engine, finite elements method (FEM), wet cylinder sleeve

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# THE ANALYSIS OF TEMPERATURE DISTRIBUTION IN THE WET CYLINDER SLEEVE IN NONSTATIONARY STATE

**Summary.** In this study the analysis of temperature distribution in the wet cylinder sleeve in the initial phase of the work of turbocharged engine in nonstationary state were determined. The computations were performed by means of the two-zone combustion model, the boundary conditions of III kind and the finite elements method (FEM) by using of COSMOS/M program [1]. The characteristic surfaces of the cylinder were analyzed. The results of numeric calculations 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 in the wet cylinder sleeve.

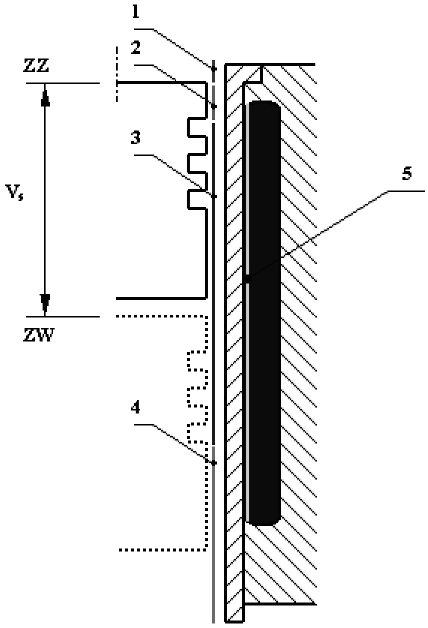
# ANALIZA ROZKŁADU TEMPERATURY W MOKREJ TULEI CYLINDROWEJ W STANIE NIEUSTALONYM

**Streszczenie.** W niniejszej pracy dokonano analizy rozkładu temperatury w mokrej tulei cylindrowej dla doładowanego silnika z zapłonem samoczynnym w początkowym okresie jego pracy w stanie nieustalonym. 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. Analizie poddano charakterystyczne powierzchnie cylindra. Wyniki obliczeń numerycznych pokazują możliwość korzystania z oryginalnych dwustrefowych modeli spalania oraz metody elementów skończonych do analizy wartości i tymczasowego rozkładu temperatur na poszczególnych powierzchniach mokrej tulei cylindra.

## 1. MODELING OF THE HEAT LOADS OF THE WET CYLINDER SLEEVE

The analysis of the temperature distribution in the wet cylinder sleeve on the basis of the periodically changing of the boundary conditions III kind which describes the convective heat transfer coefficient $\alpha$ as well as the temperature *T* of the working medium surrounding the surfaces of the cylinder sleeve was carried out by means of the two zone combustion model [1]. The analysis was carried out from the moment of starting engine to the time when the temperature changed in a small range. While modeling 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 concern of the nonstationary state, three basic physical properties of the used material were necessary - density $\rho$, specific heat capacity $c_p$ and thermal conductivity $\lambda$. While analyzing the heat load it was assumed that at the beginning (at the moment t =0[s]) temperature distribution in the cylinder sleeve is stationary and equal to the temperature of the surroundings.

In the analyzed cylinder sleeve (Fig. 1) five characteristic heat exchange surfaces were defined and the boundary conditions values of III type were attributed to them [2, 3].




Surface:

*1 – from the side of combustion chamber,*
*2 – from the piston head in the inner dead centre (ZZ) to the first ring in ZZ of the piston ,*
*3 – from the first ring in the inner dead centre (ZZ) to 3rd ring in the outer dead centre (ZW) of the piston,*
*4 – below the 3rd ring in ZW of the piston,*
*5 – from the side of the cooling liquid*

Fig. 1. The wet cylinder sleeve
Rys. 1. Mokra tuleja cylindra

Where:

- surface 1 (from side of combustion chamber) – washed constantly by working medium about variable the temperature and pressure in the time of singular cycle - for this surface the changing boundary conditions were accepted,
- surface 2 (from the piston head in the inner dead centre – ZZ to the first fire ring in ZZ of the piston) washed in dependence from the piston position by working medium or surface of the piston (from head piston to first fire ring) – for this surface the changing boundary conditions were accepted,
- surface 3 (from the first ring in the inner dead centre – ZZ to 3rd ring in the outer dead centre – ZW of the piston) – washed in dependence from the piston position by working medium or surface of the piston (from head piston to first fire ring, as well as the ring section of piston and below 3rd ring) – for this surface the changing boundary conditions were accepted,
- surface 4 (surface of cylinder sleeve below the 3rd ring in ZW of the piston) exchange the heat with piston surface below 3rd ring – for this surface the changing and average boundary conditions were accepted.

## 2. THE RESULT OF COMPUTATION

In Fig. 2 the temperature distribution in the wet cylinder sleeve of turbocharged engine with direct injection about capacity 2390 $cm^3$ and power rating 85 kW were introduced. The computations were executed for excess air ratio $\lambda$ = 1,66 and output torque 265 Nm for engine speed $n$ = 2000 $min^{-1}$.

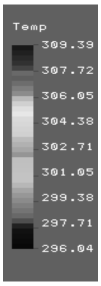
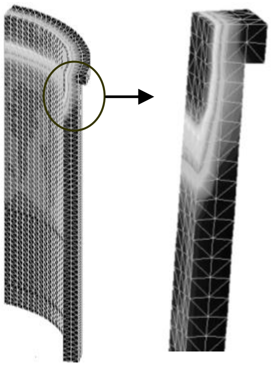
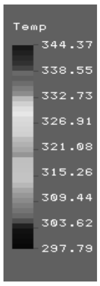
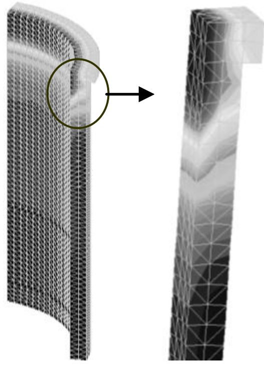
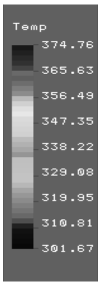
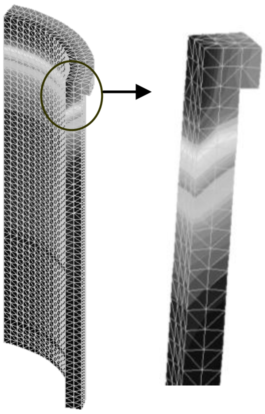
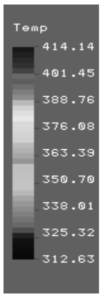
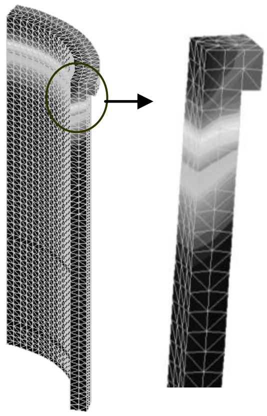
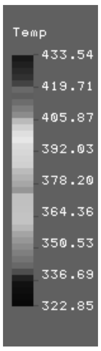
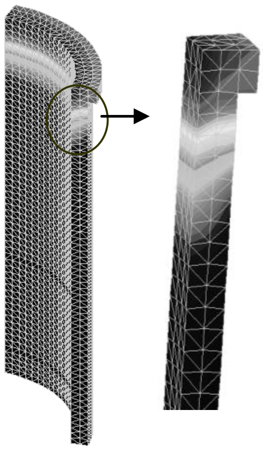
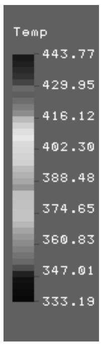
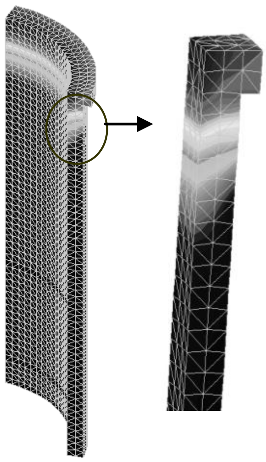
| Wet cylinder sleeve, cycle: filling 5 [deg crank angle] | | | |
|---|---|---|---|
| T [K]<br> |  | T [K]<br> |  |
| TIME [s] | 0,5 | TIME [s] | 5 |
| T [K]<br> |  | T [K]<br> |  |
| TIME[s] | 10 | TIME [s] | 20 |
| T [K]<br> |  | T [K]<br> |  |
| TIME [s] | 30 | TIME [s] | 40 |








