THE COMPARATIVE ANALYSIS OF BUS 6C(T)107 ENGINE PARAMETERS FUELLED WITH COMPRESSED CNG AND LIQUID NATURAL GAS LNG

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Abstract

The paper presents results of research the naturally aspirated 6C107 and turbocharged 6CT107 spark ignited bus engine fuelled with natural gas (CNG or LNG). The natural gas engine parameters have been shown in comparison with diesel version of the engine. The paper includes information about natural gas engine modifications in particular modification shape of the combustion chamber, spark plugs seating and ignition system. The description of test stand is shown. The summary and conclusions end comparative analysis engine parameters.

1. Introduction

The 6CT107 engine has been produced by ANDORIA-MOT Company in Poland since 1967. Production has started on the basis of Leyland license. Initially this engine was produced as SW400 and constantly modernized. The current model of the engine is used as a modern driving unit for 8÷12 meters-long buses, combine-harvesters and generator units, pumping engines and building machines. Over 300 thousand engines have been produced for 25 years, included 20 naturally aspirated gas engines (LPG and CNG). These gas engines have been introduced in city buses and coaches, and they have covered over 10 million-kilometers distance since 1995. Currently new modernization has been started. It is connected with preparing series of production of turbocharged gas engine fuelled with natural gas stored in the liquid form (LNG).
Technical parameters of the engine fuelled with diesel oil are presented in the table below.

Table 1. Technical parameters of the diesel engines

Engines type / Parameters	6C107	6CT107
Design and arrangement	in-line engine, vertical	
Process	naturally aspirated	turbocharged and intercooled
Number of valves	2 per cylinder	
Combustion process	Diesel, 4-stroke, direct injection into the toroidal combustion chamber situated in the crown of the piston	
Displacement [liter]	6,54	
Bore x stroke [mm]	107,19 x 120,65	
Compression ratio	16,5	
Range of engine speed [rpm]	1000÷2600	
Diesel fuel injection system	in-line fuel injection pump with independent drive	
Cooling system	forced circulation water cooling	
Maximum horsepower [kW] at engine speed [rpm]	101,5/2600	125/2400
Peak torque [Nm] at engine speed [rpm]	423/1600	600/1600
Specific fuel consumption [g/kWh]	258	210
The intake manifold is located on the right side and the exhaust manifold on the left side of the cylinder head. So the engine modernization is possible, because there are not limitations by exhaust manifold (cooling system).		

The external characteristic of 6CT107 engine fuelled with diesel oil has been presented on the fig.1.

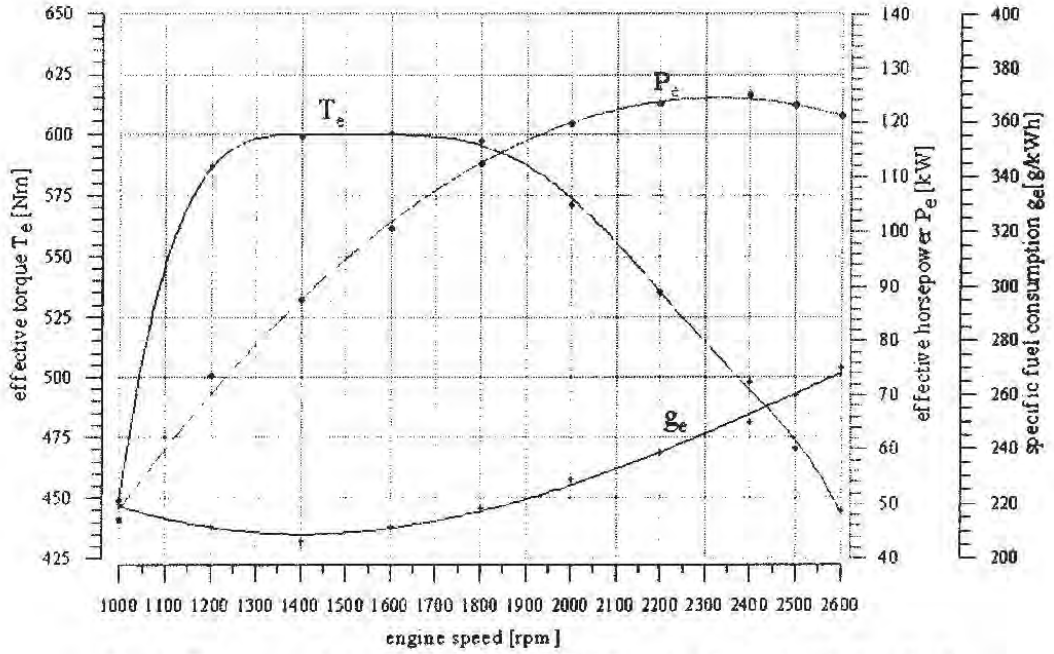

Fig. 1. The external characteristic of 6CT107 engine fuelled with diesel oil

2. The 6C(T)107 NG engine modifications

Researches of the engine fuelled with natural gas have been carried out for two engine types: naturally aspirated (6C107) and turbocharged (6CT107). The compression ratio was decreased from ε=16,5 to ε=11 and the shape of the combustion chamber was changed from toroidal to open type in the crown of the piston (fig.2) during preparing naturally aspirated engine fuelling with natural gas.

