THE MODELING OF THE HEAT LOADS IN THE EXHAUST VALVE FROM AND WITHOUT REGARD OF THE CARBON DEPOSIT

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Abstract

This paper presents the modelling of the heat loads in the exhaust valve from and without regard of carbon deposit in initial phase of work of the turbocharged Diesel engine by using the two-zone combustion model, finite elements method (FES) and program Cosmos/M. In order to illustrate the problem the valve face is divided into two equal areas, then it was assumed that one of them is covered with a thin layer of carbon deposit. Modelling was conducted based on the boundary conditions III kind as a function of time, which describes the convective heat transfer coefficient and the temperature of the surrounding surfaces of valve. As a result of the calculations was compared obtained temperature distribution on the surfaces of the valve - with and without carbon deposit. The study also performed an analysis of the stress distribution that arises in the valve by the presence of the carbon deposit on the surface of the face valve. The analysis showed that the face valve heats up unevenly, more slowly on the side of the carbon deposit. Moreover small increase of the temperature causes the increase of the stress values. Maximum values of stresses do not appear in a valve face under a layer of carbon deposit but on the line distributing the surface covered with carbon deposit and without carbon deposit, near the valve face. These stresses cause the growth of microcracks in the area of the valve face, which finally give occasion to the defect of material, the damage of the valve and engine failure.

Keywords: *numerical techniques, analysis and modelling of the heat loads, valve, carbon deposit, FEM*

1. Introduction

Exceeding the permissible thermal loads exhaust valve deteriorating working conditions of the engine and thereby reduces its life, and in extreme cases even lead to its immobilization. The effects of excessive heat loads associated physicochemical actions of the working medium of high temperature and mechanical damage resulting from excessive temperature gradients. Exhaust valves are characterized by high temperatures and the values are quite intense gas corrosion, which leads to carbon deposit on the surfaces of the valve. In order to illustrate the problem of carbon deposit and its impact on the change in value of temperature gradient distributions were adopted during the modelling assumption that one half of the valve plate is covered with a thin layer of carbon deposit while the other half of the plate is no carbon deposit. As a result of the calculation of temperature distributions received in the valve outlet, which changes associated with changes in temperature gradients, that is, the additional thermal stress which could eventually lead to its failure. The analysis was also brought to identify areas in which there are maximum values of thermal stress and displacement during the warm-up valve. Modelling was carried out by applying the two-zone combustion model, the finite element method FEM and program Cosmos/M. For the calculations used the boundary conditions of type III, as a function of time describes the heat transfer coefficient and the temperature of the surrounding surface of the valve.

2. Modelling of the heat loads

The modelling of the heat loads outlet valves were applied the III kind boundary conditions which characterizes the temperature T working medium, determined on the basis of the course indicated pressure (Fig. 1) by using the two-zone combustion model as well as the coefficient α of the heat transfer (Fig. 2) in the engine. Analysis of the distribution of temperature fields and the distribution of temperature gradients was carried out during the initial 20 seconds of worktime engine.

