

CNC MILLING MACHINE BIAxIAL LINEAR ERROR MEASUREMENTS USING LASER INTERFEROMETERS AND INFRARED THERMOGRAPHY

ДВУОСЕВИ ИЗМЕРВАНИЯ ЗА ЛИНЕЙНАТА ГРЕШКА НА CNC ФРЕЗМАШИНА С ИЗПОЛЗВАНЕ НА ЛАЗЕРНИ ИНТЕРФЕРОМЕТРИ И ИНФРАЧЕРВЕНА ТЕРМОГРАФИЯ

Phd.Student Eng. Grigore Pop¹, Phd. Student Eng Camil Chetrea², Phd.Student Eng Tirla Andrei³, Asist. Phd. Student Eng. Contiu Glad⁴,
Technical University of Cluj , Romania^{1,2,3,4}

Abstract: The paper presents an experimental approach for the analysis of the machines from a workshop using thermographic investigations and interferometer encoders which provide the ultimate accuracy in linear position. The measurements for the optimization of a CNC milling machine, SA MULLER CH-2555 BRUG/BIENNE, from the laboratory of the Technical University of Cluj-Napoca, Faculty of Machine Building. Thermal maps were accomplished using a Flir Thermacam E45, with which we could gain a good visibility of the temperature distribution of the investigated object. Linear positioning errors on two axes of the machine were measured using a laser interferometer ML 10 from Renishaw, which provide the ultimate accuracy in linear position. Combining 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.

Key words: thermography, laser interferometers, thermal behavior, linear positioning

1. INTRODUCTION

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. According to a CIRP evaluation, more than 50% of the machining errors even in the case of modern machine-tools are due to the thermal phenomena. In fact the errors having static, dynamic causes or resulting from wear have been in greater proportion already studied and obviated [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. Infrared thermography is a visualization technique of the temperature distribution at the surface of the corpse (invisible to human eye) and the measurement of the temperatures in any point of the image. Thermography is a visualization method from the radiation point of view, radiation emitted by the objects that it's not detected by the human eye. Thermography measures the thermal field by registering the infrared radiation and the visualization of the temperature distribution on the surfaces observed [2]. 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. Laser interferometer ML10

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. Used for the comprehensive accuracy assessment of machine tools, CMMs and other positioning systems, the ML 10 laser measurement system is by far the best tool for the job [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]. Quick and safe alignments with a tripod mounted laser, all alignments' can be undertaken comfortably and safely outside the machine. No need to lose axis travel or suffer the effects of cable drag on the measurement. Portability-one case, a tripod and a notebook PC is all that is needed for a complete system. The system is ready for the use of high accuracy measurements in 15 minutes after power-up. All optics housing are made from hard anodised aluminium, resulting in light, durable optical components that thermally acclimatise to any environment. 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.



Fig. 2. Renishaw ML10 laser [7]

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.



Fig. 3. EC10 compensation unit [7]

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.

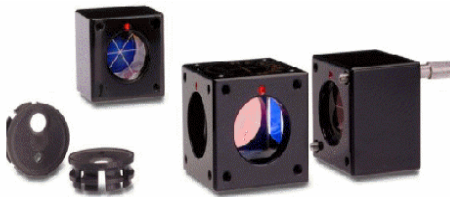


Fig. 4. Linear optics [7]

2.2. 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 to 1.0. Precision of $\pm 2^\circ\text{C}$ and $\pm 2\%$, 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.

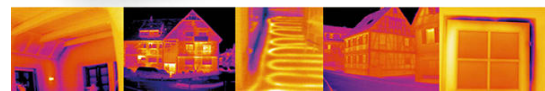


Fig. 1. Flir ThermoCam E45[6]

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. 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.

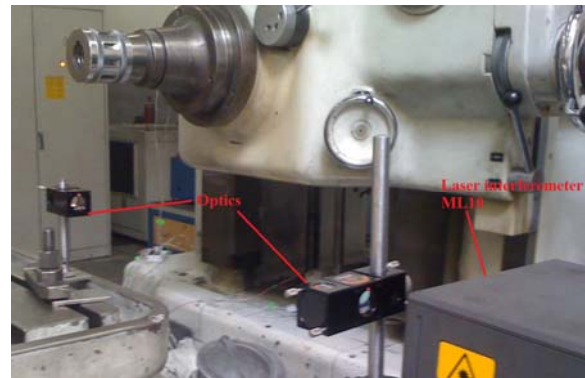


Fig. 5. Experimental set-up for linear measurements

First 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 is done we start the CNC machine at a certain speed for fifteen minutes, as the standard ISO 230-3 requires. Then we made the temperature measurements using the thermal camera from Flir, Thermacam E45 followed by the position monitoring using the laser interferometer.

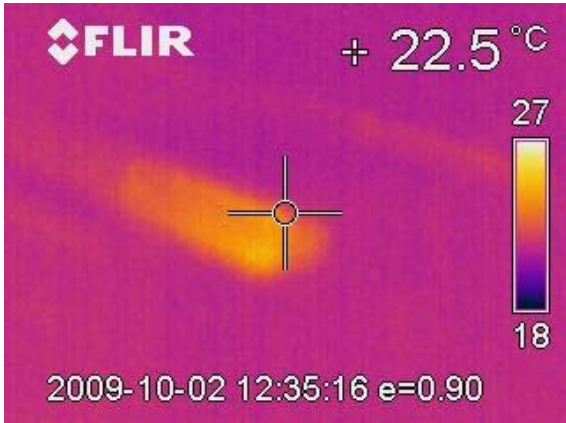
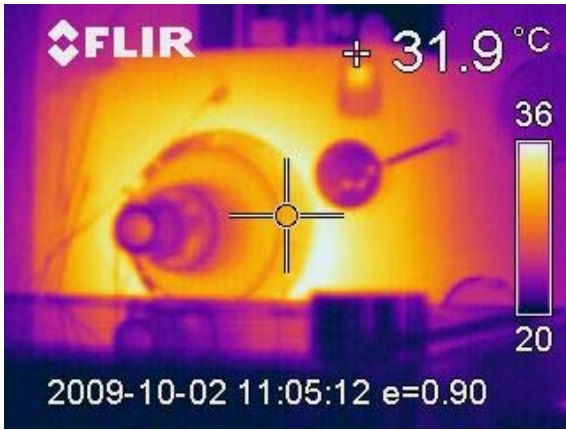


Fig.6 thermal maps memorized during the research

After we set, the machine's and the laser at a "0" we started moving the table on the x axe and after approximately 30 mm the 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, when the machine has heated at maximum 27 °C ,in some parts, and 36°C, in other parts. 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. The procedure was repeated for linear measurements on the y axe.



Fig. 7 Values measured with the interferometer



Fig.8 Values shown on the machine's display

Because the measurements were made in a controlled environment the EC 10 compensation unit was not connected to the laser.

4. CONCLUSIONS

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 they are fit for the required purpose it will be less likely to produce scrap.

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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