Piotr GUSTOF*, Aleksander. HORNIK
Silesian University of Technology, Faculty of Transport, Department of Vehicle Service
Krasińskiego St. 8, 40-019 Katowice, Poland
**Corresponding author*. E-mail address: piotr.gustof@polsl.pl

THE INFLUENCE OF THE ENGINE LOAD ON VALUE AND TEMPERATURE DISTRIBUTION IN THE VALVE SEATS OF TURBO DIESEL ENGINE

Summary. In this paper was presented the numerical computations of the influence of engine load on value and temperature distribution of characteristic surfaces of the heat transfer of the valve seats in Turbo diesel engine at the beginning phase of its work. The computations were performed by means of a two-zone combustion model, the boundary of III kind conditions and the finite elements method (FEM) by adaptation of the COSMOS/M program.

WPŁYW OBCIĄŻENIA NA WARTOŚĆ I ROZKŁAD TEMPERATURY W GNIAZDACH ZAWOROWYCH DOŁADOWANEGO SILNIKA Z ZAPŁONEM SAMOCZYNNYM

Streszczenie. W niniejszej pracy przedstawiono wyniki obliczeń wpływu obciążenia na wartość i rozkład temperatury charakterystycznych powierzchni wymiany ciepła gniazd zaworowych dla doładowanego silnika z zapłonem samoczynnym w początkowej fazie jego pracy. Obliczenia numeryczne zostały przeprowadzone przy zastosowaniu dwustrefowego modelu procesu spalania, warunków brzegowych III rodzaju oraz metody elementów skończonych (MES) za pomocą programu COSMOS/M.

1. INTRODUCTION

In this paper the description and numerical calculations of the values and temperature distribution of the five characteristic surfaces of inlet and outlet valve seats in dependence on the engine loads in the initial stage of its running were presented. The computations were done by use of the finite element method (FEM) in COSMOS/M application. The subject of research was turbo Diesel engine with direct injection about engine cubic capacity 2390[cm^3] and power rating 85[kW]. The calculations were done for constant engine speed n=2000[rpm] and two different air excess ratio λ=1,66 and λ=3,08 during 60 seconds of engine working.

2. MODELLING OF HEAT LOADS OF THE INLET AND OUTLET VALVE SEATS

The phases of creating the geometrical model of analyzed valve seats:

- creating two-dimension of the half intersection of the inlet and outlet valve seats,
- creating three-dimension model (3D) by 180° turning,
- division the mesh of analyzed elements (meshing).

During division of the 3D model the solid element with four nodes (TETRA4) about 1[mm] dimension was used (fig.1) [1].

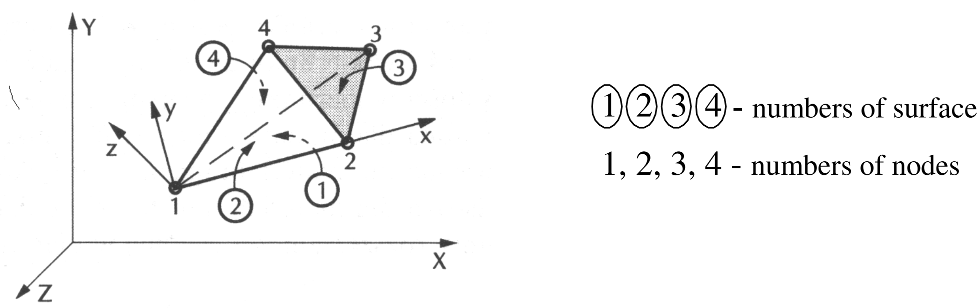


Fig. 1. Element TETRA4
Rys. 1. Element TETRA4

The following stages of creating valve seats models.

