# ENDOSCOPY AND THERMOGRAPHY IN THE PROCESS OF MAINTENANCE OF AUTOMOTIVE VEHICLES

**Ryszard Jedliński**

*University of Technology and Life Sciences in Bydgoszcz*
*Faculty of Mechanical Engineering*
*Department of Thermal Technology and Metrology*
*85-796 Bydgoszcz, tel/fax: (052) 3408654, e-mail: jedlin@utp. Bydgoszcz.pl*

***Abstract***

*The process of automotive vehicles maintenance requires thorough assessment of the state of the vehicle and its systems. This is necessary for every day monitoring of changes of the vehicle technical state which, in turn, is the basis for scheduling and performing necessary operations involving repair or replacement of the parts whose fatigue life have come to an end. Detection of the reasons of inefficient operation of interacting systems and subsystems is also of great importance. Traditional methods and tools are often ineffective for providing the right diagnosis. The author discusses the possibilities of endoscopy and thermovision when used for assessment of the vehicle technical state*

## 1. Technical Endoscopy

### 1.1. Introduction

Endoscope is an optical tool used for examining closed, inner spaces. Endoscopy technique developed, first of all, for medical purposes, where its application is undoubtedly irreplaceable ( avoidance of use of invasive therapy and diagnostic methods) In case of technical objects this technique, involving introduction of the endoscope end into the cylinder through an opening left after unscrewed sparkling plug or an injector, allows examinations of the engine working surfaces ( valves, cylinder bearing surface, combustion chamber, an assembly of crankshaft piston and connecting rods, and the piston bottom) thanks to very bright halogen lighting.

Two kinds of endoscopes find practical application: stiff –probe made in the form of a metal rod [1] and elastic ones making use of a beam of fibers. The elastic probe is featured by much better capabilities of reaching hardly available places. The stiff probe is characterized by certain restrictions in reaching these hardly available places. However, the latter one has a picture of higher quality, and a lower price. The basic assumption of the tool operation is the possibility of diagnosing the vehicle technical state without a necessity to disassemble (no invasion) its structure, thereby not causing any damage or change of the object. All examination methods involving accompanying assemble-dissemble methods introduce hazard of disruption in machine parts cooperation which, in turn, may appear to be very costly and time consuming. These disruptions result from disarrangement of elements and seals, which often involves a necessity of running them in, again. Simple workshop endoscopes of American make have been available on the Polish market since 2005. These are endoscopes with a high picture resolution 7500 pixels. They are capable of remembering the shape, and an attachment enabling observation at an angle. The discussed endoscopes can be purchased at the price below 200 PLN. Therefore, it is possible for car service stations, associations of experts, and even private persons to buy these devices.

## 1.2. Practical Aspects of Using Endoscopy in Engineering

As far as evaluation of diagnostic susceptibility of automotive vehicles is concerned, it should be noted that they are not adjusted to being examined with the use of endoscopy. Constructors did not design appropriate ways of access to basic engine subassemblies or drive systems of vehicles. In practice only openings designed for the sparkling plug and injectors are used, this being the only way to see the head from the side of the cylinder, the piston surface or the valve head. Fig.1 presents a view of an open exhaust valve recorded by means of an endoscope (carbon deposit visible on the valve walls).

*Fig. 1 View of an open exhaust valve recorded by an endoscope ( carbon deposit visible on the walls of the valve)*

As for the remaining sets of automotive vehicles assemblies, apart from applicability for identification of the engine and chassis numbers it can be widely employed for assessment of the vehicle body state using its technological openings. It is the only way of looking into closed profiles as well as exposure and assessment of the metal plate corrosive wear. (fig.2).

*Fig. 2 View recorded by an endoscope: corroded surface of metal plate of a closed profile of an automotive vehicle door*

Possibilities that are provided by endoscopy could be largely extended if constructors took into consideration design of proper ways of access to ‘inner organs’ of an engine. This refers mainly to the valve system and the assembly of crankshaft piston connecting rods (fig.3).

In order to demonstrate the possibilities of endoscopy, when applied in vehicle technical service, we can refer to one case when a transport company applied with a request to explain some unserviceability. It was about finding reasons of inefficient work of an engine. The symptoms were: difficulties to start the engine, decreased power, black exhaust fumes and knocks coming from the crankshaft-piston area.

