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RESEARCHES REGARDING THE THERMAL BEHAVIOR OF A CNC MILLING MACHINE USING IR THERMOGRAPHY IN COMPEARANCE WITH ODER CONVENTIONAL METHODS

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Abstract: *At temperatures higher than 0ºK, the absolute zero temperature, each body emits heat (thermal) radiation. The intensity of this radiation depends on wavelength λ and the body's temperature. Herschel named them 'invisible rays' or the 'invisible thermometrical spectrum' and later they were commonly named 'infrared rays'. This paper presents an analyze of the thermal behavior of a milling machine using two measurement methods. One representing a non-destructive testing technology (NDT) using infrared thermography, and the other one, a conventional method, using thermal sensors applied directly on the investigated object. The images were taken in the laboratory of the Technical University of Cluj Napoca on a CNC milling machine according to ISO 230-3.*
Key words: *thermography, non-destructive evaluation, thermal behavior*

1. INTRODUCTION

F.W. Herschel's experiment, resulting in the discovery of infrared radiation, had fundamental significance for the rise and development of research in the infrared spectrum. In his experiment Herschel (1800a–d, 1830) observed heat effects associated with different spectral ranges of the Sun's radiation (Waldemar, 2009). He placed blackened containers of sensitive mercury thermometers along the spectrum obtained by splitting the Sun's radiation in a glass prism. The energy of incident rays was absorbed by the containers and the thermometers indicated temperatures higher than the ambient temperature. On investigating the results of his experiment, Herschel discovered that the readings of the thermometers located beyond the red end of the spectrum were higher than those of the thermometers located within the visible range (Waldemar, 2009). The experiment proved that the full spectrum of the Sun's radiation is wider than the visible range, and that directly beyond the red end there exist rays, weakly refracted by the prism, invisible to the naked eye. Herschel named them 'invisible rays' or the 'invisible thermo metrical spectrum' and later they were commonly named 'infrared rays' (Waldemar, 2009). At temperatures higher than 0ºK, the absolute zero temperature, each body emits heat (thermal) radiation. The intensity of this radiation depends on wavelength λ and the body's temperature.
Thermal vision infrared cameras measure this radiation using special sensors; then they convert and shows it as thermal images. Thermography makes heat visible and measurable. This is a modern technique, of high performance, which allows the visualization and the engendering of thermal maps(thermal images), in real time, of the biological or technical systems being under investigation **(**Medgenberg, 2007).

2. FLIR THERMACAM E45

The necessity of generating thermal maps, which 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 (Medgenberg, 2006). In figure no. 1 we can see an example of a Thermal camera,used for the experimental measurements, 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 13µm, the reproduced image is jpeg format, 16k colors, 160x120 pixels. IR camera construction is similar to a digital video camera. 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 ThermaCam E45

3. EXPERIMENTAL RESEARCH

3.1 Measurements using thermocouples

According to ISO 230-3, The temperature measurements on the CNC milling machine were made in some critical points, according to ISO 230-3. The measured areas are shown in the following picture with black arrows.

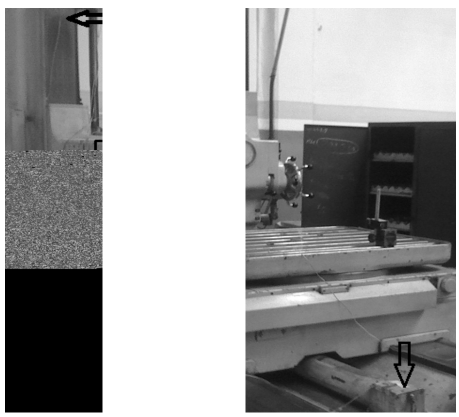
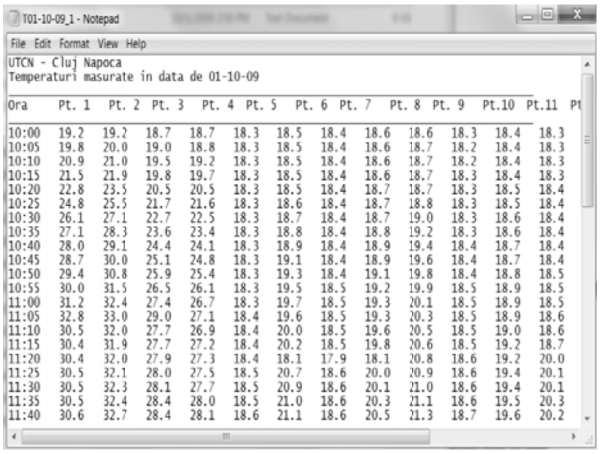