Fig. 2. Distribution of temperature in the wet cylinder sleeve
Rys. 2. Rozkład temperatury w mokrej tulei cylindrowej

Moreover the calculations were carried out for 5 degree crank angle after inner dead centre ZZ in filling up cycle and for temperature of coolant 303 K.

In Fig. 3, 4, 5 and 6 the graph of changes average temperature on the analyzed surfaces of the cylinder sleeve from moment of starting engine to time when the temperature distribution in next working cycles changed insensibly was introduced.

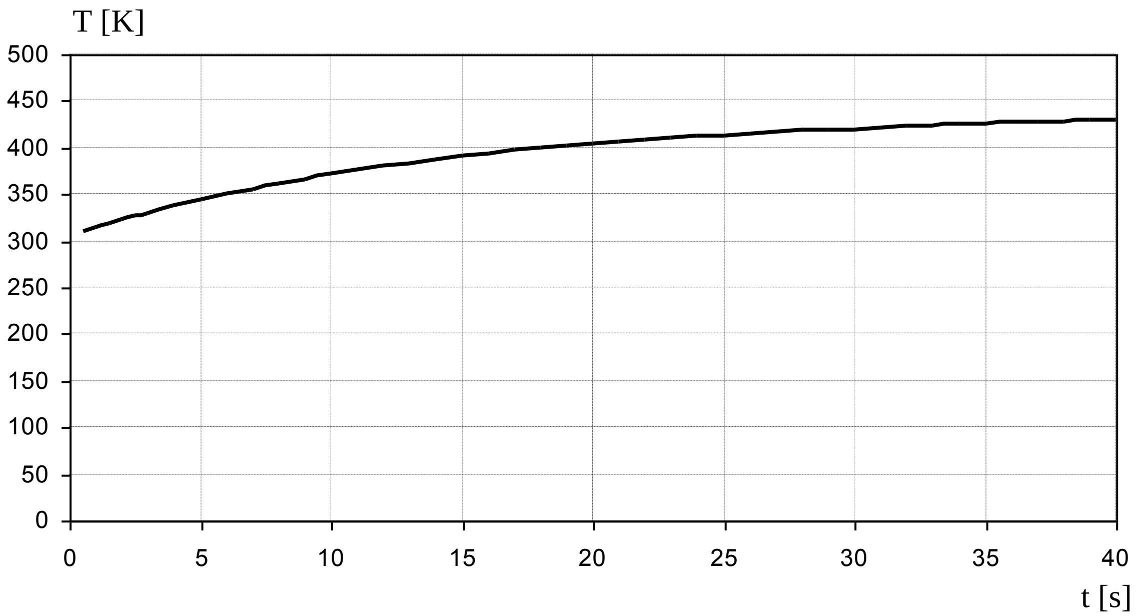



Fig. 3. The graph of changes average temperature on surface no. 1
Rys. 3. Wykres zmian średniej temperatury na powierzchni nr 1

