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UTILIZATION OF THERMOGRAPHIC DEVICE FOR FAULT DIAGNOSIS IN OLD VEHICLE

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Abstract: Nowadays, the application of thermal imaging is an irreplaceable part of many industries, including energy, telecommunications, construction, medicine, ecology, transport and fire protection. It is also increasingly used in mechanical engineering. The automotive industry is becoming a key area where thermal imaging is used to diagnose faults that would otherwise require mechanical disassembly of machines or their parts. This approach allows potential problems to be quickly and efficiently identified and fixed before they become serious. Thermal imaging in the automotive industry thus contributes not only to time and cost savings, but also to increased vehicle safety and reliability.
Keywords: thermal imaging, automotive, fault diagnostics, safety, reliability

1. INTRODUCTION

Although thermodiagnostics is a relatively young discipline, included in the field of technical diagnostics, its benefits have been verified many times. However, in a large number of cases, this diagnosis is irreplaceable or very difficult to replace by other diagnostic methods. [8] Thermal imaging offers one of the most effective ways to determine heat leaks and thermal differences on the monitored surface. [4] The essence is to illustrate the surface temperature distribution by measuring the intensity of infrared radiation from the surface. [10] The result of the measurement is a thermal imaging image on which trouble spots with a disturbed temperature field can be accurately located. [3]

Thermal imaging measurement is currently of great importance, as it helps to detect not only thermal insulation failures, but also deficiencies of plumbing, electrical wiring and installations, pipes, hidden leakage failures, etc. [9, 13] The applicability and application of thermal imaging measurement is therefore wide, from small family houses [20] through larger building structures to complex technologies in industry, energy [14] or automotive [2].

Infrared radiation is a part of a broad spectrum of electromagnetic radiation that has the same physical nature as visible radiation. [12, 15] It consists of transverse electromagnetic waves that propagate in homogeneous environments, in vacuum, in gases, in liquids and solids approximately in a straightforward manner. [16]

Currently, passenger cars older than 10 years show increased mechanical damage, especially to engine components, leading to increased failure of engine parts, both external and internal [5, 18, 19]. This results mainly from the stresses of these parts by high heat, pressure, friction, etc. [21, 23]. The authors of the paper worked to solve a problem with a gasoline internal combustion engine that showed signs of poor compression, insufficient power, poor combustion, and increased emissions. [11]

The authors tried to carry out diagnostics without the need to disassemble internal combustion engine components, such as the engine head, engine head cover, exhaust system heat shield and intake and exhaust manifolds. [6]

2. MEASUREMENT TECHNOLOGY

For experimental measurements, a thermal imaging camera from FLUKE was used. The following Figure 1 shows the FLUKE Ti25 thermal imaging camera. The technical parameters of the thermal imaging camera are clearly shown in Table 1.

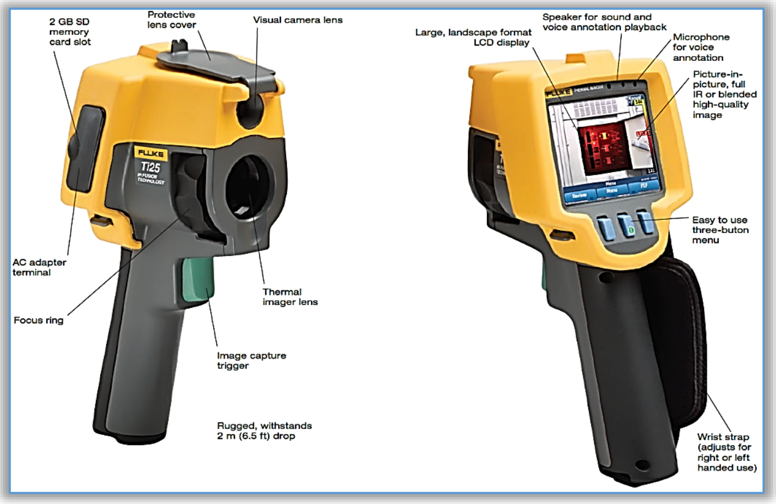

Figure 1. Thermal imaging camera FLUKE Ti25 [17]

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Table 1. Technical parameters of the thermal imaging camera [17]

