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INFLUENCE OF ENGINE SPEED AND THE COURSE OF THE FUEL INJECTION CHARACTERISTICS ON FORMING THE AVERAGE COMBUSTION TEMPERATURE IN THE CYLINDER OF TURBO DIESEL ENGINE

Summary. Average combustion temperatures inside a turbo diesel engine for the same load and the same total doze of fuel for two rotational speeds: 2004 [rpm] and 4250 [rpm] are presented in this paper. The aim of this work is also the evaluation of the influence of the temporary course of the fuel injection characteristics on forming temperature in the engine cylinder space for these temperatures. The calculations were carried out by means of two zone combustion model [1].

WPŁYW PRĘDKOŚCI OBROTOWEJ I PRZEBIEGU CHARAKTERYSTYKI WTRYSKU PALIWA NA KSZTAŁTOWANIE SIĘ ŚREDNIEJ TEMPERATURY SPALANIA W CYLINDRZE DOŁADOWANEGO SILNIKA Z ZAPŁONEM SAMOCZYNNYM

Streszczenie. W pracy zostały przedstawione obliczenia średniej temperatury spalania wewnątrz doładowanego silnika z zapłonem samoczynnym, dla tego samego obciążenia i tej samej sumarycznej dawki paliwa dla dwóch prędkości obrotowych: 2004[min^{-1}] oraz 4250[min^{-1}]. Celem realizowanej pracy była również ocena wpływu chwilowego przebiegu charakterystyki wtrysku paliwa na kształtowanie się temperatury w przestrzeni cylindra silnika dla tych prędkości. Obliczenia zostały przeprowadzone przy zastosowaniu dwustrefowego modelu procesu spalania [1].

1. DESCRIPTION OF THE APPLIED FUEL INJECTION CHARACTERISTICS

Two models of the course of fuel injection to the combustion chamber of the turbo diesel engine were modeled in this work. Equation (1.1) describes a single-phase, non-gradual course of the fuel injection characteristics while equation (1.2) does it for a single-phase gradual one. In model one the fuel injection course was modeled by the following equation.

$$\frac{\Delta Q_1}{\Delta \varphi} = \frac{Q}{h} \cdot \frac{\Delta h}{\Delta \varphi} \tag{1.1}$$

where: $\Delta Q_1/\Delta\varphi$ - temporary doze of injected fuel [mm^3/ crank angle], Q - total value of the fuel dose [mm^3], h - total value of the needle lift [mm], $\Delta h/\Delta\varphi$ - the speed of needle lift of the injector [mm/ crank angle]

While in model two the equation was as follows:

$$\frac{\Delta Q_2}{\Delta\varphi} = \frac{\frac{\Delta h}{\Delta\varphi}\cdot\varphi_w}{6\cdot n\cdot h\cdot F_w\cdot\sqrt{\frac{2\cdot\Delta P}{\rho}}} \tag{1.2}$$

where: $\Delta Q_2/\Delta\varphi$ - temporary doze of injected fuel [mm^3/ crank angle], $\Delta h/\Delta\varphi$ - the speed of needle lift of the injector [mm/ crank angle], φ_w - duration of the injection [crank angle], n - rotational speed of the crankshaft engine [rpm], h - total value of the needle lift of the injector [mm], F_w - total value of the surface area of the injector holes [mm^2], ΔP - pressure difference between the injection pressure and the pressure in the cylinder [MPa], ρ - fuel density [kg/dm^3].

Figure 1 shows the course of the fuel injection for model one and model two for engine speed 2004 [rpm], while figure 2 shows it for the speed of 4250 [rpm].

