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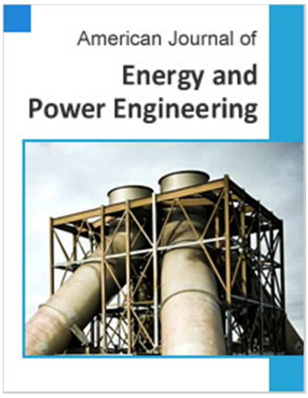

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Studying Turbocharging Effects on Engine Performance and Emissions by Various Compression Ratios

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Abstract
According to the Global Fuel Crisis, it seems necessary to increase the efficiency of internal combustion engines. One way for achieve this target, is engine downsizing by using turbocharger. Turbocharger using makes combustion more efficient and better. The purpose of this paper is studying effect of turbocharger using on engine performance and emissions by various compression ratios. The simulated model was validated in different engine RPMs for gasoline, were injected into the engine at full load condition. The results of simulation was had good agreement with experiments. The results shown that by turbocharger, engine power and torque, Due to increased pressure inside the cylinder, increased. Pollutant emissions such as NO_X, HC and CO due to hydrocarbon fuels incomplete combustion is reduced by increasing the amount of oxygen involved in the reactants. But CO_2 pollution has increased due to the complete combustion of hydrocarbons.

1. Introduction

XU7 engine is used in many products in Iran KHODRO Company. This engine was used in France in the French company Peugeot in 1993 and has a relatively old technology. Due to older technology in the design and construction as well as the low efficiency in comparison to new engines, then the engine structure needs to be revised in order to increase its efficiency. Using turbocharger it can be increases engine power, torque and power to engine size ratio and constant volume engine power and torque will be increased, but because of the increasing amount of intake air into the cylinder, incylinder pressure of the engine will be increased and this can increase tear of parts. To avoid this, using a lower compression ratio appears favorable. Understanding the turbocharger effects requires an empirical test, but due to its costly and time-consuming feature, in the early stages it be can used the computer simulation to investigate its effect on engine. The simulation results can be validated with experimental data's, and then the results can be generalized to the various Compression ratios conditions.

2. History of Research

Murat Karabektas studied diesel fuel and biodiesel impact on the performance of a turbocharged diesel engine [1]. Ankit Agarwal and his colleagues studied turbocharching effect for various compression ratio and injection pressure on the performance and emission characteristics of CI engine. Their results showed that it can improve engine performance characteristics [2]. Andalibi studied turbocharging on Paykan engine to achieve the same performance for gas and petrol fuels in Bi-Fuel engine [3]. Pishgui use of variable valve timing system with XU7 engine simulation using GT-Power software and his results showed less brake specific fuel consumption for engine [4]. Kasraie used GT-POWER software for the simulation of XU7 internal combustion engine [5]. Riahi used GT-POWER software for the simulation of B5 internal combustion engine [6]. Kakaei used GT-POWER software for simulation and Optimization of the Input runner in XU7 engine [7].

The purpose of this research is studying turbocharger effect on XU7 engine performance and emission using engine simulation in GT-POWER software. Similar researches such as this research can show the effects of engine structure parameters changes on the engine performance to prevent large expenditures for its optimization.

3. Engine Modeling

The modified turbocharged engine used in this research is built on the basis of XU7JP/L3 gasoline engine. The main technical parameters of the gasoline engine are listed in table 1. Also Table 2 shows turbocharger specifications used in this study.