Imager size:	267 mm x 127 mm x 152 mm	Minimum span (Auto/Manual):	5 °C / 2,5 °C
Weight (including battery):	1,2 kg	Temperature range:	–20 °C – 350 °C
Water and dust resistant:	IP54	Accuracy:	± 2 °C or 2 %
Thermal: Field of View (FOV)	23° horizontal x 17° vertical	Measurement modes:	the middle point
Minimum focus distance:	15 cm	Digital display:	9,1 cm diagonal landscape color VGA (640 x 480) LCD
Thermal sensitivity (NETD)	≤ 0,1 °C at 30 °C (100 mK)	Storage medium:	2 GB SD card stores up to 3000 .bmp IR images or 1200 .IS2 IR–Fusion images

3. MEASUREMENT TEST

Each thermal imaging test is preceded by a detailed mapping of the surrounding conditions and the location of the thermal imaging measurement. [1, 22] The external air pressure, wind speed, air humidity and ambient temperature were recorded. Considering the state in which it was located, the measurement object did not show any signs of surface moisture, and due to its location in the engine compartment, the influence of the wind, which reached a speed of 4 km.h^{-1} at the time of the thermal imaging test, was not significant.

The subject of the thermal imaging measurement was a Z5–DE DOHC 16V gasoline combustion engine (Figure 3) manufactured by Mazda from 1998 (Figure 4). The measurements took place in a continuous sequence in a time span of 14 minutes at a frequency of 10 seconds per thermal image. In this way, we ensured a detailed mapping of the thermal areas of the engine block, engine head and exhaust pipe to identify the problem part of the combustion engine. The tests took place at an ambient temperature of 17°C. The following Figure 2 shows the motor part of the motor vehicle.

Figure 2. View of the motor part

Figure 3. Engine type Z5–DE DOHC 16V

Figure 4. A view of the 1998 MAZDA 323F motor vehicle

The measurement was carried out on the campus of the Technical University of Kosice (Figure 5) specifically on Komenskeho Street No. 8, on 20.05.2023 from 11:57:09 to 12:19:54. On the day of the measurement, the ambient temperature was 17 °C.

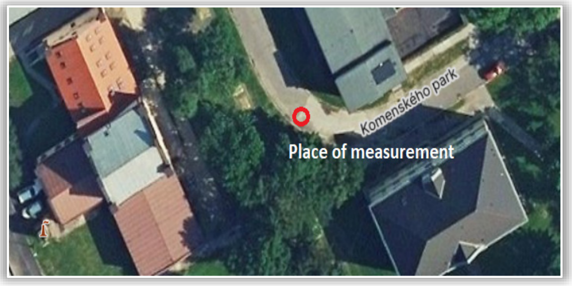

Figure 5. Measuring point

The internal combustion engine in question was fully cooled at the time of the start of the tests in order to map all thermal changes without being affected by surrounding objects that could generate reflective radiation on the surface of the measuring object, while avoiding concealing the error by heat transfer from already heated parts of the internal combustion engine.

The problem area was mainly the engine head and exhaust manifold, which we focused on when taking measurements. After starting the internal combustion engine, detailed records were made of engine surface temperatures, ambient temperature in the vicinity of the combustion engine and emphasis was placed on the absence of any objects in close proximity that could negatively affect thermal imaging of the object.

A sequence of 84 thermal imaging images was created from starting the engine to fully warming it up and opening the second cooling circuit. As soon as the second cooling circuit began to be cooled by a fan on the coolant, the thermal imaging measurement was completed and the results stored on a storage medium, later processed using a software from FLUKE SmartView [7] (Figure 6).

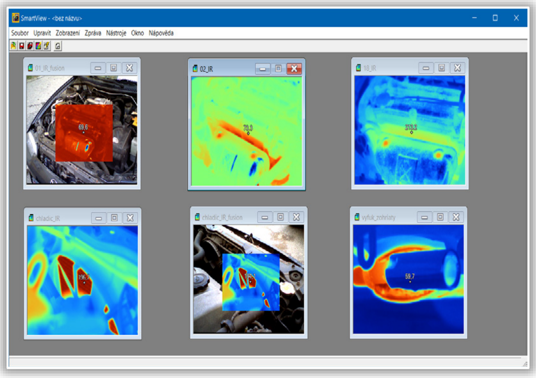

Figure 6. Software SmartView

3. EVALUATION OF THERMAL IMAGING MEASUREMENT

As anticipated during a test drive by an authorized service personnel, the engine showed signs of damage or defect, the diagnosis of which would mean disassembling the engine, and even this would not ensure the correctness of the diagnosis only by visual assessment or assessment with measuring instruments in the garage equipment. Time–consuming service diagnostics turned into a matter of several minutes.

