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THE INFLUENCE OF INTENSITY OF CHARGE AIR INTERCOOLING ON DIESEL ENGINE GAS

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Abstract

The intercooling of charge air is one way of possible arrangements done while preparing fuel for diesel engines with the objective of lowering the environmental load. Such intercooling has other positive effects, e.g. the output increase, decrease in the maximal temperature of engine working cycle, decrease in thermal load of functional parts in the combustion space. Coolers of different constructions and versions are used for the charge air intercooling. As we have already presented in conferences and professional journals, we have been engaged in basic research into the non-conventional energetic system with the cooling combustion engine (the engine cooling circle is the ejector of absorption cooling). The obtained cold can be used for different purposes, e.g. for air conditioning of the maintenance room, cooling of goods storage space in trucks and also for more intensive intercooling of the charge air. Simultaneously with the mentioned topics we have been partially dealing with the influence of more intensive intercooling on the engine ecological parameters. We have presented some results of mathematical modeling connected with the mentioned topic. The paper is a continuation of previous publications and focuses on results of the experiment observing a two-stage charge air intercooling to lower temperatures. The air-to-air cooler was used as the first intercooling stage while the second stage was performed by means of the water-air intercooler.

Keywords: *air intercooling, lowering the environmental load, two-stage charge air intercooling, lower temperatures, air-to-air intercooler, water-air intercooler*

1. Introduction

The increase of energetic effectiveness, development and utilization of renewable energy resources and decrease of environmental load are attributes featuring the real potential contributing to the creation of a sustainable energetic system with a turbocharged combustion engine in its application within higher level cogeneration systems (e.g. complex combined cogeneration). The main requirements for the contemporary development in the area of conversion of energy into mechanical energy - for converters, i. e. machines which are determined by minimization of environmental load mostly due to gas emissions and also by minimization of fossil fuels consumption or by utilization of unconventional fuels.

Supercharging of piston combustion engines fuelled by liquid fuels is the thought as old as the engine itself. And the intercooling of filling medium has also been used for almost a hundred years. From the mentioned it results that not only theoretical fundamentals of supercharging of combustion engines fuelled by liquid and gas fuels but also their practical utilization have been well-known and widely recognized. The share of production and utilization of supercharged combustion engines has significantly increased recently. It is the case of both supercharged compression ignition engines and also of supercharged spark ignition engines. While the supercharging of combustion engines fuelled by liquid fuels is widely used not only for stationary engines but also for engines designed for mobile means, supercharging of gas combustion engines is more frequently used in stationary engines, though in real practical conditions they are also used mostly in road vehicles. Within the context of decreasing harmful pollutants in exhaust gases of supercharged engines, relatively high pressure losses in the catalytic converter – if it is integrated in the exhaust tract – have to be respected. Pressure losses negatively influence the cooperation of the engine and turbocharger, or its adjustment with the turbocharger.

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Simultaneously with the mentioned topics we have been partially dealing with the influence of more intensive intercooling on the engine ecological parameters. We have presented some results of mathematical modeling connected with the mentioned topic.

The basis of purposeful basic research lies in the monitoring of possibilities of unconventional (ultralow temperatures) mixture intercooling of the charge on the selected ecological and economic parameters of a gas turbocharged combustion engine in specific operational conditions (periodic starts and stops).

From the point of view of the structure of the research priorities in the horizontal classification level the objective belongs to the category “The application of progressive principles of energy production and transformation“, as a sectional program direction. In the vertical classification, i.e. in thematic program directions of the research and development the aim ranks among the category “Competitiveness of economics“. The main scientific aim is the specific oriented basic research into the influence of mixture of ultralow temperatures of charge air behind the intercooler in a turbocharged engine from the point of view of the harmful gas emissions formation (with focus on NOx) and specific effective consumption. The research into the influence of mentioned ultralow temperatures of the charge air behind the intercooler on the other parameters of a turbocharged engine not only in standard operation but also under specific conditions (periodic engine starts and stops) can be characterized as secondary aims. The main anticipated contribution at the highest level will be results of mathematical modeling confronted with the experiment pointing to possible improvements in technical, economic and ecological parameters of supercharged combustion engines within the frame of permanent sustainable development within the context of ultralow temperatures of intercooling of the charge.

