THE HEAT BALANCE OF ENGINE FED BY DIESEL OIL AND BMD BIOFUEL

M.Sc.Eng Monika Andrych, DSc. PhD., Prof. Lech J. Sitnik, PhD. Eng Wojciech Walkowiak,

The Division of Vehicle Engineering- Wroclaw University of Technology, Poland
monika.andrych@pwr.wroc.pl, lech.sitnik@pwr.wroc.pl, wojciech.walkowiak@pwr.wroc.pl,

Abstract: *In the present paper the issue of external heat balance in the diesel engine is presented. The methodology of heat balance estimation, as well as the comparison of the researches results concerning engine with the common rail injection system, which is fed by mineral diesel oil and BMD biofuel has been presented. The impact of biofuel on the nature of changes in the heat balance has been estimated. The researches were performed on the measurement station based on the 13 points ESC test. It has been stated that the use of fuel assigned in the ESC test in the engine fed by biofuel (BDM) slightly increases in comparison to the engine fed by mineral diesel oil (ON). However, there can be noticed the change of the flow of energy input in the heat balance of the engine fed by both types of fuel.*

KEY WORDS: HEAT BALANCE, DIESEL OIL, BIOFUEL, ESCK

1. Introduction and theoretical basics of the heat balance

The heat balance in the internal combustion engine is an equation thanks to which the energetic changes of the circuit can be estimated. Making use of the balance makes it possible to indicate the value of energy carried to the engine, the value of energy carried from the circuit as usable work, and the value of energy that is lost as emitted heat. On the basis on the measurement results of the mechanical engine work and thermal energy emitted by engine, the external heat balance can be determined. For the purpose of that determination the law of energy conduct that provides the heat balance equation is used. Thisequation goes as following:

$$Q_0 = L_e + Q_{ch} + Q_w + Q_{ns} + Q_{dys} + Q_r, \qquad (1.1)$$

Where :
Q_o – total amount of heat carried to engine, L_e – usable work, Q_{ch} – heat carried to cooling factor, *Qw* – heat loss of fumes exhaust,, *Qns* – amount of heat lost due to imperfect and incomplete fuel combustion,, *Qdys* – dissociation heat loss,
Qr – the rest of balance which includes elusive heat loses carried to ambient

The basics for assigning the heat loss in the internal combustion engine is the calculation of energy carried to it in fuel.
The heat flow carried to the engine is determined form the dependence: in order to assign the heat flow carried to engine Q_0 it is necessary to know its value and $G_{e.}$

$$Q_0 = G_e W \qquad (1.2)$$

Where:

Ge- weigh of fuel carried in a time unit . kg, W- the fuel value of fuel kJ/kg

The next heat balance component is the heat flow carried from the circuit into the cooling system Q_{ch}.

Another important component of heat balance is the heat flow of engine fumes $Q_{w.}$

Other significant components of heat balance are heat losses coming from imperfect and incomplete fuel combustion Q_{ns} as well as dissociation losses $Q_{dys.}$

$$Q_{ns} + Q_{dys} = (1-\xi)G_e W, \qquad (1.3)$$

Where:

ξ - heat release rate

Heat loses coming from engine radiation are called the balance rest Q_r

Calculations algorithm will be presented due to the use of data from point 2 of engine work according to ESC test. During measurement, the 2[nd] engine was working with rotational speed of 2412.5 rotations/minute and the load of 35.9 Nm.

In the presented calculations the fuel value W of diesel oil has been assumed as constant and equal of 42700 kJ/kg.

$$Q_0 = G_e W = 0{,}79 \cdot 42700 = 33{,}733, kW \qquad (1.4)$$

The usable engine power was assigned from the dependence:

$$N_e = \frac{M \cdot \pi \cdot n}{30} = \frac{0{,}0359 \cdot \pi \cdot 2412{,}5}{30} = 9{,}065[kW] \qquad (1.5)$$

While:

$$M = \frac{N_e}{\omega} = \frac{60 \cdot N_e}{2 \cdot \pi \cdot n} = \frac{30 \cdot N_e}{\pi \cdot n}[kNm] \qquad (1.6)$$

The next heat balance component is the heat carried to cooling factor Q_{ch} . To compute it, one needs to know the input and output temperature of the cooling system and take into account their differences in the calculations. During measurement, it is essential to measure the speed of water flow (m) flowing through water meter. According to the fact that studied engine is cooled by the water solution, in the calculations the specific cooling factor heat has been assumed as the specific heat of water c_w=4,18, kJ/kg·K.

