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CONSIDERATIONS ON THERMAL FATIGUE INTERNAL COMBUSTION ENGINES

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ABSTRACT: This paper refers to the principle of thermal fatigue research on internal combustion engines, particularly for Dacia engine ignition engines. Knowing the negative effects in case of any harm caused to the gears making up the internal combustion engines, in order to mitigate the causes of destruction caused by cracking, we must do some thorough, complex, theoretical, and experimental research on thermal fatigue, using new theoretical and experimental approaches. Research is done in three directions: to study the thermal component of part machineries, to study and perform experimental determination of variable fields of surface temperature of machine components, to perform experiments on thermal fatigue life samples subjected to different regimes of stress. The main objective of this paper is to solve complex problems of internal combustion engines by acquiring new, original, theoretical and experimental knowledge on the thermal fatigue phenomenon that occurs in part machinery enabling the transfer of heat from the combustion chamber to the cooling fluids for engines fitted to motor vehicles.
KEYWORDS: thermal fatigue, internal, combustion, engine, cyclic

❖ INTRODUCTION

Basic research on thermal fatigue of internal combustion engines is an important problem both from a theoretical or an experimental point of view, but also in economic terms.

Machine gears of motor vehicles participate in the working cycle. This cycle is characterized by temperature variations. Such variations are important for heat developed inside the combustion chamber and sent forwards to the cooling fluid. Thus, within certain parts of their gears, they create some temperature fields triggering cyclic tension. The rate of temperature change is very important in case of internal combustion engines fitted to motor vehicles; they create some variable and cyclical thermal fields up to a speed measured in seconds or even tenths of seconds, producing specific thermal fatigue cracks. These cracks appear after a certain number of thermal cycles; their number depends on the material machine gears are made of, as well as on the operating mode of the engine parameters. If the number of thermal cycles increases, it develops and increases heat exhaustion, and cause some specific surface cracks across the entire surface layer of the gears, negatively changing energy and economic indices of the engine.

Knowing the negative effects in case of any harm caused to the gears making up the internal combustion engines, in order to mitigate the causes of destruction caused by cracking, we must do some thorough, complex, theoretical, and experimental research on thermal fatigue, using new theoretical and experimental approaches. We must study and do important research on thermal fatigue, not only mitigating the raging crack, but also avoiding thermal shock, which is particularly dangerous during working of the engine. Classical methods of resistance calculation for machine gears inside internal combustion engines which are exposed to thermal fatigue do not consider the demands of certain items, which are caused by variations of temperature fields across the surface and within the surface layer. Such phenomena occur during the engine working, and it is being offset by increasing the allowable tension values.

Although scientific literature referring to the research on internal combustion engines is quite extensive, research do not refer particularly to the phenomenon of thermal fatigue within the superficial layer of fixed and mobile machine gear. The research of thermal fatigue of internal combustion engines, particularly of fixed and mobile machine gears, is less studied both on national and international level.

So far, there are no specialized publications covering thermal fatigue of internal combustion engines in detail, both theoretically and experimentally. Within the context of market economy, a new development in basic research of thermal fatigue of machine gear is necessary. This research should use the most modern and efficient solutions.

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❖ METHODOLOGY AND DISCUSSION

The main objective of this them of researches is to solve fundamental and complex problems of internal combustion engines by acquiring new, original, theoretical, and experimental knowledge on thermal fatigue occurring inside all machine gears that enable the transfer of heat from the combustion chamber to the cooling fluid inside internal combustion engines.

During internal combustion engines working, specific fatigue cracks appear within the surface layer of any item enabling the transfer of heat, and they grow slowly due to thermal cyclic variations of temperature fields, [1].

Thermal fatigue cracks appear on the surface and within the outside layers of the parts participating in the heat transfer. Thermal fatigue cracks specific that develops gradually because of cyclic temperature variations. These cracks appear and on the upper layers and on the surface of parts machineries (although in the most favorable operating conditions), limiting their use to situations which have negative effects on energy and economic indices of the engine[2],[3].

