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Thermographic Evaluation of Electro-mechanical Relays' Quality in Railway Automation

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ABSTRACT

By using thermal photography the quality of an electro-mechanical relay can be examined during production and the reliability of the series can be guaranteed at higher electric current values during commutation process. During exploitation thermal photography is provided information about the degree of wearing out of contacts and to help determine which contacts need to be replaced. By means of thermal photography the duration of gas discharge is determined and this duration is an indicator about the speed of wearing out of the contacts. The article offers a method to determine the quality of electro-mechanical relays especially developed for switching of powerful electrical circuits used in railway automation.

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1. INTRODUCTION

Thermal imaging has evolved into one of the most valuable diagnostic tools used for predictive maintenance. Thermal imaging, also called thermography, is the production of non-contact infrared, or "heat" pictures from which temperature measurements can be made. By detecting anomalies often invisible to the naked eye, thermography allows corrective action before costly system failures occur. Portable infrared (IR) imaging systems scan equipment and structures, then instantly convert the thermal images to visible pictures for quantitative temperature analysis [1].

Quantitative infrared thermography NDE methods are non–contact full–field techniques whereby an IR camera with digital sensors is used to detect small changes of temperature due to different sources [2]. The later can be in the form of an irreversible applied electro-mechanical load. The overall goal is to subject the structure or the material to thermo mechanical deformation that produce spatial variations in the surface temperatures and allow correlation between measured IR field and the stress or strain on the surface. Under adiabatic and reversible conditions in isotropic materials, the application of a small cyclic load will induce small and repeated variations in temperature that are proportional to the sum of principle stresses.

At present the Railway automation still uses utterly relay systems for train traffic management. There have been used relays with specific construction, defined as elements with asymmetrical failure. Within these elements the probability for failure type $0 \rightarrow 1$ (instead of logical 0 in case of failure in the exit to appear logical 1) is slightly small, compared to probability for transition $1 \rightarrow 0$. Based on that, the securing systems are synthesized in way that when system failure occurs to avoid danger-out development of the transport process. This leads only to motion suspension of the machine, but not to crash. In a system like this, for middle sized train stations are used over hundred relays. A problem of significant importance for the train traffic is the contacts wearing-out and performing optimal regime for replacement.

The diagnostics of relays (functional test, calibration and control of degree of wearing-out of contact closures) usually includes removal of the relay from service to a test environment. Injecting current and/or voltage into the relay and observing the response according to the manufacture's test procedure verifies the recommended settings. Calibration of electro-mechanical relays is recommended fairly frequently since operating mechanisms can wear and get out of adjustment.

2. RESEARCH METHOD PRECONDITION FOR THERMOGRAFY STUDY OF RELAY CONTACT CLOSURES

There are four working regimes of the contacts. The difference is result of the electrical conditions, physical processes and the wearing-out. Two of these principles are in our scope of interest: closed contacts and opened contacts.

Closed contact main parameter is the transience resistance R_0. Common ground point of the contacts is not extended over the whole covered surface. No matter how good the contacts are polished, there are some protruding spots in which exactly the contact has been made. Currents/electricity lines are gathering at the contact areas. This defines the density resistance *Rc*. It depends of the material of the contacts, the total shared surface and the contacts pressure. By increasing the contact pressure, the numbers of contact points are also increased. The contact resistance depends also from the resistance of thin layers formed on the surface of the contacts. Transience resistance is increasing in the working process with the contacts wearing out. A thermographic can display the gathering of the lines, respectively the count and the total contact surface. In this manner back at producing stage the bad contacts can be removed, in order the reliable relay work to be guaranteed at high voltage commutation. In the exploitation process the thermographic can provide information of contacts wearing-out degree and to determine which contact closures are subject of replacement.

Under contact opening the resistance is changing from R0 to ∞. When opening contacts a tension between them occurs. In the beginning the distance between the contacts is small and it is possible occurrences of discharge phenomena. Those phenomena are connected to destroying or carrying out material from one contact towards another. If demolition does not occur, then occurs high increasing of the roughness, respectively to the transience resistance of the closed contact. This stands behind the conception "contacts wearing-out".

