SIMULATION RESEARCH OF UNITARY FUEL CONSUMPTION OF MAN ENGINE

Janusz Mysłowski, Jaromir Mysłowski

The Technical University of Szczecin, Poland

INTRODUCTION

The previously done research [1] has made it possible to state, that Leidemann's equations defining the power and torque curve are inadequate when concerning modern engines, both the spark and the self ignition ones. The modification of ratios has been stated, basing on statistical research and engine testing. The result obtained was fully satisfactory and made it possible to determine the diagram of the above mentioned curves with sufficient accuracy [1, 2].

It has been a reason for running another research basing on an equation defining the unitary fuel consumption. The research has been made for diesel engines used in trucks. The research concerned both slow-suction and turbocharged engines with powers from 59 up to 390 kW. The average power of engines under examination was 176 kW, and unitary fuel consumption was on the level of 210.3 g/kWh (155 g/KMh) which was, as it can be seen, a very low one. The examined engines originated from producers like: Scania, DAF, SW 680 and SWT (Leyland's license), MAN, Steyr, Avia, Volvo and Andoria (Leyland's license). These are in majority modern engines with direct injection, which leads to low unitary fuel consumption. On the other hand, Lidemann's equations were giving very disadvantageous description of direct injection engines, due to the technological level of that time, concerning fuel engine form vehicles operation.

RESEARCH DESCRIPTION

The research has been done comparing producers' data concerning the unitary fuel consumption of the examined engines, with the data obtained using the Leidemann's equation, in the form of:

$$g_x = g_{eN}\left(1.2 - \frac{n_x}{n_N} + 0.8\frac{n_x^2}{n_N^2}\right) \tag{1}$$

where:

g_x – the sought value of unitary fuel consumption,
g_{eN} – the value of unitary fuel consumption with the rated power,
n_x – the turning speed for the sought value of unitary fuel consumption,
n_N –the rated turning speed.

As a result of the simulation research of 26 engines an average value of unitary fuel consumption of 210.3 g/kWh has been obtained which, compared with the producers' value of 213.3 g/kWh, gives a 1.5 difference.

Such method of research simplifies the problem a lot, since it does not take the sign under consideration. It means that it ignores the fact, that for different engines the value of unitary fuel consumption can be higher (+ sign) or lower (– sign) then the value used as a comparison base.

There still remains the problem of turning speed for which the minimal unitary fuel consumption occurs. As the statistical research of the examined engines has proved, also for this value the shift of minimum has been discovered and, moreover, into the higher turning speeds. The value of the shift was 9.5% compared with the values calculated using Leidemann's equation. The schema for these results is presented in Fig. 1.

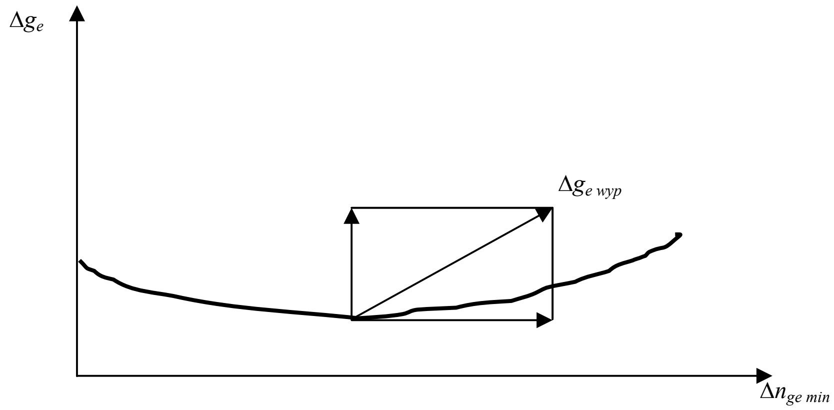

Fig. 1. Difference of placement of minimum unitary fuel consumption for direct injection diesel engines

The state presented in Fig. 1 results from the fact, that modern diesel engines have highly broadened operational turning speeds range, which leads to the increase of their flexibility, but also influences the shift of minimum unitary fuel consumption into the higher turning speeds.

To present this state in a better way, the characteristics of the unitary fuel consumption has been made for DAF DK 1160 engine, using Leidemann's equation, and then it was presented compared with the producer's characteristics (Fig. 2).

The resultant shift of the minimum unitary fuel consumption $\Delta g_{e\,wyp}$ in Fig. 1, resulting from the characteristics shown in Fig. 2 and Fig. 3, needs a correction of number factors in Leidemann's equation (1), so it could be possible to obtain with this equation used for the simulation an identical plot of the unitary fuel consumption as the one derived from an engine testing.

It is not an easy case, as it demands statistical research and test of a great number of engines, having, as it can be suspected, a different plot of the unitary fuel consumption curve depending on the method of the burning mixture preparation and the combustion process as well as on stroke-bore capacity, power and torque. But if the sample of the examined engines is big enough, the result providing the proper reliability can be obtained.

