POSSIBILITIES OF USING VARIABLE GEOMETRY TURBOCHARGER WITH DIESEL ENGINE ANDORIA 4CT107

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Abstract

Internal combustion engine is reaching perfection now. Nowadays, there is no sensible competition for it. Modern engines are facing new ecological restrictions, and also are more and more user friendly.

For engine constructors the most important is to improve thermal efficiency of engines. Better efficiency means less consumption of fuel and less emission. When we look at energetic balance of engine, we can see, that 30÷40% of total energy of fuel is wasted in exhaust [6]. This is the reason, why turbochargers are becoming very popular.

1. Structure and operation

Turbocharger is composed of an exhaust gas driven turbine and a radial air compressor mounted at opposite ends of a common shaft and enclosed in cast housings. The compressor and turbine housings are attached to a center housing, in which is enclosed and supported the shaft. The turbine is usually centripetal, radial- or mixed-inflow device, while the compressor is centrifugal or radial-outflow device. In center housing there are precise bearings and oil seals which are working properly when the shaft rotates and oil pressure rises [4].

Exhaust gases are directed through the exhaust manifold into the turbine housing, where its pressure and heat energy drives the turbine wheel. Fresh air goes through filtration system into compressor housing in which it flows centrally, past the compressor wheel blades, and exits at the outer diameter of housing. The compressor is driven by the turbine.

In traditional turbochargers part of exhaust gases passes by the turbine through a wastegate controlled by pressure actuator connected with turbine output. Only during accelerating, when boost pressure level decreases, wastegate is closed and all exhaust gases goes through turbine.

In Variable Geometry Turbocharger (VGT) there is a possibility to adjust gas cross section at the inlet of the turbine wheel and thanks that to adjust turbine power at various loads. At low engine speed and small gas flow, the gas cross section is reduced, and the gas speed rises, so the turbine power rises too. It helps to keep high boost pressure level and high engine torque. At full engine speed and/or load the gas cross section is increased and despite of high gas flow, its speed is relatively low to avoid turbocharger overspeed and to keep the boost pressure level required by engine. Variable geometry of the turbine nozzle can be adjusted by a mobile multivane system composed of a number of vanes which pivot on their axis or by a mobile nozzle piston system [2]. The gas cross section can be controlled directly by the compressor using pressure actuator, or by the engine management system using vacuum actuator. The latest innovation in controlling VGT is electric actuator which has been developed by Garrett since early 1990s. This device is called REA (rotary electric actuator) and is much more precise than any pneumatic actuator. Thanks that, engine controlling unit

has direct control over the boost pressure, turbocharger speed and vane position. Engine equipped with precisely controlled turbocharger responds quickly and has low emission.

2. Turbocharger selection

Turbocharger must strictly match engine to which is attached. Amount of air volume required by the engine results from power output need. Most of the data comes off the engine construction. The compressor can be selected when required pressure and volume of the boosting air is known. Then must be selected the turbine power and size. Selecting the size and weight of compressor and turbine wheels is very important because of its inertia. Small size turbochargers respond quicker but at full engine load their output can be inadequate. Big size turbochargers can't work properly at low engine speed, because exhaust gas pressure level is too low, but at full engine speed they can keep the boost pressure level required by engine. Moreover, turbine and compressor wheel and shaft of big turbocharger accelerate slowly causing poor engine and vehicle acceleration.

Results of calculations must be compared with turbochargers characteristics and then the engine should be checked on a test bed with few types of turbochargers attached.

Selecting and testing VGT is more complicated, because there is another adjustable parameter – gas cross section at the inlet of turbine. Fortunately VGT covers wider range of engines.

Results of test bed investigation, performed under supervision of prof. Jerzy Jaskólski on diesel engine 4CT107 in Cracow University of Technology, shows that incorrectly matched turbocharger can worsen the engine characteristics. The scope of tests was to determine, whether the engine, equipped with different types of turbochargers, could meet requirements of EURO III (emission norm).

Firstly, there was taken an outside characteristic of the engine without changes. This characteristic is shown on fig. 1.