At circuit commutation with inductive characteristics when contacts has been open, a jump in the voltage is been observed. This increasing is due to the saved within inductivity magnetic energy. The size of the occurring tension is directly proportional to inductivity, of the speed of the decreasing voltage and it is inversely proportional to the active resistance of the circuit. The inductive characteristics sub serves the arising of discharge phenomena and the wearing-out of the contacts. Total avoidance of those phenomena is not possible. The question is conditions to be created for quick suspension of these undesired events.

3. METHODOLOGY OF THE THERMOGRAFY EVALUATION OF THE ELECTRO-MECHANICAL RELAY

Two types of electro-mechanical relays have been researched: neutral relays of the НМШ1-400 type, which are designed to work in DC electrical circuit and which are used for signaling, centralization and interlock devices in railway automation and neutral starter relays of the НМПШ-900 type, which are designed to work in DC electrical circuit and which are especially developed for switching systems used in railway automation.

Signatures of thermographic measurements were registered at various active loads (0.5 A, 1A, 3A, and 6A) and at various frequencies and commutated power (65VA, 150VA, and 300VA).

The degree of wear-out has been determined by comparing thermographic signatures of new carbon-metal and metal-metal contact closures and used contact closures. This comparison was also used to determine remaining resource values of contact closures.

For the thermographical researches it is used IR camera type FLIR P640 with 24^0 lens and close up lens 50 µm [1]. Thermography is based on relays real-time process of working. The image has been taken as sequences with different frequency of reiteration and for different volt-ages of commutation. An accelerated test of the wearing-out of the relays was also carried out. The criterion of wearing-out is the alternation of the resistance, respectively temperature under equal commutation voltage. Under data processing was recognized the fact that the heat is generated buried deep inside a relays structure with loss of thermal insulation between the heat source and the surface the IR camera sees (indirect measurements). After identifying the zones with increased temperature and defining the possible reasons, the tested relays were disassembled for confirmation of the reached conclusions.

Fig.1 shows thermograms of an unsealed relay with close up lenses.

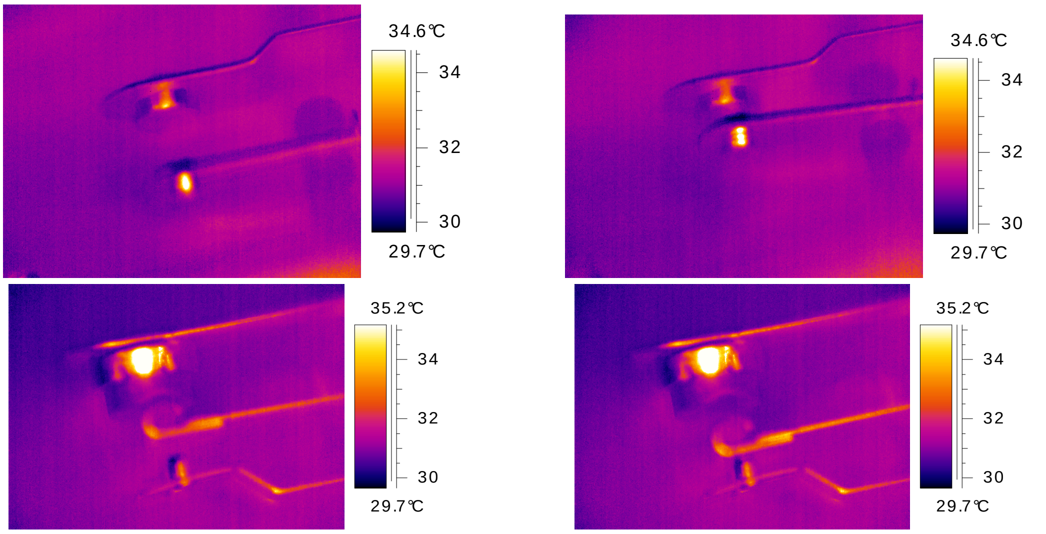

Figure 1. Thermograms of new contact closures commutating at idle: a) contact type metal-metal and b) contact type

Fig.2 shows thermograms of contact closures of the carbon-metal and metal-metal type loaded with reactive load and commutation frequency 3.5 Hz.