For the engine described, the test of changing the factor in Leidemann's equation has been made, to obtain the value of minimum unitary fuel consumption equal to that of the producer's data. As a result the demanded consistency has been obtained, using the equation:

$$g_x = g_{eN}\left(1.294 - \frac{n_x}{n_N} + 0.721\frac{n_x^2}{n_N^2}\right) \tag{2}$$

which is presented in Fig. 4. The simulation value of unitary fuel consumption was equal to 232 g/kWh, for two points presented in the Figure and marked as $g_{e\mathrm{min.\ sym}}$, the value of minimum unitary fuel consumption according to the producer's data, equal to 230 g/kWh, is placed on the same curve defined with the equation (2).

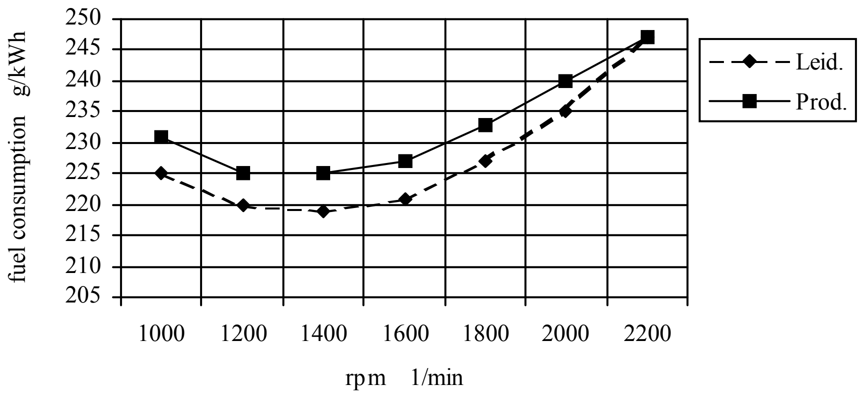

Fig. 2. Characteristics of fuel consumption of an engine DAF DK 1160

The difference in the plot of the unitary fuel consumption can also be clearly seen in Fig. 3 in a three-dimensional form.

In reality the situation is more complex than it is shown in Fig. 1, which does not take into consideration the signs of shift in fuel consumption obtained in the simulation compared with the producer's data. In the examined sample of engines, those shifts where positive (sign +, simulated consumption higher than the producer's data) and negative (sign –, simulated consumption lower than the producer's data). Using the arithmetical average the lower value has been obtained for the simulated fuel consumption. It also concerns the change of turning speed with the minimum value of the unitary fuel consumption. The plot of this situation is shown in Fig. 5, with the beginning of the coordinate system in the point of the minimum simulated fuel consumption.

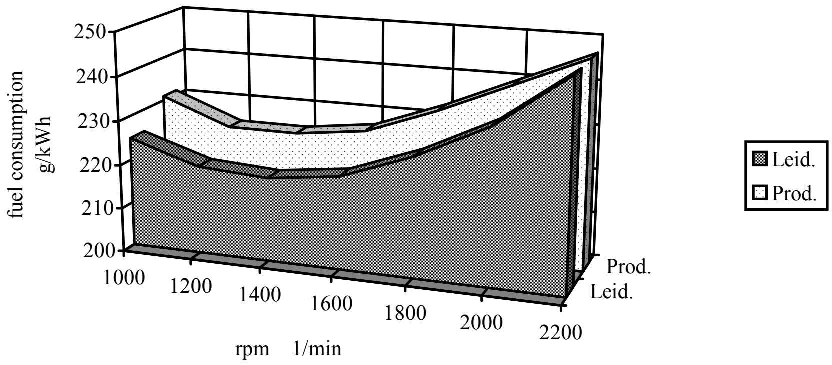

Fig. 3. Characteristics of unitary fuel consumption value of an engine DAF DK 1160

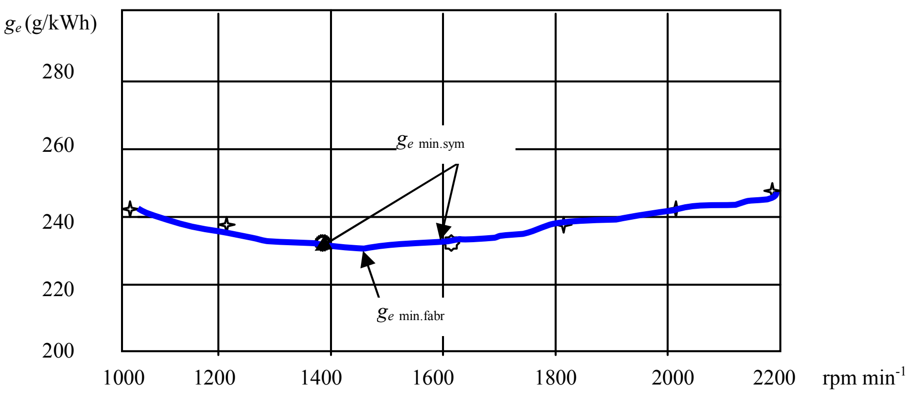

Fig. 4. The simulated unitary fuel consumption value according to the modernized equation, engine DAF DKA-1160, the value is between two signs o – o.