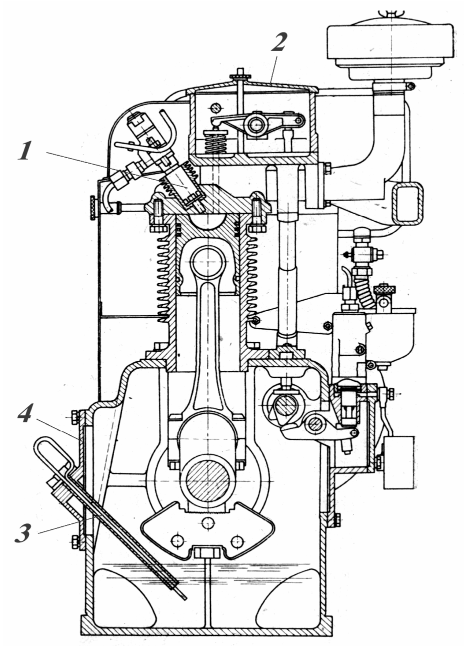


*Fig.3 proposed places of the endoscope access to the engine inside: 1-opening of the injector or the ignition spark, 2- blinded opening in the valve cover, 3- bayonet opening of the oil level meter, 4- opening for introducing endoscope in order to assess the state of the crankshaft - piston system*

After getting familiar with the engine maintenance course (work cards, damage register, service register) a measurement of compression pressure was carried out in particular chambers of the engine in question.

The measurement result (fig.4) showed unmistakably too low compression pressure in one of the cylinders. Before having this measurement performed the owner of the car had made several attempts to repair it, including injection pump regulation, replacement of fuel filters and high pressure cycle.

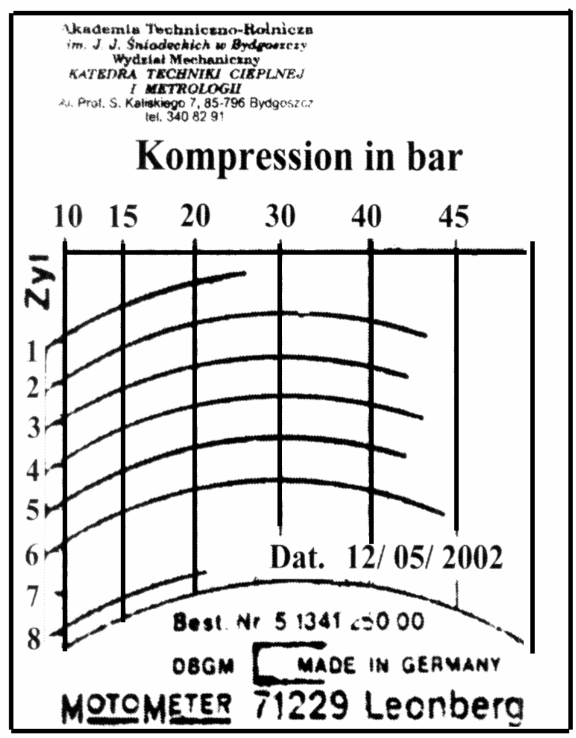


*Fig 4 Results of compression pressure measurement in cylinders*

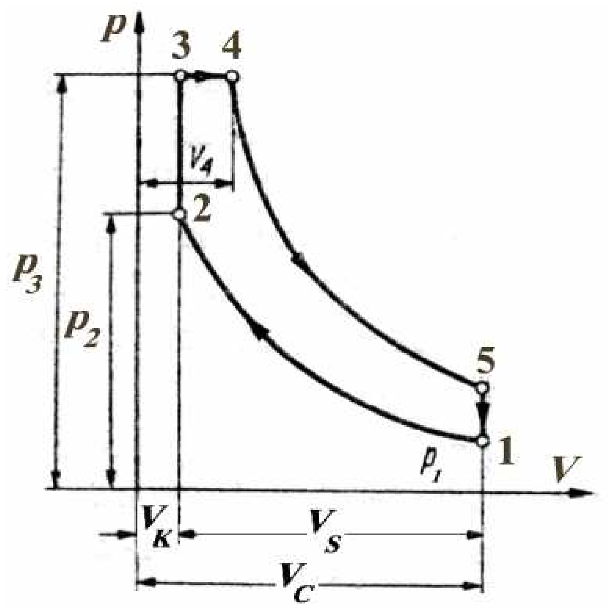


*Fig.5 Comparative cycle of a self ignition engine*

Before starting activities connected with disassembly of the engine, an attempt was made to determine analytically real parameters characterizing the engine in question. Thus, the pressure at the end of the compression weld $p_2$ can be calculated [4] from the dependence:

$$p_2 = p_1 \cdot \varepsilon \tag{1}$$

hence, the compression degree value $\varepsilon = \sqrt[n]{\frac{p_2}{p_1}}$ . Using the calculated compression degree value the temperature of the compressed air, in point 2 of the comparative cycle, was determined from the formula:

$$T_2 = T_1 \cdot \varepsilon^{n-1} \tag{2}$$

Calculation results are set up in Table 1.

