INVESTIGATION ON GASOLINE ENGINE CHARACTERISTICS WITH SINGLE ENTRY AND TWIN ENTRY TURBINE [1]

M. Eng. Emil Mitev, PhD Student
Department of Engines and Vehicles
University of Ruse "Angel Kanchev"
Tel.: +359 89 494 9777
E-mail: emitev@uni-ruse.bg

Assoc. Prof. Simeon Iliev, PhD
Department of Engines and Vehicles,
University of Ruse "Angel Kanchev"
Tel.: +359 82 888 331
E-mail: spi@uni-ruse.bg

Abstract: *Modelling and study of power and exhaust emission characteristics of a turbocharged gasoline engine with one and two turbine entrances is presented in this paper. A one-dimensional analysis using AVL "Boost" software was performed in the study. The model was designed considering the parameters of the engine and turbocharger, based on an Audi TT 1.8 SI gasoline engine with turbocharger with one and two turbine entrance. The study focuses on comparing engine performance with turbochargers with one and two turbine entrance in terms of torque, rotation speed and compressor efficiency at low engine speeds in the 1000-4000 min^{-1} range. This study shows the potential benefits of introducing a twin entry turbocharger.*

Keywords: *Twin entry turbine, Single entry turbine, AVL Boost, Gasoline engine*

INTRODUCTION

Turbochargers improve engine power and torque without increasing the volume of cylinders. However, the turbine has slower reaction at low engine speeds in 1000-4000 min^{-1} range. There are different solutions to this problem, such as variable geometry turbochargers, two-stage turbochargers and various combined methods. In one of the studies (Arnold D., 2004) it is noted that at a small angle of the blades in the turbine housing and at low engine speeds the exhaust flow to the impeller increases, thus increasing the productivity of the compressor. In another study (Hawley J., Wallace F., Cox A., Horrocks R. & Bird G., 1999) to overcome slow turbine reaction at low engine speeds, the turbocharger is coupled to a transmission that directly is connected to the crankshaft of the engine. This allows the turbocharger to act as a compressor at lower rpm. Another method (Chadwell C.J. and Walls M., 2010) to overcome the slow turbine reaction is the use of two turbochargers for low and high pressure, running in series.

EXPOSITION

One method that is not fully explored is the use of a twin entry turbocharger. These turbochargers are known as turbochargers with impulse turbines. They can improve the turbine response at lower engine speed, mainly due to a split-pulse manifold, thus avoiding the interaction between the various exhaust gasses pulses in the collector and improving the transmission of energy from the exhaust gas to the turbine impeller. This improves turbine performance. In Fig. 1 is shown a turbocharger with single entry turbine and in Fig. 2 is shown a twin entry turbocharger.

[1] The report was presented at a student scientific session on May 27, 2019, with an original title in Bulgarian: ИЗСЛЕДВАНЕ ХАРАКТЕРИСТИКИТЕ НА ДВИГАТЕЛ С ПРИНУДИТЕЛНО ВЪЗПЛАМЕНЯВАНЕ, С ЕДИН И ДВА ВХОДА НА ТУРБИНАТА

Twin entry turbochargers are already being used in high-power engines, but research on smaller power engines is still insufficient (Aghaali, H & Hajilouy Benisi, Ali., 2008). Therefore, more research is needed to see the benefits of using this type of turbocharger.