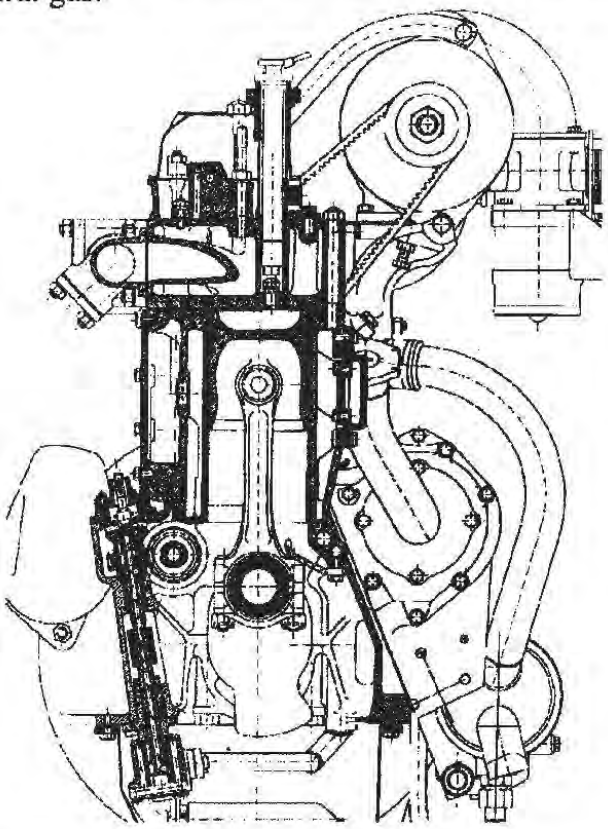

Fig. 2. The cross section through naturally aspirated 6C107 engine fuelled with natural gas.

The compression ratio ε=9,5 for turbocharged type of the engine has been selected by increasing combustion chamber capacity taken from naturally aspirated 6C107 NG engine. The spark plugs seating have been made in place of diesel oil injectors. The electronic high-energy ignition system made by NGV AUTOGAS has been used. Moreover, the new intake manifold has been worked out to make a possibility of using the gas mixer and the gas injection fuel system.

The cylinder head has been redesigned for mounting the sparking plug close to valves under the valve's cap. The new pilot sleeves have been used to isolate the spark plugs and ignition cables from moving parts of the cylinder head.

The ignition system with single coil per cylinder has been used. To accomplish research aims a special type with manual changing of the ignition timing advance has been used. But in production the integrated ignition system with a mixture ratio regulation system has been used. This integrated system relies on lambda sensor due to the 3-way catalyst converter in exhaust system. The microprocessor is the main part of the system. It reproduces the fuel charge and ignition timing advance from the map depending on the signal from the lambda sensor.

The engine cooling system has been increased because a medium working temperature has been increased, due to increasing capacity and surface of combustion chamber and decreasing compression ratio well, expansion ratio. The necessity of increasing the cooling efficiency was known from other operation researches of gas engines worked out on the basis of diesel units.