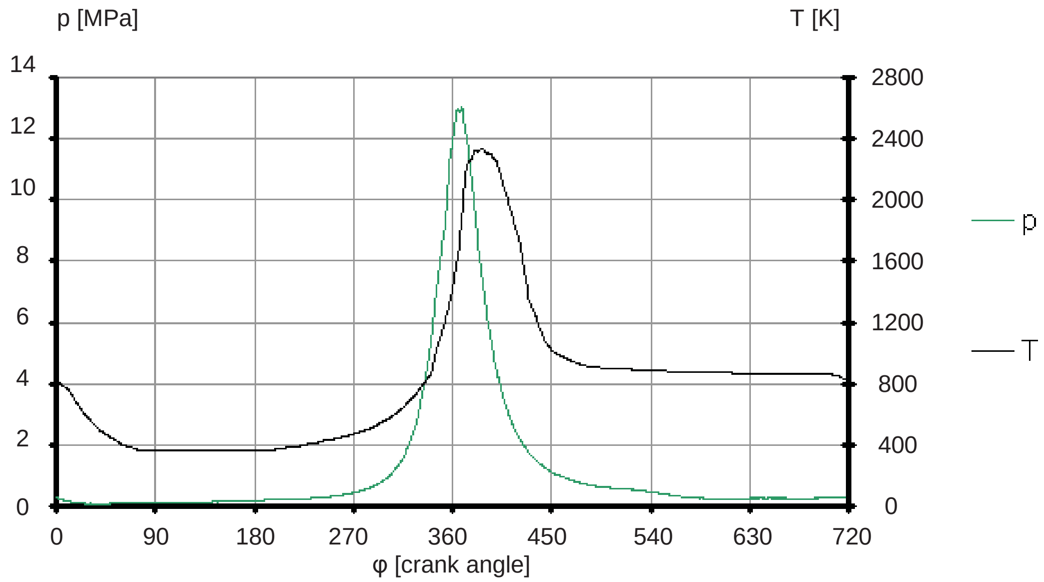

Fig. 1. The course of pressure and temperature of working medium in turbo Diesel engine (N = 85 kW, n = 4250 rpm)

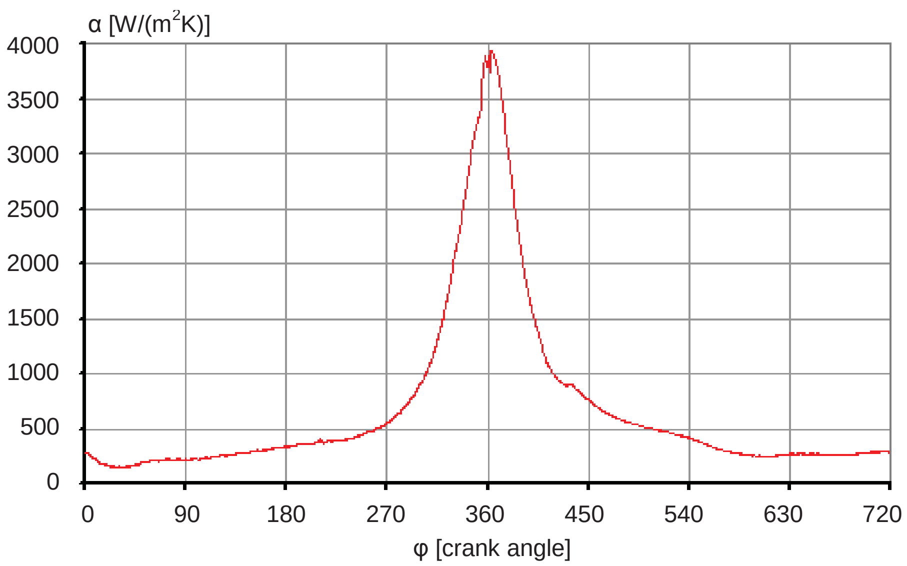

Fig. 2. The course of changes of total heat transfer coefficient in the speed engine function for 4250 rpm and the access air coefficient λ = 1.69

3. Explicitness conditions

In the case analysis of the unestablished heat transfer in the valves it should consider the explicit conditions to which geometrical, physical and initial conditions belong.

3.1. Geometrical conditions

Geometrical conditions describe shapes and sizes of the considered body. The analyzed geometrical models of the valves were executed by the means of tetrahedral units lump 3-dimension about 4 nodes (TETRA 4) and accessible dimensions 1mm in the system Cosmos/M.

3.2. The physical conditions

These conditions define the physical properties of the substance created by the body, namely density, proper heat capacity and also thermal coefficient conductance. At the outlet valve was accepted chromium-nickelsteel 5H13N15W2. The program COSMOS/ M makes possible for use of the curves of the temperatures in the thermal analysis. For the inlet and outlet valve accepted the variable value of thermal coefficient conductance in function of temperature T (Fig. 3).

