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MODELLING OF THE HEAT LOAD IN THE PISTON OF TURBO DIESEL ENGINE - CONTINUATION

Summary. In this study the mathematical description of characteristic surfaces of the heat exchange of the piston and temperature distribution of the turbo diesel engine at the beginning phase its work was presented. The computations were performed by means of the two-zone combustion model, the boundary conditions of III kind and the finite elements method (MES) by using of COSMOS/M program.

MODELOWANIE OBCIĄŻEŃ CIEPLNYCH TŁOKA DOŁADOWANEGO SILNIKA ZS - KONTYNUACJA

Streszczenie. W niniejszej pracy przedstawiono matematyczny opis charakterystycznych powierzchni wymiany ciepła tłoka oraz rozkład ich temperatury dla doładowanego silnika z zapłonem samoczynnym w początkowej fazie jego pracy. Obliczenia numeryczne zostały przeprowadzone przy zastosowaniu dwustrefowego modelu procesu spalania [1], warunków brzegowych III rodzaju oraz metody elementów skończonych (MES) za pomocą programu COSMOS/M.

1. MODELLING OF THE HEAT LOAD IN THE PISTON

In analysing the engine piston 16 characteristic surfaces of the heat exchange (fig.1) were distinguished which definite the values of the boundary conditions of III kind were attributed [2,3,4].

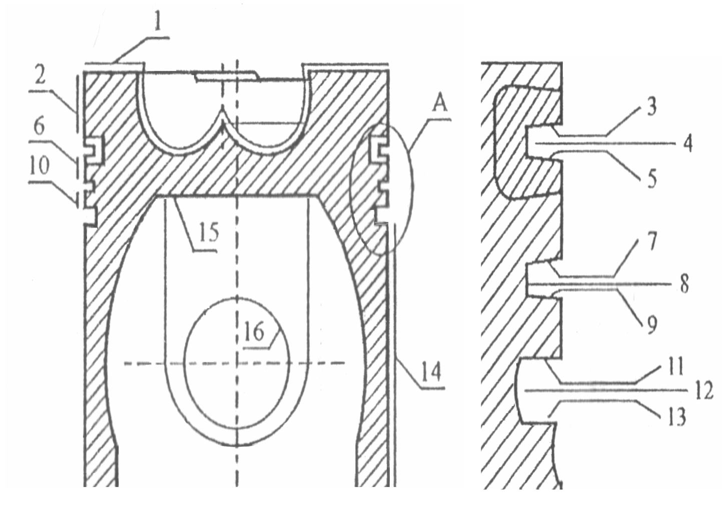

Fig. 1. Surfaces of the heat exchange of the piston
Rys. 1. Powierzchnie wymiany ciepła tłoka

Surface:
1 – *piston head,*
2 – *flank piston over I ring,*
3 – *upper groove of I ring,*
4 – *bottom groove of I ring*
5 – *under groove of I ring,*
6 – *between rings I-II,*
7 – *upper groove of II ring,*
8 – *bottom groove of II ring,*
9 – *under groove of II ring,*
10 – *between rings II-III,*
11 – *upper groove of III ring*
12 – *bottom groove of III ring*
13 – *under groove of III ring,*
14 – *leading of the piston,,*
15 – *internal of the piston,*
16 – *the point of contact of the piston pin with the engine piston*

1.1. Surface of the piston head

In calculations the whole surface of the piston head was accepted for equivalent heat conditions in combustion chamber engine for individual cycles its work:

$$\alpha_1(\varphi_i) = \alpha_g(\varphi_i) \quad \left[\frac{W}{m^2 K}\right] \tag{1}$$

$$T_1(\varphi_i) = T(\varphi_i) \quad [K] \tag{2}$$

where: $\alpha_g(\varphi_i)$ - coefficient of surface film conductance in crank angle function, $T(\varphi_i)$ - temperature of engine working medium in crank angle function.