*Table 1 Setting up of calculations of compression degrees and temperatures*

| Specification | Compression degree | Temperature at the end of the compression stroke |
|---|---|---|
| Cylinder II…VI | 21,8 | 947 |
| I cylinder | 14,1 | 780 |

As the calculations show the compression degree in cylinder 1 varies significantly from the values in the remaining cylinders.
In result of decreased compression pressure at the end of the compression stroke, temperature in cylinder 1 did not reach the required value of about 900 K [4]. It was the cause of disruption of the combustion process in this cylinder which resulted in inducing less power and black exhaust fumes. In result of carried out disassembly it was revealed that the cause of the problem was a twisted connecting rod, and in consequence damage of the cylinder sleeve in cylinder 1 (fig.6).

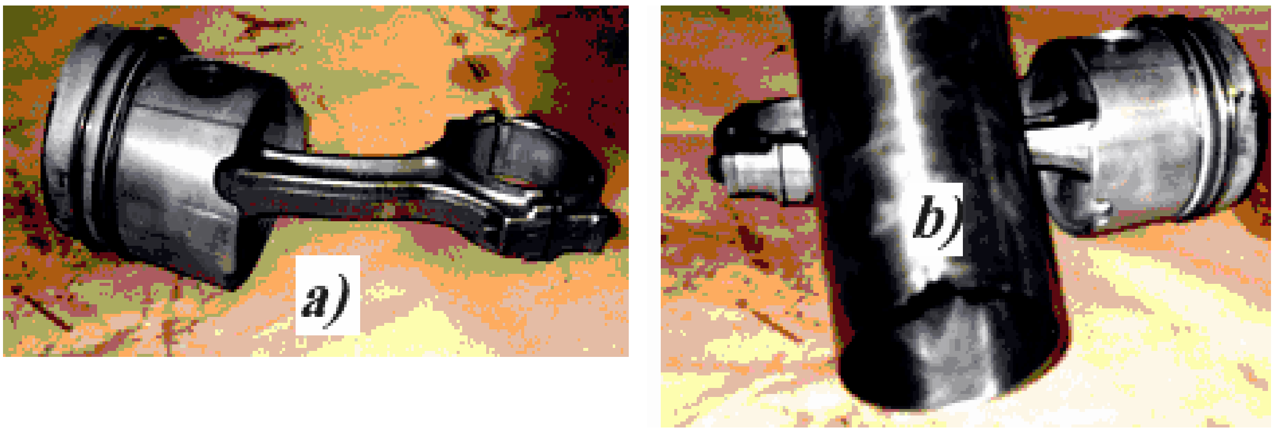


*Fig. 6 View of damaged: a) connecting rod, b) cylinder sleeve*

A conclusion can be drawn that reasons of the engine inefficiency could be found out much earlier if there had been possibilities of using an endoscope for examinations of the crankcase interior. Also, the costs connected with the vehicle demurrage and other indispensable service activities.

## 2. Using Thermography in the Process of Vehicle State Monitoring

### 2.1. Introduction

Each body with temperature higher than absolute zero is the source of radiation in the band of infrared IR, and its intensity depends on the body surface temperature and features. Thermovisual apparatus is a variety of television sensitive to a fragment of infrared radiation range. Creation of a thermo-visual picture consist in recording radiation emitted by a given object by a camera, and next processing it into a colored map of temperatures. While measuring infrared radiation emitted by a given body also the body temperature is being measured in an indirect way. For a perfectly black body the correlation of temperature with infrared radiation intensity is presented in the following way:

$$T = \sqrt[4]{\frac{E_O}{C_O}} \cdot 100 \qquad \textbf{(3)}$$

where:

Eo - thermal radiation intensity, W/m2

Co- radiation constant of a perfectly black body is equal to 5.77 $\frac{W}{m^2 \cdot K^4}$

T – absolute temperature of K surface.

