TURBOCHARGING OF NATURALLY ASPIRATED SPARK IGNITION ENGINE WITHOUT MODIFICATION OF A COMPRESSION RATIO

Bronisław Sendyka*, Jan Filipczyk, Marcin Noga*, Marcin Kula***

**Section of Special Engine*
Faculty of Mechanical Engineering
Cracow University of Technology
Al. Jana Pawła II 37, 31-864 Krakow, Poland

***Chair of Automobile Exploitation*
Faculty of Transport, Silesia University of Technology
Krasińskiego 8, 40-019 Katowice
e-mail: Jan.Filipczyk@polsl.pl

Abstract

The objective of research was to determine total efficiency and performance of turbocharged small displacement SI engine without modifying engine control unit. The engine used during the investigation was Toyota yaris 1296 cm3 displacement SI engine with modified intake manifold. There was variable and fixed geometry turbocharger mounted in the exhaust system. Inlet air pressure was controlled by introducing a waste gate valve. Specific values of maximum boost pressure were obtained thanks to implementation of different valve springs. The outcome of investigation shows that there is a possibility of introducing turbocharger without modification of intake system and engine's control unit. Implementation of turbocharger with variable turbine geometry and waste gate valve controlling maximum boost pressure permits significant improvement in torque characteristic without exceeding permissible harmful exhaust gases emissions. Change of waste gate valve spring's characteristic allowed reaching higher torque and making its value constant in wide range of engine's rotational speed.

Change of waste gate characteristic permitted to achieve advantageous torque characteristic, maximum torque rise and its constant value in wide range of engine's speed.

Keywords: *transport, combustion engines, turbocharging*

1. Introduction

State of the art turbocharging of SI engine is using fixed geometry turbochargers. One of the few examples of variable turbine geometry in SI engine is Porsche's recently released engine.

Important question is possibility of turbocharging already existing, naturally aspirated engine without decreasing compression ratio and modifying engine's control system.

Innovative technical solutions of variable geometry turbochargers and research work over turbocharging simulation indicate that mentioned above solutions will accommodate in SI engine's area. Paper contains comparison between variable and fixed turbine geometry turbocharging system introduced into medium displacement engine.

2. Intake and exhaust system modification

The object of investigation was Toyota Yaris SI engine with displacement of 1296 cm^3. In order to introduce turbocharging, intake and exhaust system was widely modified. It was necessary to change length of intake ducts to achieve successful adaptation of turbocharger instrumentation. Fig.1 presents block diagram of mentioned turbocharging system.

In variable geometry turbocharger's system there was additional device (waste gate valve)

allowing controlling mass flow of exhaust gases heading towards turbine (fig. 2). Regulation of boost pressure was possible thanks to application of valve springs with different characteristics.

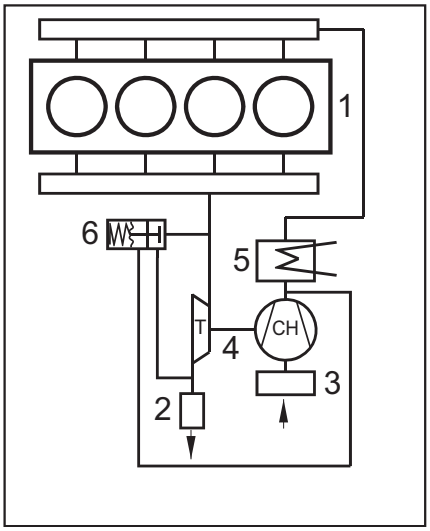


Fig. 1. Variable geometry turbocharger system's scheme, 1 – engine, 2 – catalytic converter, 3 – air filter, 4 – turbocharger, 5 – air cooler, 6 – waste gate valve

3. Results of investigation

Values of torque *Mo*, power *N*, fuel consumption *Ge*, air-flow mass *mpd*, air temperature *tpd*, intake manifold air pressure *ppd*, CO, CO2, HC emission and air to fuel ratio λ were measured during engine's test. Engine's coolant and turbine temperature, as well as ignition advance angle were important values to be controlled. In specific condition of engine's run when the throttle was slightly opened and rotational speed wasn't exceeding 2000 [rpm] the highest value of torque was achieved with use of variable geometry turbocharger followed by maximum boost pressure limited to 0.5 bar (fig. 2). This system in the range of 2000 to 4000 [rpm] was close with its performance to fixed geometry turbocharger's system, which results to be competitive only above 4000 [rpm].

