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RESEARCHES ON SPECIFIC MALFUNCTIONS DIAGNOSIS OF HYDRAULIC DRIVE SYSTEMS EQUIPMENTS USING THE INFRARED THERMOGRAPHY METHOD

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Abstract: *The paper aims to present a modern diagnosis method of specific malfunctions of hydrostatic drive systems equipments, which is not yet used in the maintenance of these equipents. The diagnostic technique described is using the infrared thermography and can be considered a non destructive examination practice of hydraulic systems. The thermovision cameras, along with the computer* equipments *prove their full efficiency in all industrial maintenance activities, when punctual intervention is desired, quickly and inexpensively.*

Keywords: *diagnosis, hydrostatic drive, thermography, infrared, maintenance*

1. Introduction

Thermography (or Thermovision) is a technique for measuring the thermal field of a physical body, which uses the infrared radiation, for recording and visualization of temperature distribution on the studiate surfaces.
Termography is a non-destructive method that does not require direct contact with the analyzed surface and is particularly useful in malfunctions diagnosing in the industrial systems, because it is not necessary to interrupt the technological flow.
Thermography is an application that derives from the military techniques and it has found, since the mid of the ‘50 years of the last century, a wide application in science, technique, industry, biology, agriculture or medicine.
The energy conservation involves the optimum use of resources and represent an imperative when it comes to the application of measures to develop an economy based on healthy growth. For this reason, it is necessary to obtain accurate informations about the energy performances of equipments, installations or machinery. The information is obtained by drawing of energy balances or analysis based on data resulting from the inspection of selected objectives. The industrial equipments presents energy losses which depend on configuration, quality and sealing installation.
The evaluation of all energy losses susceptible to reduce the efficiency of a system, requires a good vision on the thermal distribution of its components. This is achieved by thermography technique, which allows to monitor the temperature distribution on the equipments surface, by a method of measuring the infrared radiation, [1].
The effective use of a modern methods of diagnosis and prevention is necessary when the objectif of the maintenance is the extending of lifetime and the proper functioning of equipments and machineries. The proper use of the specialized instruments in nondestructive diagnosis can detect and recogniz the equipment malfunctions, with a high degree of accuracy, if it is known the principle of functioning of these instruments, [2].
Alongside the vibration analysis, contamination control fluid or ultrasound control, thermography is one of the safest methods of predictive maintenance that could be used in hydraulic drives. Currently, the method of thermografy is successfully worldwide used in building maintenance and electrical wires maintenance. Our aim is to adapt the thermography method to the hydraulic system

maintenace and to obtaine a thermal map for each type of hydraulic equipment in according with the nature of its malfunction.

2. Specific rules and terminology to the field of thermography

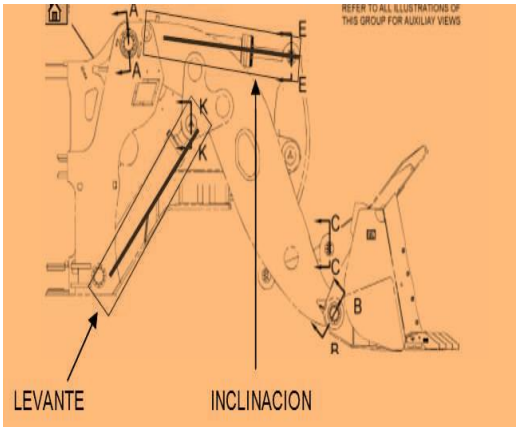
The evaluation of materials using thermal waves is based on the link between the distribution mode of the waves and the studied properties. For example, a discontinuity causes an anomaly regarding the distribution of the heat flow and thus, the temperature of the material. Monitoring of these abnormalities allows finding some useful informations about the sizes, shape or position of discontinuities.
In the field of thermography there are several specific concepts, some of which are defined in the state standard SR 13340 since 1996, September entitled "Non-destructive testing, Infrared thermography. Vocabulary, translation of the French rule A 09-400-1987". The field of spectrum called infrared (IR) is actually a band of the electromagnetic radiation spectrum which is situated on the threshold of the visible domain with radio waves domain, [1].
The thermography term comes from the Greek language "thermos" means heat and "graphein" means writing. The concept of thermography requires a description mode of the temperatures distribution on a surface or in a volume. In SR 13340-1996 standard, is uses the thermography term. There are works that uses the term "thermography" for purposes of techniques itself illustration, by approximating of "radiography" term and the result is called a thermogram.
In the above standard it is given the following definition: "The Infrared Thermography is a technique that allows obtaining with a suitable device, of the thermal image of a thermal scene observed in a spectral range from infrared. Understanding the thermal image as a structured representative data distribution of infrared radiation obtained from a thermal scene and the thermal scene - as part of the space - object observed with infrared thermography apparatus ".
In the field of thermal methods of examination are used many concepts. Some of the most used concepts are the *Thermographic inspection* and *Thermography system*. *Thermographic inspection* means observation, measurement, interpretation of the thermal scene characteristics with a set of apparatus and instruments named thermography system. Thermography system means a set of devices that allow reception and processing of a thermal image.
Thermogram - (according to SR 13340) is the result of transcription in temperature of one or more of temperature luminance maps; the encoded image of a thermal scene.
Other commonly used international standards that regulates the field of infrared thermography are "A 09-400-1991 Essais non destructifs. Thermographie infrarouge. Vocabulaire"; "A 09-420-1991 Essais non destructifs. Thermographie infrarouge. Vocabulaire relatif a la caracterisation de l'appareillage"; "E 168-1999 Standard practices for general techniques of infrared quantitative analysis" and " ASTM E 1149-1987 Standard definitions of terms relating to NDT by infrared thermography", **[3].**