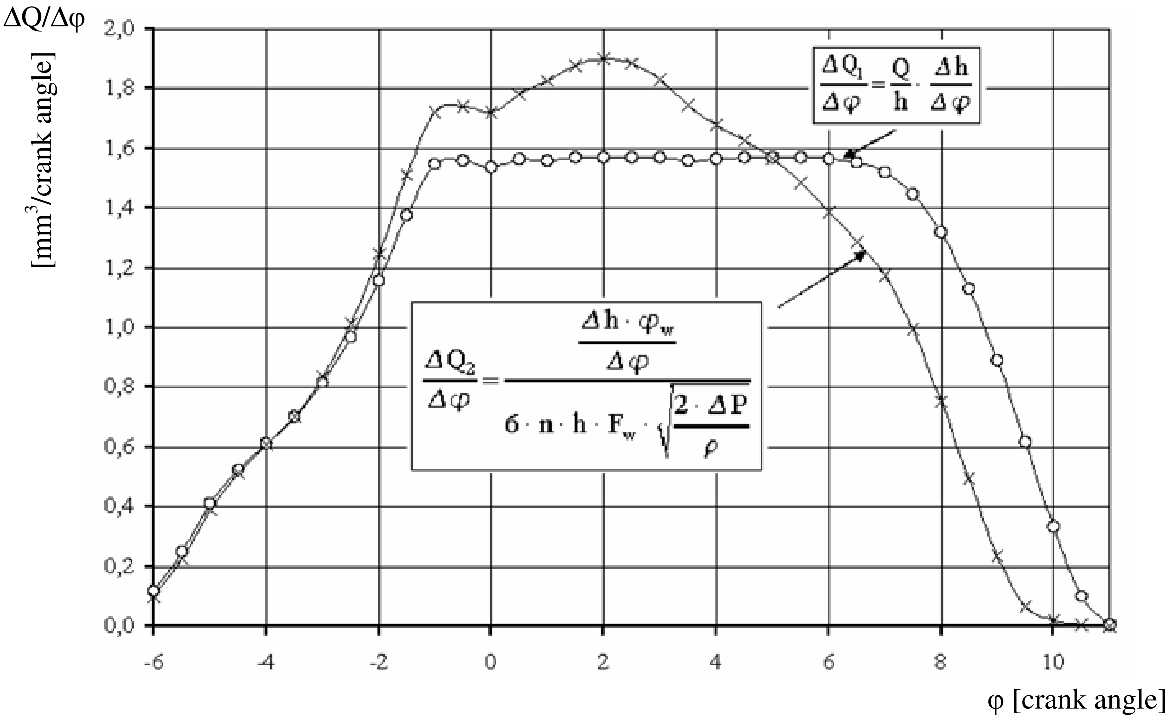
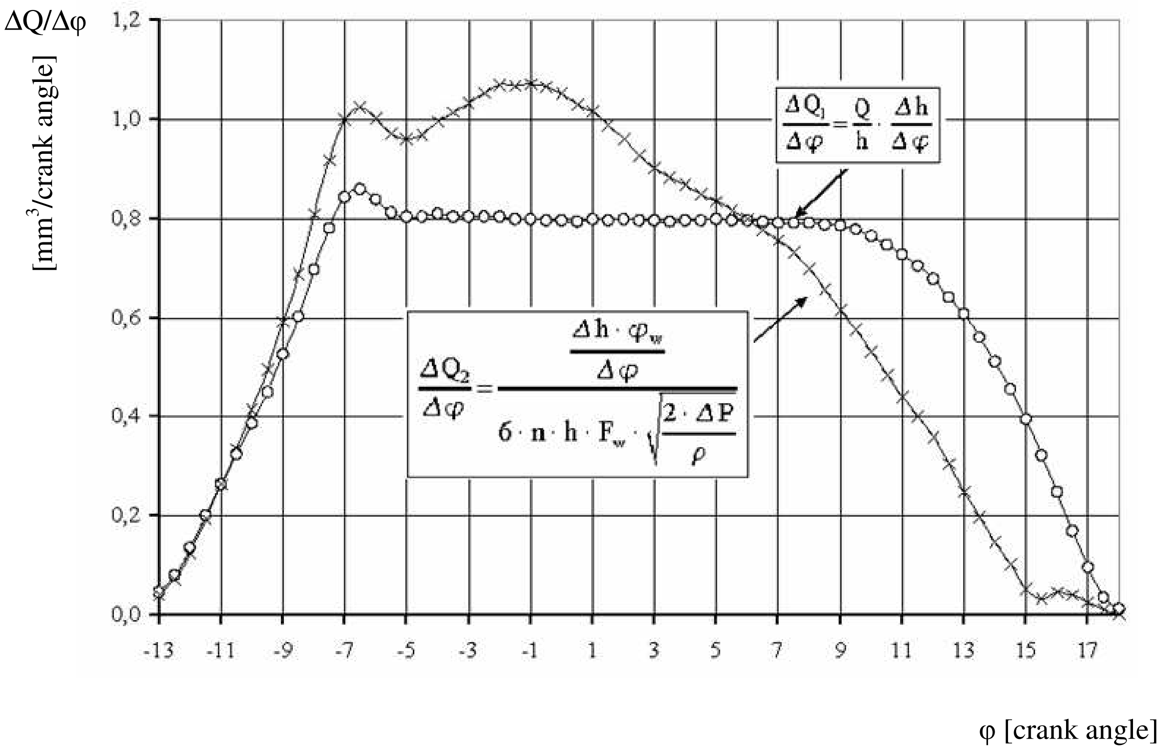