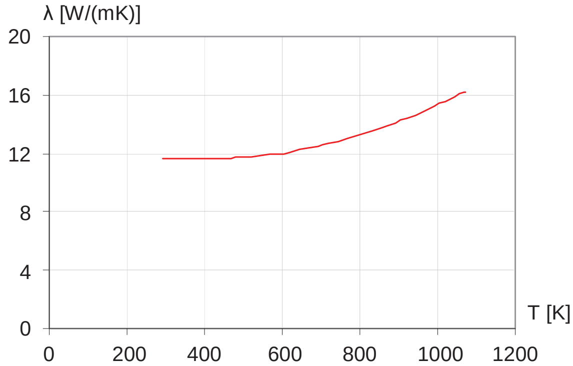

Fig. 3. The courses of changes of thermal coefficient conductance of the steel outlet valve - in the temperature function

3.3. Initial conditions

The Initial conditions defined in whole, were occupied by body temperature distribution in the initial moment of the time $\tau = 0$. During the heat loads analysis there were constant temperature distributions and even the ambient temperature.

3.4. Boundary conditions

In examining the influence of loading on the value and distribution of temperature and temperature gradients in the valve includes the following areas (Fig. 4): the plate (1), the valve face (2), valve spindle in the inlet channel (3), face surface of the valve spindle in the engine head (4) and surface of the valve spindle over the head (5). In addition, the surface (1) was divided into two equal surfaces: surface covered with a thin layer of carbon deposit (1a) and the surface without the carbon deposit (1b).

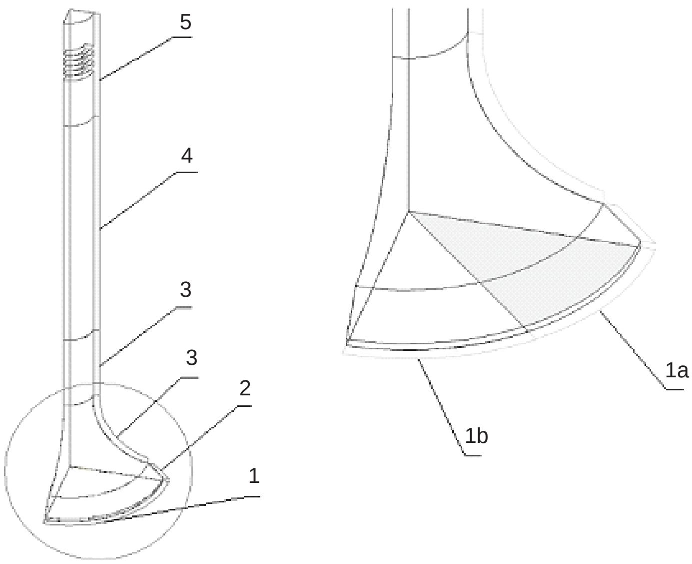

Fig. 4. Drawing of the outlet valve

4. Results of calculations

This work has introduced the heat loads in the exhaust valve from and without regard of the carbon deposit in turbo Diesel engine with direct injection to the combustion chamber with the capacity of about 2390 cm^3 and power rating 85 kW at the speed of 4250 rpm. Fig. 5 and 6 presented the following phases of the warm up of the valves responding the piston position carrying out 5 crank angle after 0.5 s, 10 s, 15 s and 20 s of the work of the turbo Diesel engine. These drawings are presented in both the temperature distribution and the distributions of temperature gradients. We can observe on these figures the growth process of thermal stress and the place of the local maximum concentration. Fig. 7 presented a comparison of average temperatures in the face valve coated with carbon deposits and without it. Fig. 8 shows the mean temperature gradients along divisional lines on the surface of the valve face and Fig. 9 shows the distributions of temperature gradients on the circumference of the valve plate in 20 seconds of engine working.