The theoretical analysis, consequent mathematical modeling and experiments with utilization of ultralow temperatures of intercooling of charge air behind the intercooler in the range from 40°C to closely above zero temperatures of the supercharged engine should define trends of changes in its power parameters and exhaust gas emissions production, mostly NOx. At the same time the influence of ultralow temperatures of intercooling on the engine inner corrosion at periodic engine starts and stops should be assessed.

To obtain necessary input data for mathematical modeling and consequent verification of calculations and selection of elements a test bench equipped with a supercharged combustion engine with a two-stage intercooling was designed to be used for experiments. The used measuring chain and methodology of measurement with be the topics of another paper.

2. Test bench

The experiments were carried out on the test bench – Fig. 1. with a charged six-cylinder water cooled engine braked with a vortex dynamometer with a test cooling circuit of intercooling to achieve a required and stabilized temperature of water cooling the charge air. Fuel consumption was measured by means of the mass method.

Two-stage intercoolers were employed. An air-to-air exchanger was used for the first stage and water-air exchanger was employed for the second stage – Fig. 2.

Gas emissions - analysis (CH, CO, CO_2, NO_x) and smoke (AVL) were measured with an AVL laboratory emissions analyzer.

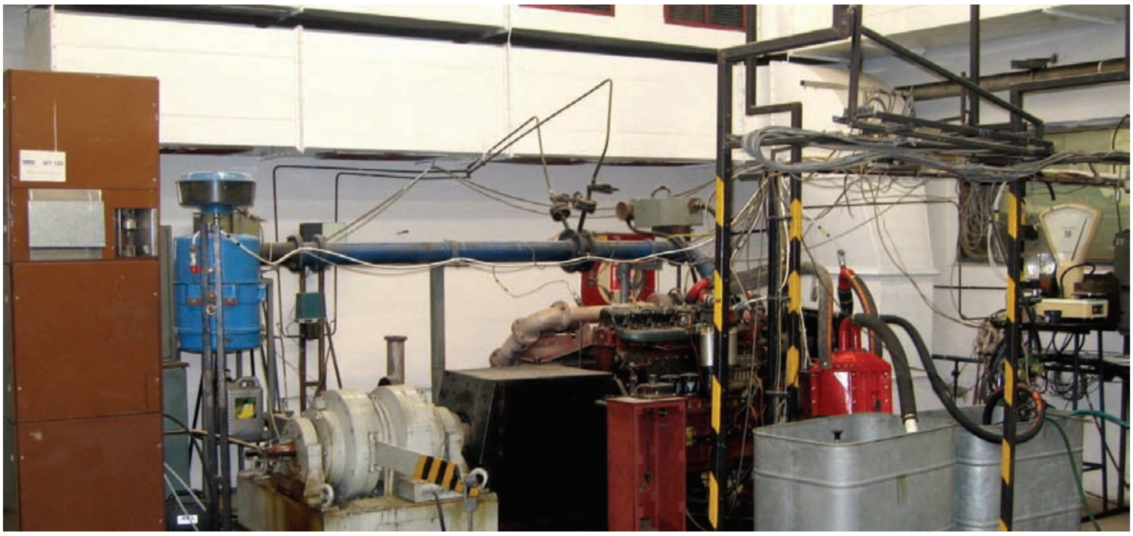

Fig. 1. Test bench

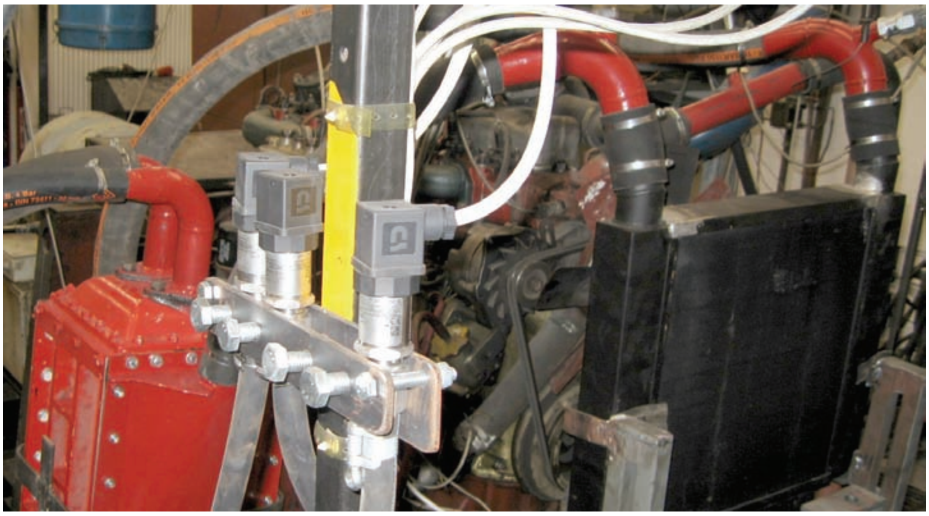

Fig. 2. Intercoolers of charge air

3. Results of measurements

The engine tests were carried out in five points of its external rotation characteristic. The parameters of an engine without intercooling were taken as the basis. Consequently, parameters of the engine and gas emissions in two stages of intercooling were taken:

- intercooling in the first stage (air-to-air intercooler) and flow of the charge air through the second stage of intercooling without its being cooled,
- intercooling in both stages (cooling of charge air also in the water-air intercooler).

The results of the experiment are presented as graphical dependences on the engine revolutions in Fig. 4-7., where the following symbols are used:

n	engine rpm,
Mt	torque,
mpe	specific effective consumption,
$T_{\text{za TBD}}$	temperature behind charger,
$T_{\text{za Turbínou}}$	temperature behind turbine,
$T_{\text{MCH 1}}$	temperature behind intercooler 1, air-to-air type,
$T_{\text{MCH 2}}$	temperature behind intercooler 2, water-air type,
DYM.	smoke emissions.

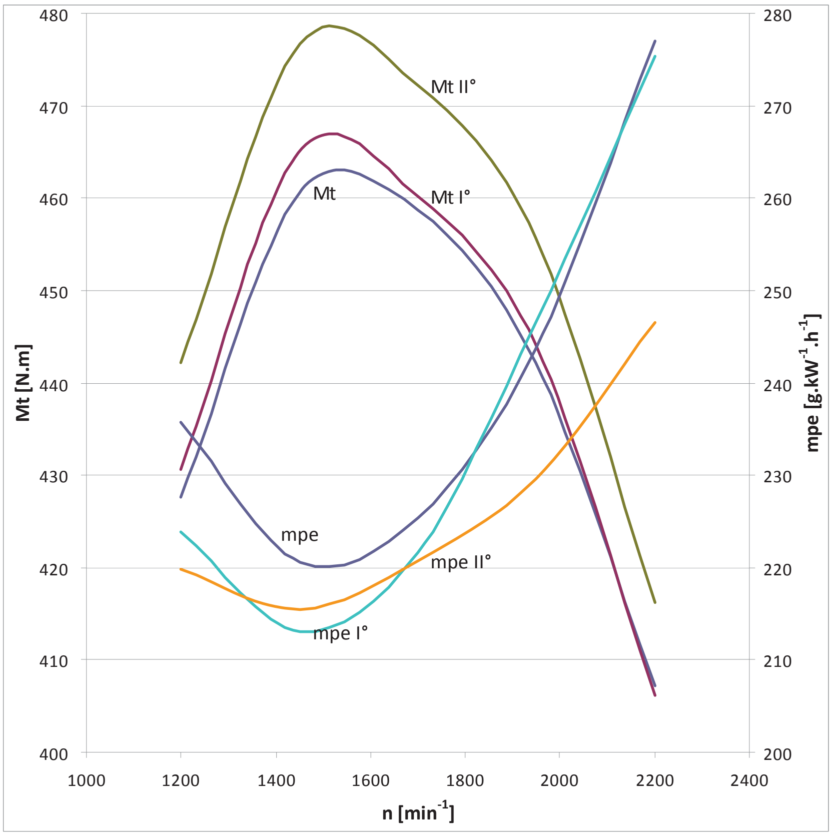

Fig. 3. Course of torque and specific effective consumption in the external rotation engine characteristic

The diagram in Fig. 3. illustrates the course of basic parameters – torque and specific effective consumption in the external rotation characteristic of the engine. The diagram shows a noticeable increase in the torque value and decrease in the specific effective consumption with the growing intensity of charge air intercooling. The maximum torque value increased by 5 Nm when the charge air temperature on the engine entry decreased from 51°C to 44°C (intercooling in the first stage) at the decrease of the specific effective consumption by approx. 10 g.kW-1.h-1. When the charge air was cooled in both stages of intercooling then its temperature on the engine entry was 22°C, the maximum torque increased by 16 Nm and the specific effective consumption decreased approx. by the same value but its course was more favorable.