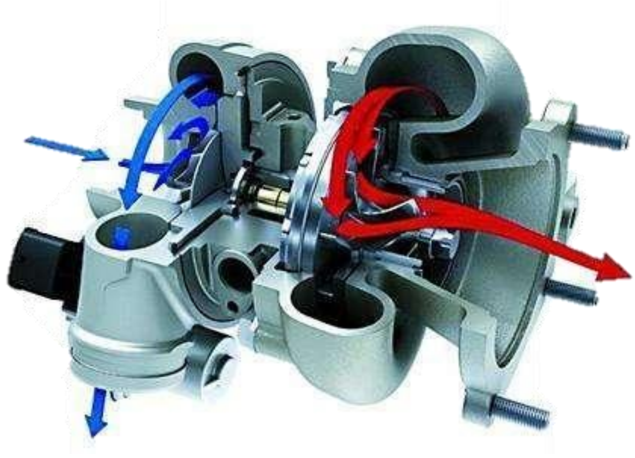

Fig. 1. Turbocharger with single entry turbine

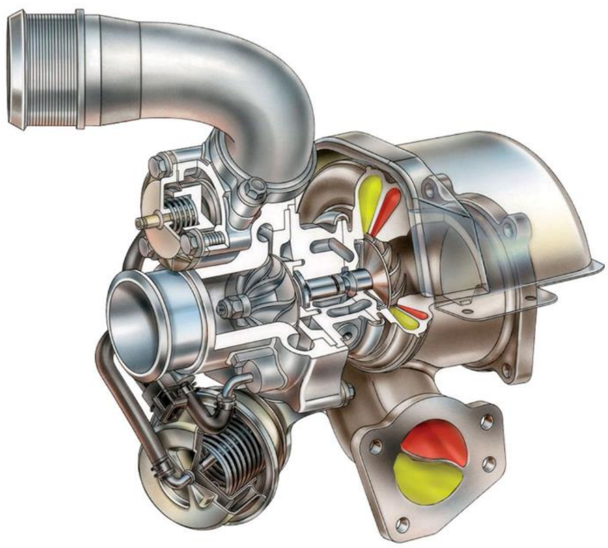

Fig. 2. Turbocharger with twin entry turbine

The data from the Audi TT 1.8 SI gasoline engine used in the 1-D model (Figure 3) (Bellisa V., Marellib S., Bozzaa F., Capobiancob M, 2010) was used as a basis for the study. The engine is equipped with a single entry turbine as part of its standard specification. The research includes a standard engine analysis and the same engine equipped with a twin entry turbine. Tab. 1 shows the basic parameters needed to build the model in AVL Boost.

Table 1. Basic parameters needed to create a model in AVL Boost

Engine	**1.8L SI**
Piston diameter	81 mm
Piston stroke	86 mm
Exhaust valve stroke	9.3 mm
Intake valve stroke	7.67 mm
Degree of compression	9.5:1
Number of cylinders	4
Valves per cylinder	5

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Fig. 3. Gasoline engine with single entry turbine Audi TT 1.8 SI

For the purpose of this study, engine modeling is based on Audi TT 1.8 SI and has been simulated with variable engine speed in the range from 1000 min^{-1} to 5000 min^{-1}. The profiles and dimensions of the filling and exhaust manifolds are defined on the basis of data from the manufacturer in order to achieve real operating conditions in the combustion cycle. The data for single and twin entry turbine are taken from the manufacturer. This provides more precise boundary conditions, as the flow characteristics of the compressor will only be influenced by the differences in turbine configurations and the corresponding exhaust manifold geometry.

In Fig. 3 is shown an Audi TT 1.8 SI engine model with standard turbocharger configuration. The exhaust manifold geometry is configured so that the four exhaust manifolds are combined into one common pipeline. This means that the energy transfer from the exhaust to the turbine impeller is not optimized, thus not fully realizing the exhaust gas potential.