Thus

$$Q_{ch} = c_w \cdot m \cdot \Delta T\left[\frac{kJ}{kg \cdot K} \cdot \frac{kg}{h} \cdot K\right] = \left[\frac{kJ}{h}\right] = \left[\frac{kJ}{s} \cdot \frac{1}{3600}\right] \quad (1.7)$$

$$Q_{ch} = \frac{4{,}18 \cdot 246 \cdot 10{,}9}{3600} = 3{,}1[kW] \quad (1.8)$$

The heat loss of fumes exhaust Q_w has been assigned from the dependence:

$$n_p = \frac{p_{ot}}{T_{ot}} \cdot \frac{V_s}{MR}\eta_v = \frac{1009000}{296} \cdot \frac{0{,}001248}{8314{,}3} \cdot 0{,}658 = 0{,}000336[kmol] \quad (1.9)$$

- The amount of kilo moles of fumes and air (n_s, n_p) in time unit
- Average specific heat for constant pressure Mc_p
- Fumes and air temperature

The filling factor for four-stroke engine is calculated in the following way:

$$\eta_v = \frac{V_p}{30niV_s} \quad (1.10)$$

$$n_s = n_p \cdot 1{,}04 = 0{,}000336 \cdot 1{,}04 = 0{,}000350[kmol] \quad (1.11)$$

After calculating the amount of kilo moles of fumes and air, it is necessary to calculate how many of them fall on the time unit. The calculations are to be made with the use of the following equation:

$$n_p = \frac{i \cdot n}{120} \cdot n_s = \frac{4 \cdot 2412{,}5}{120} \cdot 0{,}000350 = 0{,}000469\left[\frac{kmol}{s}\right] \quad (1.12)$$

$$n_s = 1{,}04 \cdot n_p = 0{,}000488\left[\frac{kmol}{s}\right] \quad (1.13)$$

The assigning of specific air and fumes heat requires the analysis of their components in the determined conditions during the time when engine is working. It is necessary to determine the percentage performance of each component and then, according to temperatures, match the proper specific heat of each of them.

$$(Mc_p)_s = (Mc_v)_{N_2}\int_t^0 z''_{N_2} + (Mc_v)_{0_2}\int_t^0 z''_{O_2} + (Mc_v)_{CO_2}\int_t^0 z''_{CO_2} + (Mc_v)_{H_2O}\int_t^0 z''_{H_2O} \quad (1.14)$$

$$(Mc_p)_s = 28{,}016 \cdot 0{,}7553 \cdot 0{,}742 + 32 \cdot 0{,}703 \cdot 15{,}45 + 44{,}01 \cdot 0{,}8039 \cdot 0{,}1545 + 18{,}02 \cdot 1{,}4792 \cdot 0{,}053 = 30{,}68\left[\frac{kJ}{kmol \cdot K}\right] \quad (1.15)$$

$(Mc_p)_p$ is assigned analogically to $(Mc_p)_s$.

After substituting all already calculated values Q_w totals :

$$Q_w = n_s(Mc_p)_s T_s - n_p(Mc_p)_p T_p = (0{,}000488 \cdot 30{,}68 \cdot 509) - (0{,}000469 \cdot 21{,}35 \cdot 296) = 4{,}66[kW] \quad (1.16)$$

Dissociation losses Q_{dys} and losses resulting from incomplete fuel combustion Q_{ns} are assigned together. They are included in the combustion losses similarly to the previously mentioned component Q_w.

$$Q_{ns} + Q_{dys} = (1-\zeta)G_e W \quad (1.17)$$

Supercharged diesel engine has been studied. The heat release rate ζ for the engine is placed in limits of 0.6-0.8. It has been determined that ζ=0,8.

$$Q_s = Q_w + Q_{ns} + Q_{dys} \quad (1.18)$$

thus

$$Q_s = 4{,}66 + 6{,}74 = 11{,}41[kW] \quad (1.19)$$

Whereas Q_r: has been assigned in test point 2 as :

$$Q_r = Q_0 - N_e - Q_{ch} - Q_w - Q_{ns} - Q_{dys} = 33{,}73 - 9{,}065 - 3{,}1 - 4{,}66 - 6{,}74 = 10{,}1[\mathrm{kW}] \quad (1.20)$$

2. Measurement methodology and research location.

For the purpose of the study there have been used diesel oil and BMD fuels. They were compared in the area of made-up heat balance concerning , above all, reached power.

In the present studies there were used commonly available diesel oil and fuel with BMD (Bio Mix Diesel) addition which were tested in the diesel engine of Fiat 1.3 JTD. BMD fuel is a mixture of three components. In the first production phase rapeseed oil is mixed with butanol. Butyl alcohol is alcohol of high density and it is used as rapeseed oil solvent. Such an order of mixing both components results as mixture of similar density to diesel oil. This mixture is called BM (Bio Mix) [1] [2] [3] [6].

The studies which make use of two different types of fuel were made on 1.3 JTD Miltijet engine which is the second generation of turbocharged engine with CommonRail system.