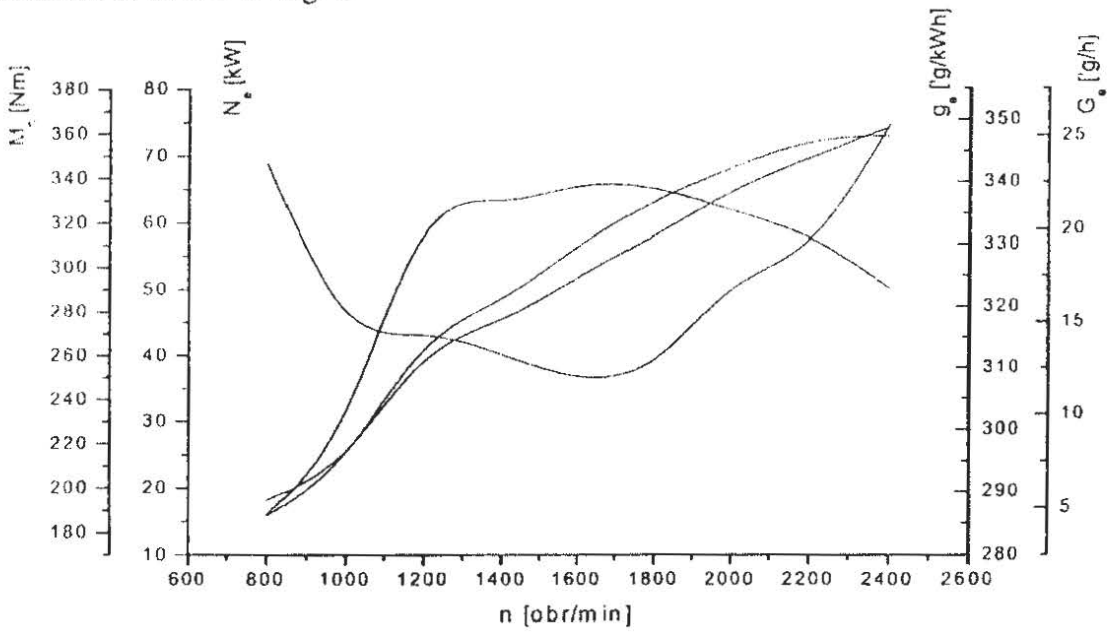

Fig. 1. The speed characteristic of 4CT107 engine

Then the engine was equipped with variable geometry turbocharger – Garrett TF2 and after that with another turbocharger – Garrett GT35. Results of these tests are shown on fig. 2 and 3.

