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Determination of the temperature distribution in the wet cylinder sleeve in turbo diesel engine

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Analysis and modelling

ABSTRACT

Purpose: The determination of the temperature distribution in the wet cylinder sleeve in initial phase of the work of turbo Diesel engine.
Design/methodology/approach: The results of calculations of the temperature distribution in the wet cylinder sleeve of the turbo Diesel engine were received by means of the two – zone combustion model and the finite element method.
Findings: The computations presented the possibility of use of the mathematical models of the combustion processes and the heat transfer on individual surfaces of the wet cylinder sleeve used by the variable values of the boundary conditions and temperature of the working medium in initial time of the work engine.
Research limitations/implications: The modeling of the heat loads was executed for analysis of the values and temperature distribution in the wet cylinder sleeve in initial phase of the work of turbo Diesel engine until the moment of achievement quasi stabilized temperature values.
Originality/value: The results of numeric calculations of the heat loads of the wet cylinder sleeve displayed the possibility of the use of the original two-zone combustion model and finite elements method to analysis of values and temporary temperature distribution on individual surfaces of the cylinder.
Keywords: Numerical techniques; Heat loads of the wet cylinder sleeve; FEM

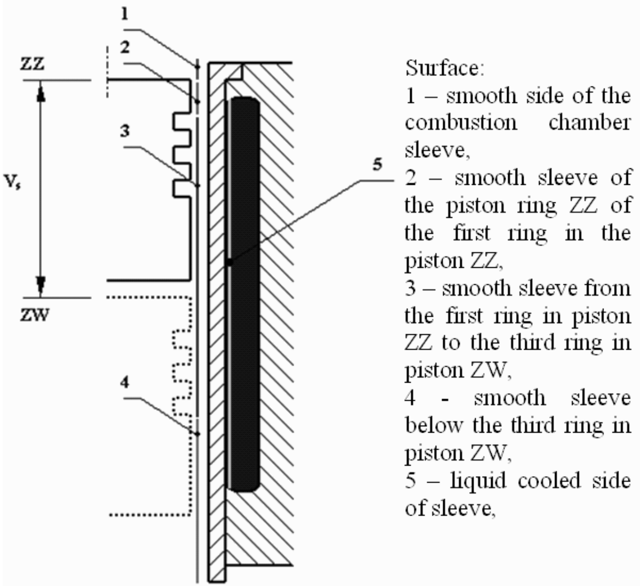
1. Introduction

Modelling of heat loads of a cylinder sleeve was carried out on the basis of periodically changing boundary conditions of type III which describe the surface film conductance α as well as the temperature T of the working medium surrounding the surfaces of the sleeve appointed on the basis of the two-zone combustion model [1-5]. The analysis was carried out from the moment of starting the engine to the moment when the distribution of temperatures changed in a small range with the use of finite element method [6-8].

While modelling the heat loads of the wet cylinder sleeve it was assumed that it is made from silchrom with small additions of Cr (about 0.5%) and Mo (about 0.2%), with large content of phosphorus (0.4-0.7%). Because the calculations of the heat flow in the sleeve concerned unsteady state, three basic physical properties of the used material were necessary – density ρ, specific heat capacity c_p and thermal conductivity λ (changes of this coefficient in the temperature function were taken into consideration) [9-11]. While analyzing the heat load it was assumed that at the beginning (at the moment t =0[s]) temperature distribution in the sleeve is steady and equal to the temperature of the surroundings. Further information about the heat loads of the other engine components can be found in ref. [12-16].

2. Analysis of boundary conditions

Five characteristic of the heat exchange surfaces were distinguished in the analyzed sleeve (Fig.1) and definite boundary conditions values of type III were attributed to them.



Surface:
1 – smooth side of the combustion chamber sleeve,
2 – smooth sleeve of the piston ring ZZ of the first ring in the piston ZZ,
3 – smooth sleeve from the first ring in piston ZZ to the third ring in piston ZW,
4 - smooth sleeve below the third ring in piston ZW,
5 – liquid cooled side of sleeve,

Fig. 1. Drawing of the wet cylinder sleeve

Because the thermal surface charges of (1), (2), (3), vary in a full cycle of a working engine, for them to be acceptable depends on temporary, conditional variable boundaries of the third type. For the surface of number (4) there's an acceptable variable (surface film conductance) and also the average conditional boundaries (temperature). However, for surface number (5) it must have average conditions acceptable for thermal exchange.

2.1. Sleeve sliding surface on the side of the combustion chamber (1)

On the whole surface of the wet cylinder sleeve sliding on the side of the combustion chamber, heat exchange conditions equal to conditions in the engine combustion chamber can be assumed [2].