3. Tests stand description

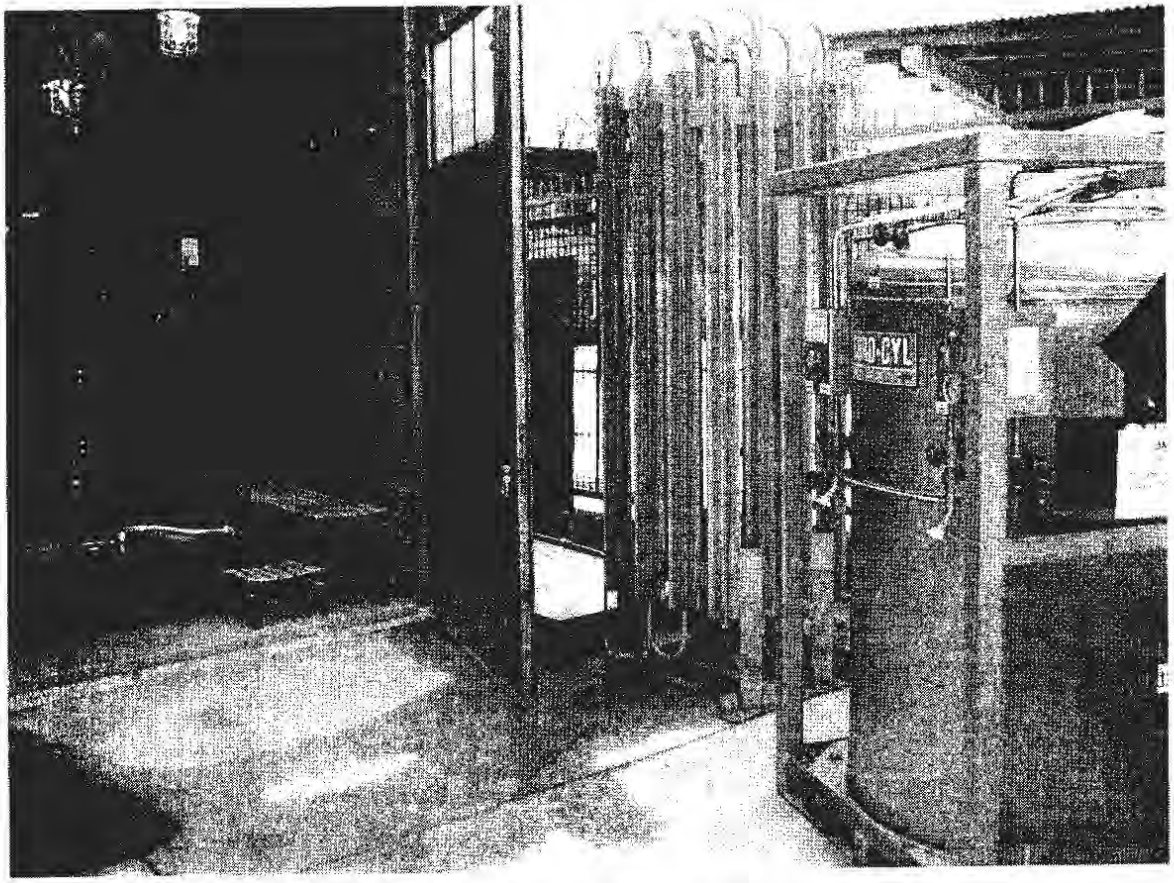

Fig. 3. The LNG fuel tak with the vaporizer

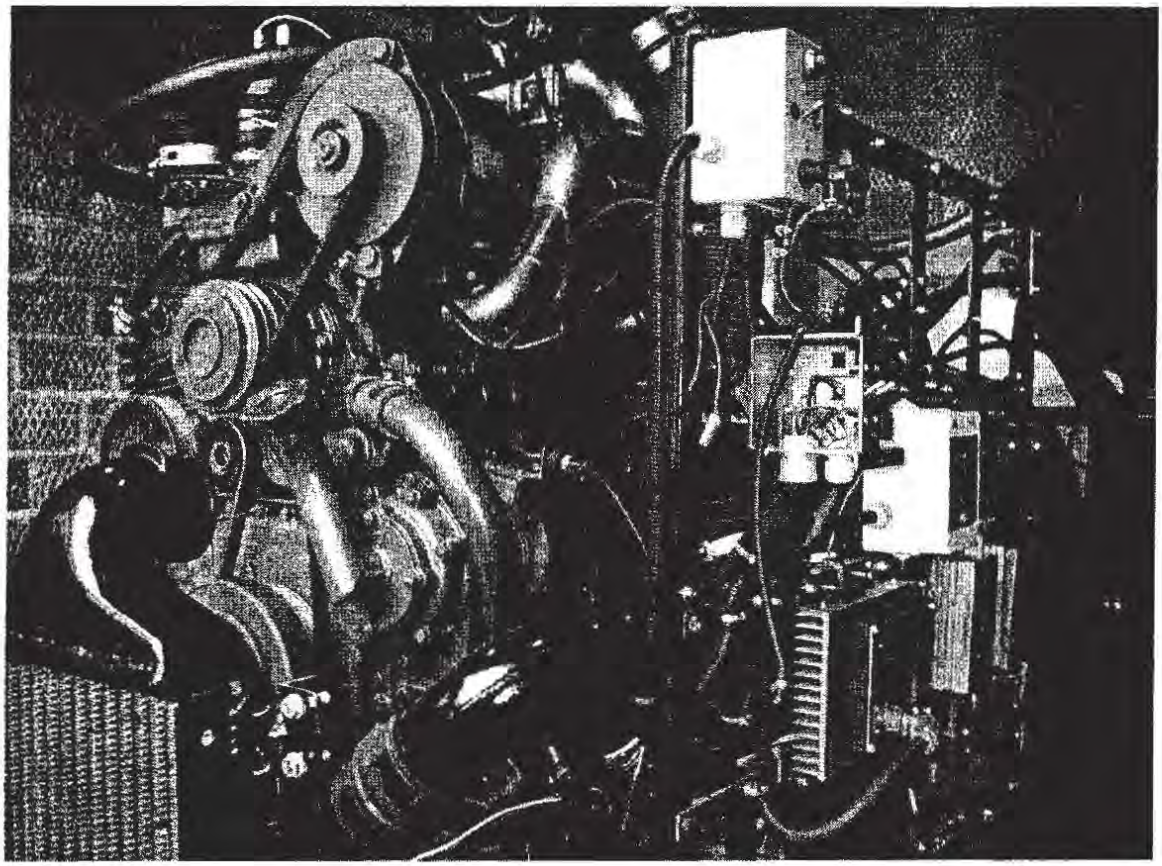

Fig. 4. The general view of the 6CT107NG engine

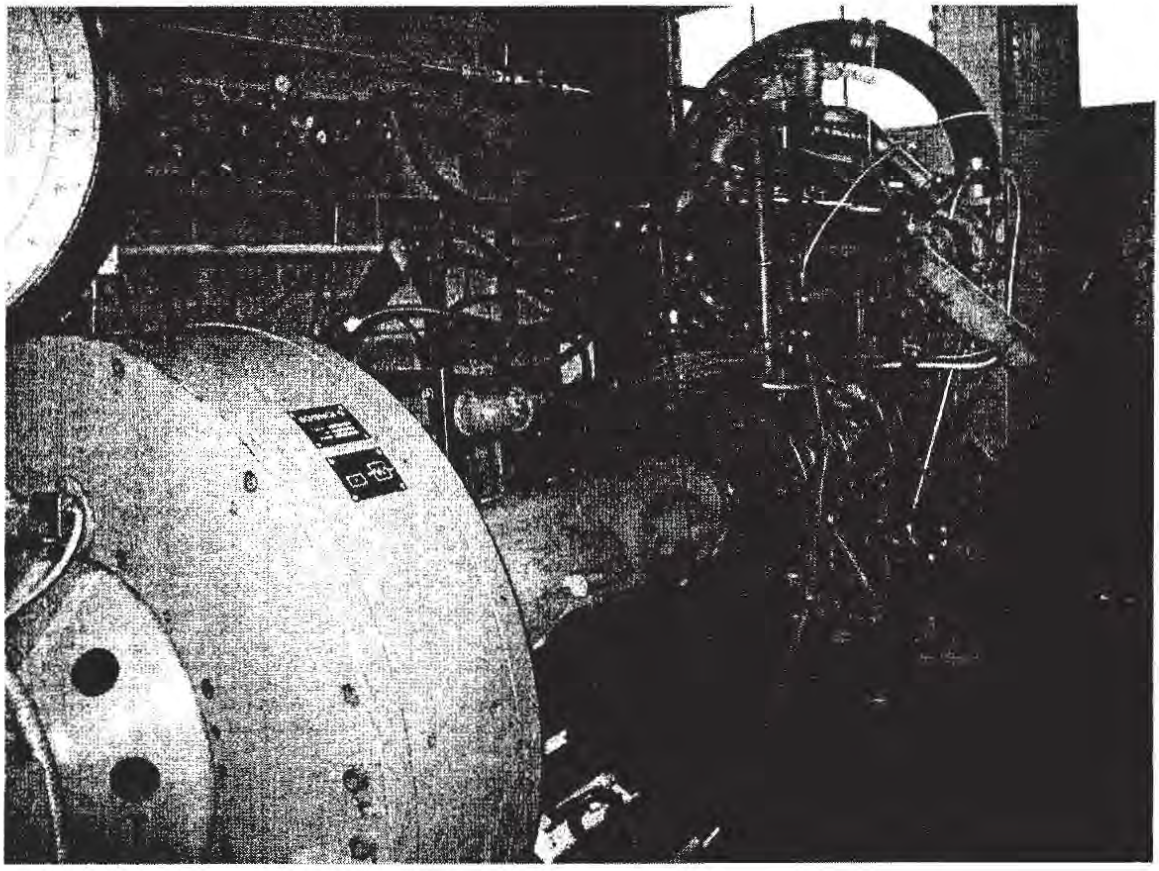

