CNC milling machine**,** SA MULLER CH-2555 BRUG/BIENNE, from the laboratory of the Technical University of Cluj-Napoca, Faculty of Machine Building. Because the measurements were made in a controlled environment the EC 10 compensation unit was not connected to the laser. Measurements were made according to ISO 230-3, using temperature measurements and interferometer encoders. In the next picture we show the laser interferometer mounted on the milling machine for the determination of the linear errors on the x axe.

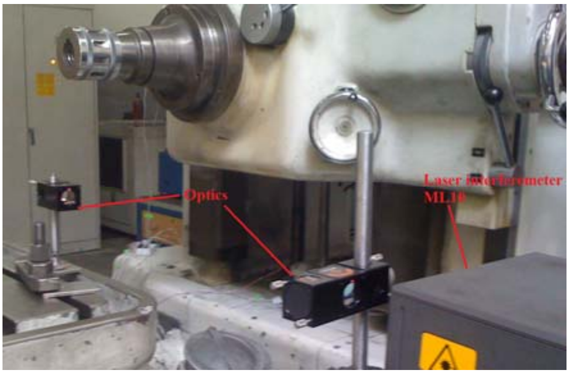

Figure 3. Experimental set-up for linear measurement

After the laser interferometer was mounted on the machine according to the specifications for the linear measurement of a single axe. The laser was started and connected to the PC After the laser and the optics are mounted on the machine so that the laser beam is reflected back in the ML10 without obstructions. After this was done the CNC machine was started at a certain speed for fifteen minutes, as the standard ISO 230-3 requires. Then the temperature measurements were made using the thermal camera from Flir, Thermacam E45 followed by the position monitoring using the laser interferometer.

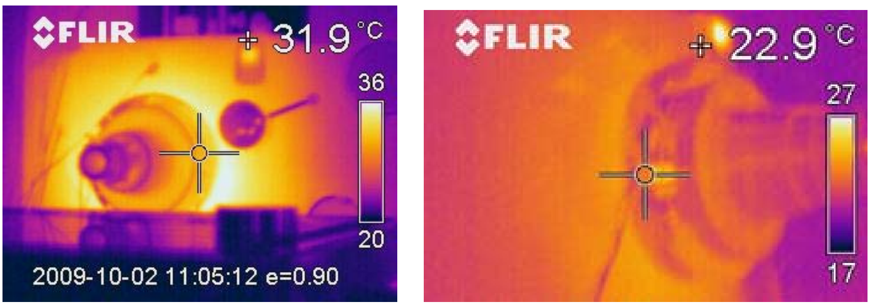

Figure 4. Thermal maps memorized during the research

After setting the machine and the laser at a “0” the table of the machine was moved on the x axe, and after approximately 30 mm it was stopped. On both displays, the machine’s and the computer’s, we will have the linear movement of the table, in mm. The difference between this values, represent the linear errors at different temperatures. The system measures linear positioning accuracy and repeatability by comparing the position displayed on a machine’s readout with the true position measured by the laser. These values can then be viewed, printed and statistically analyzed by the system’s software to national and international standards Position errors were measured with an error of 0.1µm, but the laser system allows measurements with an error of 0,001µm. Linear and thermal measurements were repeated every fifteen minutes, after the machine worked at different speeds, according to ISO 230-3.

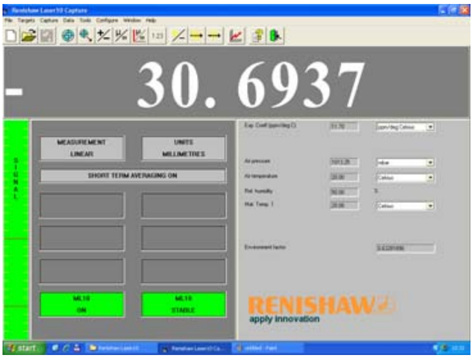

Figure 5. Values measured with the interferometer *Figure.6 Values shown on the machine's display*

Table 1. Measurements on the x axe

Time	Value measured by the interferometer [mm]	Value measured by the machine [mm]	Linear error [mm]	Temperature ºC
15'	26,7168	26,736	0,0192	27,7
30'	30,6938	30,712	0,0182	27,7
45'	34,6578	34,678	0,0202	28,1
60'	28,4187	28,436	0,0173	28,1
75'	32,6713	32,690	0,0187	29,4
90'	30,9716	30,990	0,0184	30,7
105'	27,0687	27,084	0,0153	31,1
120'	28,7704	28,788	0,0176	32,4
135'	27,9231	27,940	0,0169	33,7
150'	26,7334	26,748	0,0146	34,1
165'	34,0169	34,036	0,0191	35,4
180'	29,8990	29,918	0,019	36,7
195'	30,4687	30,488	0,0193	37,1
210'	31,1619	31,180	0,0181	38,4
225'	30,9480	30,968	0,02	39,8
240'	27,0593	27,074	0,0147	40,2

4. CONCLUSIONS

On many of today's machine tools, it is also possible to take this process one step further and automatically download the measured data to a compensation table in the machine's controller[7]. In this way, a machine's positioning accuracy can be verified and significantly improved, quickly and easily. Fast accurate measurement of machine performance, quickly allows you to isolate mechanical or electrical problems and then fix them, either by repair or by optimising machine error maps. A detailed analysis of machines helps to identify the impact of new design features on machining performance [3]. By keeping a record of the performance of each machine we gain good visibility of any production engineering problems [7]. By the calibration of the machines, we will be able to grade them according to their relative machining ability. We will be able to assign specific tolerance jobs to machines capable of holding these tolerances. By ensuring that a machine is working to specification, the chance of scrap will be minimized. It also enables tighter tolerances to be held on jobs, improving overall accuracy and quality. Certain types of machine errors can lead to excessive wear in the drive system and guide-ways of the machines. If they are determined and eliminated these at an early stage, the working life of a machine can be improved. A very important aspect is the connection between metrology and the thermal behaviour of machine tools [8]. A condition for the assurance of quality parameters at machine-tools are both its reception and especially its behaviour at different trials. The reception of machine tools concerns the construction's accuracy, but it is only partial relevant for its accuracy during operation. The final aim is the knowledge and the maintenance of processing accuracy under the influence of all environment conditions and during different mechanical and operating conditions. By combining these two unconventional methods we can gain a detailed picture of how each characteristic of a machine's performance is varying over time. Maintenance work can be predicted and contingency plans can be established in advance.

5. REFERENCES

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