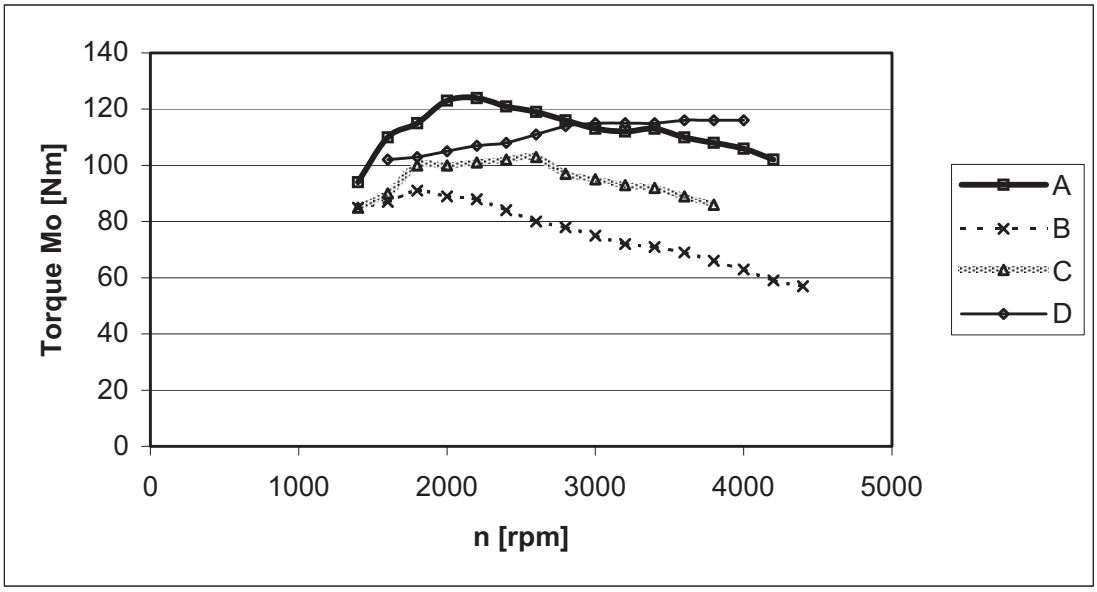


Fig. 2.Torque characteristic for 27o of throttle opening angle, A –variable geometry turbocharger's system with boost pressure 0.5 bar, B –naturally aspirated engine , C – variable geometry turbocharge's system with boost pressure 0.25 bar, D –fixed geometry turbocharger

Both systems reach higher values of torque, significantly improving engine's characteristic. The same effect can be easily observed when the throttle opening angle is considerably increased.

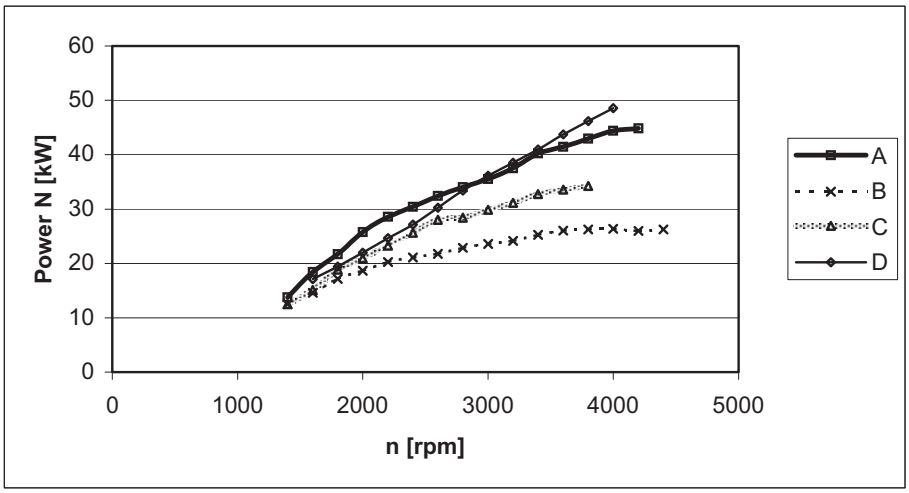


Fig. 3. Power characteristic for 27o of throttle opening angle, A –variable geometry turbocharger's system with boost pressure 0.5 bar, B –naturally aspirated engine , C – variable geometry turbocharger's system with boost pressure 0.25 bar, D –fixed geometry turbocharger

