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APPLICATION OF INFRARED THERMOGRAPHY IN MONITORING OF PETROL ENGINE WITH AIR COOLING

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Abstract: *Infrared thermography has emerged, over the past few years, as an attractive and reliable technique of non-destructive testing in cases such as testing different materials and monitoring the operation of complex systems. The paper presents the possibilities of wide application of infrared thermography for monitoring the operation of a four-stroke petrol engine BMW and a three-cylinder petrol engine OPEL CORSA 1.0. A quantitative analysis of the temperature of parts of the engine made of different materials was carried out during the operation of the open engine with air cooling.*

Keywords: *pulsed thermography, non-destructive testing, infrared thermography, petrol engine.*

1. INTRODUCTION

Infrared thermography (IRT) based on infrared radiation, provides particular advantages in different fields, as it is non contact, non invasive technique [1]. Any object which has a temperature above the temperature of absolute zero (i.e., $T > 0$K) emits infrared radiation (spectral range > 0. 7 µm) [2, 3]. Measuring devices acquire infrared radiation emitted by an object and transform it into an electronic signal producing a detailed infrared image of the scene, since the human eye cannot see this type of radiation. Infrared camera detects the radiations emitted by the heated object and presents it in the form of a thermogram.

Thermographic testing may be used to record of the operating temperature distribution on the certain visible parts of engine. It is known that not all parts of the engine are made of the same material, and hence the exposure of materials of a particular engine to a higher temperature. The deviation of the measured temperature from the referent range one indicates the malfunction of the discharge of the cooling water supply hose, combustion of seals made of rubber and other poles, etc., as well as permanent damage to engines requiring general overhaul.

In this paper, we present the results of using IRT technique for temperature monitoring of parts of four-stroke petrol engine BMW 325i and a three-cylinder petrol engine OPEL CORSA 1.0. The thermal imaging are used for calculation and estimation temperatures of chosen parts of the engine.

2. THE TEMPERATURE MONITORING OF ENGINE HEATING BY TERMOVISION CAMERA

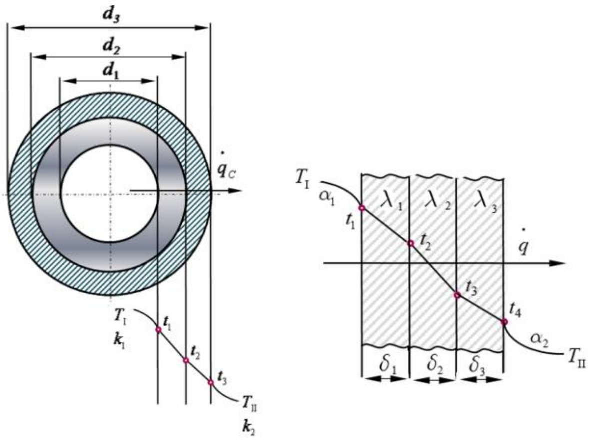
In the following text, an attempt were made to measure the thermogram of the engine in operation and investigate the possibilities of using an infrared (IC) camera to monitor the operation of the engine heating. The thermograms of temperature distributions on the surface of the engine in function of time were used for calculation and estimation temperatures of chosen parts of the engine.

2.1. Description of engine and his parts to be monitored

Depending on the types of energy that motor drive machine converted into mechanical work exist:

- electric,
- thermal, hydraulic,
- pneumatic motors, etc..

Especially, internal combustion engines belong to the group of heat engines, which are used in everyday use for mastering an external resistance and the realization of a work. This type of engines are used in land, water and air transport, agricultural and heavy machinery, industrial and aggregate application and others.
Some description of parts that are observed by thermal imaging camera we will only give in this text. Recordings were made on: electromagnetic valve and cooling pipe tube which enters the engine.



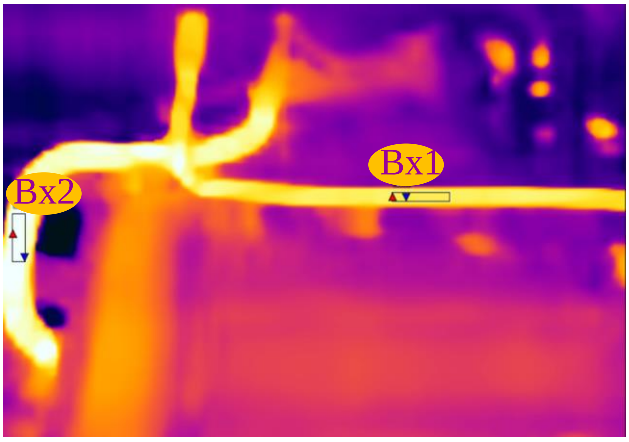
a) *b*)

Picture 1. Example of: a) radial heat flaw in a cylinder and b) heat flaw through a *n*=3 parallel layers flat wall.