Fig. 2. Thermocouples mounted on the machine

This contact method for temperature measurements involves a lot of cables; the mounting of the sensors takes a lot of time being necessary to stop the production process in order to mount the sensors on the machine. Actual manufacturing machines must follow a repeatable and accurate behavior. Unfortunately, thermal deformations up to 150 microns can be found e.g. in milling machines working at medium load (Popa, 2009).

3.2 Results

Experimental measurements were made using both methods. The temperatures measurement results using thermocouples can be seen in the next figure, and the results using IR thermography are shown in figure 5.



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10:05	19.8	20.0	19.0	18.8	18.3	18.5	18.4	18.6	18.7	18.2	18.4	18.3
10:10	20.9	21.0	19.5	19.2	18.3	18.5	18.4	18.6	18.7	18.2	18.4	18.3
10:15	21.5	21.9	19.8	19.7	18.3	18.5	18.4	18.6	18.7	18.3	18.4	18.3
10:20	22.8	23.5	20.5	20.5	18.3	18.5	18.4	18.7	18.7	18.3	18.5	18.4
10:25	24.8	25.5	21.7	21.6	18.3	18.6	18.4	18.7	18.8	18.3	18.5	18.4
10:30	26.1	27.1	22.7	22.5	18.3	18.7	18.4	18.7	19.0	18.3	18.6	18.4
10:35	27.1	28.3	23.6	23.4	18.3	18.8	18.4	18.8	19.2	18.3	18.6	18.4
10:40	28.0	29.1	24.4	24.1	18.3	18.9	18.4	18.9	19.4	18.4	18.7	18.4
10:45	28.7	30.0	25.1	24.8	18.3	19.1	18.4	18.9	19.6	18.4	18.7	18.4
10:50	29.4	30.8	25.9	25.4	18.3	19.3	18.4	19.1	19.8	18.4	18.8	18.5
10:55	30.0	31.5	26.5	26.1	18.3	19.5	18.5	19.2	19.9	18.5	18.9	18.5
11:00	31.2	32.4	27.4	26.7	18.3	19.7	18.5	19.3	20.1	18.5	18.9	18.5
11:05	32.8	33.0	29.0	27.1	18.4	19.6	18.5	19.3	20.3	18.5	18.9	18.6
11:10	30.5	32.0	27.7	26.9	18.4	20.0	18.5	19.6	20.5	18.5	19.0	18.6
11:15	30.4	31.9	27.7	27.2	18.4	20.2	18.5	19.8	20.6	18.5	19.2	18.7
11:20	30.4	32.0	27.9	27.3	18.4	18.1	17.9	18.1	20.8	18.6	19.2	20.0
11:25	30.5	32.1	28.0	27.5	18.5	20.7	18.6	20.0	20.9	18.6	19.4	20.1
11:30	30.5	32.3	28.1	27.7	18.5	20.9	18.6	20.1	21.0	18.6	19.4	20.1
11:35	30.5	32.4	28.4	28.0	18.5	21.0	18.6	20.3	21.1	18.6	19.5	20.3
11:40	30.6	32.7	28.4	28.1	18.6	21.1	18.6	20.5	21.3	18.7	19.6	20.2