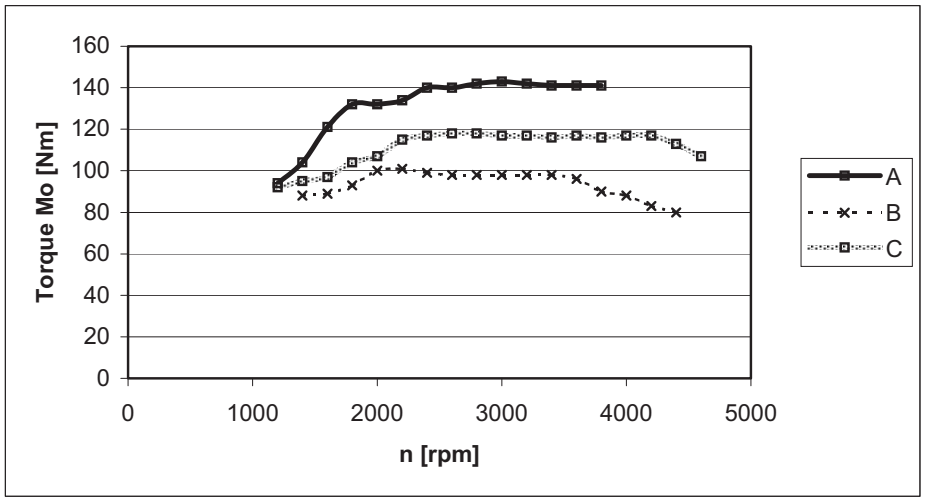


Fig. 4. Torque characteristic for 75o of throttle opening angle, A –variable geometry turbocharger's system with boost pressure 0.5 bar, B –naturally aspirated engine , C – variable geometry turbocharge's system with boost pressure 0.25 bar

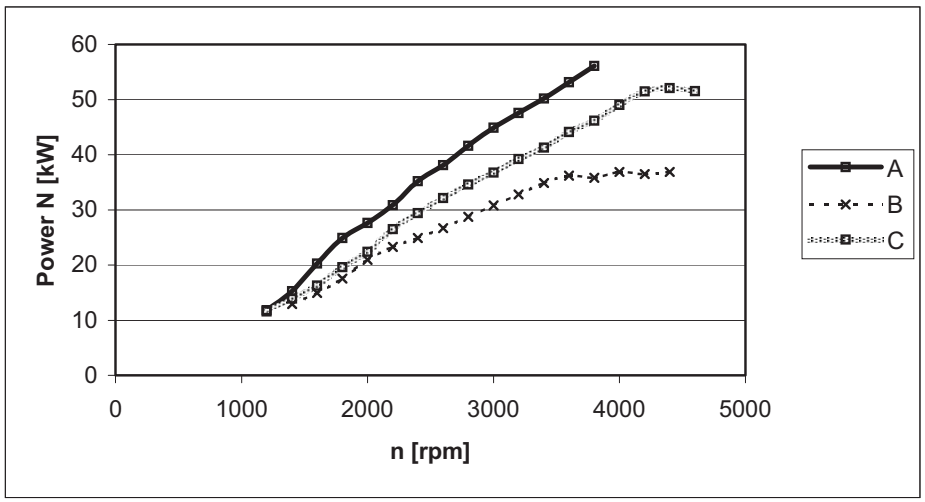
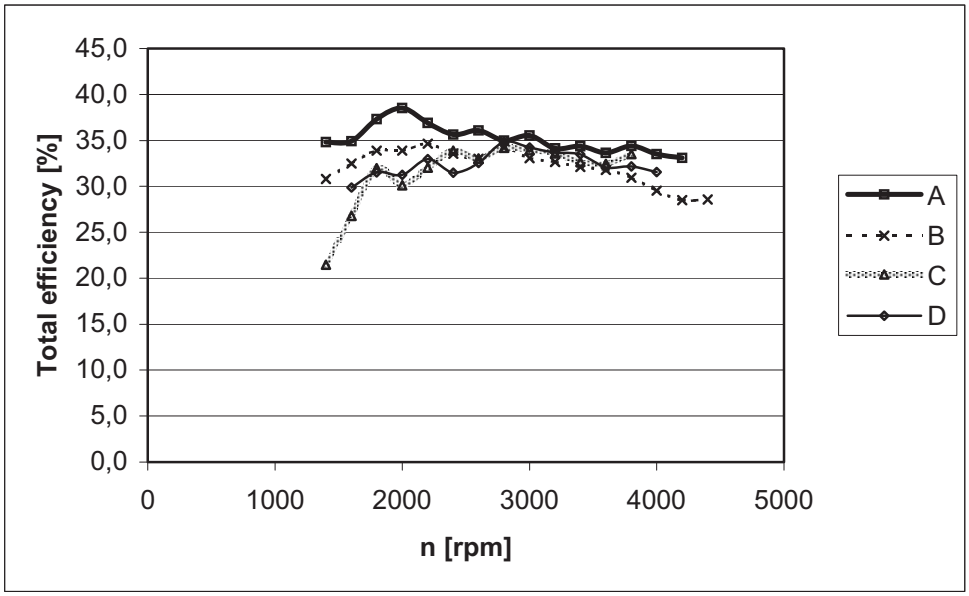


Fig. 5. Power characteristic for 75o of throttle opening angle, A –variable geometry turbocharger's system with boost pressure 0.5 bar, B –naturally aspirated engine , C – variable geometry turbocharge's system with boost pressure 0.25 bar

For variable geometry turbocharger's systems values of torque were high and rather constant in wide range of engine's rotational speed and power curve was characterized by stable growth (fig. 5).