Tab. 1. The decrease of exhaust gases with the decrease of charge air temperature

	without intercooling		intercooling I°		intercooling II°	
n [min^{-1}]	$T_{MCH\ 2}$ [°C]	$T_{za\ Turbínou}$ [°C]	$T_{MCH\ 2}$ [°C]	$T_{za\ Turbínou}$ [°C]	$T_{MCH\ 2}$ [°C]	$T_{za\ Turbínou}$ [°C]
2200	59.5	532.1	51.5	525.3	27.0	500.8
1950	62.1	547.7	53.1	539.0	26.5	512.5
1700	55.9	542.1	47.5	531.8	24.9	507.1
1450	51.1	521.7	44.2	513.4	22.0	488.2
1200	45.3	493.7	40.4	490.6	20.5	470.1

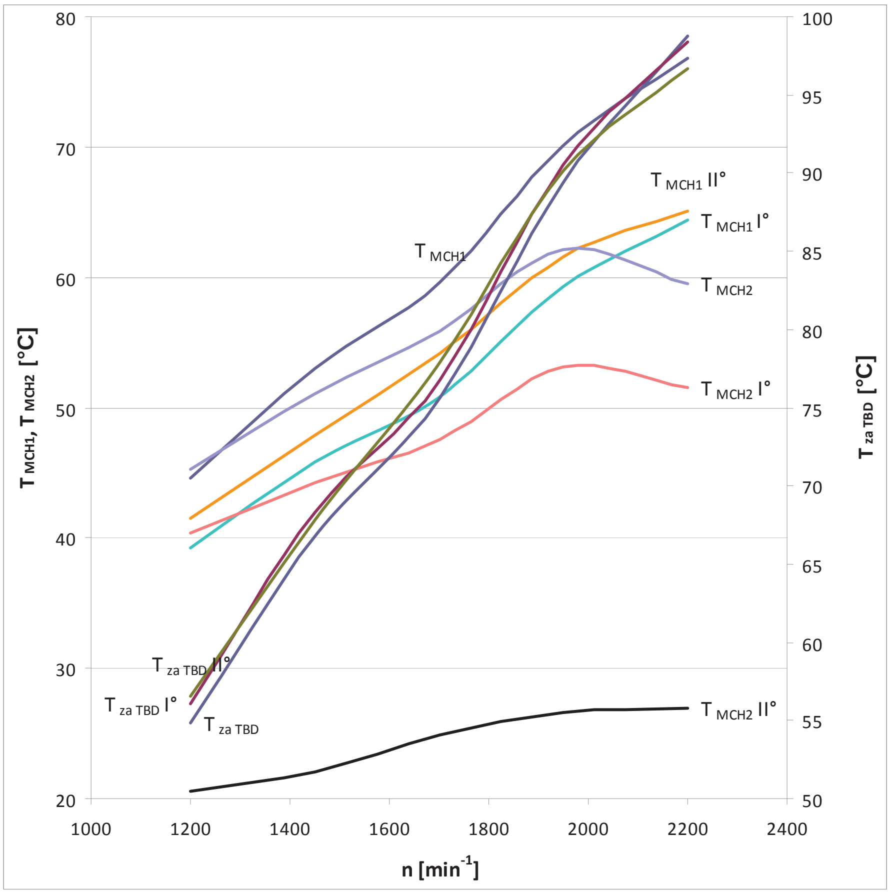

Fig. 4. Courses of temperatures behind charger, on exit from first stage of intercooling and on cylinders entry

Figure 4. illustrates courses of temperatures behind the charger, on the exit from the first stage of intercooling and on the exit from the second stage of intercooling. The experiment confirmed the decrease of exhaust gases with the decrease of charge air temperature – Tab. 1.