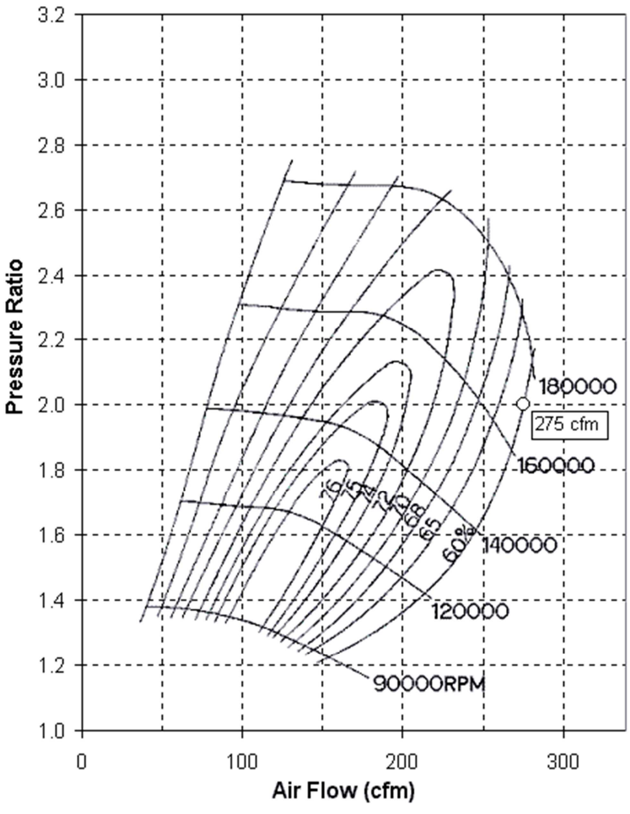

Figure 1. *Compressor performance map.*

Table 1. *General specification of test engine.*

parameter	value
No. of cylindres	4
Engine type	In line
Bore	83 (mm)
Stroke	81.4 (mm)
Con rod	150.5 (mm)
Ignition order	1 – 3 – 4 – 2
Engine volume	1761(cc)
Compression ratio	9.3:1
fuel	gasoline
Max power	70.8(kW)@6000
Max torque	153.4(N-m)@2500
No. of valve	8
Fuel system	MPFI

Table 2. *Turbochargercharacteristics.*

Constant pressure with waste gate	grouping
0.50	Hosing A/R
0.50	Compressor A/R

In this study, for turbocharger effect on naturally aspirated engine studying we use various compression ratios as 9.3, 8.7, 8.2 and 7.7. Weib function is used for combustion modeling [8]. For this purpose, two parameters are needed:

1. Crank angle between the TDC and completed 50% of combustion, this parameter is generally 5 to 12 degrees.
2. Crank angle between 50% and 90% complete combustion, this parameter is generally 25 to 35 degrees.

Combustion model is based on two-zone temperature and other properties for both burned and unburned mixture is calculated independently.

Fuel injection model equation is as following and injection time is between 180 to 210 degrees duration of crankshaft.

$$M_{delivery} = \eta_v N_{rpm} V_d (F / A) \frac{6}{(\# CVL)(Plusewidth)} \quad (1)$$

Heat transfer rate in the cylinder is calculated using woschni model and heat transfer coefficient calculated using the woschni function as following equation:

$$Hg = 3.2 B^{-0.2} P_r^{0.8} T_r^{0.53} V_c^{0.8} \quad (2)$$

$$V_c = C_1 V_m + C_2 \frac{V_d T_{r1}}{P_{r1} V_{r1}} (P_r - P_{mot}) \quad (3)$$

In the above equation in the suction and discharge:

$$C_1 = 6.18 + 0.417 (\frac{V_s}{V_m}) \quad (4)$$

And in the compression and expansion:

$$C_1 = 2.28 + 0..308(\frac{V_s}{V_m}) \quad (5)$$

And Dalton model was used to combine the two fuels [9].

The main assumptions in the simulation include:

1. Passes through the crankcase gases are negligible.
2. Air-fuel mixture is homogenous at the inlet valve closing time.

3.1. Engine Model

Figure 2 shows the simulation model. Based on the main technical parameters above, the turbocharged engine is modeled by using GT-Power software. Furthermore, the parameters of intake and exhaust model, turbocharger model, heat transfer model, fuel injection model and crank train model are set respectively.