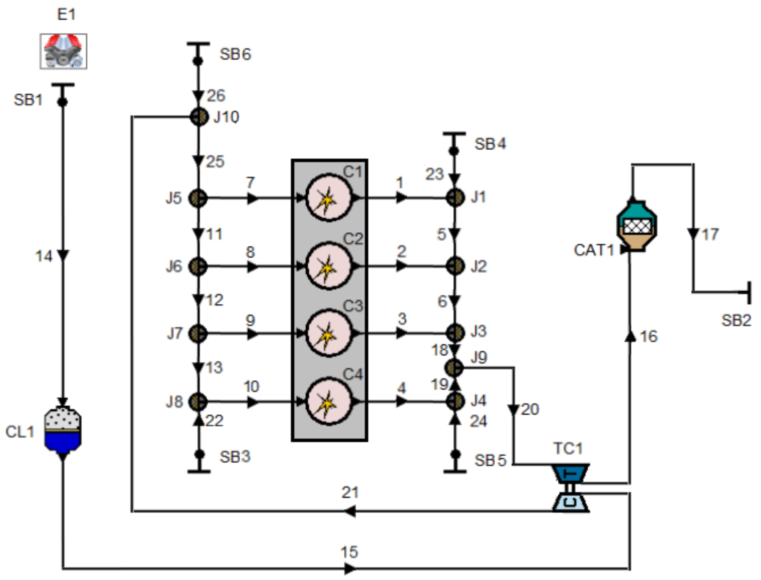

Fig. 4. Model of gasoline engine Audi TT 1.8 SI with single entry turbine

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A firing line (1-3-4-2) is used in which the four exhaust manifolds of the exhaust manifold are combined in one common line and changed so as to allow the exhaust gases from the cylinders 1 and 4 to remain separated by 2 and 3, as shown in Fig. 4.

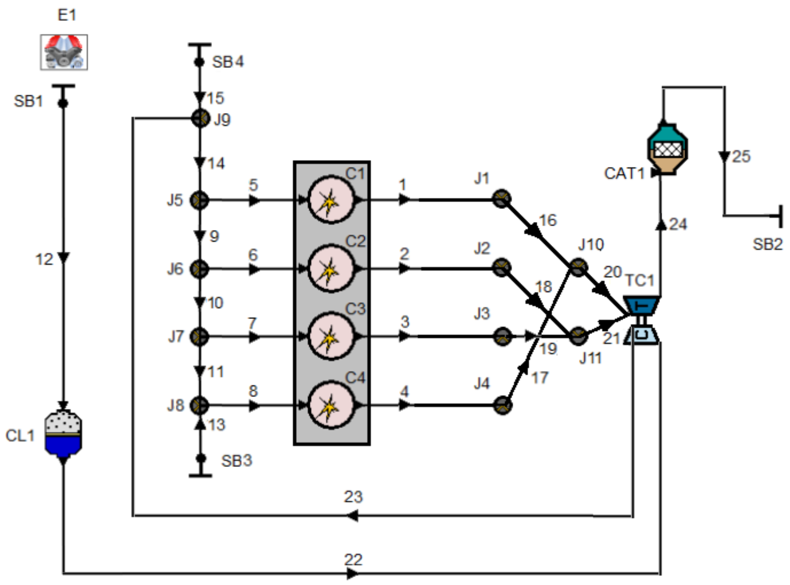

Fig. 5. Model of gasoline engine Audi TT 1.8 SI with twin entry turbine

Verification of the model was performed using parameters of a standard Audi TT 1.8 SI single-input turbocharged engine and the results were compared with those provided by the manufacturer. The engine data that is shown in Table 1 was used.

Fig. 6 and Fig. 7 shows the power and torque respectively as a function of engine speed in the range of 1000 min^{-1} to 7000 min^{-1}. It is clear that the simulated engine model has produced relatively accurate calculations for maximum power at an engine speed of 6500 min^{-1} compared to the manufacturer's data 6000 min^{-1} shown in Fig. 6. For torque results, there are some discrepancies between the simulation data and the manufacturer. This is probably due to the combustion shape parameter, which determines the combustion characteristics within each cylinder in the AVL Boost simulation code.