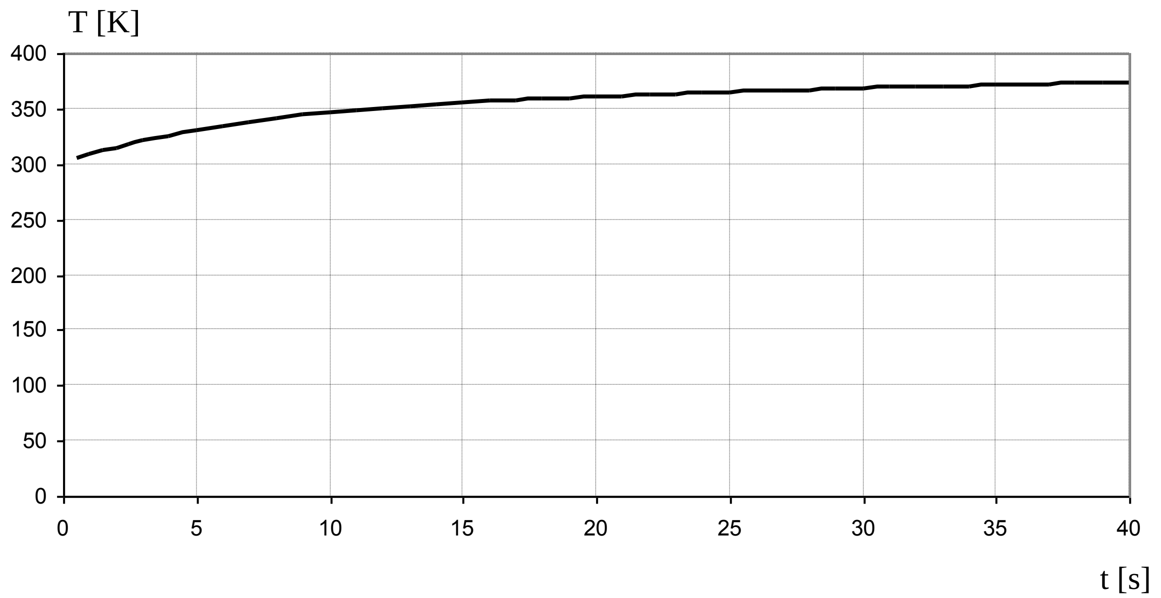



Fig. 4. The graph of changes average temperature on surface no. 2
Rys. 4. Wykres zmian średniej temperatury na powierzchni nr 2