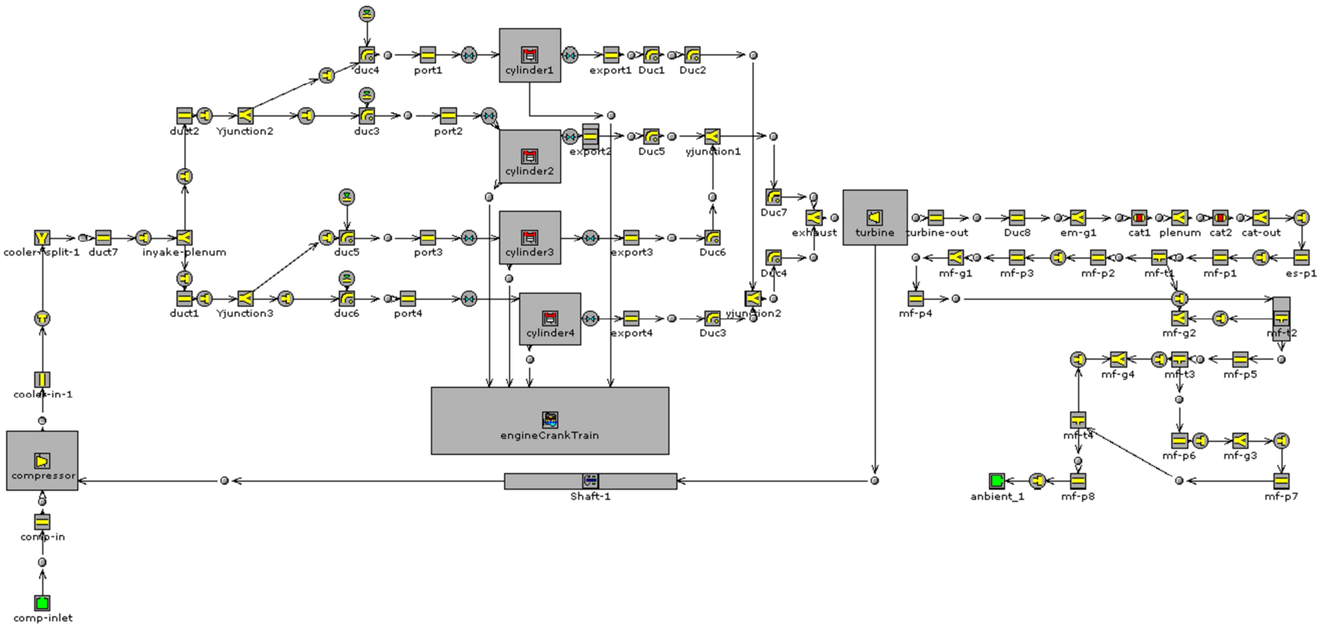

Figure 2. *Engine model.*

3.2. Verification of Model

In order to ensure that the simulation model can indicate the practical working process of the engine and predict running performance of the engine definitely, the simulation model is validated by using experimental data of the gasoline engine through test bench. To investigate the effect of turbocharger on gasoline engine, research is needed to build a reliable model. In this study, the engine model was simulated in GT-POWER software. To verify the results of the simulation, naturally aspirated engine model results were compared with experimental results. To ensure the accuracy of the simulation results of the gasoline engine in 3000 RPM compared with experimental results. Experimental data's was provided from IPCO Company. The base engine is a gasoline XU7 engine and its data's are used to verify the results at 3000 RPM in gasoline injection mode. All results are in full load [10].

The pressure of simulated engine results has been shown in Figure 3 in comparison with experimental results. It is seen that the difference is about 8%. Indicated among the reasons for this difference, can be the passage of the crankcase gases into the combustion chamber.