Fig. 5. The general viwe of the test stand

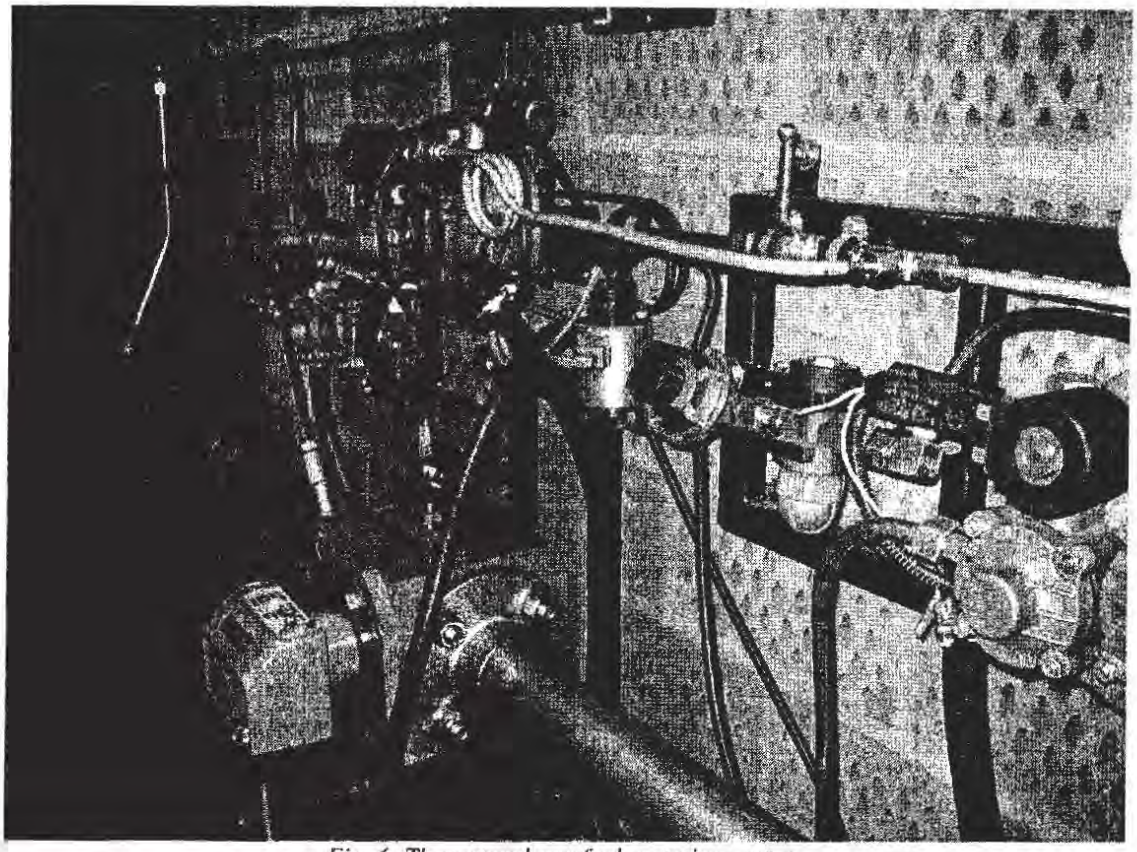

Fig. 6. The natural gas fuel metering system

4. Aim and course of the researches

The production version 6CT107 engine fuelled with natural gas for city bus and mini bus was the main aim of the work.