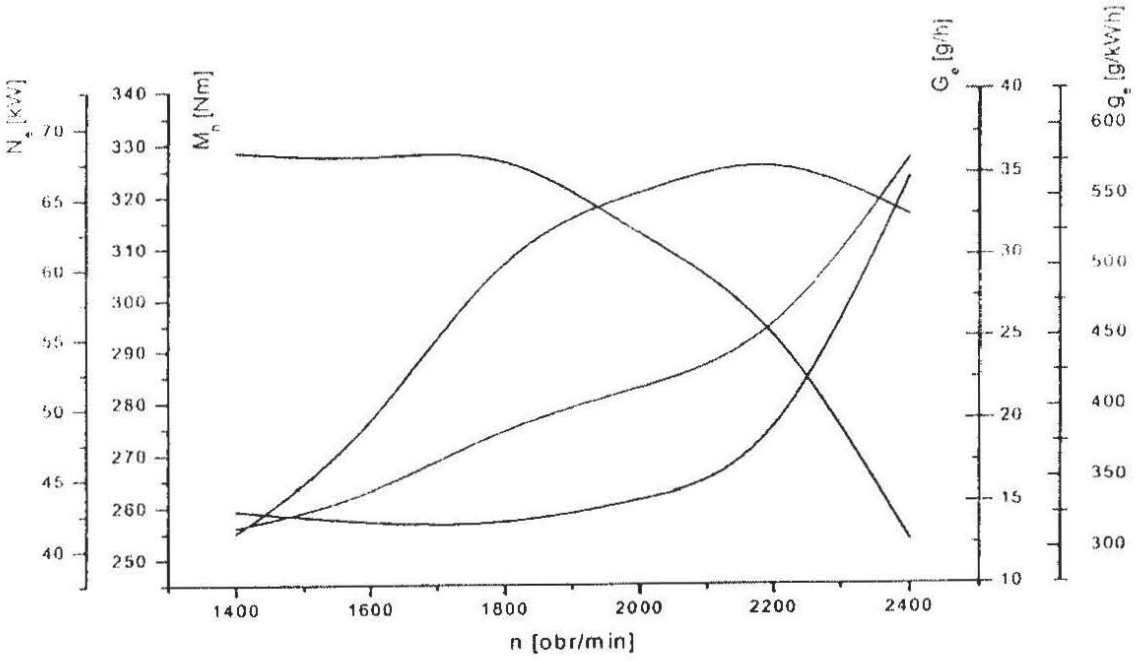

Fig. 2. The characteristic of 4CT107 engine with Garrett TF2 turbocharger

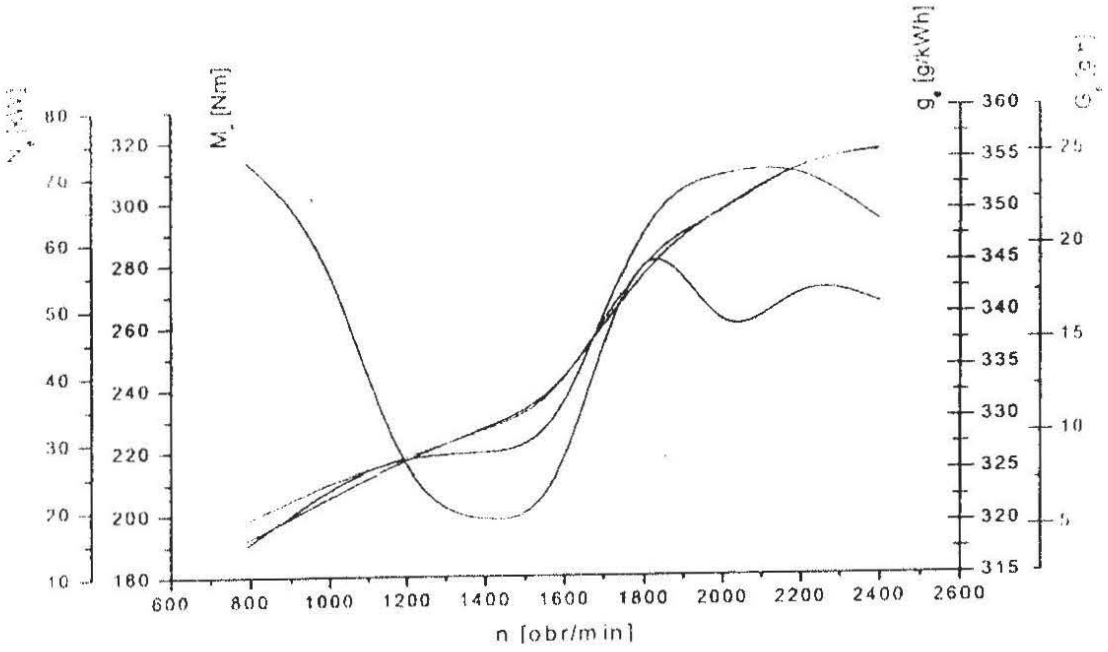

Fig. 3. The characteristic of 4CT107 engine with Garrett GT35 turbocharger

The most important conclusion from those tests is, that engine with improperly matched variable geometry turbocharger can have much worse output than the one with properly selected traditional turbocharger. Another conclusion is that not only VGT, but also variable geometry control device must properly fit engine.

4CT107 engine was later tested with better matching VGT equipped with modified actuator. Results of this test are shown at figure 4.