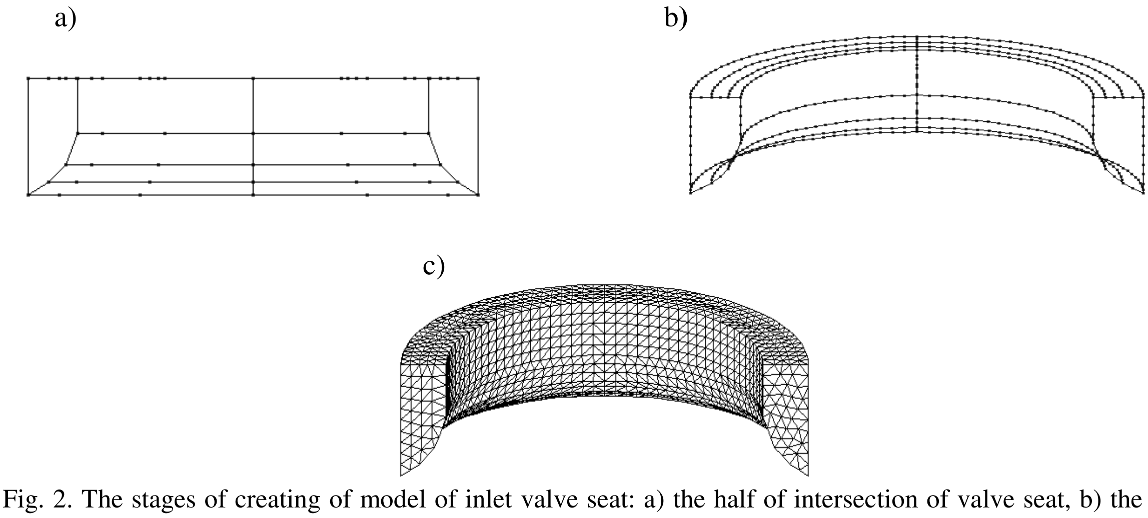


Fig. 2. The stages of creating of model of inlet valve seat: a) the half of intersection of valve seat, b) the three-dimensional model, c) the mesh of elements
Rys. 2. Etapy tworzenia modelu gniazda zaworu dolotowego: a) połowa przekroju gniazda, b) model przestrzenny, c) siatka elementów modelu

The inlet valve seat model consists of 7747 elements, 1833 nodes, 5 points, 35 curves, 15 surfaces, 1 outline, 1 region, 1 polihendry. However the outlet valve seat model consists of 7166 elements, 1673 nodes, 5 points, 35 curves, 15 surfaces, 1 outline, 1 region, 1 polihendry.

2.1. Physical conditions

To realization of an analysis of unstable state of the heat transfer in valve seats, three physical properties must be known [1]:

- λ – thermal conductivity of material [W/(mK)],
- ρ – density of material [kg/m^3],
- c_p – thermal capacity of material [J/(kgK)].

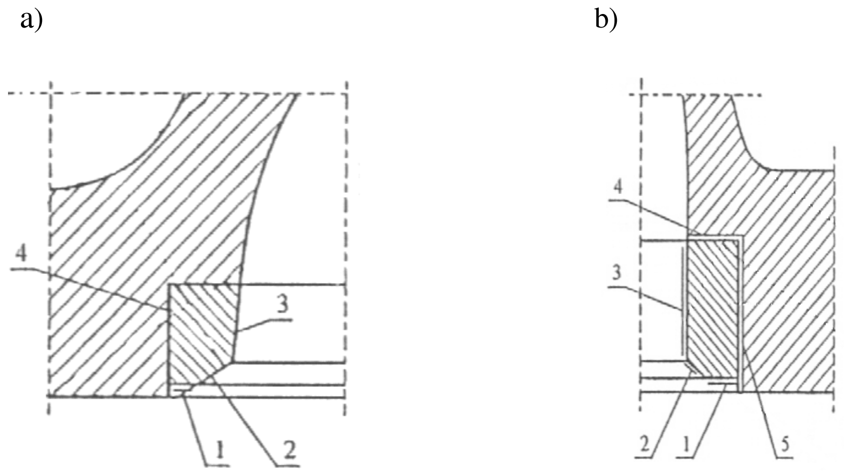
To calculate of the inlet and outlet valve seats the same material - the aluminium bronze Cu95Al5 was taken [2].

2.2. Initial conditions

The initial conditions describe the temperature distribution in whole space occupied by a substance in initial moment of time. In analyzed the valve seats was assumed that their temperature distribution in initial instant of time τ = 0[s] is constant and has value T_0 = 296[K].