2.2. Sleeve sliding surface from the piston crown in ZZ to the first ring in ZZ of the piston (2)

Because this surface is heated depending on the position of the piston, the step of analysis in this paper was assumed after the sleeve length of 8[mm] which corresponds to 20[crank angle]. The analysis of the heat exchange conditions for surface No. 2:

- 0-20[crank angle] (step 1), 340-380[crank angle] (step 17-19) and 700-720[crank angle] (step 35-36) – average value of the temperature and surface film conductance characteristic for the adequate piston surface (from the piston crown to the 1st ring) was assumed.
- 20-340 [crank angle] (step 2-17) and 380-700[crank angle] (step 19-35) – heat exchange conditions equal to conditions in the engine combustion chamber were assumed.

2.3. Sleeve sliding surface from the 1st ring in the piston ZZ to the 3rd ring in the piston ZW (3)

Average surface film conductance beyond work was assumed for this surface [2]. This factor was assumed because of similar working conditions for both engines (the engine examined at work: n=2004[rpm] and N=85[KW] and the engine adopted beyond work [2]: n=2300[rpm] and N= 82.3[KW].

Conditions of heat exchange on this surface depend on the position of the piston, because this surface is heated by the characteristic surfaces of the piston (from the piston crown to the 1st ring, ring surface, surface below the 3rd ring) and by the working medium. The assumed step of the analysis was 20[crank angle]:

- 0-20 [crank angle] (step 1), 345 -380[crank angle] (step 17-19) and 705-720[crank angle] (step 36) – average temperature value characteristic for the surfaces between rings of the piston and the gases in the crankcase was assumed.
- 25-40 [crank angle] (step 2), 325-340[crank angle] (step 20) and 685-700[crank angle] (step 35) – average temperature value from the piston crown to the 1st ring, surface between rings and gases in the crankcase was assumed.
- 45-315 [crank angle] (step 3-16), 405-680[crank angle] (step 21-34) – average temperature value from the piston crown to the 1st ring, surface between rings, gases in the crankcase and working medium was amused.

2.4. Sleeve sliding surface below the 3rd ring in ZW of the piston (4)

On the whole surface No. 4 heat exchange conditions were assumed the same as below the 3rd ring [2].

2.5. Sleeve surface on the side of liquid coolant (5)

It was assumed that the temperature T_5 for a wet sleeve on surface No. 5 increases together with the increase of the temperature of the liquid coolant by 1[K] in 1[s] (fig. 2).

Because there are no literature data regarding surface film conductance on the side of liquid coolant in a unsteady state (engine warm-up phase) it was assumed that the value of coefficient α_5 (average surface film conductance on the side of liquid coolant taking into consideration the sedimentary scale α_5 – 1450 [W/(m^{2}K)] for a wet sleeve will be achieved after about 5 minutes of engine work (from the moment of the engine starting). It was assumed that the coefficient α_5 in the time of 0-5[min] has a linear course.

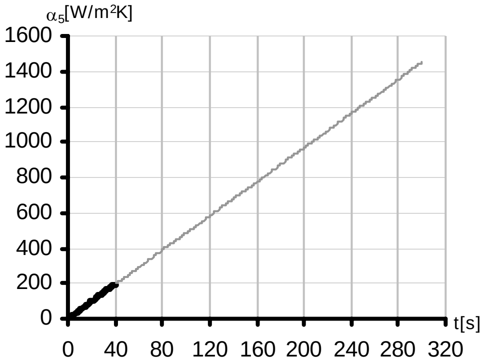


Fig. 2. The average surface film conductance α_5 for surface No. 5. (——) The course of the surface film conductance in the time of 40÷300[s]. (—)The course of the surface film conductance for the first 40[s] of the engine work

3. Conclusions results

In the work there were modelled heat loads of the wet cylinder sleeve for turbo Diesel engine with a direct injection, engine capacity of 2390[cm^3] and nominal power of 85[KW] whose engine speed is 2000[rpm]. Figure 3, 4, 5 shows following phases of the wet cylinder sleeve heating up for the same position of the piston which was 5[crank angle] on the top dead centre (filling cycle) after 0.5, 20, and 40[s] of the engine work.

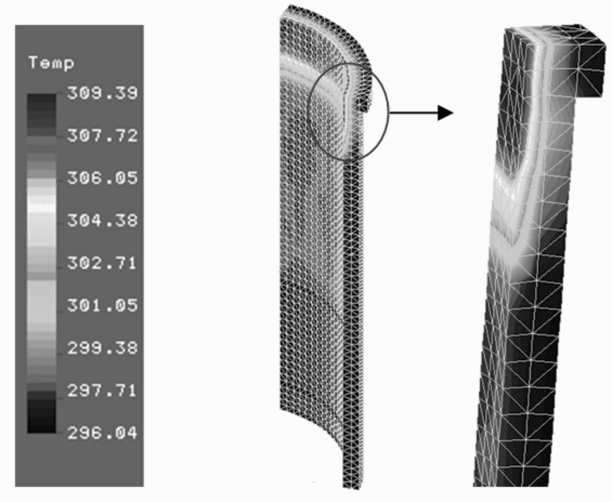


Fig. 3. The following phases warming up of the wet cylinder sleeve after 0.5[s]