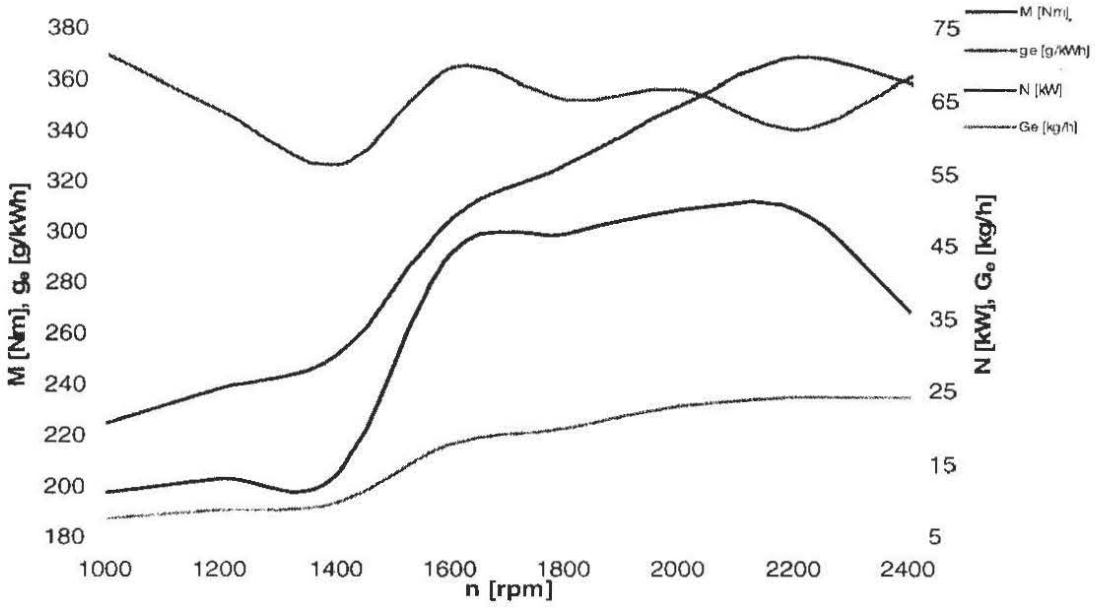

Fig. 4. The characteristic of 4CT107 engine with Garrett turbocharger

It's not easy to find turbocharger that will perfectly match engine. Usually turbocharger is selected by compromise between engine torque characteristic in usable range of engine speed and maximum power. It is also very important to take under consideration emission of pollutants and fuel consumption.

3. Future of turbochargers

Turbochargers are becoming standard in many types of engines. All modern diesel engines are equipped with turbochargers. Also turbocharged gasoline engines came from motor sport into serial production.

The most important advantage of turbocharger is using of exhaust gases power. In naturally aspirated engines, this energy is wasted.

Thanks to electronic control units, turbocharged engines (especially equipped with VGT) are powerful, economic and user friendly.

From the user's point of view, the most important imperfection of turbocharged engine is slow reaction during accelerating called 'turbo lag". Its severity depends on engine and turbocharger size and sometimes is fairly inconvenient.

But there are new conceptions of electrically assisted turbochargers (which also may have variable geometry), that should eliminate most of turbochargers weaknesses and also have some new advantages [1]. The electric assisted turbocharger consists of typical compressor and turbine and electric engine placed in the medium of turbocharger shaft. This engine can also work as a generator. During acceleration, electric engine drives turbocharger shaft and thanks that, boost pressure is adequate since the lowest engine speed. When engine is running at full speed/load the same engine retards turbocharger shaft ensuring not too high boost pressure. When electric engine drives turbocharger, it takes energy from vehicle battery, when this engine works as a generator it can load the battery back. Electric assist turbocharger is perfect solution for hybrid vehicles [3].

Now there are still technological problems in electric turbo development. Especially construction of electrical, brushless engine, which can immediately reach about 50 000 rpm and work in high temperature and voltage of vehicle electrical installation must be solved [5].

Probably in future, until something better will replace it, all internal combustion engines will be equipped with turbochargers.

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