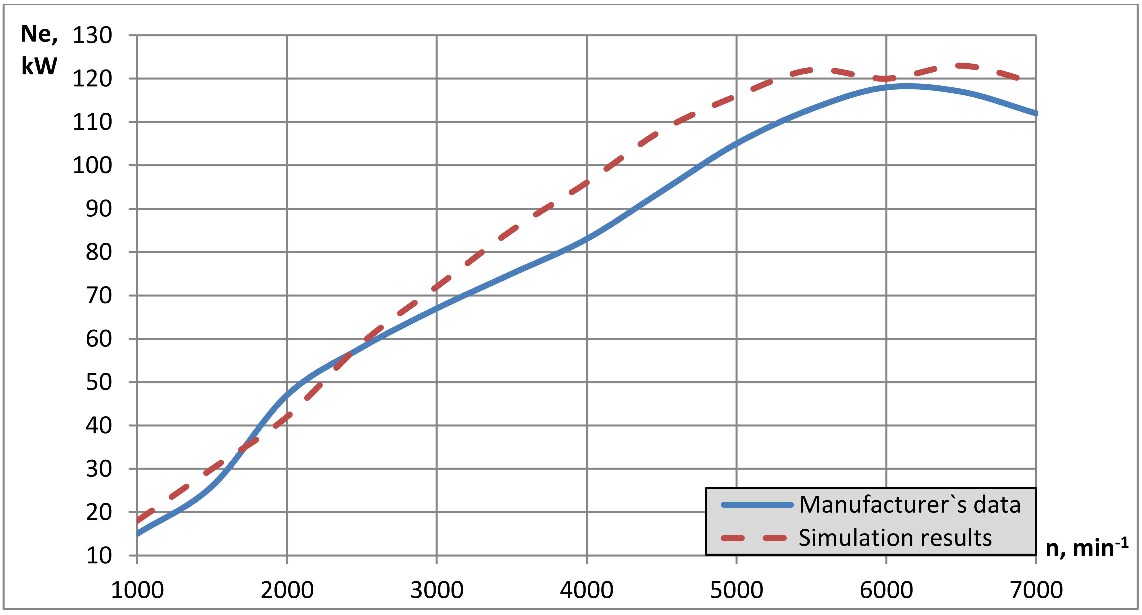

Fig. 6. Change of engine power (Audi 1.8L SI) at different speeds

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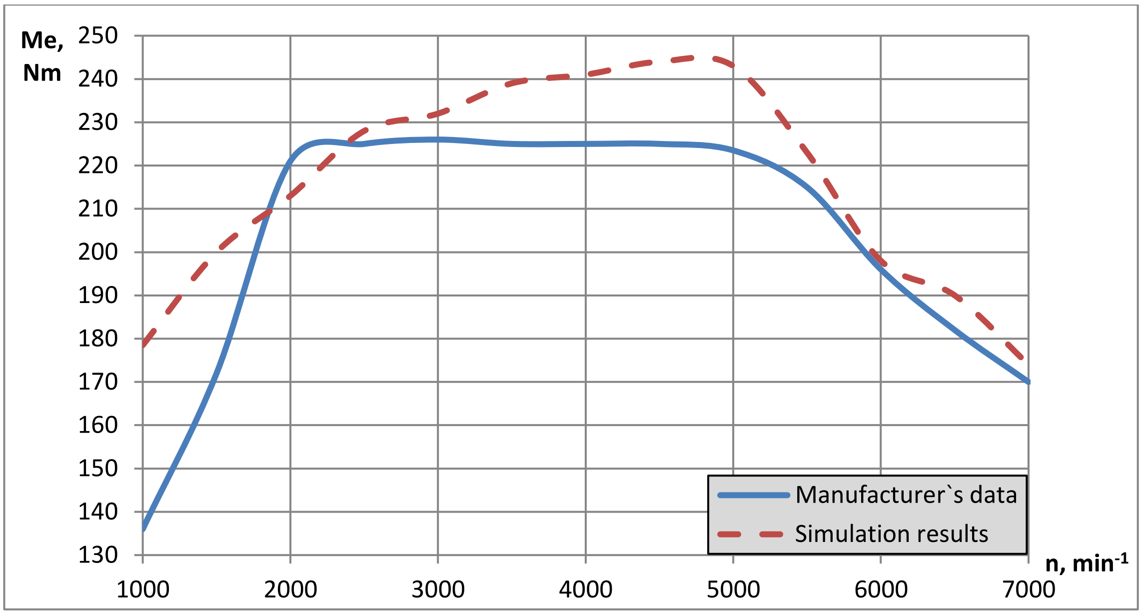

Fig. 7. Torque variation of the engine (Audi 1.8L SI) at different speeds

Based on the results above, it can be concluded that the simulation model of an Audi 1.8L SI engine, equipped with a single-input turbocharger, provides relatively accurate simulation results.

In low-power engines, low speeds are an essential area for the turbocharger with twin entry turbine. A common turbocharger problem with these engines is the turbine response time, which must reach a high enough speed to allow the compressor to work efficiently.

Fig. 8 shows comparison of power between single and twin entry turbine. The highest power gain for the twin entry configuration reaches 5500 min^{-1}, providing approximately 15% extra power. This increase in power is the result of increased compressor performance, due to improved power transmission from exhaust to turbine.