The calculations show that upper parts of the sleeve i.e. near the mount flange heat up the fastest while the temperature in the lower parts i.e. below the 3rd ring in the position ZW of the piston is the lowest. Additionally it was stated that the maximum temperature (after 40[s] of the engine work) is about 444[K] and it occurs in the upper part of the sleeve near the upper mount flange. High temperatures near the upper mount flange of the wet sleeve are caused by the impeded outflow of the heat from this surface to the liquid coolant.

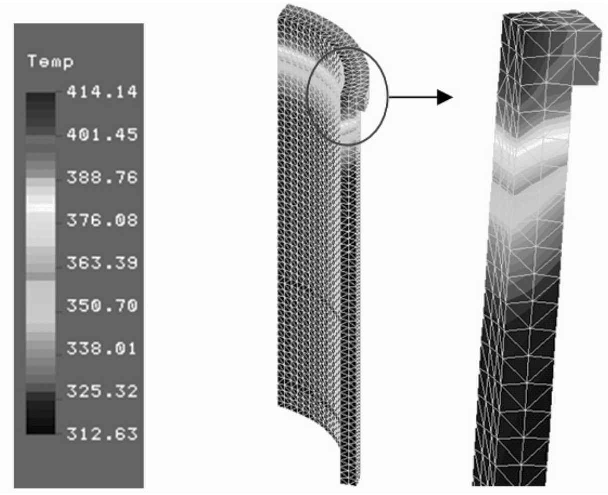


Fig. 4. The following phases warming up of the wet cylinder sleeve after 20[s]

The diagram of average temperatures of the whole cylinder sleeve and its individual surfaces is presented in Figure 6. Surface No. 5 is not included in this case as average conditions of heat exchange were assumed for it. The highest average temperature occurs near the upper mount flange of the sleeve (1) while the lowest average temperature occurs at the bottom part of the sleeve (4).

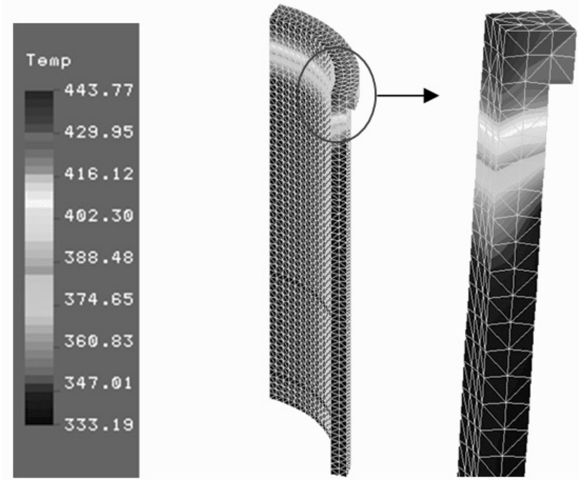


Fig. 5. The following phases warming up of the wet cylinder sleeve after 40[s]

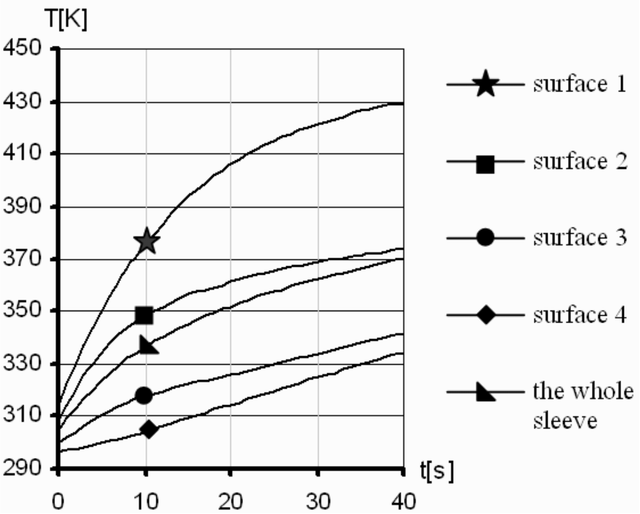


Fig. 6. The diagram of average temperatures changes of the whole cylinder sleeve and its surfaces

4. Summary

In the result of carried out calculations it was stated that the maximum temperature of the wet cylinder sleeve (in 40s of engine work) is about 444[K]. The calculations show that the cylinder sleeve heats up the fastest during the first 20 seconds of the engine work (on average about 3[K] per second) then the temperature starts to stabilize and in 40[s] it changes in a small range (about 0.7 [K] per second).

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