Figure 5. shows changes in temperatures on cylinders entry without intercooling, with cooling of charge air in the first stage of intercooling and with two-stage cooling. The courses of these temperatures “copy” the courses of temperatures behind the charger. Difference in the temperature decrease before entering the engine without intercooling and with two-stage cooling is on average approx. 25°C along the torque characteristic. Decrease in temperature before the engine entry by approx. 30°C in the field of maximum torque was achieved due to two-stage intercooling employing cooling water whose temperature was 15°C on the intercooler entry and after heating in the intercooler it increased by approx. 3°C.

The objective of extreme intercooling of charge air is to find out its influence on engine gas emissions.

The experiments show that extreme intercooling results in the decrease of engine smoke in the whole range of torque. In the fields of maximum torque and specific effective consumption at two-stage intercooling the decrease is approx. by 5% - Fig. 6.

As already mentioned, two-stage intercooling was manifested in the decrease of specific effective consumption, which was also reflected in the decrease of produced carbon dioxide within the whole range of torque. It was the most noticeable in the vicinity of the maximum value of torque, by approx. 7% - Fig. 6. During the experiment a potential presence of carbon monoxide was also detected. Its content in exhaust gases was negligible – about 0.1%.

Dependence of the course of nitrogen oxides found in exhaust gases in the external torque engine characteristic did not change with the change in temperature on the cylinders entry, i. e. with intensive intercooling – Fig. 7. One-stage intercooling (decrease in temperature on the

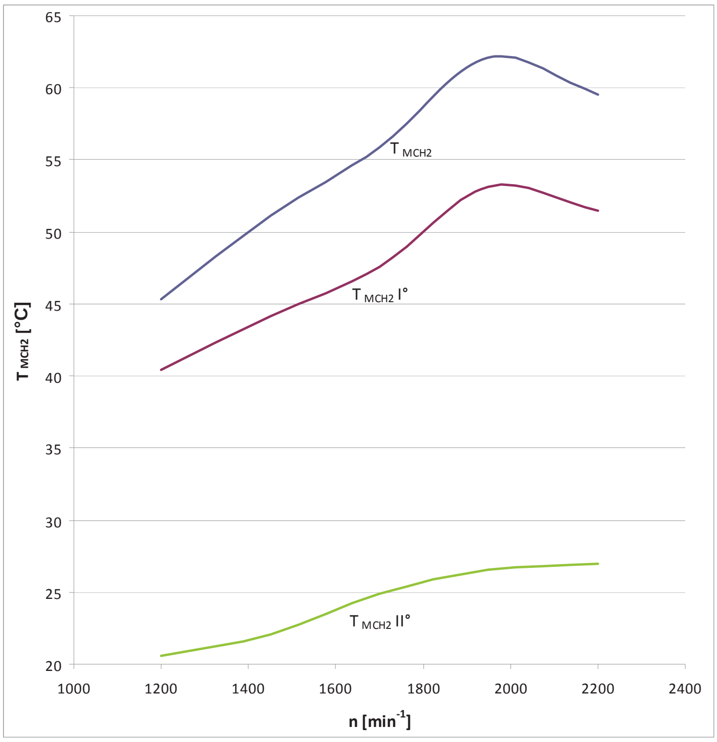

Fig. 5. Courses of temperatures on cylinders entry

cylinders entry by approx. 8°C) did not have great influence on content of nitrogen oxides. But with two-stage intercooling (decrease in air temperature on the cylinders entry on average by approx. 28°C) there was a decrease in nitrogen oxides in the whole range of torque by approx. 200 ppm, which represents 14% in the vicinity of the maximum torque and as many as 22% in the specific effective consumption.