As it can be seen in Fig. 5, the picture of the shift of the minimum unitary fuel consumption value for the examined sample of engines shown in Fig. 1, was a very simplified one. But anyway it made it possible to draw conclusions concerning the continuation of the research, and stated the base for the statistical methods, for which the matter of the reliability of results depends mainly on the size of the examined sample of objects.

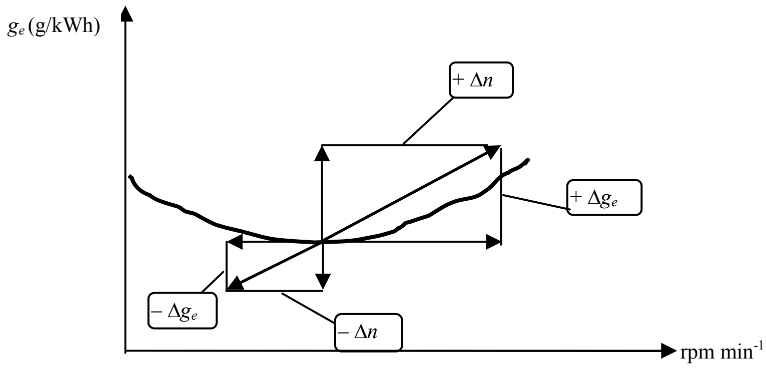

Fig. 5. The real plot of shift of the minimum unitary fuel consumption point

In a similar way the efficiency of the method was proved for the MAN D2866 LF26 engine, which meets the EURO III conditions, concerning the toxicity of fumes and is a modern engine with a big flexibility on the level of 2.76 which is 7.8% more then the average flexibility value of 20 engines produced by MAN, meeting the EURO III conditions. The comparison of unitary fuel consumption plot of this engine is shown in Fig. 6.

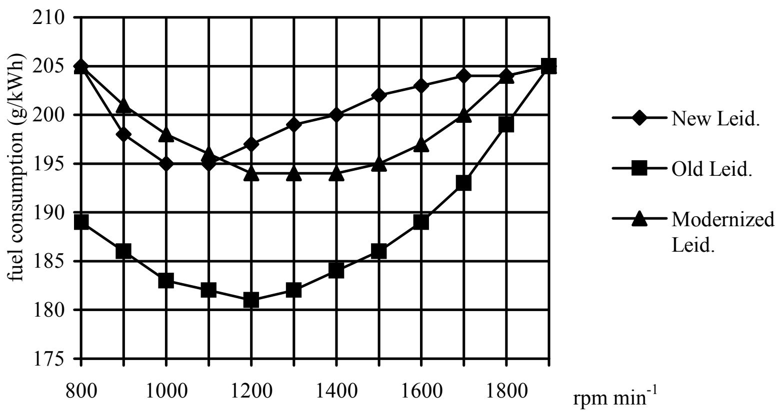

Fig. 6. Comparison of unitary fuel consumption of MAN D2866 LF26 engine

As it can be seen in Fig. 6, the unitary fuel consumption stated using the old Leidemann's equation differs significantly from the one derived from the modernized version of the equation and from the producer's data. It differs similarly as in Figures 2 and 3 (the same tendency of changes). If it comes to the minimum value of the unitary fuel consumption, it differs in the simulation research with the value of 1 g/kWh, which means 0.5%. The shift of the minimum towards higher turning speeds equals to 5.2%, which means an improvement compared with the previously examined sample (1.5% and 9.5% respectively).

It seems, that for the quick, approximate definition of operational parameters of an engine, the described Leidemann's method used with a proper modification is quite adequate.

CONCLUSION

The presented preliminary research and assumed inference method, gives a hope for reliable results during the simulation research of unitary fuel consumption of car combustion engines with different methods of combustion and combustion mixture preparation. To obtain this goal it is necessary to run the research on significantly larger sample of engines, of every mentioned kind, which would make it possible to generalize the obtained result.

The research done so far was based on an analysis of the unitary fuel consumption of modern diesel engines in turbo charged version (mainly) and in non-charged version. 27 engines have been examined, which is a too small sample for a statistical estimation of the results. However, the goal of the research was to test the methodology.

In future it may be necessary to separate from the sample the turbocharged engines, usually used in high-load trucks, but lately also in passenger cars (TDI, HDI, JTD).

REFERENCE

1. **Mysłowski J., Kołtun J.**: Flexibility of piston combustion engines. WNT, Warszawa 2000.
2. **Talaga K.**: Statistical analysis of Leidemann's equation's reliability. Operation of combustion engines, book no. 4. Technical University of Szczecin, Szczecin.

SUMMARY

The paper presents a test of using the Leideman's equation for the simulation of the unitary fuel consumption plot for direct injection diesel engines. They are the main power source in the group of high-load trucks and use significant amounts of fuel. Any decrease in fuel consumption significantly reduces environmental pollution and in that way is desirable, regardless of the economic effect.