To study thermal fatigue of the organs that make up fixed and mobile internal combustion engines the following objectives must be achieved:

- to study the thermal behaviour of part machinery of vehicle engines participating in the transfer of heat from the combustion chamber cooling fluid during operation;
- to experimental and determine all variable fields and surface temperature of the upper layers of part machinery;
- to perform experimental research on fatigue resistance of samples subjected to different thermal regimes request.

The operation of an internal combustion engine is characterized by a set of values that define the operating system. The operating regime is defined by three fundamental dimensions: speed, load, and temperature characterizing the thermal regime of the engine. The thermal regime is the body temperature indicating the degree of enforcement mechanism for heating the engine. Thermal regime is indicated by the exhaust gas temperature "t_{ge}" or cooling fluid temperature "t_r" [2].

To achieve thermal regime we have built a trial bench to measure the temperature inside the combustion chamber and cylinder head wall temperature in the intake and exhaust valves, fig.1.

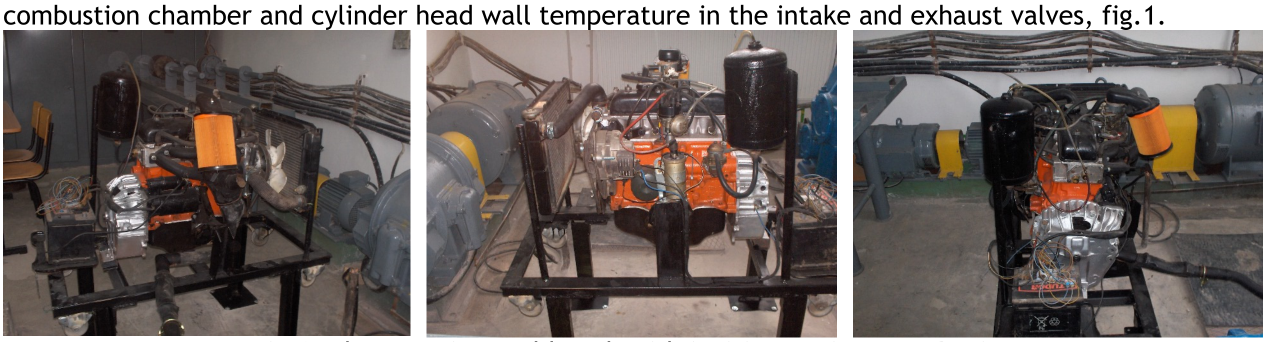

Fig.1. The experimental bench with ignition engine type Dacia

Experimental bench includes a Dacia spark ignition engine, with all related auxiliary facilities that allow normal functioning. The engine is mounted on a resistance structure which enables a rather good stiffness to the bench and eliminates engine vibration during operation, a phenomenon that would adversely affect experimental measurements.

The thermal study raises questions about [1], [2],[4], [5] how to: clarify the limit; evaluate heat passing through the pieces as part of the heat developed in the combustion chamber;

The main technical parameters considered for a thermal study of spark ignition engine are [1], [2], [4], [5]: gas temperature; pieces on the wall temperature chamber and the cooling fluid; heat transfer coefficient.

Of all these parameters, the temperature of the combustion chamber is necessary to determine how precisely it influences major heat transfer and thermal default application of part machinery of the engine structure, both directly and through the coefficients of convection, radiation and conduction heat [1], [4]. Thus, the gas temperature in the engine combustion chamber is determined analytically and experimentally.

In terms of analytical research, gas temperature in the combustion chamber is determined based on the indicated chart, and the method involves choosing a number of sizes that varies a lot, which means obtaining the actual values who differ from the regular ones.