In case of fixed geometry turbochargers systems stable work of the engine was possible to achieve only with small throttle openings. With speed above 2600 rpm, when throttle opening angle reached 350, to high boost pressure was starting to produce unstable engine's run due to excessively lean mixture entering the cylinder. For variable geometry turbocharger system with maximum boost pressure 0.5 bar, stable run of engine was achieved up to 3800 rpm. When taking into consideration engine's total efficiency and torque characteristic (fig. 6 and 7) we can see that variable geometry turbocharger's system seems to be the most effective.



Rys.6. Engine's total efficiency for 27o of throttle opening angle, A –variable geometry turbocharger's system with boost pressure 0.5 bar, B –naturally aspirated engine , C – variable geometry turbocharge's system with boost pressure 0.25 bar, D –fixed geometry turbocharger

Variable geometry turbocharger's system with higher boost pressure is an advantage when the throttle is slightly opened and engine runs with low and medium rotational speed (fig. 6). When the throttle opening is increasing difference between systems is no longer of that importance (fig. 7).

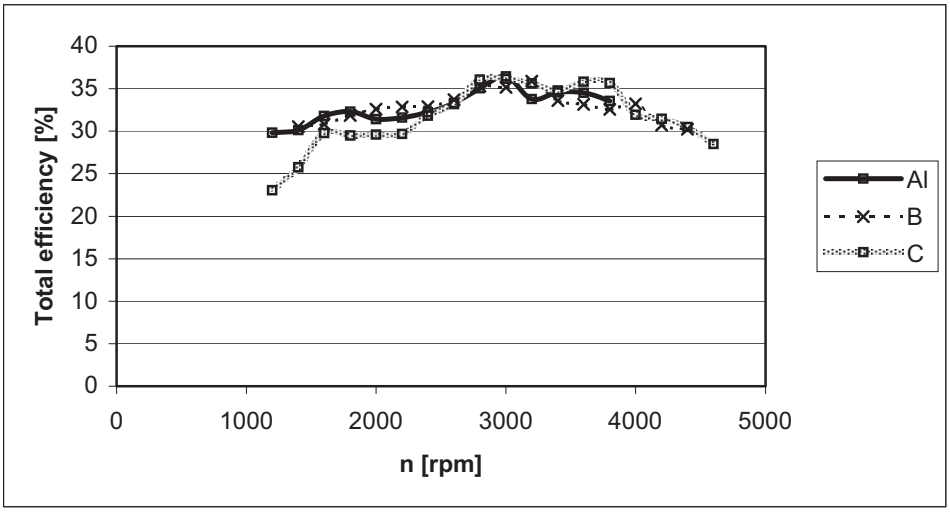


Fig. 7. Engine's total efficiency for 75o of throttle opening angle, A –variable geometry turbocharger's system with boost pressure 0.5 bar, B –naturally aspirated engine , C – variable geometry turbocharge's system with boost pressure 0.25 bar

In conditions of full throttle opening and higher engine's rotational speed there is a need to reduce boost pressure with use of waste gate with regulated characteristic.

4. Conclusions

Tests performed on Toyota's engine showed possibility of introducing turbocharging without modification of existing engine. Variable geometry turbocharger's system with proper maximum boost pressure, regulated by a waste gate, allows improving torque characteristic without exceeding permissible toxic exhaust gases emissions. Change of waste gate characteristic permitted to achieve advantageous torque characteristic, maximum torque rise and its constant value in wide range of engine's speed.

References

[1] Westin, F., *Simulation of turbocharged SI-engines – with focus on the turbine, Doctoral thesis*, KTH School of Industrial Engineering and Management, Royal Institute of Technology Stockholm, 2005.

[2] Gabriel, H., Schmitt, F., Weber, M., Lingenauber, R., Schmalzi, H-P., *Neue Erkenntnisse bei der variablen Turbinen- und Verdichtergeometrie fur die Anwendung in Turboladern fur Pkw-Motoren*, BorgWarner Turbo Systems Academy, 2000.