This paper contains comparative analysis of 6C(T)107 NG engine parameters for naturally aspirated and turbocharged versions (CNG and LNG). A lot of control characteristics have been made to optimize effective parameters of the engine in point of view pollution exhaust gases before basic researches. The naturally aspirated 6C107 NG engine has been the object of the first stage of basic researches. The external characteristic of this engine has been presented on the fig.9 and universal characteristic on the fig.7.

Much better parameters have been accomplished by turbocharged 6CT107 NG engine. The external characteristic of this engine has been presented on the fig.10 and universal characteristic on the fig.8.

Table 2. Technical parameters of the natural gas engines

Engine type / Parameters	6C107 NG	6CT107 NG
Process	naturally aspirated, stoichiometric combustion	turbocharged, stoichiometric combustion
Compression ratio	11	9,5
Range of engine speed [rpm]	900÷2500	
Maximum horsepower [kW] at engine speed [rpm]	88/2500	160/2300
Peak torque [Nm] at engine speed [rpm]	373/1650	780/1700
Specific fuel consumption [g/kWh]	233	209
Peak total efficiency [%]	31,6	35,3

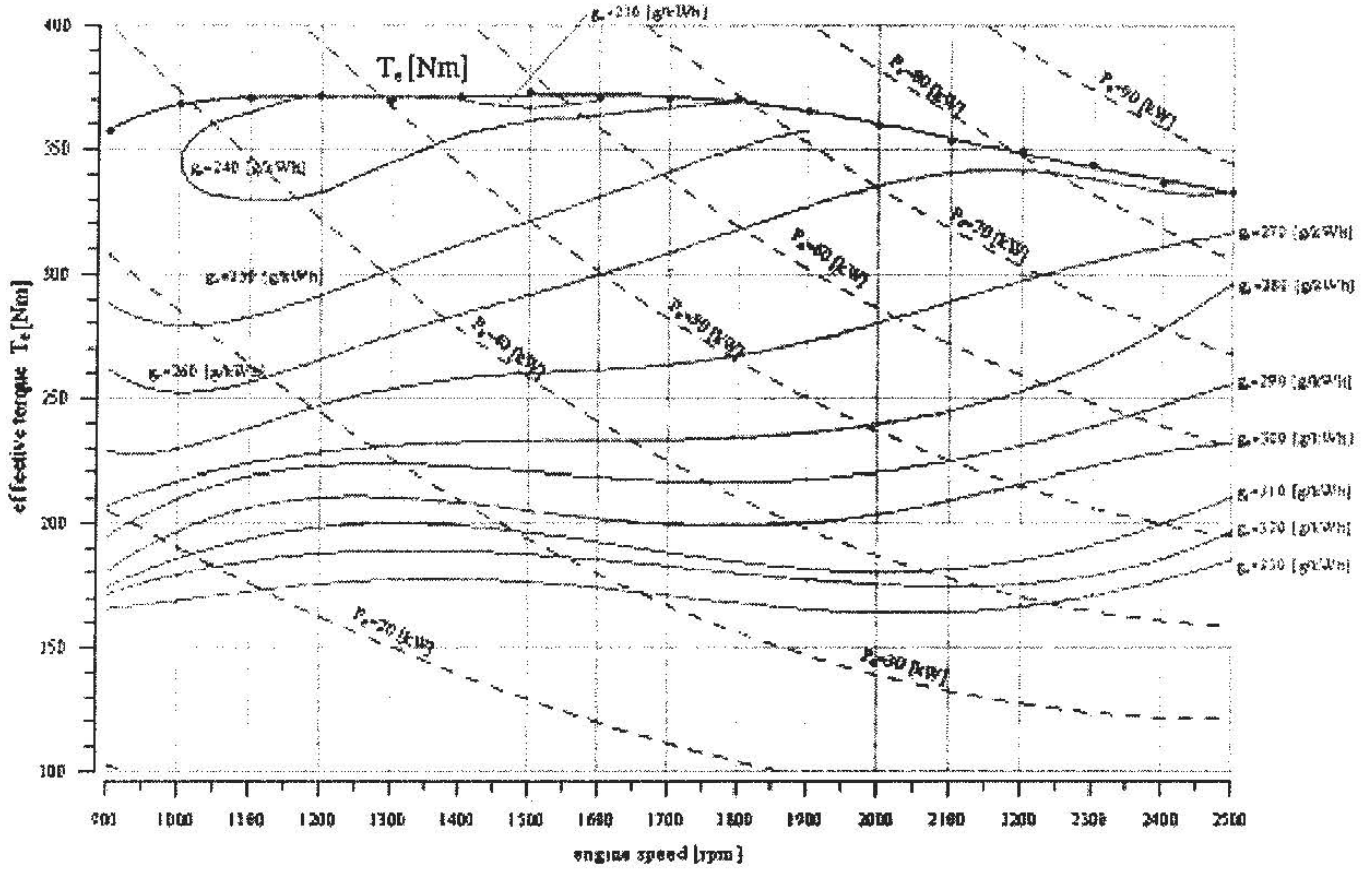

Fig. 7. The universal characteristic of constant specific fuel consumption of naturally apirated 6C107 NG engine