Fig. 1. The course of fuel injection for model 1 and 2 for engine speed 2004 [rpm]
Rys. 1. Przebieg wtrysku paliwa dla modelu pierwszego i drugiego dla prędkości 2004 [obr./min]



$$\frac{\Delta Q_1}{\Delta\varphi}=\frac{Q}{h}\cdot\frac{\Delta h}{\Delta\varphi}$$

$$\frac{\Delta Q_2}{\Delta\varphi}=\frac{\frac{\Delta h\cdot\varphi_w}{\Delta\varphi}}{6\cdot n\cdot h\cdot F_w\cdot\sqrt{\frac{2\cdot\Delta P}{\rho}}}$$

Fig. 2. The course of fuel injection for model 1 and 2 for engine speed 4250 [rpm]
Rys. 2. Przebieg wtrysku paliwa dla modelu pierwszego i drugiego dla prędkości 4250 [obr./min]

Model one takes into consideration the total value of the fuel dose, the total value of the needle lift and the speed of the injector needle lift. While model two takes into consideration the speed of the injector needle lift, the duration of the injection, speed of the crankshaft engine, total value of the injector needle lift, total value of the injector holes surface area, pressure difference between the injection pressure and the pressure in the cylinder and the density of the fuel.

2. OBJECT OF THE ANALYSIS AND THE RESULTS OF THE CALCULATIONS

The calculations of the two zone model were carried out on the basis of the data obtained from the measurements taken at the engine test. The testing was done on the five-cylinder, high-pressure engine with the capacity of 2390 [cm^3], direct injection in two measure series – the first one for the engine speed of 2004 [rpm] and the second one for 4250 [rpm]. In picture 3 and 4 the injector needle lift speed changes and the injection pressure for two analyzed engine speeds are put together.

The increase of the engine speed is accompanied by the increase of the injection pressure and the increase of the injector needle lift. The maximum injection pressure for the engine speed of 2004 [rpm] was 49 [MPa] while for the speed of 4250 [rpm] it was 78 [MPa], which gives the difference of 37%. The maximum injector needle lift for the engine speed of 2004 [rpm] was 0.282 [mm] while for the speed of 4250 [rpm] it was 0.305 [mm], which gives the difference of 8%.
For the engine speed of 2004 [rpm] the injection lasted 17 [crank angle] and for the speed of 4250 [rpm] it lasted for 31 [crank angle].

In figure 5 the changes of average combustion temperature for model one and two for engine speeds 2004 [rpm] and 4250 [rpm] are presented.