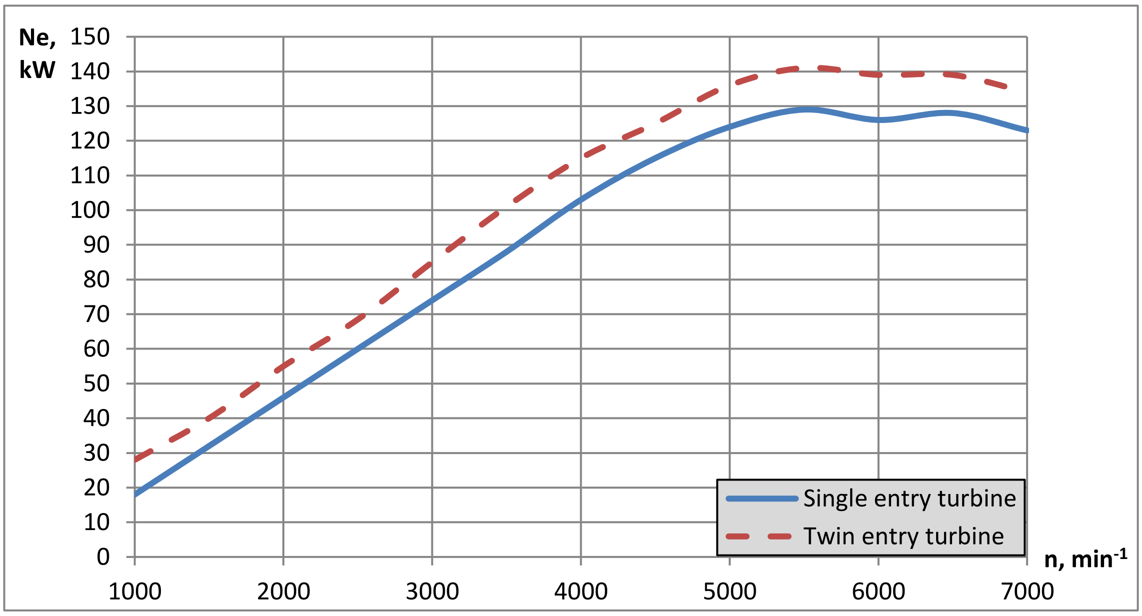

Fig. 8. Engine`s power variation (Audi 1.8L SI) of turbocharger with single and twin entry turbine