1.2. Surface side of the piston over I ring

However for side surface of piston the following conditions of the heat exchange were accepted [5]:

$$\alpha_2(\varphi_i) = \frac{1}{2}\alpha_g(\varphi_i) \quad \left[\frac{W}{m^2 K}\right] \tag{3}$$

$$T_2(\varphi_i) = 0{,}8T(\varphi_i) \quad [K] \tag{4}$$

1.3 Upper surface of the groove of I, II, III ring

In case of upper surface of groove of I, II, III ring (3,7,11) the average substitute overall heat-transfer coefficient $\alpha_{z(3,7,11)}$ as well as temperature $T_{3,7,11}(\varphi_i)$ of medium surrounding the analyzed surfaces was accepted by work [2]:

$$\frac{1}{\alpha_{z(3,7,11)}} = \frac{1}{\alpha_{d(3,7,11)}} + \frac{l_{sr}}{\lambda_p} + \frac{1}{\alpha_{p\,tu}} \quad \left[\frac{m^2 K}{W}\right] \tag{5}$$

$$T_{3,7,11}(\varphi_i) = T_x(\varphi_i) \quad [K] \tag{6}$$

where: $\alpha_{z(3,7,11)}$ - average substitute overall heat- transfer coefficient in place of the contact of ring from upper surface of the groove, $\alpha_{d(3,7,11)}$ - average coefficient of surface film conductance in place of the contact of ring from upper surface of the groove, $\alpha_{p\,tu}$ - average coefficient of surface film conductance in the place of contact of the ring from the cylinder liner of the engine [6], l_{sr} - the average road of the heat stream from the surface of the groove of the ring to the cylinder liner, λ_p - coefficient thermal conductance of the ring, $T_x(\varphi_i)$ - temperature of the internal surface of the cylinder liner represented the individual positions of the piston in function of crank angle engine.

1.4. Bottom surfaces of the groove of I, II, III ring

In regard to the gap among internal surface of I, II, III ring and the surface of the bottom of the groove (4,8,12) the heat exchange is very low on these surfaces. In calculations was assumed the fault of heat exchange from these surfaces (adiabate) [2].

$$\alpha_4 = \alpha_8 = \alpha_{12} = 0 \quad \left[\frac{W}{m^2 K}\right] \tag{7}$$

$$T_{4,8,12}(\varphi_i) = T_x(\varphi_i) \quad [K] \tag{8}$$

1.5. Under surfaces of the groove of I, II, III ring

For under surface of the groove of I, II, III ring (5, 9, 13) the average substitute overall heat-transfer coefficient $\alpha_{z(5,9,13)}$ and temperature $T_{5,9,13}(\varphi_i)$ of medium surrounding the analyzed surfaces was accepted by work [2]:

$$\frac{1}{\alpha_{z(5,9,13)}} = \frac{1}{\alpha_{d(5,9,13)}} + \frac{l_{sr}}{\lambda_p} + \frac{1}{\alpha_{p\,tu}} \quad \left[\frac{m^2 K}{W}\right] \tag{9}$$

$$T_{5,9,13}(\varphi_i) = T_x(\varphi_i) \quad [K] \tag{10}$$

where: $\alpha_{z(5,9,13)}$ - average substitute overall heat- transfer coefficient in the place of contact of the ring from under surface of the groove, $\alpha_{d(3,7,11)}$ - average coefficient of surface film conductance in the place of contact of the ring from under surface of the groove.

1.6. Flank surfaces between rings of the piston

For the flank surfaces between rings of the piston (6,10) as well as the leading surface (14) the coefficient of surface film conductance $\alpha_{6,10,14}(\varphi_i)$ and individual temperatures of medium surrounding the analyzed surfaces was described as follows [6,7]:

$$\alpha_{6,10,14}(\varphi_i) = \frac{\alpha_1(\varphi_i)}{3} \quad \left[\frac{W}{m^2 K}\right] \tag{11}$$

$$T_6(\varphi_i) = 0{,}665 T_2(\varphi_i) \quad [K] \tag{12}$$

$$T_{10}(\varphi_i) = 0{,}69 T_2(\varphi_i) \quad [K] \tag{13}$$

$$T_{14} = 348 \quad [K] \tag{14}$$

1.7. Internal surface of the piston

However for internal surface of the piston following averages conditions of the heat exchange were accepted [2]:

$$\alpha_{15} = (60 \div 90) \quad \left[\frac{W}{m^2 K}\right] \tag{15}$$

$$T_{15} = (333 \div 363) \quad [K] \tag{16}$$

1.8. Surface of point of contact of the piston pin with the engine piston

In case of the heat exchange of surface point of contact the pin from the piston the boundary conditions α_{16} and T_{16} were described by means of the following equations [2]:

$$\frac{1}{\alpha_{16}} = \frac{1}{\alpha_{ts}} + \frac{l_{st}}{\lambda_{sw}} + \frac{l_{sk}}{\lambda_{sw}} + \frac{1}{\alpha_{sp}} + \frac{1}{\alpha_{pk}} + \frac{s_p}{\lambda_p} + \frac{s_k}{\lambda_k} + \frac{1}{\alpha_{15}} \quad \left[\frac{m^2 K}{W}\right] \tag{17}$$

$$T_{16} = (333 \div 363) \quad [K] \tag{18}$$

where: $\alpha_{ts} = \alpha_{sp} = \alpha_{pk}$ - average coefficient of surface film conductance in place of contact the piston- piston pin, the piston pin – bearing bush, the bearing bush – connecting rod, $\lambda_{sw}, \lambda_p, \lambda_k$ - heat conductivity of the piston pin, the bearing bush and the connecting rod material, S_p, S_k - thickness of wall of the bearing bush of the piston pin and the head connecting rod.

2. THE RESULT OF COMPUTATION

In this work the heat loads of the piston of turbo diesel engine with direct injection about capacity 2390 cm^3 and power rating 85 kW were introduced. The computations were executed for excess air ratio λ = 1,66 and speed of engine n = 2000 min^{-1} making the visualization of the distribution of temperatures on the piston surfaces to 5 degree crank angle after inner dead centre in filling up its cycle. The examples results of numeric calculations for 9 and 18 seconds of the work of analyzed engine were introduced on figure 2.

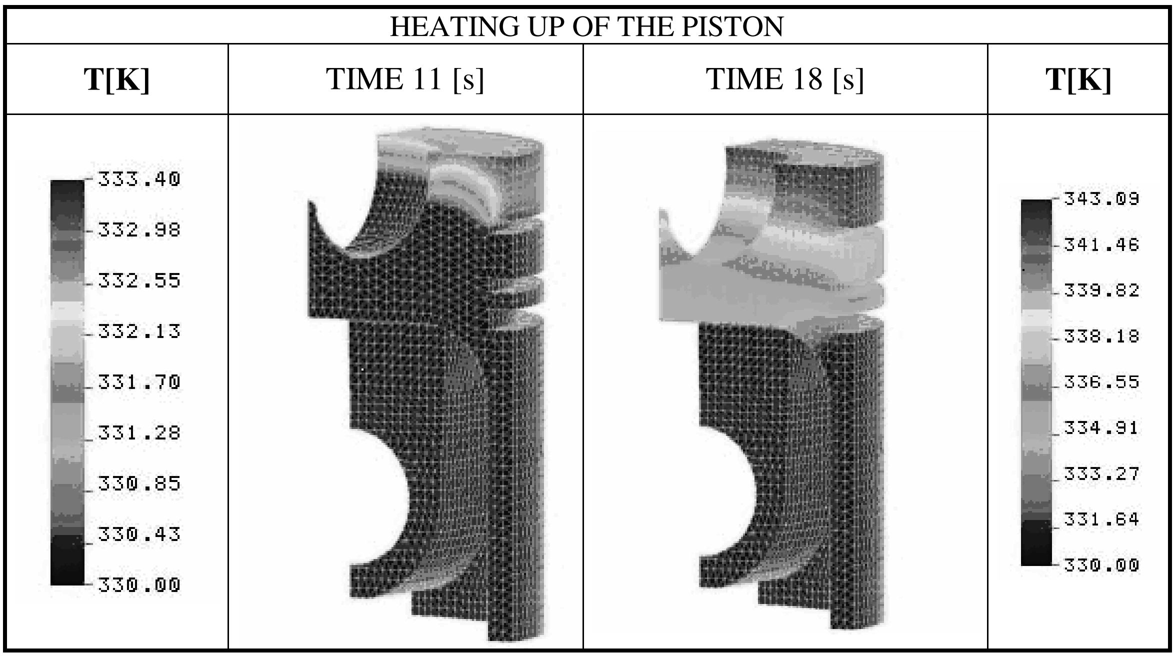

Fig. 2. Phases heating up of the piston
Rys. 2. Fazy nagrzewania się tłoka

Next the executed numeric computations will become verified on the specially to this aim prepared the engine which will allow to make the complex research on the measurement station (fig.3).