3. The hydraulic cylinders thermography

An example of practical application of thermography of the malfunctions hydraulic equipments analyzed, is shown below, by SIMCO company.
Specifically, it is a Caterpillar loader, model 993 K CAT series Z9K (Fig. 1) provided with six cylinders (two for lifting, two for lower tilting and two for upper tilting - see Fig. 2). The designer has provided for them a period of 8000 hours of operation under normal conditions. After a while, it was noticed that the machine was not working properly due to loss of pressure in the lift cylinders, working slowly.
As a first step was decided to make a thermographic inspection of all the hydraulic cylinders components, and when the temperature of the machine in working reaches 75 °C.
Following the performance tests and thermography analysis, it was found that the left lifting cylinder had a high operating temperature, causing loss of internal pressure in the cylinder (there internal leaks by sealing - see Fig. 3 to Fig. 6).

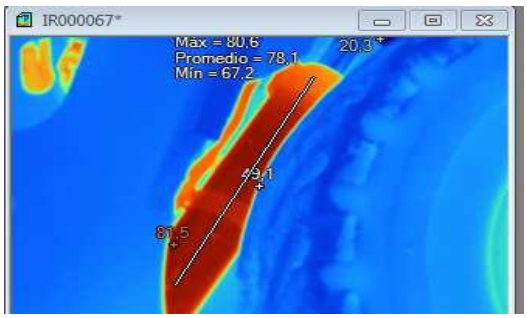
It passed to replace the cylinder seals and it have been initiated maintenance operations in the hydraulic system, **[5].**

Fig. 1. Caterpillar loader, [4]



LIFTING **TILTING**

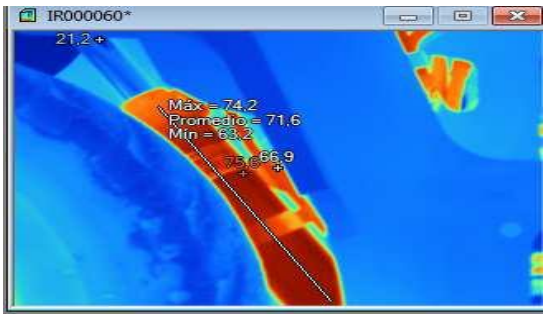
Fig. 2. Lifting and tilting hydraulic cylinders of machinery bucket, [5]



RIGHT LIFTING CYLINDER

Max. temperature	74.4ºC
Min. temperature	67ºC

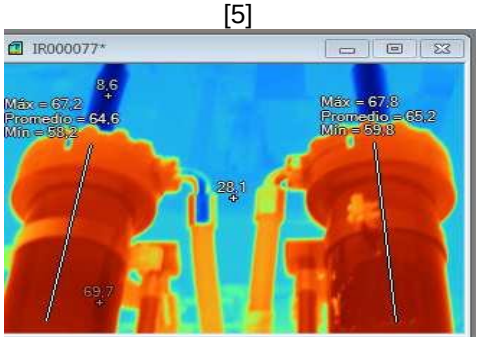
Fig. 3. The thermographic analysis for lifting cylinders indicates they are not working on the same charge, [5]