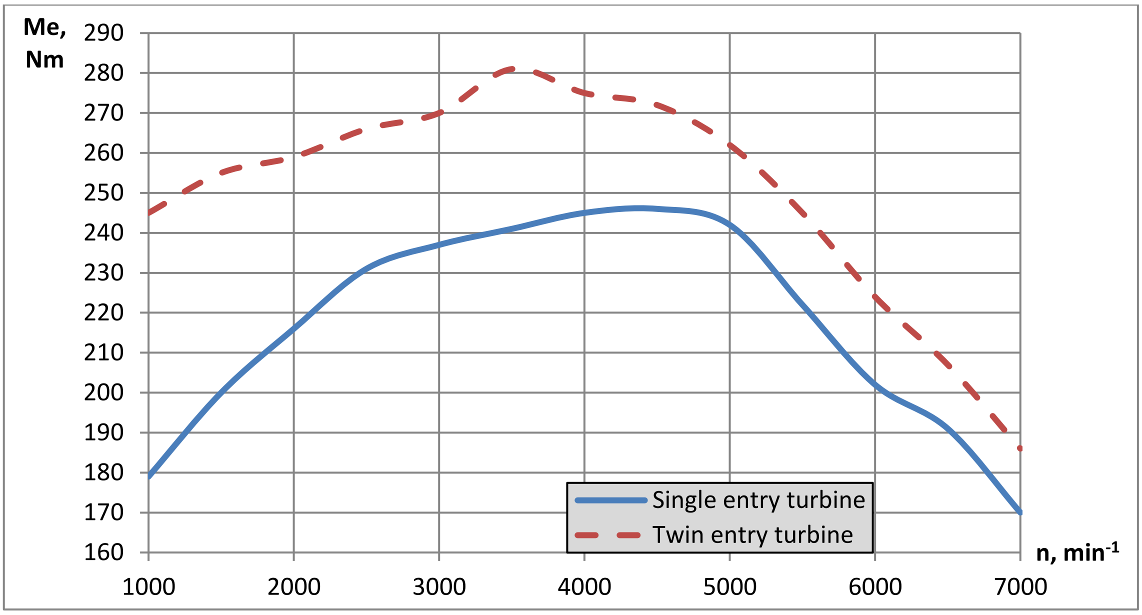

Fig. 9. Engine`s torque variation (Audi 1.8L SI) of single and twin entry turbine

The results of the simulation (Fig. 10) also showed that the mean effective pressure is increased by 16% after using the twin entry turbine engine model. Tab. 2 shows the summary results of the improvements obtained from the simulation with AVL Boost.

Table 2 - Summary of obtained improvements

Engine	**1.8L SI**
Power	14.80%
Torque	14.00%
BMEP	16.00%

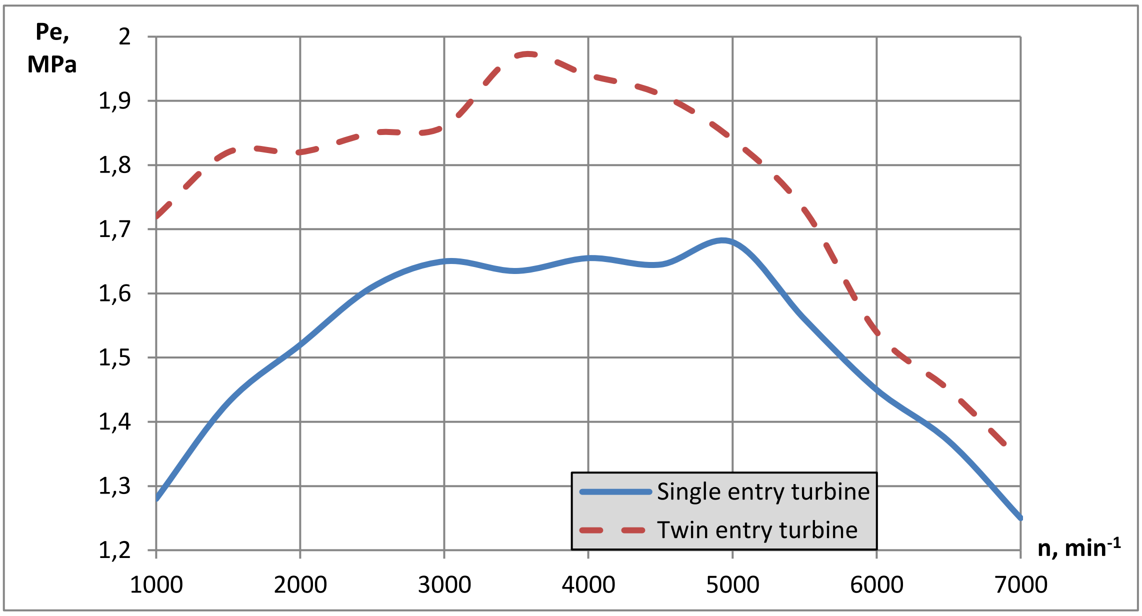

Fig. 10. Variation in mean engine pressure (Audi 1.8L SI) with single and twin entry turbine

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CONCLUSION

- The simulation results with the AVL Boost software show potential improvements in engine performance due to the use of a twin entry turbine with a modified exhaust manifold configuration.
- The simulation results obtained for the Audi 1.8L SI engine show that implementation of a twin entry turbine increases engine power at low speeds, with the highest efficiency being in the range of 1500 min^{-1} to 4000 min^{-1}, as the maximum power increment is 25%, while the mean effective pressure rise up with 27%.
- Torque and engine power are also increased by 14.8% and 14% respectively at 2000 min^{-1}. Power and torque are significantly improved at low speeds by the constructive design change of the exhaust manifold and the turbine.

ACKNOWLEDGMENTS

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