2.2. Thermographic testing of the engine heating

Observed parts with different geometries that are made of materials of different thermal conductivity and corresponding temperatures of the points were obtained by analyzing the thermogram of these parts. Further, temperatures of the interior wall of the depicted parts can be calculated.
The selected engine regions are the cooling pipe tube which enters the engine (Bx1 and Bx2, respectively) of the CORSA 1.0 ECOTEC engine. Further, selected region is electromagnetic valve of the BMW 325i (Bx3). Thermograms of the chosen parts of engine during heating and photography of the engines with those areas are shown in Pictures 2. and 3.

The process of heat transfer between two fluids separated by a solid wall, when there is simultaneous heat transfer by convection and conduction, is called heat passage. The heat transfer from the internal fluid to the wall of the tube and from the outer surface of the tube to the other fluid is via convection, while the heat exchange through the layers of the tube is conduction.



Picture 2. The upper part: infrared image acquired during operation and heating of the engine and lower part: photography of the engine CORSA 1.0 ECOTEC.

The specific heat flux in the case of a heat passage through an *n* parallel layers flat wall, see part b) in Picture 1, is given [5]:

$$\dot{q} = k \; T_{I} - T_{II} \qquad (1)$$

while resistance to heat transfer generally is calculated by the equation:

$$\frac{1}{k} = \frac{1}{\alpha_{I}} + \sum_{i=1}^{n} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_{II}} \qquad (2)$$

where is: $\dot{q}$ - specific heat flux; *k* - coefficient of heat transfer through a flat wall, in general, for a multi-layer wall; 1/*k* - resistance to heat transfer from convection and conduction; λ - coefficient of heat conductivity; δ - wall thickness; α - heat transfer coefficient.

The specific heat flux $\dot{q}_C$ (per unit length of the tube) in the case of a heat transfer through the wall of an infinite tube, see part a) in Picture 1, is given [5]:

$$\dot{q}_C = k \quad T_{I} - T_{II} \qquad (3)$$

Resistance to heat transfer (per unit length of tube) in generally case is given:

$$\frac{1}{k_C}=\frac{1}{d_1\pi\alpha_I}+\frac{1}{2\pi\lambda_i}\sum_{i=1}^{n}\ln\frac{d_{i+1}}{d_i}+\frac{1}{d_{i+1}\pi\alpha_{II}} \qquad (4)$$

where is: $\dot{q}_C$ - specific heat flux per unit length of tube; k_C - coefficient of heat transfer through wall per unit length of tube; d - tube diameter.

The interior wall temperatures of the designated parts, see upper parts of Picture 2. and Picture 3., with diferrent geometries and materials, applying equations (1) – (4) are estimated with coeficient values listed in Table 1.

Table 1. Thermal properties of some materials [5].

Material	Coefficient of heat conductivity λ [W/m·K]	Heat transfer coefficient $\bar{\alpha}$ [W/m²·K]
Aluminum	229.111	-
Brass	102.3	-
Isolation	0.05	-
Plexiglas	0.195	
Fuel mixture	-	5000

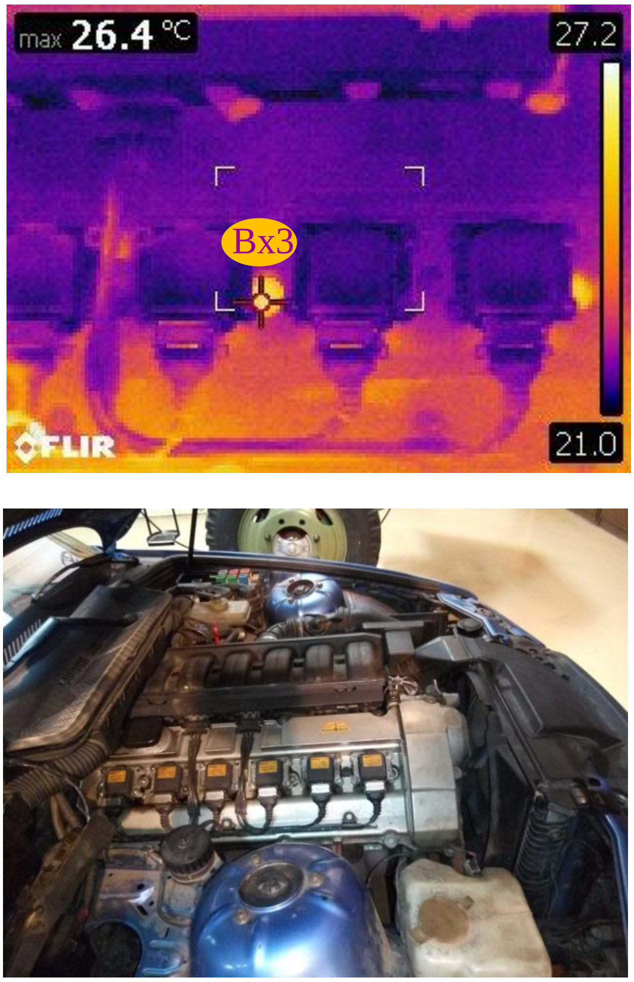
The term oil vapor in Table 1. is heat transfer coefficient from the oil vapor to the interior surface of the tube. The wall of the syringe is heat transfer coefficient from the wall of the syringe to the surrounding air and fuel mixture is heat transfer coefficient from the fuel mixture to the interior surface of the flat wall.