2.3. Analysis of boundary conditions

In the modeling of temperature fields in the valve seats, the boundary condition of third kind was used which is described by the convective heat-transfer coefficient α and temperature of medium T surrounding valve surfaces [3,4,5,6]. In analyzed valve seats five surfaces of heat exchange were used. The surfaces of heat exchange of the valve seats are shown in the fig. 3.



Surface:
1 – front washed by exhaust gases from combustion chamber,
2 – seat face of a valve,
3 – walls of valve seats in inlet and outlet channel,
4 – surface of contact between valve seat and engine head,
5 – surface of contact between exterior side of valve seat and engine head

Fig. 3. The surfaces of heat exchange of the valve seats: a) inlet seat, b) outlet seat
Rys. 3. Powierzchnie wymiany ciepła gniazd: a) gniazdo dolotowe, b) gniazdo wylotowe

The heat loads of the valve seats are changing in the time. Therefore in calculations for surfaces 1,2 and 3 in phase when valves are opened were assumed a variable values of convective heat-transfer coefficient $\alpha(\varphi)$ and temperature of medium $T(\varphi)$ in function of speed of crankshaft engine. In phase when valves are closed the average values of temperature of medium $\overline{T}$ and convective heat-transfer coefficient $\overline{\alpha}$ were taken for surfaces 2 and 3. The change of values in the time of $\alpha(\varphi)$ and $T(\varphi)$ were used during analyzing unstable state by means of the time curves – folded from the points which the coordinates is a time and corresponding the value of $\alpha(\varphi)$ or $T(\varphi)$. Analysis step $\Delta\tau$ = 0,415 [ms] was used which is equivalent to 5 degrees of revolution of the crankshaft engine. For the surfaces 4 and 5 the average conditions of the heat exchange were accepted.

3. THE RESULT OF COMPUTATIONS

The temperature distribution in the inlet and outlet valve seat for λ=1,66 and λ=3,08 at the same engine speed 2000[rpm] and after 0,5 and 60 seconds its working was presented in the fig. 4 and 5.

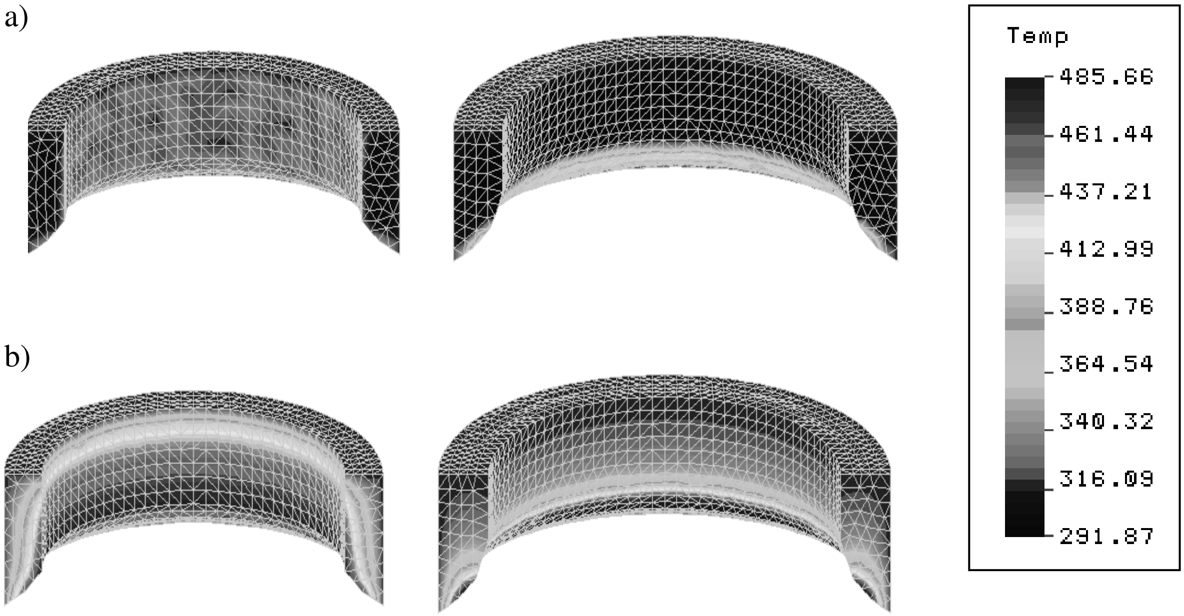


Fig. 4. The temperature distribution in outlet and inlet valve seat for λ=1,66 and engine speed 2000[rpm]: a) 0,5[s] engine work, b) 60[s] engine work