Thermovision system enables measurement of temperature in a non contact way, and in many points at the same time. However, it must be remembered that temperatures can be compared directly only within one material. The body radiation power depends on its temperature, therefore, warmer places are brighter in the visible picture. Thermovion measurement of temperature makes it possible to define distribution of temperatures on the whole surface of the examined object. Thermovision examination results can be used for assessment of heat losses from power engineering devices and other objects as well as for localization of their occurrences.

Thermovisual measurements enable detection of potential hazards early enough to schedule service and repair activities, thereby, avoiding costs connected with demurrage or unexpected failures. Application of thermovision in scientific research improves significantly the quality of gained information on thermodynamic processes, heat exchange or cooling conditions.

### 2.2. Practical aspects of thermo-vision in the process of vehicle maintenance

Thanks to the fact that this kind of examination enables making a temperature map of the whole engine, the analysis of values for particular components of thermal balance for different fuels and parameters of the engine work has become easier. As it is known [4] the heat gained from fuel combustion can not be exchanged fully into mechanical work. In the combustion engine the amount of heat exchanged into practical work is equal merely to 25-40% of the heat generated in result of fuel combustion. The remaining heat, in the amount of 60-75 %, escapes with exhaust gases, or is carried away by a cooling factor or is included in other thermal losses. In order to assess utilization of the heat supplied to the engine a thermal balance is made.
General equation of the outer balance has the form:

$$Q = Q_e + Q_{ch} + Q_w + Q_n + Q_r, \quad {}^{J}\!/_{h} \qquad \textbf{(4)}$$

where:

Q - heat supplied to the engine in J/h
Qe- usable heat (changed into usable work) in J/h
$Q_{ch}$- cooling losses
$Q_w$ –outlet losses in J/h
Qn – losses of incomplete combustion in J/h
Qr – the rest of balance in J/h

Energy losses increase the temperature of the engine parts and elements After reaching proper temperature of the engine work, the cooling and lubrication systems carry away the excess of thermal energy. The amount of carried away energy can not be too big. This is supposed to maintain the engine temperature within the required range. High temperature is also very dangerous for the engine and here thermo-vision makes it possible to reveal this fact early including the cause of such a situation. In turn, in result of too low temperature of the engine the process of fuel combustion and evaporation is disturbed. Part of not combusted fuel goes to the exhaust system where frequently occurs its firing accompanied by increase in temperature of the exhaust system elements which is also recorded by the thermovision camera.

In the Department of Thermal Technology and Metrology initial thermographic examinations of a combustion engine were performed with the use of thermograph V-20. The examined object was a high-pressure, four-stroke, 6-cylinder combustion engine S-359M.The engine is cooled by a liquid with a cycle forced by a pump. Thermograph V-20 (thermo-graphic camera) that was used, is a device designed for non contact representation of the temperature distribution on the examined area, on the basis of infrared radiation power measurement emitted by particular elements of this surface.


*Fig.7 Thermo-graphic camera V-20*

Results of the measurement are presented in the form of a colored thermogram Thermographic pictures were obtained in result of scanning the engine heated surfaces.. Some of them are presented in this article.(fig.8, 9,10). The engine heads, exhaust collector, exhaust pipe, the engine body, oil sump - right after starting and after a certain time of work, were important places to examine. It allowed evaluation of the engine rise dynamics, during its work both without and with service load.

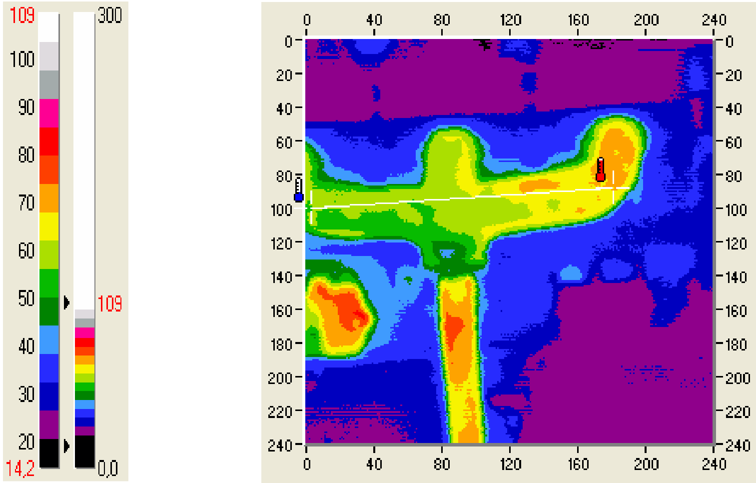


*Fig.8 Thermograph of exhaust collector of an engine without service load made after 5 min. from the engine start*