Fig. 3. Results using thermocouples

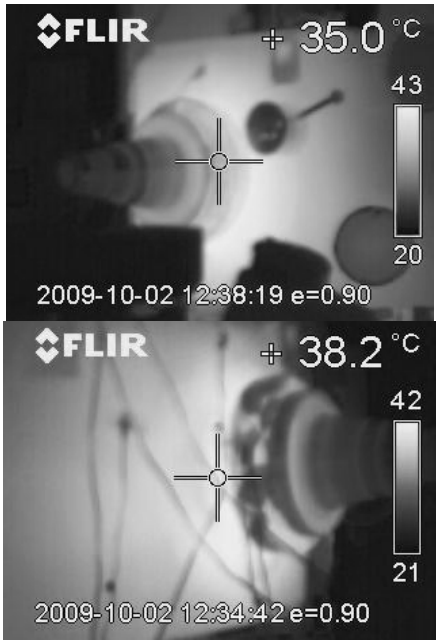

Fig. 4. Results obtained using Flir Thermacam E45

Thermographyc cameras provide thermal maps (thermal images), thermograms (fig. 5) which can be interpreted using special programs. The Flir thermacan E 45, which was used for the investigations provides a thermal map with the exact temperature in one point and a coloured scale, on the right side of the thermogram, with a minimum and a maximum of temperature, as it is shown in figure 4. Because it was needed to determine the temperature in more than one point of the machine, a program of image interpretation using Matlab was created. Its interface is shown in figure number 5. The input data for the program are the minimum and maximum temperature measured by the camera. After introducing the input data, the program generates the exact temperature in every desired point of the thermogram.

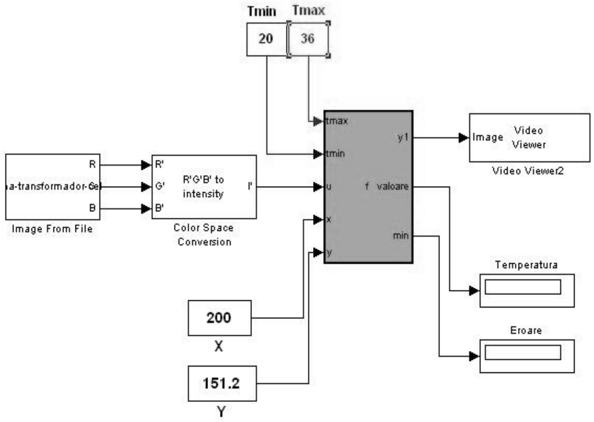

Fig. 5. Interface of the program

4. CONCLUSIONS

Thermographyc measurements have many advantages, in comparison with thermocouples measurements (Popa, 2009):

- The investigation is made efficient and fast without being necessary to stop the production process.
- Thermo vision system provides an image that allows a quick and precise identification of the overheated points.
- The obtained images can be downloaded on any PC and then analyzed.
- Allows temperature measurements from a distance without a direct contact with the object.
- It is a non destructive, non-invasive investigation method.
- Thermal maps can be interpreted using dedicated programs.

When the thermocouples are mounted on the machine, it is rather difficult to make temperature measurements while the machine is processing a part, chips can damage the wires or the sensors. Measurements with the thermal camera can be made during the production process. 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. Thermal stability, as a global concept, is seldom mentioned as a characteristic of machine tools; neither is it checked during acceptance tests (Popa, 2009). Thermography offers incredible solutions for a great number of applications: maintenance, constructions, transport medicine, research, surveillance, etc.

5. REFERENCES

Popa, M. (2009). *Advanced thermal measurements of modern manufacturing systems.* Proceedings of Fundamental and Applied Metrology, Lisbon, September 6-11, 2009, XIX IMEKO World Congress, Portugal

*** (2009) *Some applications of thermography as non destructive evaluation of the production process.* Proceedings of Trends in the development of Machinery and Associated Technology, ISBN 1840-4944, Tunisia, October 16-21, 2009, 13th International Research/Expert Conference

Minkina, Waldemar. & Dudzik, S.. (2009). *Infrared Thermography: Errors and Uncertainties,* ISBN: 978-0470-74718-6, John Wiley & Sons, Ltd

Medgenberg J. & Ummenhofer T. (2006). *Assessment of fatigue damage in low-carbonsteel using lock-in-thermography*, Proceedings of 8th International conference on quantitative infrared thermography

*** (2007) *Detection of localized fatigue damage in steel by thermography*, Proceedings of SPIE, Thermosense XXIX, vol. 6541