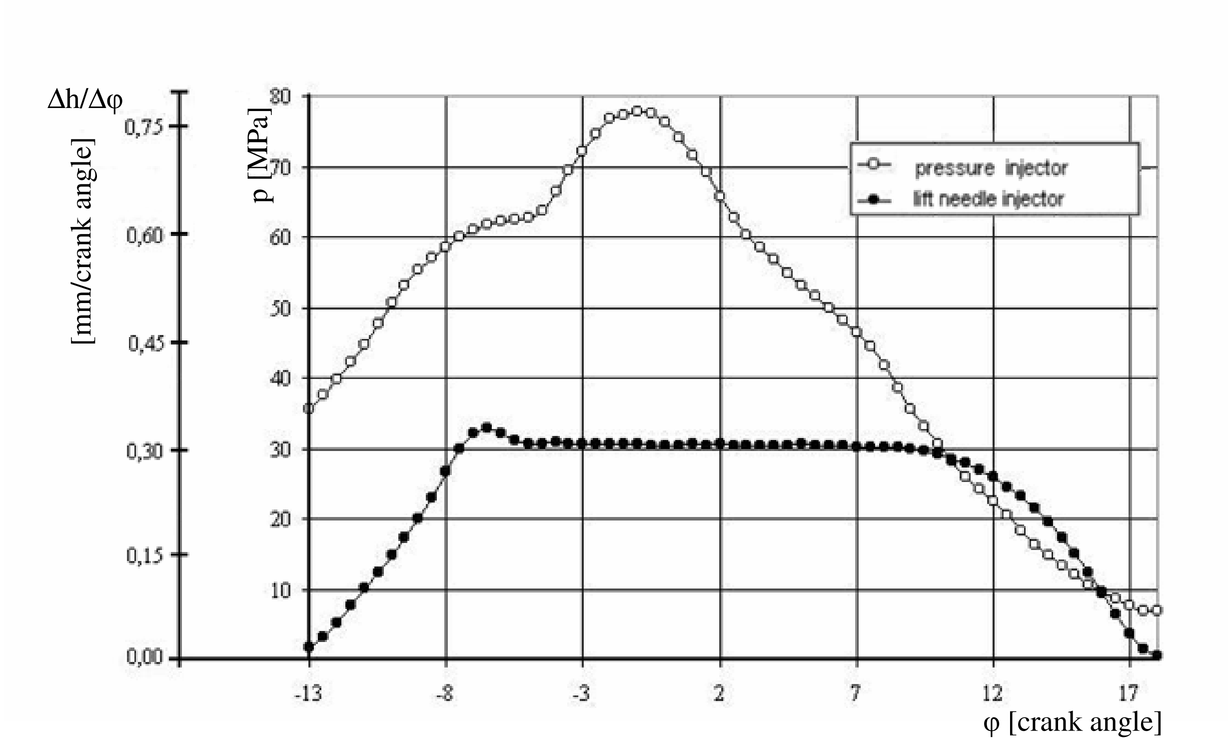


Fig. 3. The course of the injector needle lift speed and the injection pressure for the engine speed of 2004 [rpm]
Rys. 3. Przebieg szybkości wzniosu iglicy wtryskiwacza oraz ciśnienia wtrysku dla prędkości 2004 [obr./min]

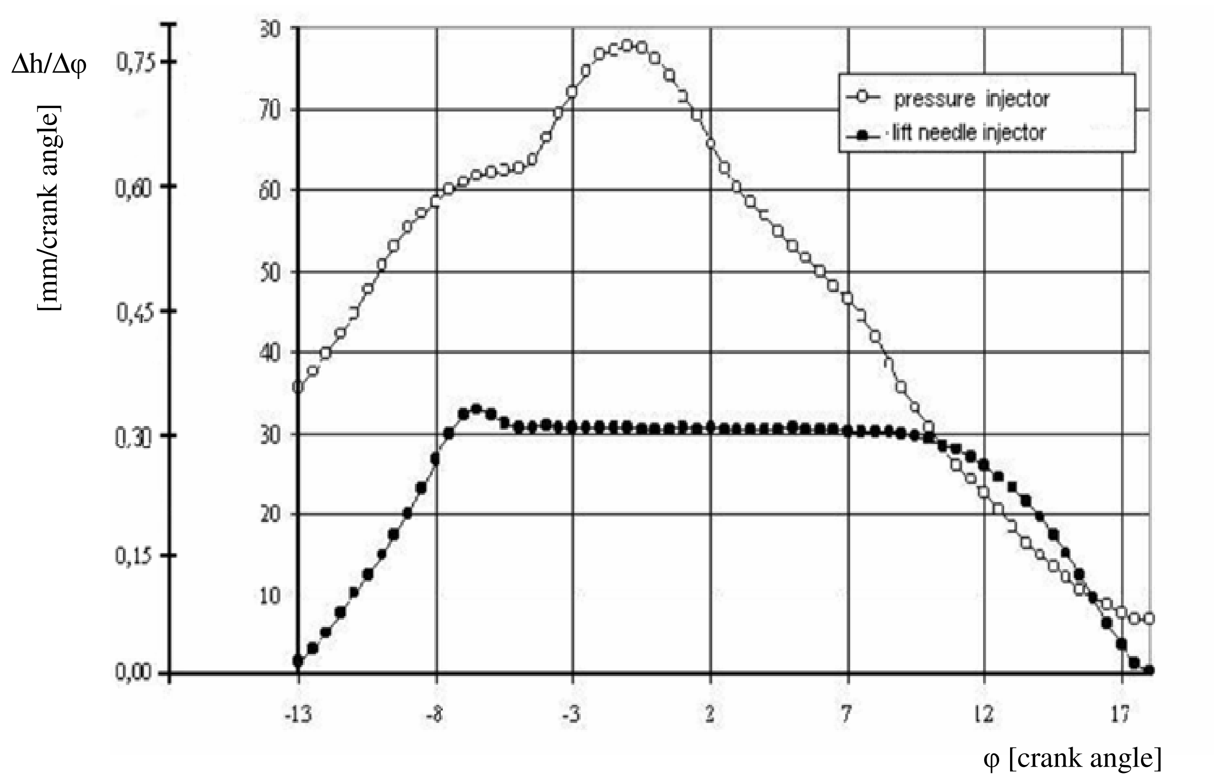


Fig. 4. The course of the injector needle lift speed and the injection pressure for the engine speed of 4250 [rpm]
Rys. 4. Przebieg szybkości wzniosu iglicy wtryskiwacza oraz ciśnienia wtrysku dla prędkości 4250 [obr./min]