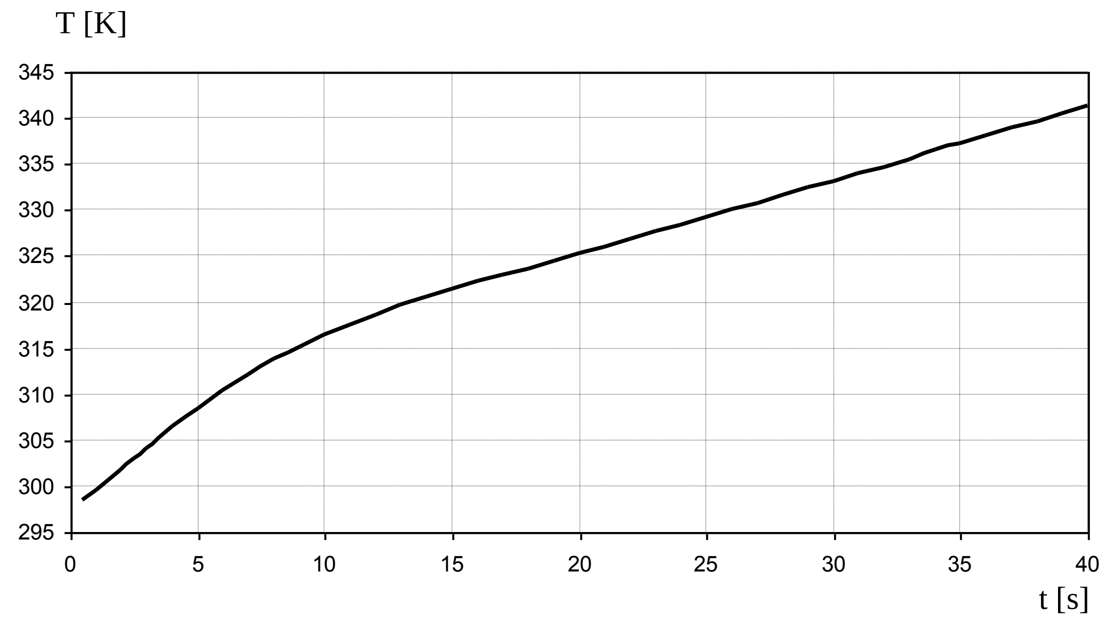



Fig. 5. The graph of changes average temperature on surface no. 3
Rys. 5. Wykres zmian średniej temperatury na powierzchni nr 3

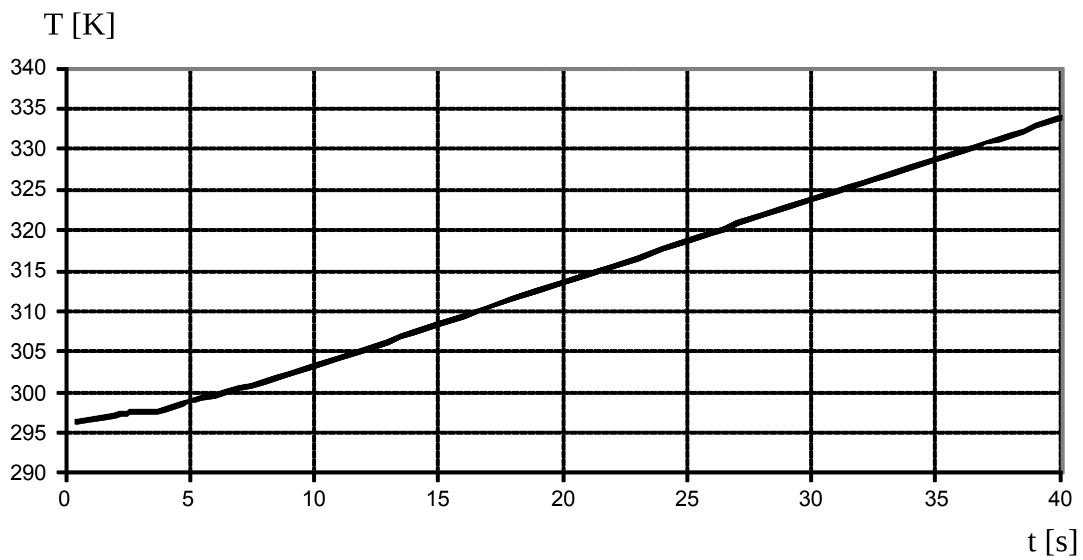



Fig. 6. The graph of changes average temperature on surface no. 4
Rys. 6. Wykres zmian średniej temperatury na powierzchni nr 4

The results of carried out calculations for wet cylinder sleeve shows that:
- the highest temperature appear in top part of cylinder in region of collar (surface 1),
- the lowest temperature appear below the 3rd ring in ZW of the piston (surface 4),
- the maximum average temperature of wet cylinder sleeve suitably carries out:
  - on surface No. 1 - 429 [K],
  - on surface No. 2 - 373 [K],
  - on surface No. 3 - 341 [K],
  - on surface No. 4 - 334 [K].

## 3. CONCLUSIONS

On basis of received calculations it was determined that the maximum temperature of the wet cylinder sleeve during 40s of engine work is about 444 K. Moreover most quickly the top part of cylinder warm oneself and the temperature below the $3^{rd}$ ring in ZW of the piston is the lowest. The speed of increase temperature of wet cylinder sleeve is the largest in initial phase of warming. On the beginning after 5s of the engine work the speed carries out about 2 K/s and after 10s the speed doesn't change. The temperature starts to stabilize after 40s and the speed changes in a small range (about 0,6 K/s).

### References

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