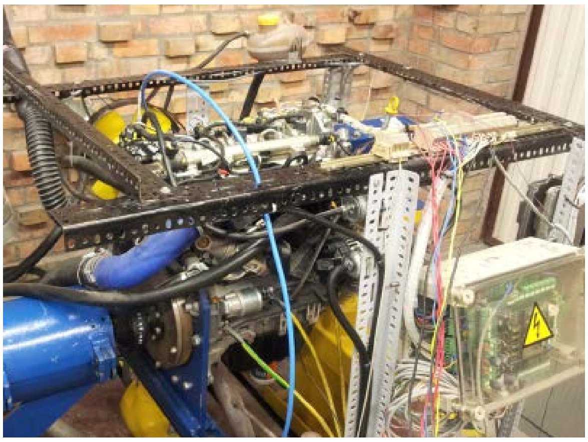

Fig. 2.1. *1.3 JTD 16V engine on the test bed.*

The researches were made in properly equipped engine roller performance tester in Department of Vehicle Engineering, Faculty of Mechanical Engineering, Wrocław University of Technology.

3. Measurements results.

Engine working points have been matched according to ESC test proper procedures. They also have taken into account the external characteristics of the engine.

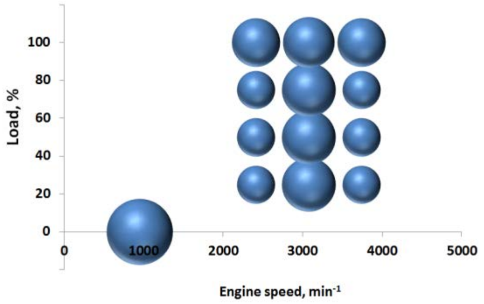

Fig. 3.1. *ESC test points*

Figures 3.2 and 3.3 present total heat balance of engine fed by BMD fuel and diesel oil.

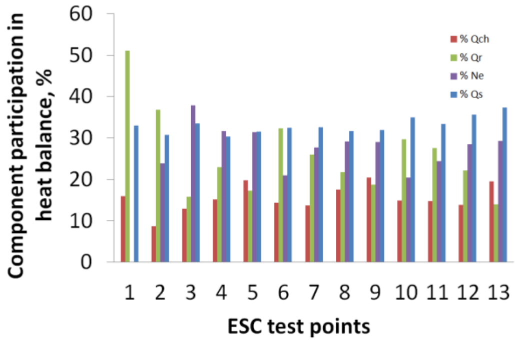

Fig. 3.2. *Engine power and heat balance formulated in kW of 1.3 JTD 70CV engine fed by BMD fuel, assigned in ESC test points*

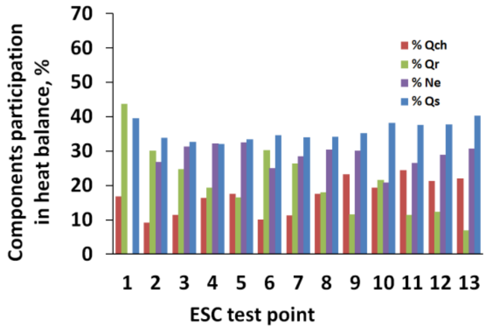

Fig. 3.3. *Engine power and heat balance formulated in kW of 1.3 JTD 70CV engine fed by diesel oil, assigned in ESC test points*

Taking units use of fuel of the studied engine in ESC test into consideration, the results are as follow:

Table 3.1 *Comparison of units use of fuel in the ESC test concerning engine fed by BMD and Diesel oil (ON) .*

ON	BMD
[g/kWh]	
304,26	**320,52**

From what has been presented it follows that the difference in units use of fuel in engine fed by both types of fuel is not significant. From the calculated data it follows that the result is 5.53%. However, the changes in distribution of heat proportions seem to be interesting. It is clearly visible in the following diagram.

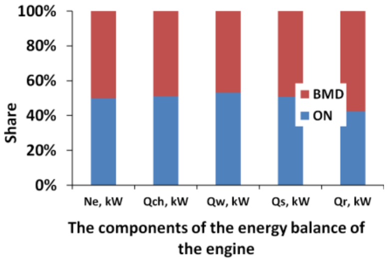

Fig. 3.4. *Participation of heat flow assigned in the ESC test of studied engine fed by diesel oil (ON) and BMD.*

4. Results analysis and conclusions

From the analysis of the performed studies it is necessary to conclude that fuel additions such as butanol and rapeseed oil mixed with diesel oil in the proper proportions give the desired energy effects.

Assigning of heat balance allows to carry out the analysis concerning the amount of thermal energy which is produced during combustion process in various conditions of working engine fed by both types of fuel and it allows to compare the proper balance ingredients.

The consumption of BMD fuel is slightly higher (due to its lower fuel value). In the performed studies under conditions of ESC test this consumption grows of 5%.

It has to be explained why particular heat flow participations are changing according to different types of fuel used in the engine, especially because of the fact that the combustion heat of both types does not significantly differ.

5. Literature:

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