Rys. 4. Rozkład temperatury w gnieździe zaworu wylotowego i dolotowego dla λ=1,66 i prędkości obrotowej silnika 2000[min^{-1}]: a) 0,5[s] pracy silnika, b) 60[s] pracy silnika

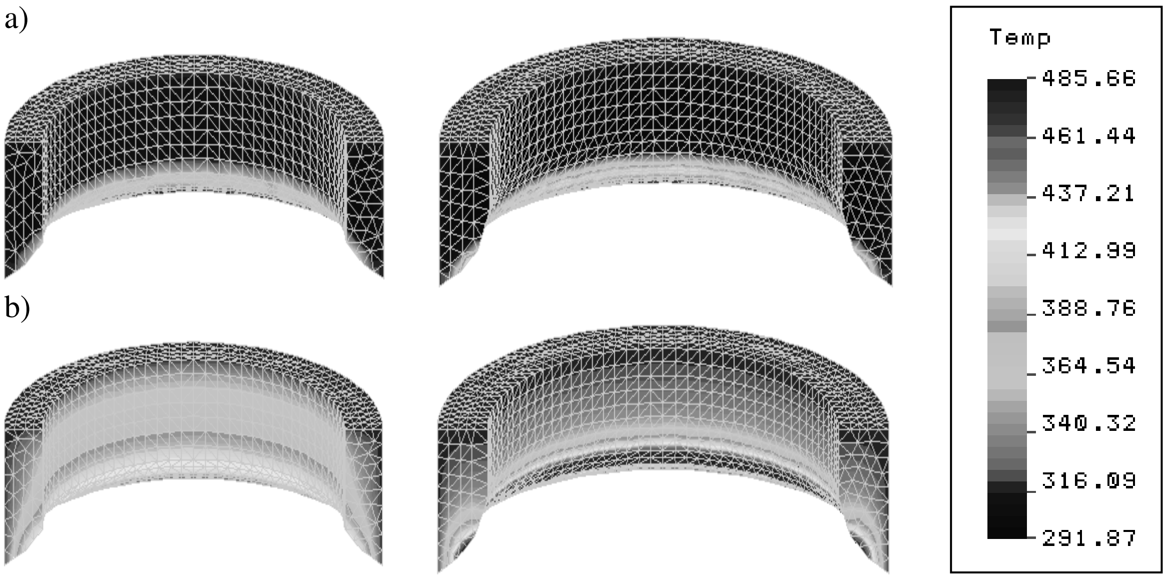


Fig. 5. The temperature distribution in the outlet and inlet valve seat for λ=3,08 and the engine speed 2000[rpm]: a) 0,5[s] engine work, b) 60[s] engine work

Rys. 5. Rozkład temperatury w gnieździe zaworu wylotowego i dolotowego dla λ=3,08 i prędkości obrotowej silnika 2000[min^{-1}]: a) 0,5[s] pracy silnika, b) 60[s] pracy silnika

The comparison of results computations of maximum temperature on the surface of the inlet and outlet valve seat for λ=1,66 is shown in fig. 6.