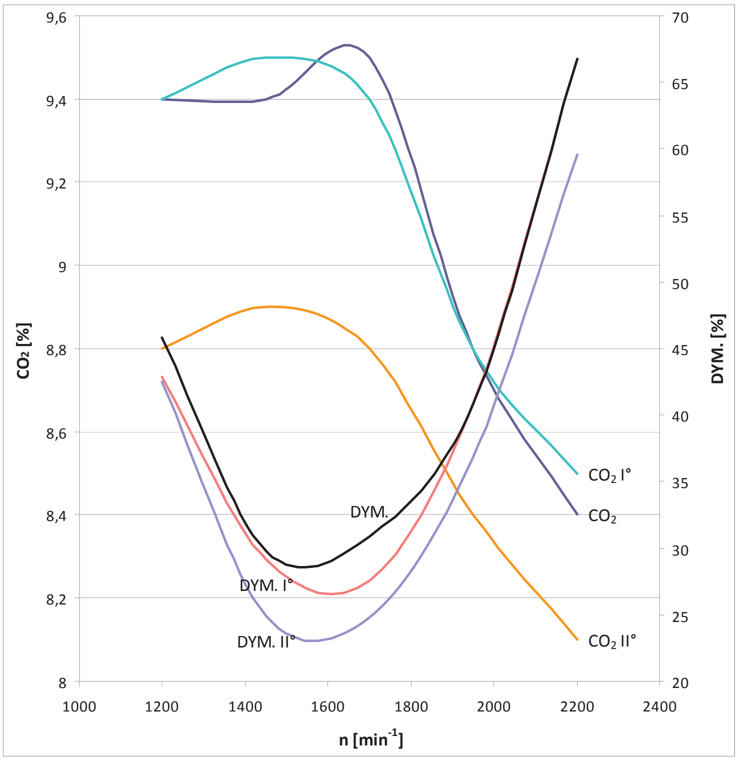

Fig. 6. Courses of temperatures on engine entry

4. Conclusion

The experiments confirmed the justness of the idea to deal with extreme intercooling of charge air. Apart from improvement of technical and economic parameters of the engine, a marked improvement of its ecological parameters was noticed. Not only its locally actuating ecological effects improved (engine smoke and production of nitrogen oxides decreased), but its global ecological actuation also improved (reduced CO2 formation). The results present the influence of intensive two-stage intercooling on the parameters characterizing the engine work without optimizing its other components (turbocharging, injection, ...).

Mathematical modeling in combination with necessary experiments alternatively solves possible risks resulting from the proposal newness and originality.

Mutual confrontation of output of simulation and experiment will be employed in the improvement of further steps to be taken to make the obtained results accessible. The engine tests were carried out in five points of its external rotation characteristic.

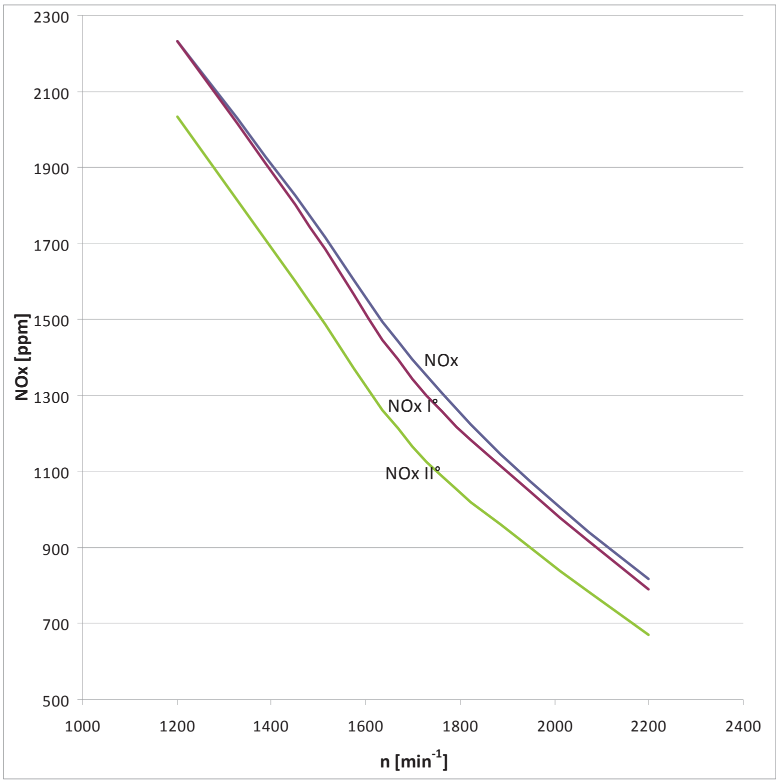

Fig. 7. Courses of temperatures on engine entry

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