From the experimental point of view, gas temperature in the combustion chamber is determined by a chamber of thermo-vision, type T200 - the characteristics of the view field are of 25 x 19 mm focus distance, min 0.4 laser semi penetrating mm, 635 HM (red) laser wavelength, and 7.2 V ionic power battery. Following the transfer of heat from flue gases to the walls of the chamber, by convection and radiation transfer that occurs inside the internal combustion engines mechanical stress, thermal stresses appear in addition. Temperatures that vary over time in the combustion chamber are transmitted as oscillations to fixed and mobile part machinery composition engine. Heat taken from them during operation is transferred to a lesser extent during the gas engine fluid change. Depending on the quantity of heat generated by engine operation and the different thermal resistance which occur during heat transfer (thermal conductivity material, building sections, etc.), part machineries suffer from temperature fields. These fields are cyclic at very small intervals (seconds or tenths of seconds) and are responsible for the occurrence of thermal fatigue.

The reason why these varying temperature fields occur is explained as follows: during the intake stroke of a piston engine, the intake valve is open, and cool air intake cools off the intake drift; during the compression stroke both valves remain closed; at the beginning of the compression cylinder walls yield air heat. In the further compression, the phenomenon is reversed, heat flows from the compressed air cylinder walls during the discharge gas resulting from combustion exhaust valve opens, and exhaust gases warm up the gallery.

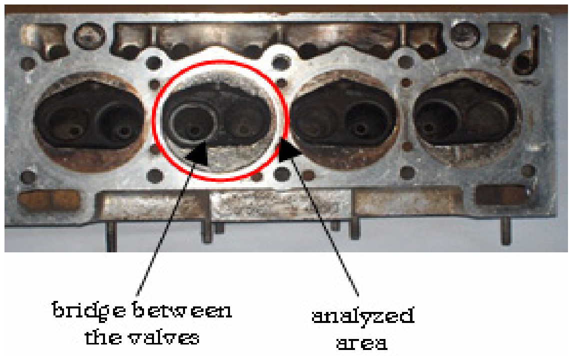

Fig.2. Studied area of Dacia engine cylinder head

Determination of the variable temperature field is the second objective of further research on thermal fatigue. Their experimental determination is made by mounting thermocouples in the wall of Dacia engine cylinder head areas of intake and exhaust valves fig. 2.

Thus, we have created a succession plan that includes next steps:

- ❖ Removing the entire engine cylinder head;
- ❖ Appropriate training to detect areas where the cylinder head and the temperature difference is high;
- ❖ Drawing and making channels in areas to be fitted thermocouples;
- ❖ Performance and installation works were thermocouples;
- ❖ Fitting the so prepared engine cylinder head assembly;
- ❖ Check thermocouples mounting and connecting them to systems of data acquisition;
- ❖ Measuring and recording changes in temperature fields;
- ❖ Assessing and obtaining experimental determinations of temperature charts;
- ❖ Highlighting areas where thermal fatigue occurs.

Following the analytical calculations, we observed that the center axle of the valve is subject to cyclical variations in temperature, fig. 3.

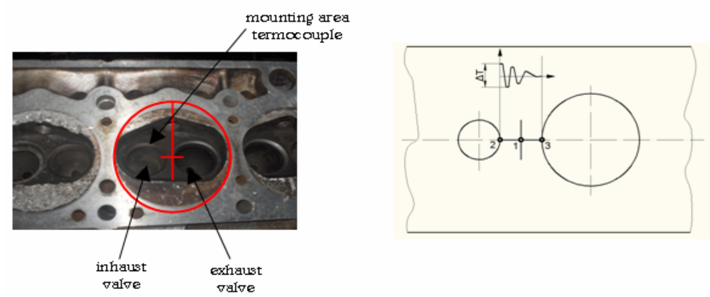

Fig.3. Location of the areas that appear schematized cyclical temperature changes

The center deck of valves - the zone is located in section 1 - the highest temperature occurs at the end of the combustion process. The highest temperature difference at the end of admission is between points 1 and 2, and between points 1 and 3 the difference still reaches the highest value at the end of the admission, but less than that between points 1 and 2. Temperature oscillation amplitude gets lower to reaching the cooling fluid. The highest amplitude of these oscillations occurs during the engine operation in overload. The effect of these oscillations and the temperature difference is the appearance of thermal stress cracks generating specific thermal fatigue. This phenomenon is more pronounced inside spark ignition engine cylinder heads due to operation in very different thermal regimes. In general, engine parts fitted vehicles is more pronounced appearance of cracks due to operation in very different thermal regimes compared to engines operating in stable regimes, [2], [3].