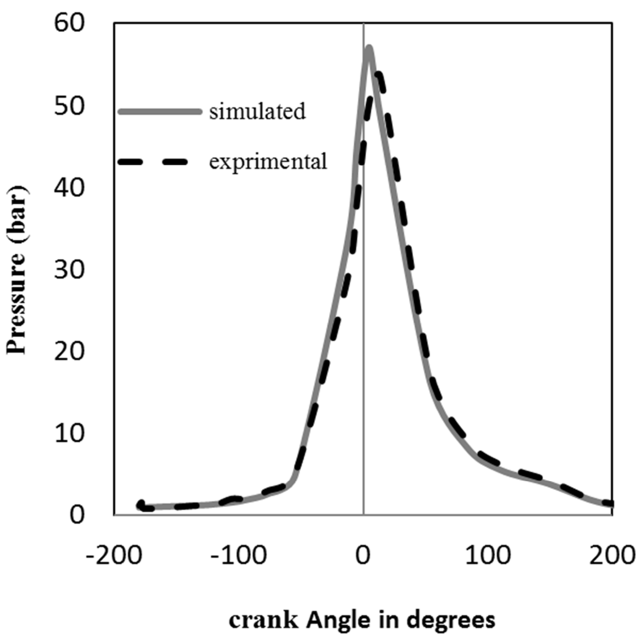

Figure 3. *Incylinder pressure-crank angle.*

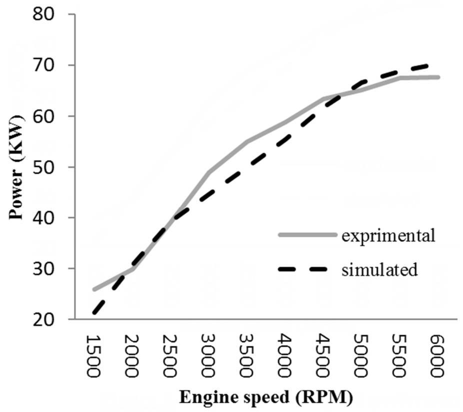

Figure 4. *Engine power – speed performance.*

4. Simulation Results

4.1. Turbocharging Effect on Engine Performance

Engine power - speed in various Compression ratios have been shown in figure 5. It is seen that engine power has been reduced because the interior component of the cylinder at the end of the engine's compression ratio increases and the cylinder pressure will decrease during the compression stage.

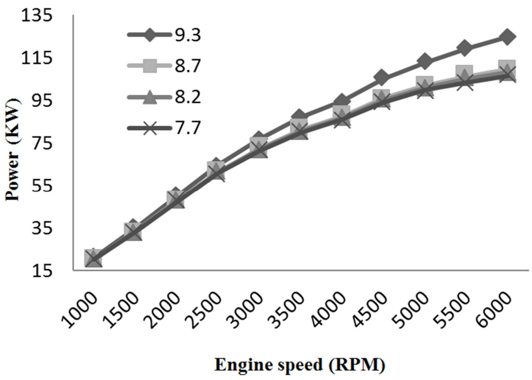

Figure 5. *Engine power - speed at various Compression ratios.*

Engine torque - speed in various Compression ratios have been shown in figure 6 It is seen that engine torque has been reduced because the interior of the cylinder at the end of the engine's compression ratio increases, the cylinder pressure will decrease during the compression stage.

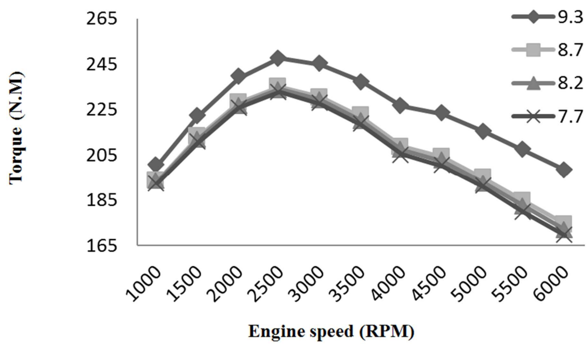

Figure 6. *Engine torque - speed at various Compression ratios.*

4.2. Effect on Engine Emissions

The engine NO_X emission has been shown in Figure 7. By Compression ratio increasing, more complete combustion is done and engine consumes oxygen and there will not be other enough oxygen to produce more NO_x. This is one reason that its production is down warded.

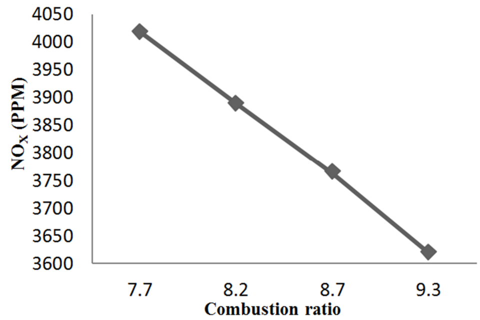

Figure 7. *NO_X emissions production in various compression ratios.*

Figure 8 shows emissions of carbon dioxide varying by various compression ratios. It can be seen the amount of carbon dioxide emissions in various compression ratios is nearly constant and changes very little from the base value.