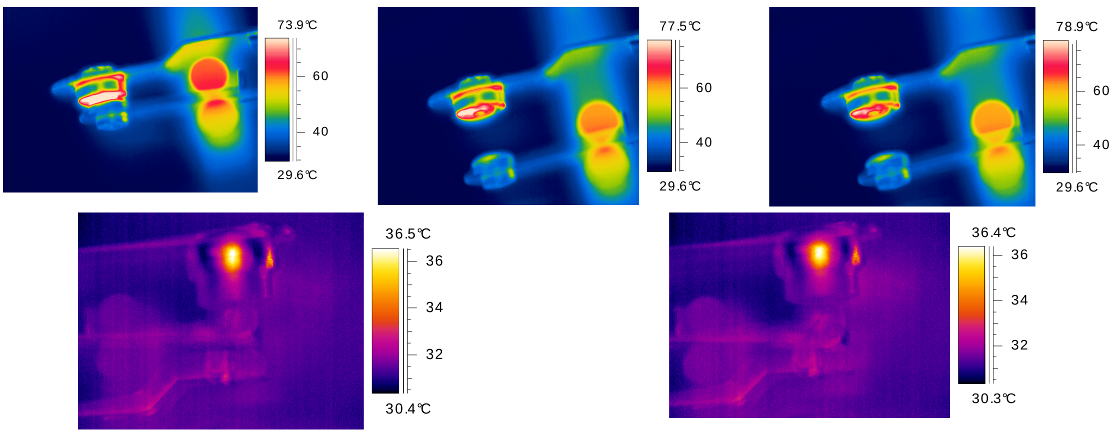

Figure 2. Thermograms showing a) an old contact closure type carbon-metal and b) a new contact closure type metal-metal

For the thermographical processing of image sequences ThermaCAM Researcher Pro 2.9 was used. Fig. 3 shows data of thermograms of hermetically sealed relays with new contact closures which are processed with this software.

Fig.4 shows results of the study of carbon-metal worn-out contact – a 3D image, thermogram, and contour analysis. In the research process a dependency between the power of a commutated circuit and the temperature of the contact system was established. The research was conducted using hermetically sealed and unsealed relays.

Research was done for both hermetically sealed and unsealed relays using synchronized and unsynchronized frequency of frames and commutations measuring the temperature of a specific commutating element at a specific power of commutation in a switching circuit when the relay is commutating.

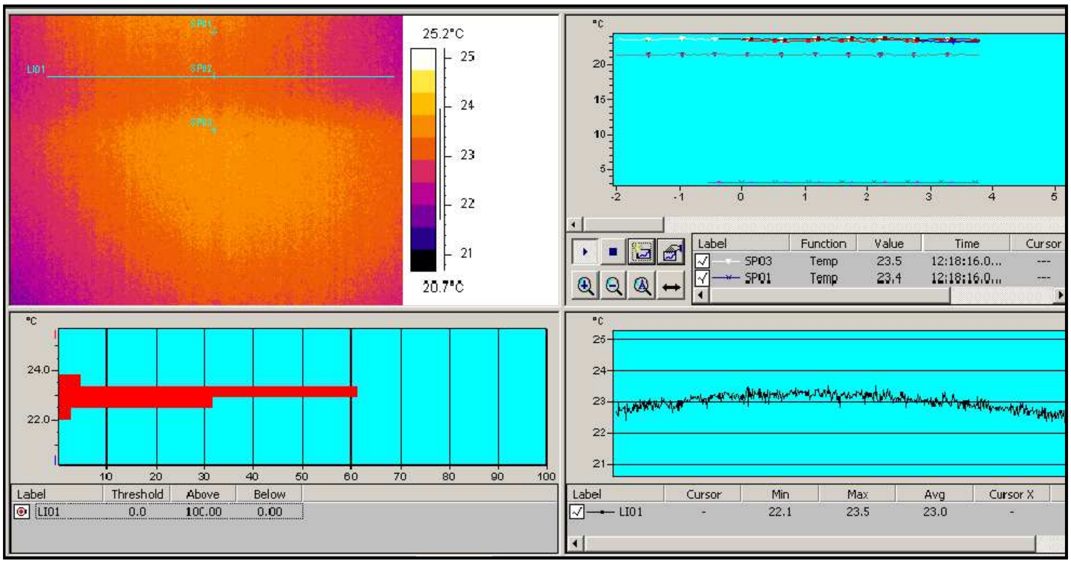

Figure 3. Results of 200 sequences of a new contact closures for hermetically sealed relay.