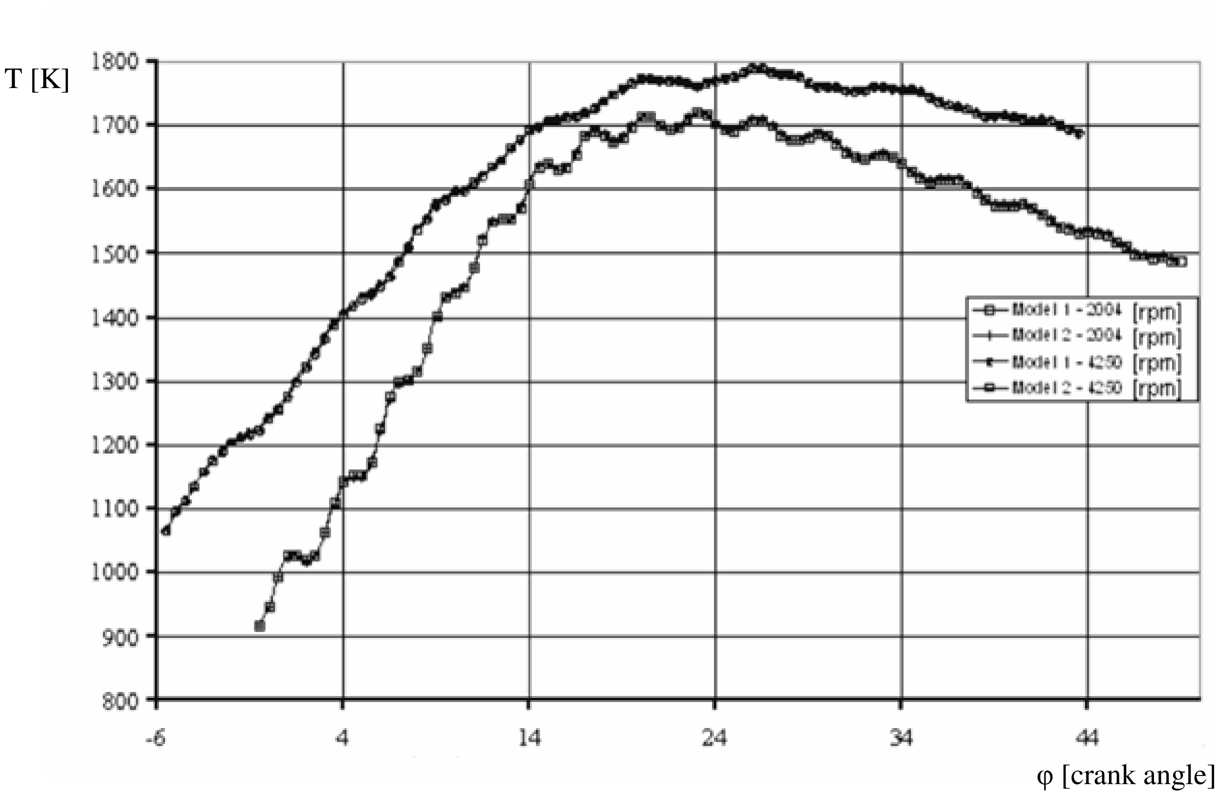


Fig. 5. The course of average combustion temperature for two engine speed
Rys. 5. Przebieg średniej temperatury spalania dla prędkości 2004 i 4250 [obr./min]

The application of one-phase fuel injection characteristics both for engine speed 2004 [rpm] and 4250 [rpm] with the same fuel dose and the same coefficient excess air did not significantly influence the change of the average combustion temperature inside the turbo Diesel engine. In the case of the speed of 2004 [rpm] the change of temperature did not exceed 0.2% and in the case of 4250 [rpm] - 0.4%. The maximum average temperature for the speed of 2004 [rpm] was 1720 [K] and for the speed of 4259 [rpm] it was 1788 [K].

3. CONCLUSIONS

The changes of temperatures for the applied injection characteristics are not great. The greatest difference occurs during the combustion. The increase of the engine speed at the same total fuel doze and coefficient excess air is accompanied by the increase of the maximum average combustion temperature by about 4%. More than double increase of the engine speed corresponds to almost double increase of the injection duration measured in degrees of the crankshaft revolution.

The increase of engine speed is accompanied by the increase of maximum pressure in the cylinder. For 2004 [rpm] it is 11.3 [MPa], for 4250 [rpm] it is 12.9 [MPa], which gives the difference of 12.5%.

Literature

1. Gustof P., Stanik Z., Wilk K.: *Utilzation of two – zone combustion model for analysis process in turbo Diesel engine*. Zeszyty Naukowe Politechniki Śląskiej, s. Transport, z. 28, Gliwice 1996.

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