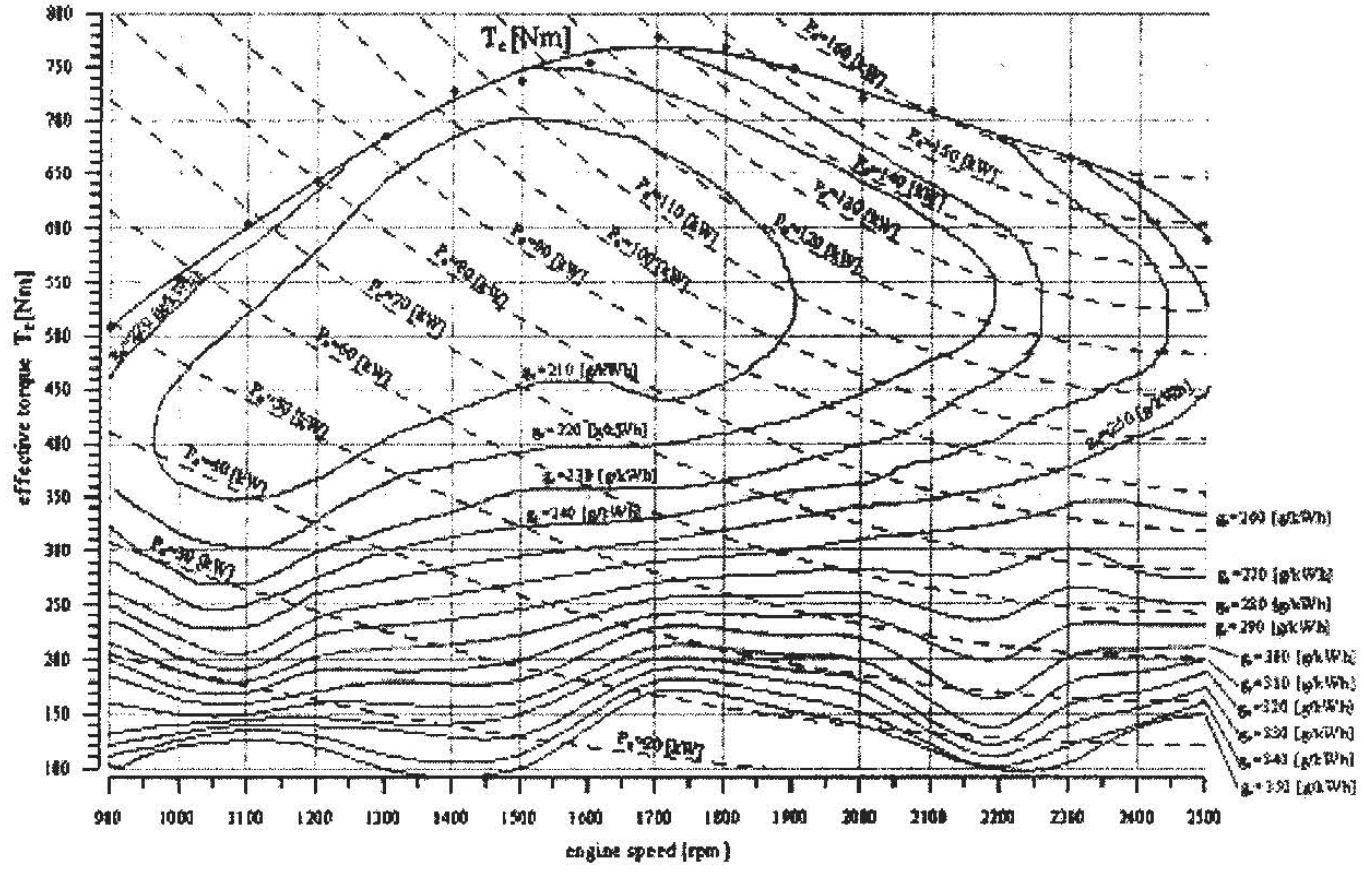

Fig. 8. The universal characteristic of constant specific fuel consumption of turbocharged 6CT107 NG engine