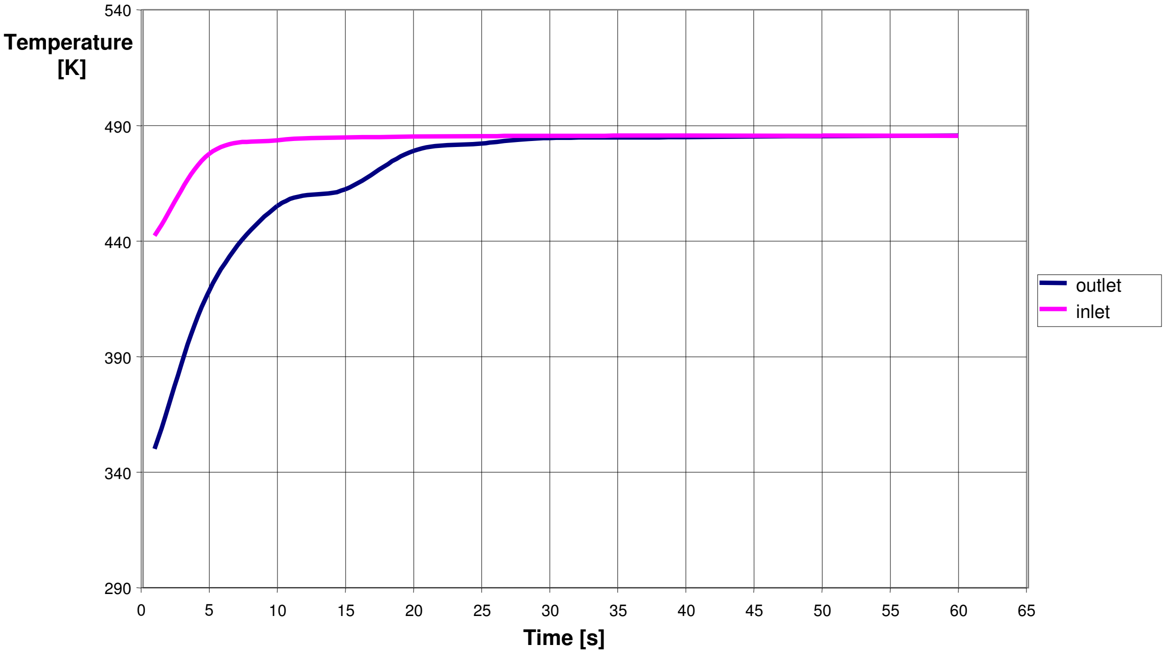


Fig. 6. The graph of changes of maximum temperatures of the inlet and outlet valve seat for λ=1,66 and n=2000[rpm]

Rys. 6. Wykres zmian maksymalnych temperatur dla gniazda dolotowego i wylotowego dla λ=1,66 i n=2000[min^{-1}]

However the comparison of results computations of maximum temperature on the surface of the inlet and outlet valve seat for λ=3,08 is shown in fig. 7.