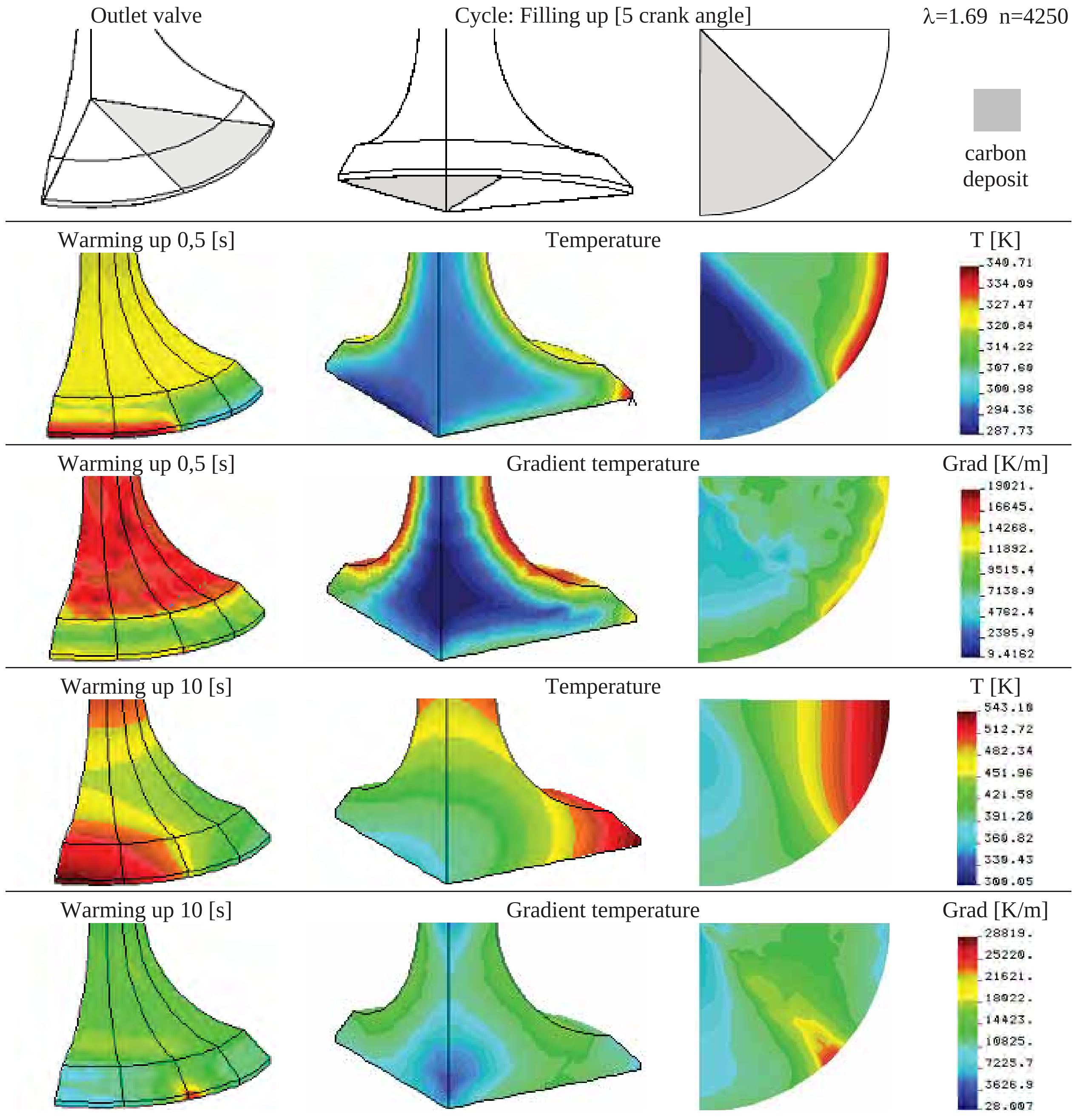

Fig. 5. The following phases warming up of the outlet valve

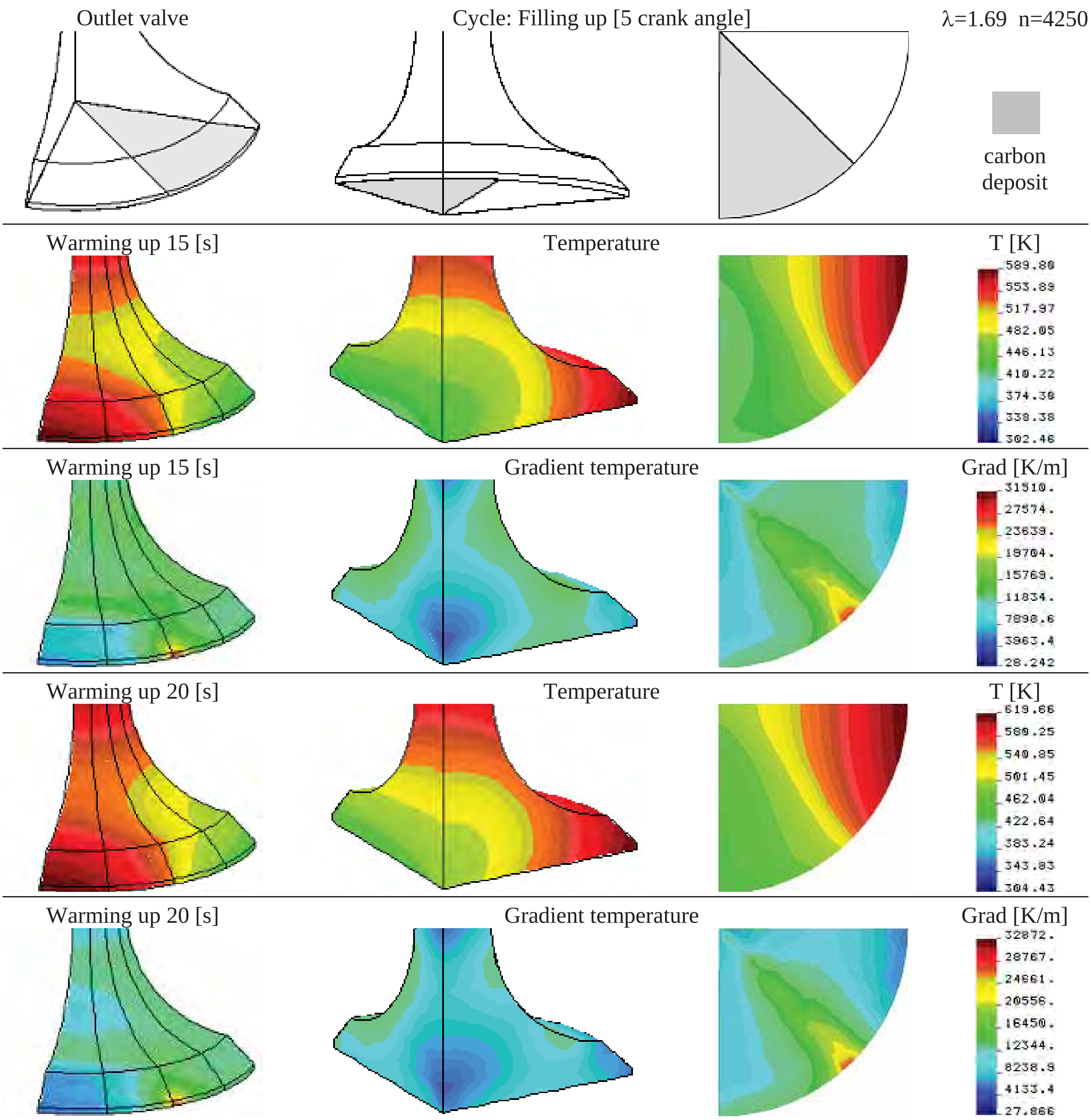

Fig. 6. The following phases warming up of the outlet valve

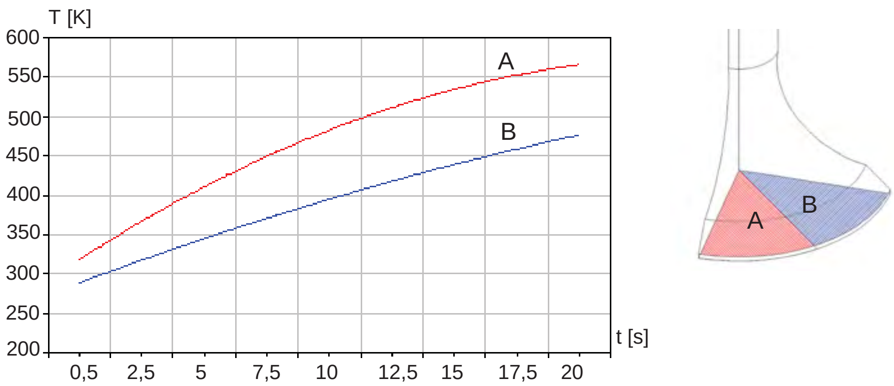

Fig. 7. The courses of changes of the average temperature outlet valve on the surface A (without carbon deposit) and surface B (with carbon deposit)