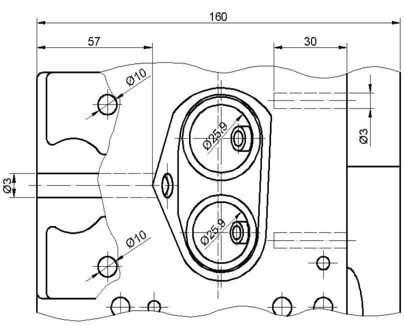

Fig.4. Position channels for mounting thermocouples

For sensing variable temperature fields were chosen thermocouple Pt, Rh-Pt, with a measuring domain of -50 ... 17500C, 0.01 mm diameter, and 6 V/0Cμby sensitivity. These thermocouples were installed near the outlet and inlet pipes and valves in the deck of under representation of fig. 4. These thermocouples are connected to a data acquisition system comprising a data acquisition card that allows recording data during engine operation. When using such a computer program experimental data are processed and converted into temperature charts. Through these diagrams temperature we are able to determine the evolution of thermal tensions causing thermal fatigue.

Further research will be done to study how thermal fatigue influence part machinery constituting the main engine, on an original design facility being registered by OSIM patent, No.

A/00439/17.05.2010. This facility was originally designed for durability determinations in thermal fatigue tests as rings, made by hot rolled cylinders.

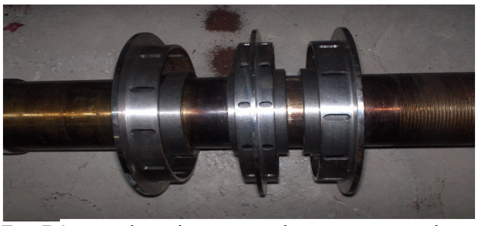

Fig.5 Lateral and intermediate support discs provided with channels mounted on the main axis, prepared for sample mounting

Fig.6 Thermocouples crossed through the main axis of the facility to connect their data acquisition system

This facility suitable for experimental determination of thermal fatigue involves mounting some samples of various sizes and shapes on the main shaft of ignition engine, and which are subject to simultaneously heating in an oven at a temperature of 1000^0 C and cooled off in different environments. Samples are mounted tangentially on all generators of rigid disks mounted on the main axis of the plant. In fig. 5 we describe the intermediate and edgeways support discs provided with channels for assembling samples that may have cross-section shapes and sizes, and different lengths, but approximately equal sets.

Thermocouples are mounted on two samples set opposite on the circumference of the supporting disc. These thermocouples response inertia correspond to thermal load cycle, whose conductors are rigid and sent to the reaming of the main shaft to the tension collector, and then to data acquisition system that allows simultaneous recording of temperature variations of experimental application. In Figure no. 6 we describe thermocouples that cross through the main axis to connect their facility data acquisition system. During experiments samples of different materials and quality are subject to cyclic thermal heating inside ovens and cooled off in different environments, fig.7 - carbonic snow, water, and air.

a - overview of the oven for sample heating

b - detail view of the oven profile

c - loop mounting resistors for electric sample heating oven

Fig.7 Oven to heat samples taken from fixed and mobile parts machinery of a ignition engine to determine thermal fatigue resistance

❖ Conclusions

The main objective of the paper is determining the main directions and principles of experimental research work on thermal fatigue phenomenon that occurs in part machinery that participate in the transfer of heat from the combustion chamber to coolant engines fitted to motor vehicles.

Importance of carrying out such research derives from the fact that thermal fatigue of vehicles' engines is less studied both nationally and internationally. So far no specialized publications which deal in detail, theoretical and experimental thermal fatigue of internal combustion engines. Market economy requires a new development in fundamental research of thermal fatigue of motor part machinery, using the most modern and efficient worldwide technology solutions.

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