LEFT LIFTING CYLINDER

		Δ (°C)
Max. temperature	80.6ºC	6.2
Min. temperature	66.9ºC	

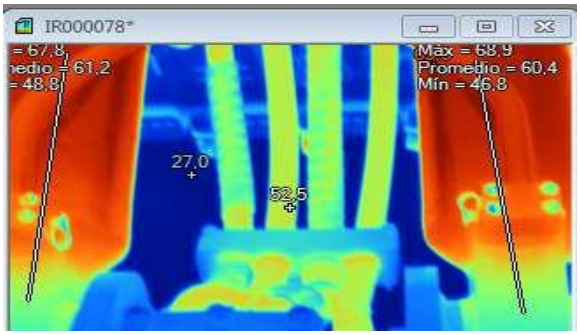
Fig. 4. The temperature difference of the right and left working cylinders (RH) and (LH) is 6 °C, [5]



LEFT AND RIGHT (HIGHER) TILTING CYLINDERS

Max. temperature	67.2ºC
Min. temperature	58.2ºC

Fig. 5. The thermographic analysis shows that the tilting cylinders of the bucket machinery



LEFT AND RIGHT (LOWER) TILTING CYLINDERS

		Δ (°C)
Max. temperature	67.8ºC	-0.6
Min. temperature	59.78ºC	-1.58

Fig. 6. The difference (Δ) of the working temperature is close to zero degrees Celsius, [5]

4. Diagnosing of malfunction in hydraulic systems using the infrared thermography

The excessive heating of the working fluid is a major malfunction, which involves monitoring the thermometer placed in the working fluid tank or handly touching of the analyzed hydraulic equipments. The hand support temperatures up to 50 °C, even when the hand it is pressed. Daily checking of the hydraulic system allows the formation of a point of view in relation to the normal operating temperature.
Overcoming of this is a warning and must done a complex analysis regarding the proper functioning of the system, [6]. Infrared thermography is a nondestructive analysis method that can be quickly highlighted the potential heating of oil installation or of the equipment components, over the normal ranges, without the need operator dispacement in the immediate vicinity of the analyzed apparatus. According to [7], a logical scheme of done stages adapted to the malfunction investigation appeared in hydraulic systems , it is described in Figure 7.