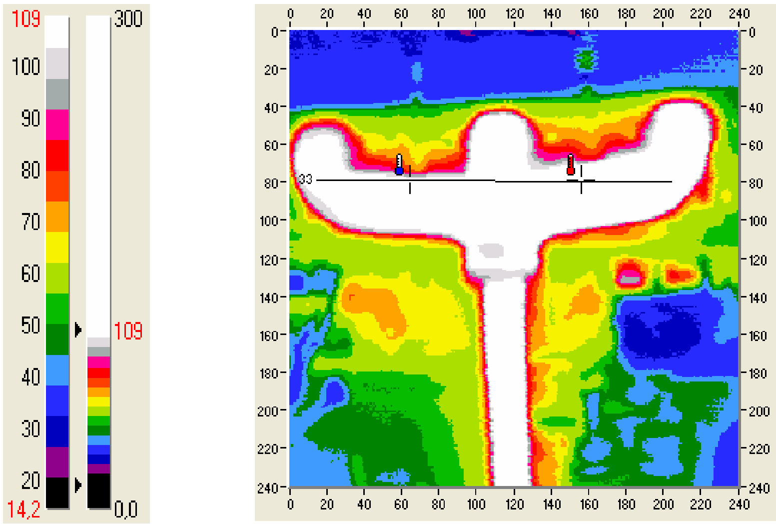


*Fig. 9. Thermograph of an exhaust collector of an engine working without service load made after 20 min. from the start*

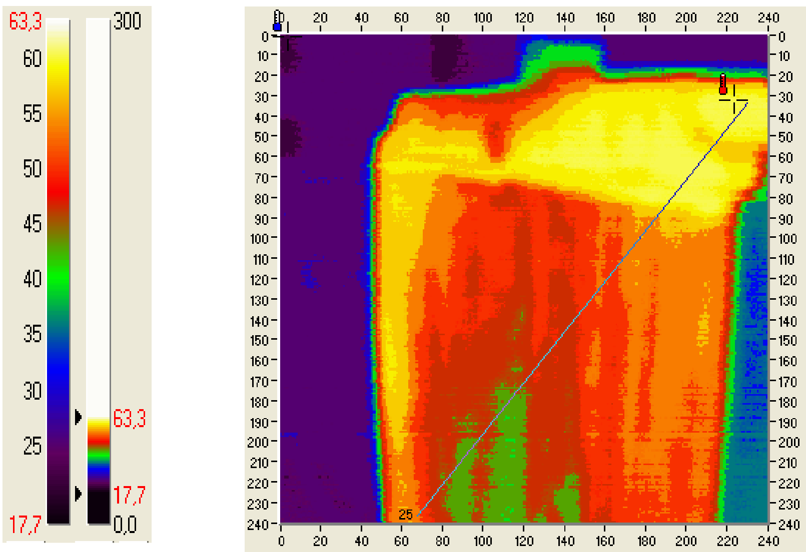


*Fig.10. Thermographic picture of an engine radiator made after 40 min. from the engine start.*

On the basis of observation of thermographs of water coolers (fig.10) it can be seen that bright colors on the cooler liquid inlet transform into cold colors on the outlet, which means sufficient cooling of the coolant .

As the information gained from the analysis of the thermographs shows, examinations of an engine by a thermovision camera should be recognized as one of diagnostic methods. This method makes it possible to obtain information about the examined object in a non invasive way, that is, without a necessity of its disassembly. Undoubtedly, a big advantage of this method is a possibility of examining the engine working with and without service load. Thermographic analysis provides information on temperature distribution on the whole surface of the examined object, in a given moment, thanks to which it gains advantage over other diagnostic methods. Using equations of thermal balance and additional measurements concerning masses and flow of media ( liquid, gas ) as well as tests results from the engine test house, one can venture to make a complex evaluation of the examined object thermal balance, its efficiency, and indication of areas where temperature anomaly occur which can be the cause of the engine failures.

## 3. Summary

Due to the publisher's restrictions the article presents only some aspects of application of endoscopy and thermography in assessment of the vehicle technical state. It should be emphasized that some objective obstacles resulting from high purchase costs have been overcome recently, and currently thermographs can be purchased at the price of about 40 thousand pln, whereas, endoscopes for 1200 thousand pln.

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