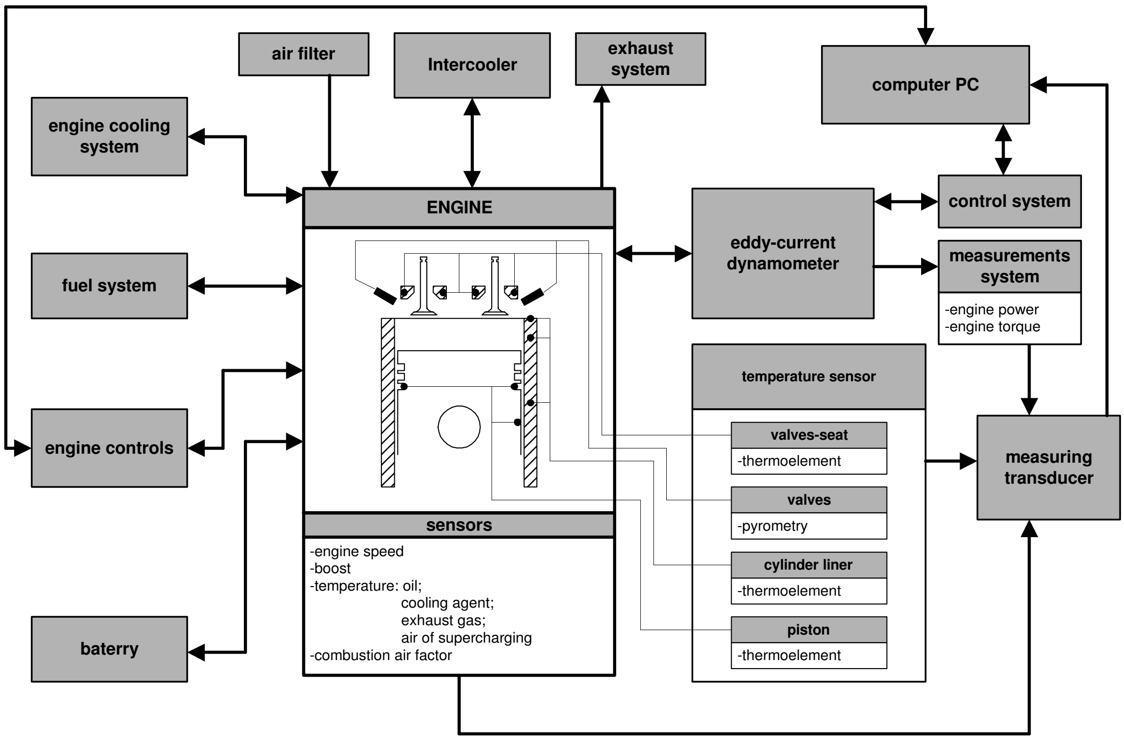

Fig. 3. Block diagram of measuring position
Rys. 3. Schemat blokowy stanowiska pomiarowego

3. CONCLUSIONS

The carried out preliminary calculation will suggest that in initial phase of the work of turbo diesel engine the place of the occurrence of the largest of the heat load of the piston is its the head as well as the flank surface above the first ring of the engine piston. The preliminary numeric computations show after 18 seconds of the engine work on the heat transfer from these surfaces into inside of the engine piston material.

The conducted analysis doesn't permit fully to qualify the heat load of this engine element in regard to short time, the carried out computations however give any picture of the temperature distribution on its individual surfaces. Moreover the correctness of conducted calculations requires on the real piston of the turbo diesel engine use of the verifying researches which will be the object of far morer investigations of the authors.

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Praca wykonana w ramach badań własnych: BW-488/RT1/2007

Received 28.11.2007; accepted in revised form 10.12.2007