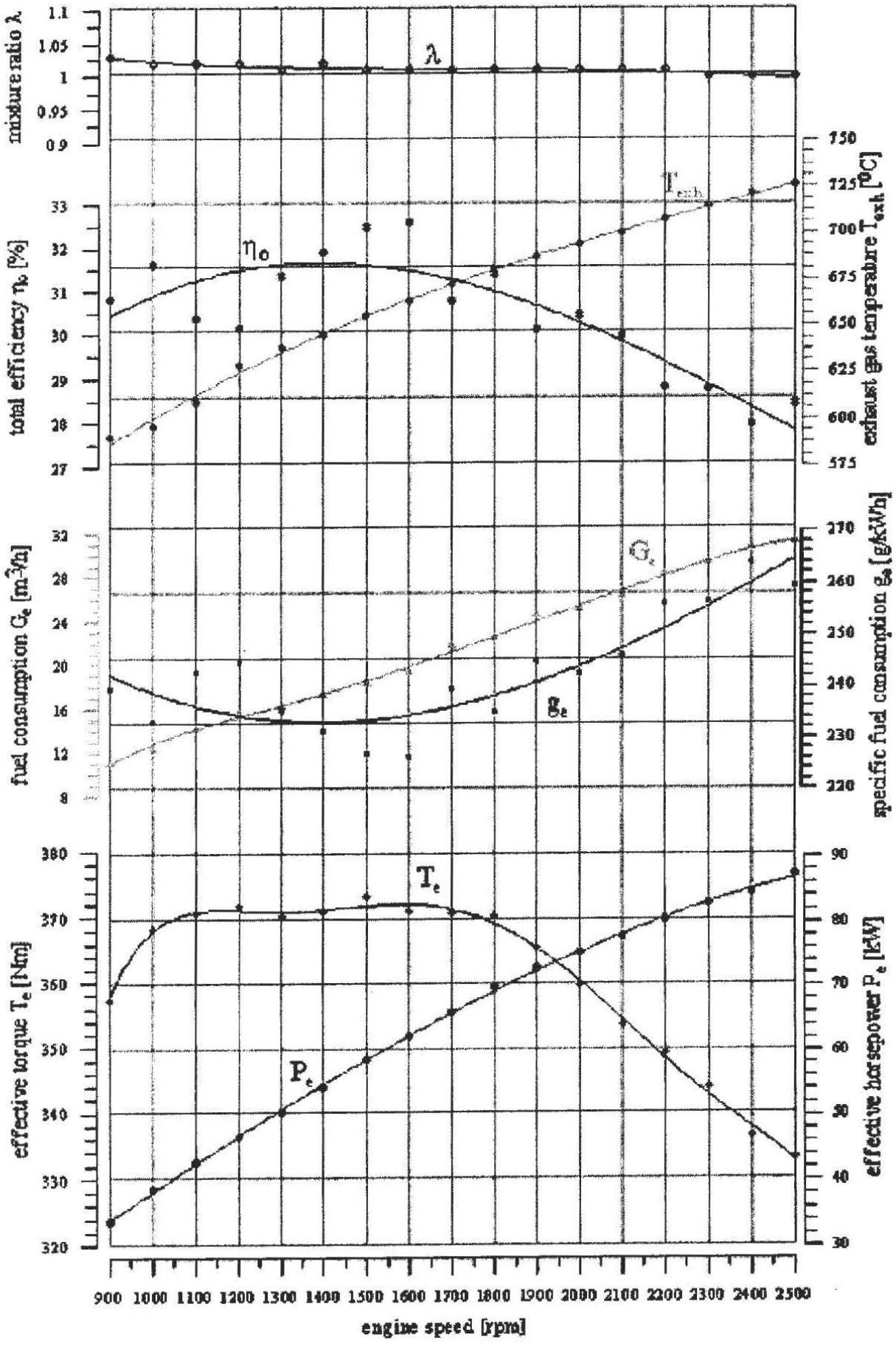

Fig. 9. The external characteristic of naturally apirated 6C107 NG engine

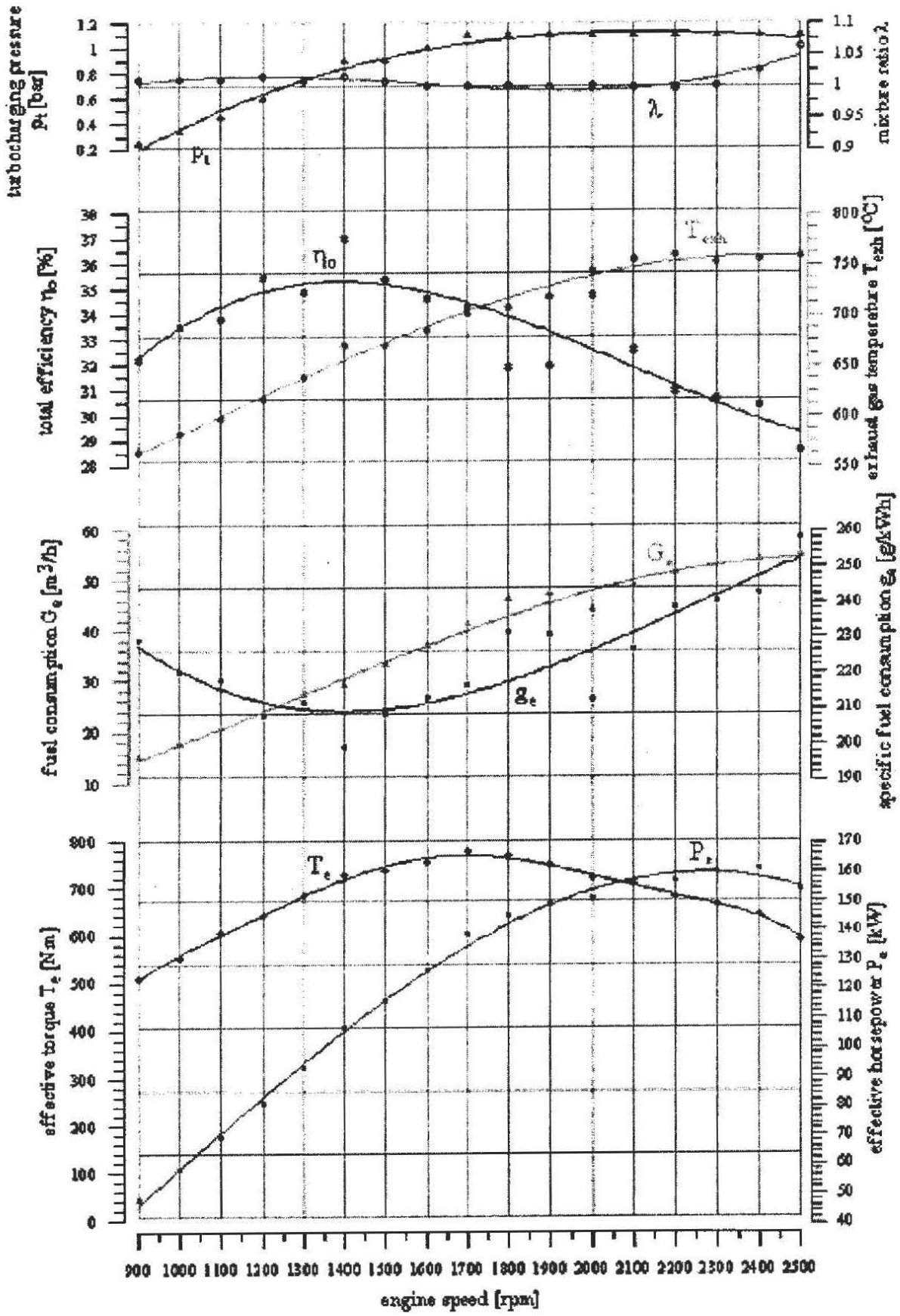

Fig. 10 . The external characteristic of turbocharged 6CT107 NG engine

5. Results of researches

Results of research should be recognizing as a very good. The turbocharged 6CT107 NG engine accomplishes almost twice as many of effective torque in all of engine speed range. The effective horsepower is much higher than for naturally aspirated type of the engine. Peak effective horsepower for turbocharged type is about 80% higher than for naturally aspirated. This increase is very surprising. The curve of volumetric efficiency can help to understand the increasing of effective horsepower (fig.11).

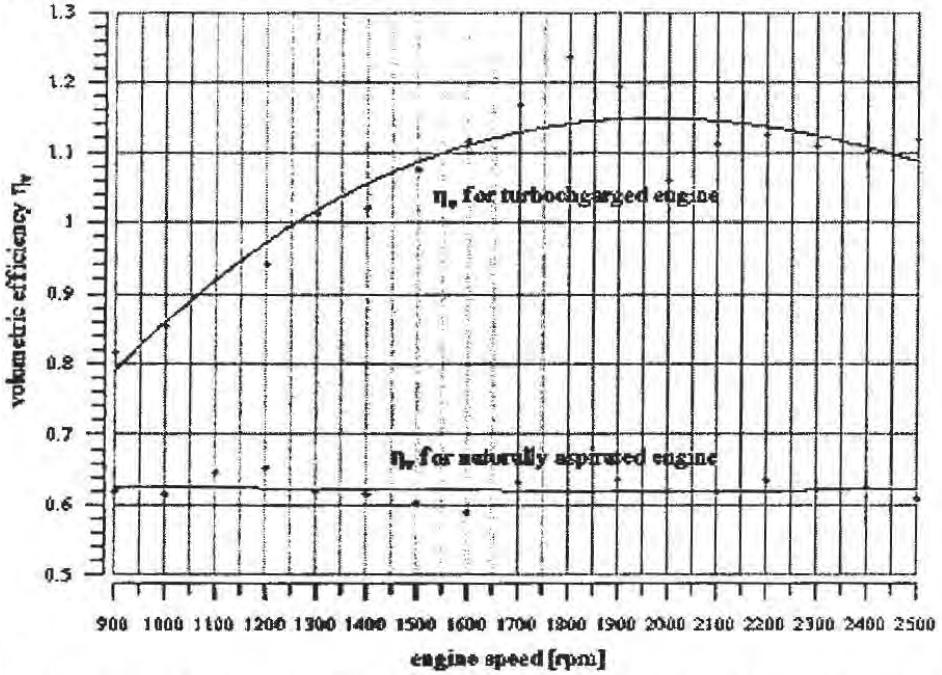

Fig. 11. The curves of volumetric efficiency for naturally aspirated and turbocharged 6C(T)107 NG engine

The volumetric efficiency accomplishes value about 0,6 in all of engine speed range for naturally aspirated engine. We can see that for turbocharged type of engine the volumetric efficiency accomplishes value 0,8 at 900 rpm and 1,15 at 1650÷2300 engine speed range. When the engine was fuelling with strongly cooled natural gas (LNG), temperature of the air-gas mixture before intake valve was lower about 25÷30°C with realtion to fuelling with compressed natural gas (CNG). It allowed to accomplisch adequate increase the effective engine parametres.

6. Conclusions

The researches have allowed working out the modern NG engine, witch will be used in city buses. The next part of the study will be presented results from the traction researches of buses equipped with 6CT107 engines fuelled with CNG and LNG. The results will presented performance and pollution exhaust gases.

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