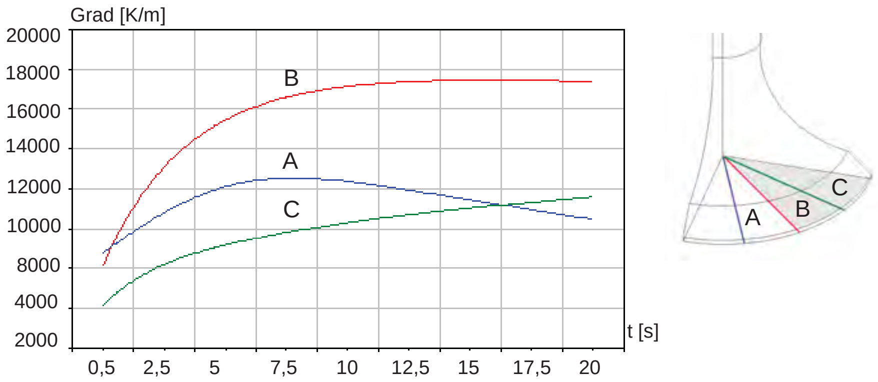

Fig. 8. The courses of changes of the average gradient temperature outlet valve: along the line A on the surface (without carbon deposit), along the line B between the surface (without carbon deposit) and the surface (with carbon deposit), along the line C on the surface(with carbon deposit)

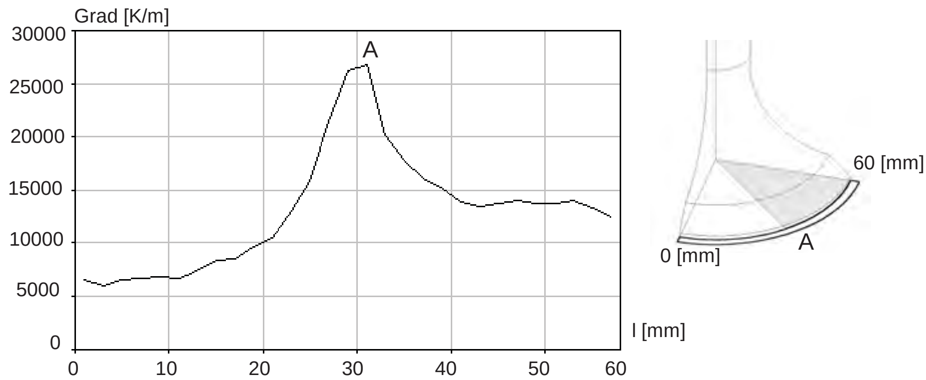

Fig. 9. The courses of changes of the gradient temperature outlet valve along the line A in 20 s working of engine

Fig. 10. Example valve damage resulting from the presence of carbon deposit

5. Conclusions

On the basis of the conducted model of the heat loads of the exhaust valve from and without regard of the carbon deposit affirmed, that carbon deposits act as thermal insulator, as the speed of heating of the surface of the valve face with carbon deposit (is about 8.5 K/s) is significantly less than the speed of heating of the surface without any carbon deposit (is about 13 K/s). The maximum temperature of face valve in 20 seconds of engine working is about 620 K, while the second analyzed the surface maximum temperature is about 510 K.

The analysis shows that a particularly dangerous case is the partial presence of the carbon deposit on the surface face valve, because the greatest thermal stress arising in the line of contact between the surface with carbon deposit and surface without carbon deposit (is about average 17400 K/m). The maximum stress concentration occurs near the valve head (is about average 26100 K/m). The place is particularly vulnerable to the emergence of microcracks, which can lead ultimately to the loss of material (Fig. 10) and damage to the valve (engine). Because of the complexity of the problem of analysis distribution temperature and distribution gradient temperature, in the exhaust valve from and without regard of the carbon deposit, it going to be further subject of analysis.

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