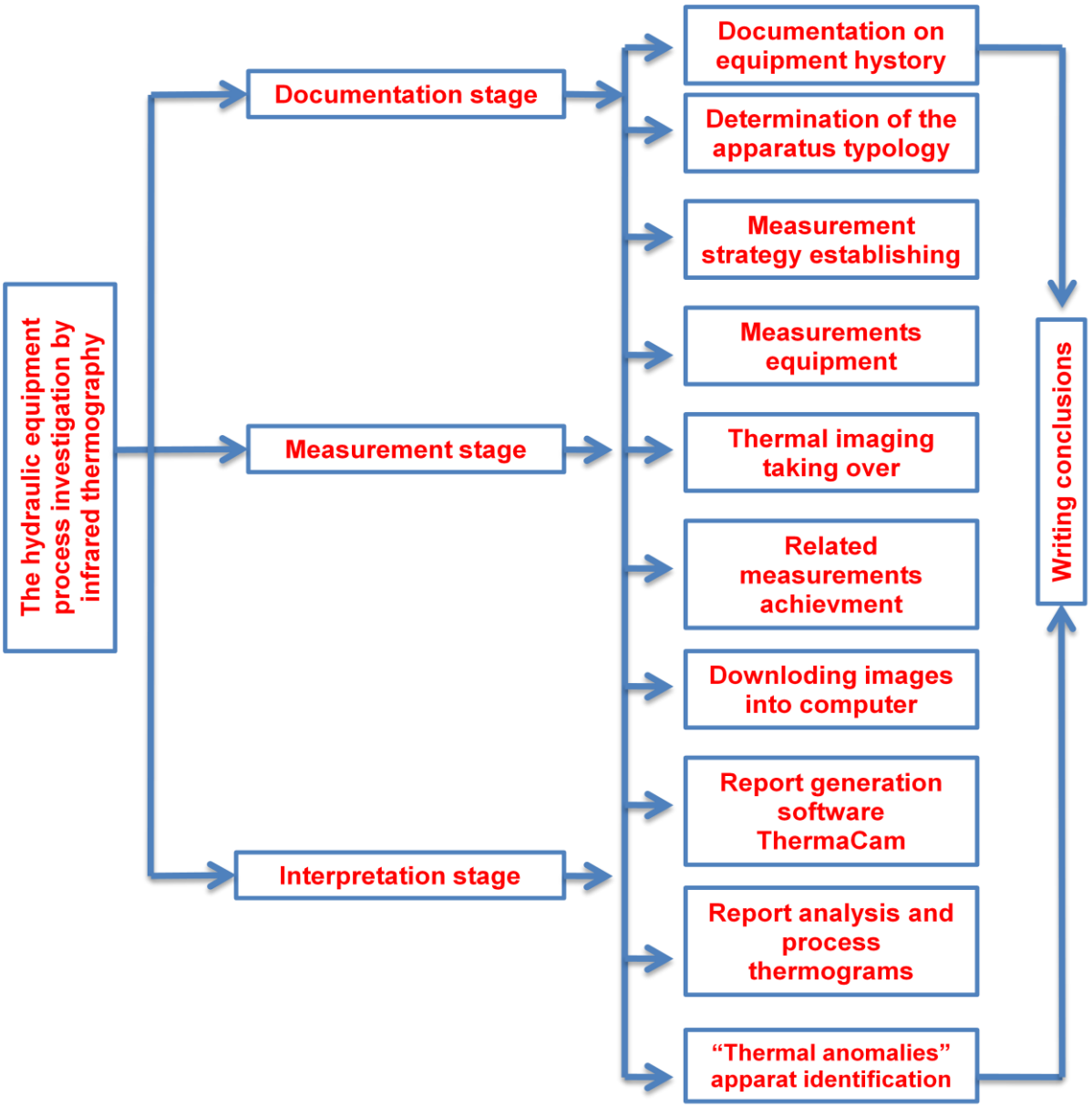


Fig. 7. Malfunction investigations of hydraulic systems. Logical scheme

5. Thermography used at INOE 2000- IHP Bucharest

The Hydraulics and Pneumatics Research Institute in Bucharest - INOE 2000 IHP has a rich experience in achieving of various stands for testing the hydraulic components.
The stands for testing of hydraulic components allow probing of hydraulic pumps and motors (rotary or linear), directional valves, valves or hydraulic and pneumatic accumulators.
For examples, in Figures 8 and 9 are presented the pumps bench with a bent axis piston pump type Brueninghaus (Germany), which was tested September 2016, (Fig. 10). As a novelty can record that this is the first time when the thermography was used in conducted tests in the Hydraulics Laboratory of the institute. The measurements were made with a high performance thermovision camera, FLIR brand.