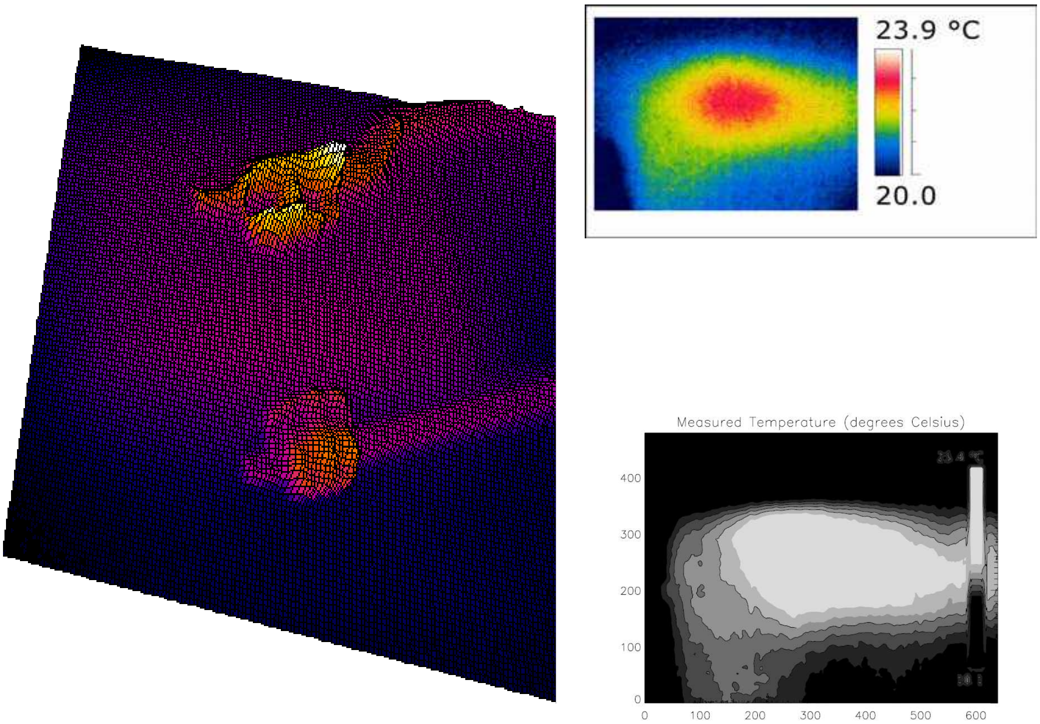

Figure 4. On the left is shown 3D view of a non package contact closure. On the right (up) are shown the thermogram and contour picture (down) of the same packaged relay contact closure.

A solution was found to the problem of estimating the commutating power when commutating elements that are not worn-out are used.

The wearing-out of commutating elements leads to increased temperatures that are 30-50^{0}C higher than the normal temperature at one and the same commutated power.

For non-contact characterization and identification of the critical contact closures is used additional specially developed software for IR image processing with 24-bit color dept. The process speed is significant 500 000 pixels are fully analyzed for 1-5 seconds. The CTE controls the pollution levels by managing separately the color channels for each pixel.

The developed approach is a comparison of image thermal histograms for one and the same object under different load stage. On Fig. 5 is shown the view of the software and on the Fig. 6 - thermal histogram of the same contact closure for temperature range of 29^0C and 49.4^0C respectively.