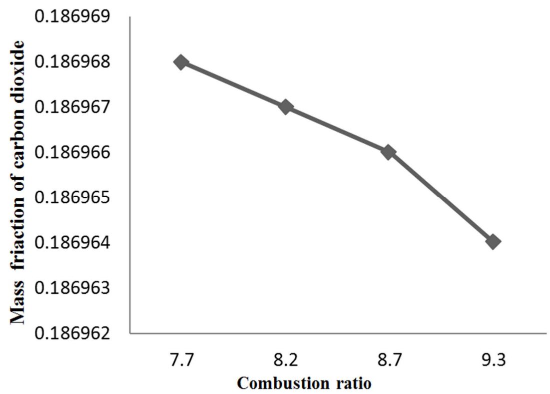

Figure 8. *Carbon dioxide emissions production in various Compression ratios.*

Figure 9 shows HC emissions as various compression ratios. This pollutant is caused by incomplete combustion of unburned hydrocarbons. The production of these emissions is almost identical just in the 8.7 of compression ratios slightly increased.

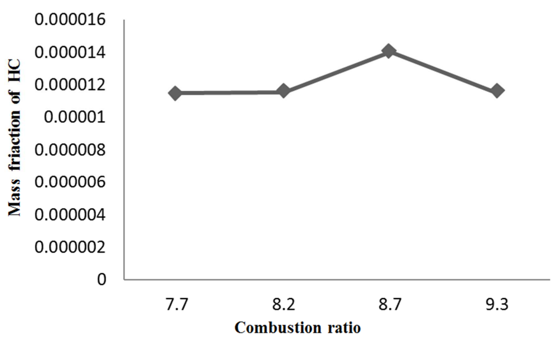

Figure 9. *HC emissions production in various Compression ratio.*

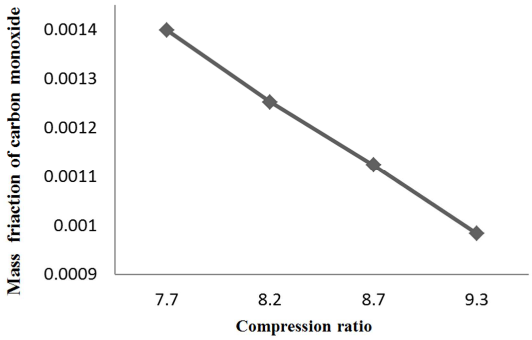

Figure 10. *CO emissions production in various Compression ratios.*

Figure 10 shows CO emissions in various Compression ratios. This pollutant is caused by incomplete combustion because of Lack of oxygen. CO production can be decreased in more complete combustion of fuel in higher compression ratios and it can be increase in cylinder temperature and pressure, and then its production can are minimized at highest Compression ratios.

5. Conclusion

This study presents a turbocharger using method to improve engine performance and emissions. This method can be used for engine downsizing and increasing its volumetric efficiency with downsizing. The main goal is increasing general efficiency of the engine.

Turbocharged and natural aspirated engine performance results comparing shown that the engine power and torque increased with turbocharging. Naturally aspirated engine mode power is about 70.8 kW, while the turbocharged one results shown that its power can be increase to 106.4 to 124.7 kW.

By increasing the engine compression ratio by using turbocharger, in the overall purpose of the emissions we see a downward trend, however increasing of Compression ratio have good performance but this increasing, cause friction increases and thereby it will be reduced the useful life of the engine and its parts.

List of Symbols

CO	Carbon monoxide emissions (mass fraction)
CO_2	Carbon dioxide emissions (mass fraction)
HC	Emissions of unburned hydrocarbons (mass fraction)
N	engine Rotate Speed (RPM)
NO_X	Nitrogen oxides emissions (PPM)
P	Power (KW)
T	Torque (N.M)
$Vr,1$	volume when Inlet valve close (m^3)
$Tr,1$	Temperature when Inlet valve close (ºk)
$Pr,1$	Pressure when Inlet valve close (kPa)
P_r	Reference pressure (1bar)
T_r	Reference temperature (0°C)
$M_{delivery}$	Delivered mass (kg)
B	Bore (mm)
V_d	Cylinder displacement volume (m^3)
P_{mot}	Cylinder pressure in the engine case handling (kPa)
V_s	The linear velocity of the piston (m/s)
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Greek Symbols

η_v	Volumetric efficiency (m^3/s)

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