3. RESULTS

Thermograms that are recorded corresponds heating engine operation. Thermogram of the engine during heating and photography of the engine are shown in upper and lower parts of Picture 2. and Picture 3.

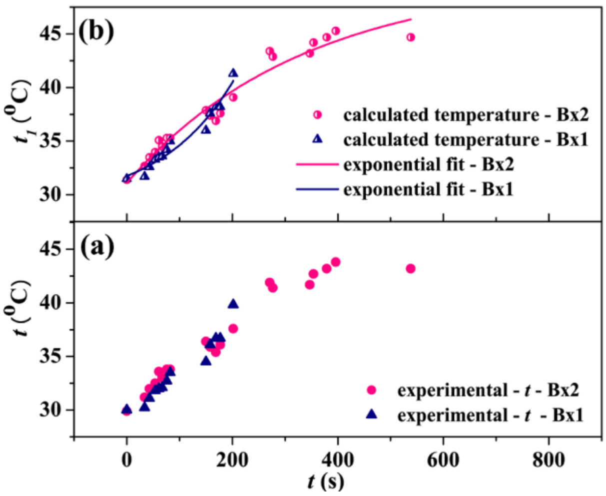
Temperature distributions on the surface of the engine (average temperature value of all pixels in corresponding areas while the surrounding temperature during experiment was 22°C) [6, 7, 8] as a function of time were obtained and analyzed, see Picture 4 and Picture 5. The temperature of outer wall of depicted areas in the mentioned cases, randomly increases with time.

The temperature of interior wall of electromagnetic valve is calculated by equations (3) and (4) with constants of thermal properties listed in Table 1. In this case temperature difference between outer and interior wall is different, see parts (a) and (b) in Picture 5. This can be explained by the existence of isolation materials in this case.



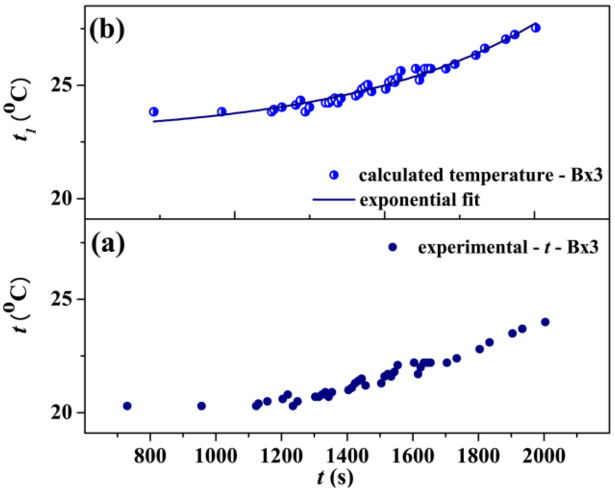
Picture 3. The upper part: infrared image acquired during operation and heating of the engine and lower part: photography of the engine BMW 325i.

In the case of thinner brass cooling tube, for Bx1, model function of temperature distribution as a function of time is: t_1 = 2.8135 exp(-(t/ -141.636)) + 28.926 while the model function of temperature distribution as a function of time



Picture 4. The dependence upon time of (a): temperature of outer walls of thinner brass cooling tube Bx1 and thicker Bx2 and (b): calculated temperatures (t_1) of interior walls of regions Bx1 and thicker Bx2.

for thicker brass cooling tube Bx2 is: t_1 = -19.1179 exp (-(t/ -336.387)) + 50.206. The temperature of interior and outer wall are similar because of good thermal conductivity of material.



Picture 5. The dependence upon time of (a): temperature of outer wall, Bx3 (b) temperature distributions of the interior wall.

In the case of a heat transfer through a flat wall with parallel layers, Bx3, temperature of interior wall of this case is estimated using equations (3) and (4) with constants values listed in Table 1. Temperature distribution as a function of time of Bx3 are modeled by: t_1 = 0.2185 exp(-t / -639.3) + 22.17.

There are temperature difference of outer and interior wall in the case of Bx3, see parts a) and (b) in Picture 5. The lower temperature correspond the outer wall.

4. CONCLUSION

The paper gives a description of thermovision temperature distribution on certain parts of the motor. Considering the type of materials as well as geometry of the parts and based on thermodynamic constants and available data, the thermodynamic characteristics of these chosen parts are calculated. In the case of brass cooling tube, temperature difference between outer and interior wall isn't significant. This can be explained by the good thermal conductivity of material. The temperature of interior and outer wall in the case of electromagnetic valve are more significant because of the existence of isolation materials in this case.

In the further work iteration, and on the basis of the obtained results, certain conclusions can be drawn about the associated load of these operations in the same way as the occurrence of any damage as a result of the occurrence of unauthorized temperature loads. This procedure gives great importance to the thermal imaging surveillance of their results and processing them are coming in fast and easy way.

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