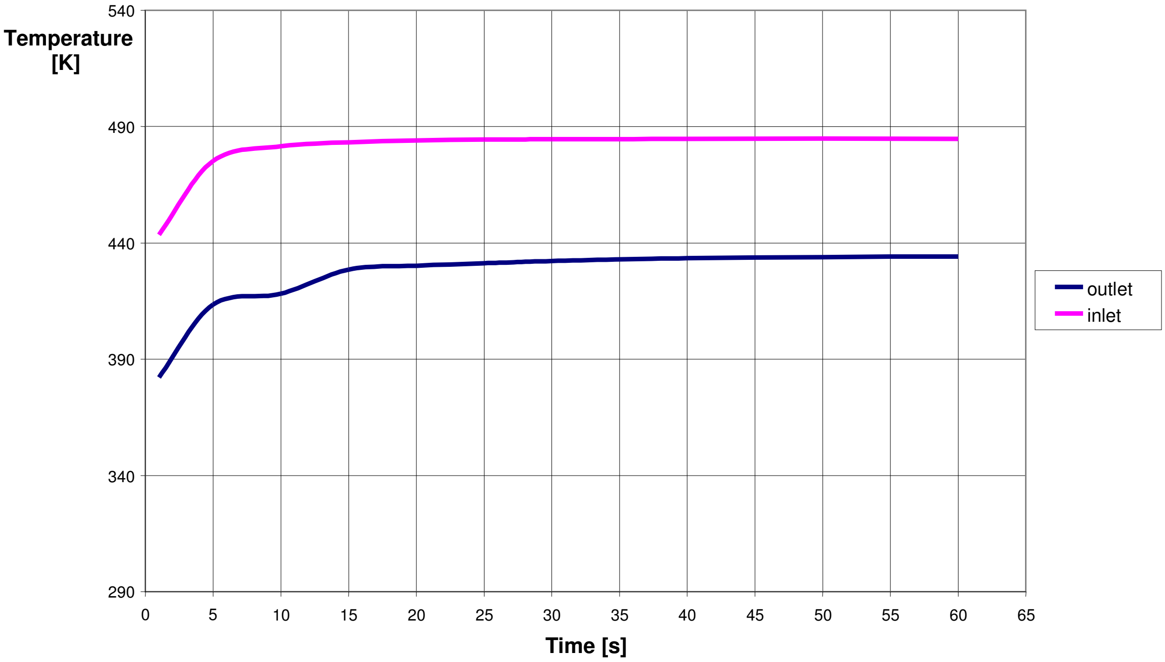


Fig. 7. The graph of changes of maximum temperatures of the inlet and outlet valve seat for λ=3,08 and n=2000[rpm]

Rys. 7. Wykres zmian maksymalnych temperatur dla gniazda dolotowego i wylotowego dla λ=3,08 i n=2000[min^{-1}]

4. CONCLUSIONS

For the excess air ratio λ=1,66 and the engine speed n=2000[rpm] the maximum temperature of inlet and outlet valve seat has value of approximately 490[K] after 60[s] of the engine working. In case of excess air ratio λ=3,08, that is for the lower engine load, the value of maximum temperature of inlet valve seat was approximately 490[K] and for an outlet valve seat about 440[K]. This is a little difference between the maximum temperatures. Probably this is caused suitable the process when the heat from the valve seats to engine head is accompanied.

The speed of increase of the temperature of inlet valve seat is initially bigger than the outlet one .For λ=1,66 the temperatures will become equal. In case of excess air ratio λ=3,08 the difference in temperatures keep on the level about 50[K].

For both excess air ratio λ the temperature distribution in the outlet valve seat is much bigger than the inlet one. The highest temperatures of valve seat there are on the seat face of a valve, it is on the surface of contact with the hot valve during the phase when the valve is closed and on the surface washed by the exhaust gases flowing from combustion chamber. On other surfaces of this valve seat there is a much lower temperature and the reason for that is cooling by the air which washes the inlet valve seat during of suction stroke.

In both cases the temperatures of valve seats become steady after approximately 20 seconds for the outlet valve seat and around 10 seconds for the inlet valve seat from the time of engine starting. After that time the changes of temperatures are marginal.

For excess air ratio λ=1,66 the maximum thermal gradient for the inlet valve seat has value about 16,5[K/mm] and for the outlet one has value about 20,8[K/mm].

For excess air ratio λ=3,08 the maximum thermal gradient for the inlet valve seat has value about 18,3[K/mm] and for the outlet one has value about 15,2[K/mm].

Praca wykonana w ramach badań własnych: BW – 510/RT1/2008

References

1. Kwaśniowski S., Sroka Z., Zabłocki W.: *Modelowanie obciążeń cieplnych w elementach silników spalinowych.* Oficyna wydawnicza Politechniki Wrocławskiej, Wrocław, 1999.
2. *Praca zbiorowa. Charakterystyki stali. Stale konstrukcyjne stopowe, stale do ulepszania cieplnego*. Wydawnictwo Śląsk, Katowice 1975.
3. Matzke W.: *Konstrukcja rozrządu silników szybkoobrotowych.* Wydawnictwa Komunikacji i Łączności, Warszawa, 1974.
4. Wiśniewski S.: *Obciążenia cieplne silników tłokowych.* Wydawnictwa Komunikacji i Łączności, Warszawa, 1972.
5. Rychter T., Teodorczyk A.: *Teoria silników tłokowych.* Wydawnictwa Komunikacji i Łączności, Warszawa, 2006.
6. Wiśniewski S.: *Wymiana ciepła.* Państwowe Wydawnictwo Naukowe, Warszawa, 1988.

Received 7.11.2008; accepted in revised form 12.06.2009