In the evaluation, we focused mainly on the image of a fully warmed up engine, in which shortcomings were obviously visible. This was mainly a thermal anomaly in the area of the exhaust manifold on the fourth cylinder (Figure 7).

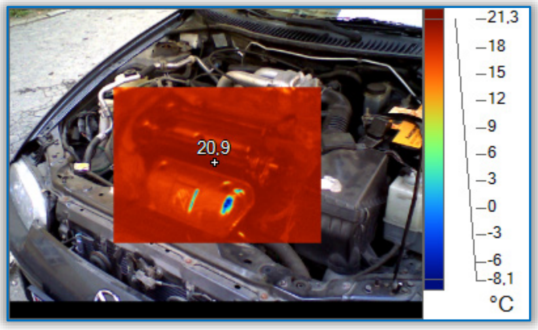

Figure 7. Thermal imaging of the engine

Due to the fact that the engine showed increased emissions and exhaust manifold noise during the emissions test, we concluded that the fourth cylinder was the problem based on the thermal imaging image of the exhaust manifold, which showed a lower temperature compared to the other three pipes under the heat shield (Figure 8).

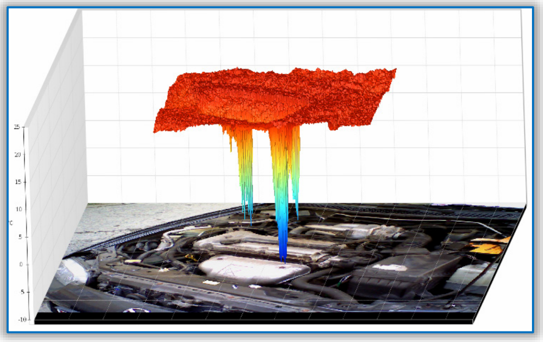

Figure 8. The chart 3D–IR

The thermal values were compared and recorded in a table for the needs of an authorized service.

Table 2. Main image of brands

Name	Temperature	Emissivity	Background
Midpoint	67,5 °C	0,95	17 °C

There were two possibilities of a cooler pipe on the 4th cylinder – poor ignition mixture supply, or poor combustion of the ignition mixture. For this reason, the injection ramp was tested for possible fuel leaks either through the injection nozzles and their seals, or due to clogging of the injection nozzles. The defect has not been confirmed at this point. The next step was to test engine compression without a combustion process and analyze the engine oil for the presence of fuel. Compression was within the standard set by the manufacturer of the internal combustion engine, but the oil showed a small proportion of unburned gasoline. This test was carried out by an authorized servicer.

The last possibility of error was the electric ignition system. Since a car ignition system is designed differently from conventional electrical systems, it is difficult to diagnose its defects using thermal imaging. Therefore, diagnostics using electrical measuring instruments were approached. Ignition cables and their resistive values were diagnosed, which had to meet the manufacturer's values for one meter of length. This test passed. Subsequently, it proceeded to the diagnosis of the spark plugs and manifold. It was in this area that the problem arose, since the primary and secondary windings of the manifold coil were outside the manufacturer's specified values, which caused the overall poor operation of the engine and low power, but the problem that caused the poor combustion process on the 4th cylinder was the distributor head with damage by the pin for distributing electrical voltage to the ignition cable and to the spark plug.

After replacing these parts and resetting the engine control unit, this error was not repeated, and the engine not only had significantly improved performance, but also emission values and combustion temperatures.

Table 3. Image information

	IR–fusion
Background temperature:	17 °C
Emissivity:	0.95
The average temperature:	67,5 °C
Image range:	10 °C – 105 °C
Camera – Model:	Ti25
Camera serial number:	Ti10–09040479
DSP version:	1.2.9
OCA version:	1.2.9.0
Manufacturer:	Fluke
Objective description:	20 mm
Lens serial number:	–
Picture time:	20.05.2023 11:57:09
Calibration range:	–25.0 °C – 125.0 °C

4. CONCLUSION

As can be seen from the results and measurement process, thermal imaging is of great importance in diagnosing machinery defects without having to shut down or disassemble such equipment for a long time. There are no additional costs due to the replacement of gaskets, which must be changed with each such disassembly. Thermal imaging is a convenient way to quickly diagnose and determine the defect and contributes not only to the correct estimation of the error, but also to the further trouble–free operation of the devices.

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