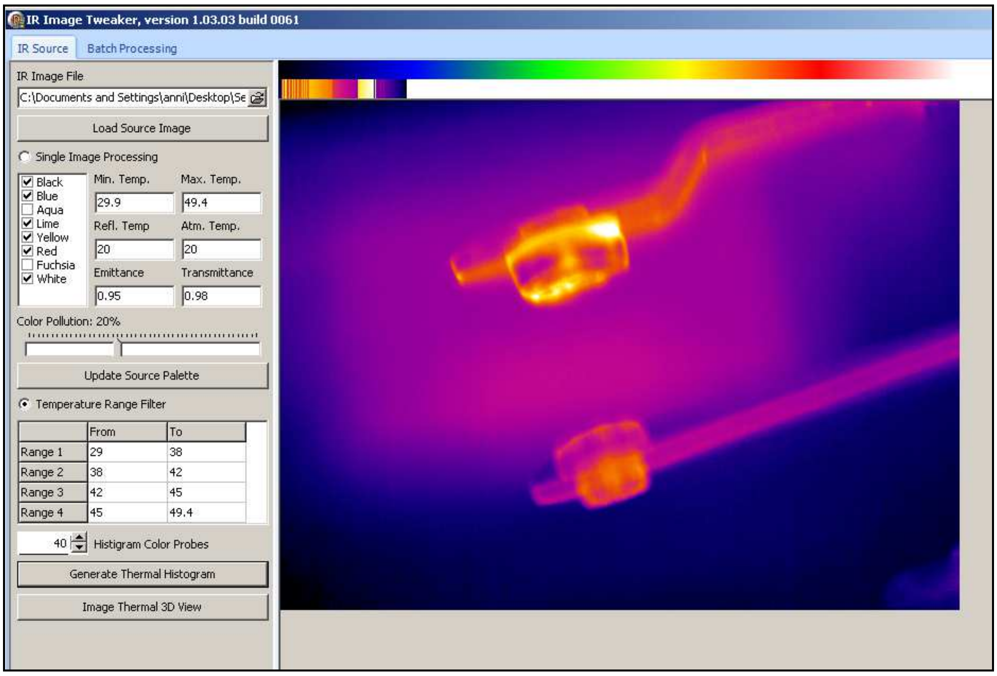

Figure 5. A view of the software of relay contact closures evaluation

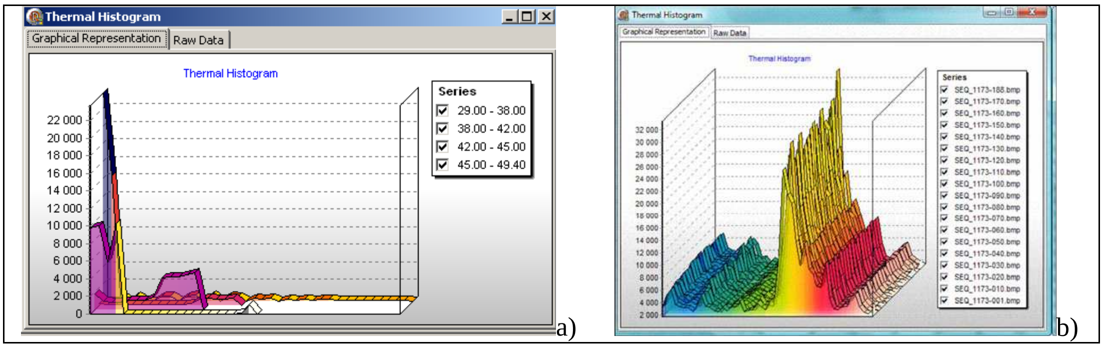

Figure 6. Thermal histograms: a) for a single thermogram and defined temperature ranges and b) batch thermal histograms of a good contact for sequences.

The thermal histograms can be compared in four arbitrarily selected temperature ranges. In case of batch processing of series of thermograms of one and same object is carried out under different working rates (respectively to different surface temperatures). In accordance of the duration of transitions process, an individual snapshots can be generated after thermodynamic equilibrium is occurred, or automatically by setting interval of time between the individual snapshots with frequency up to 30 Hz. When the camera is controlled through computer, snapshots can be taken in time interval larger than 10s.

In this manner a criteria for diagnostics and resource evaluation of the tested relays was formed on the base of the outcome thermal histograms [3].

Hot spots are formed in the areas around the contacts leading to the appearance of locally increased temperatures on the surface. On-line thermal scanning of these surfaces will identify the hot-spots and severity of the fault (see Table I). Attending these fault points will, of course, reduce the breakdown of the signal system and reliability can be improved.

Table 1. Criticality criteria of thermographic survey of the electro-mechanical relay

Severity load	Criteria (differential temperature above ambient)	Criticality condition	Recommended action
1	Up to 10^0C	Non	No action is needed
2	Between 10^0C and 20^0C	Less	Regular monitoring is needed
3	Between 20^0C and 40^0C	Semi	Close monitoring needed. Should be attended in the next opportunity.
4	Above 40^0C	Critical	Should be attended immediately as per the severity.

4. CONCLUSION

In this article are presented results from the appliance of thermo-monitoring methods and processing of IR images for diagnostics of relays contacts wearing-out. In great significance for Railway safety equipment stands the solving of the problem with the optimal regime for replacement.

On the thermographic image the areas of increased resistance and worn-out contact closures can be monitored. In such manner using periodical inspection, bad relay contact closures can be detected, removed, or replaced. A methodology and software to for the estimation of the resource of contact closures of electro-mechanical relays were developed.

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