Fig. 8. Bench of pumps

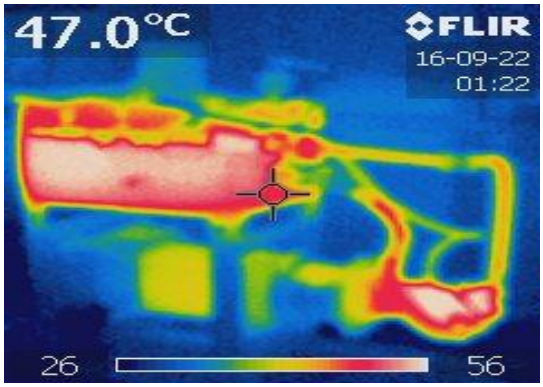


Fig. 9. The bench thermograma

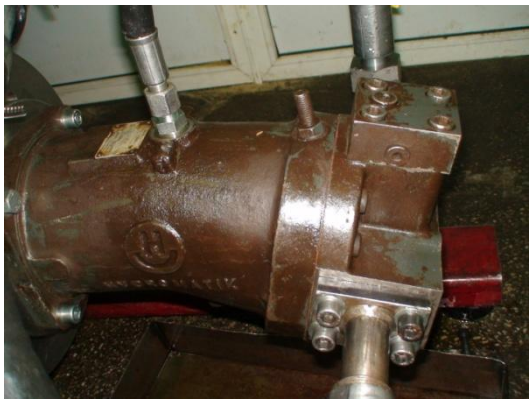


Fig. 10. The tested pump

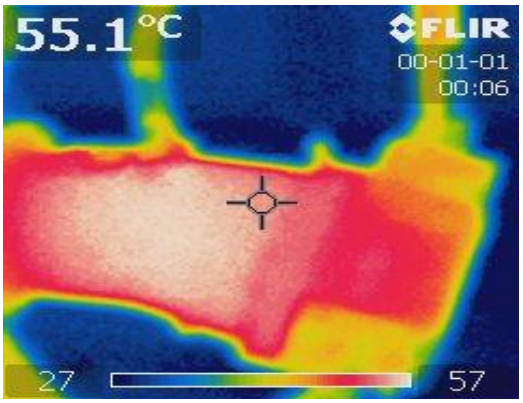


Fig. 11. The pump thermograma

Additionally, thermograms were drawn (Figure 13, Figure 15) for regulating elements (Figure 12, Figure 14) that was provided the test stand ascertaining a normal operation of there. (Their operating temperature is more under the limit value of 70ºC).

Fig. 12. Flow transducer

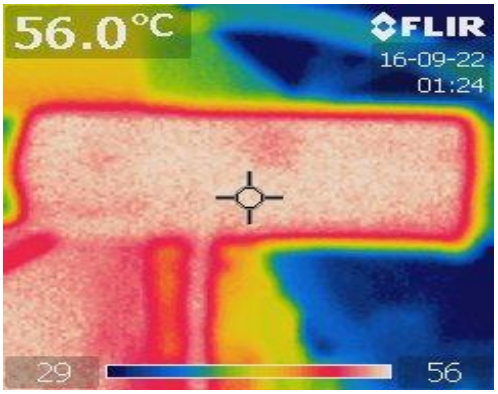


Fig. 13. Flow transducer thermogram

Fig. 14. Throttle

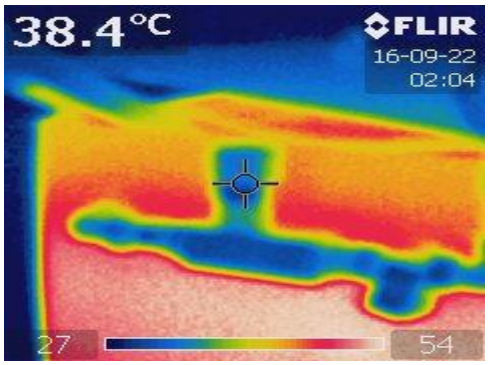


Fig. 15. Throttle thermogram

6. Conclusions

Some conclusions and comments regarding the thermography method used in maintenance prevention, at the first assessment:
a) Concerning with the carried out tests the *punctual* following *conclusions* are appropriate:
- The thermogram analisys in Figure 9 shows that the testing banch in Fig. 8 works within normal parameters. The temperature limit is not exceeded during operation of the stand (the oil temperature of 56°C being far below of the limit value of 70° C.)
- The thermogram analysis of Figure 11 shown that the tested pump of Fig. 10 operate normally. Thus, we see that on the left side, corresponding to the pistons block, the temperature is about 57ºC and on the right, where are the bearings, the measured temperature is about 54ºC. The recorded temperature difference at the pump heads is 4ºC, more below the critical value of 10ºC
- The thermograms analysis of Figure 13 and Figure 15 shows that the regulating elements of Figure 12 and Figure 14 operates in normal limits (the work oil temperature of 54ºC being more below the limit value of 70ºC.)
b) Concerning with thermography application in hydraulic drives overall the following *general conclusions* are available:
- The malfunctions diagnosis using infrared thermovision cameras provide to the staff involved in predictive maintenance works an effective analytical method of hydraulic drive systems, in a very short time, at low cost and with minimal effort.
- Alongside the classical methods of diagnosis, the thermography can be successfully used as often are balances and energy analyzes for each class of hydraulic apparatus analyzed.
- It is a particularly sensitive measurement technique that can record temperature variations of tens of degrees, both spatially and temporally if there are known the factor emmisivity of the materials.
- Are possible real-time analysis both before and after the intervention to the hydraulic equipment, in order to obtain necessary information for a forecasting of their evolution in time.

– The application of infrared thermography method to the maintenance of hydraulic systems, allows detection and correction of potential damages since in primary phase, prior to production of the failures. In this way reduces the breaks in the operation of machines by eliminating downtimes and by optimizing the operations for repair and maintenance.

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