Analysis of Turbocharger And Its Optimization For Heavy Duty CNG Engine

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Abstract- *This paper gives a brief information about the design and development of turbocharger, optimize turbocharger engine performance as per the targeted value.*
1. To match the appropriate turbocharger on an existing naturally aspirated engine.

Keywords- Naturally Aspirated 6-cylinder CNG engine, Turbocharger, 1-D simulation.

I. INTRODUCTION

Problem statement for this project is to convert the Naturally Aspirated (NA) 6-cylinder CNG engine into Turbocharged (TC) 6-cylinder CNG engine without downsizing so that the same engine can be used as higher power rating for transport application. The prediction and optimization of turbocharger engine performance is to be made by using 1-D simulation tool [1].

In this work a naturally aspirated CNG engine is converted to a turbocharged intercooled natural gas engine. Turbocharger is selected from compressor maps with the help of a mathematical model giving pressure ratio and air flow rate of compressor. The power target of engine is 162kW as against 96kW for NA engine at rated speed of 2400rpm. Also maximum torque is 700Nm as against 430Nm for NA engine in the range of 1400-2000rpm. The turbocharger is selected off the shelf and was not designed so as to reduce the development time of the engine.

II. PROPOSED METHODOLOGY

1. Literature review for NA engine and TC CNG engine.
2. Matching a TC with the NA engine using mathematical relations
3. 1-D Simulation using GT-Power of NA Engine & its Validation
4. Simulation of TC Engine Model
5. Optimization of Engine Performance Parameters for Simulated TC Engine

After reviewing through various references, the turbocharger selection and matching procedure is finalized which is to be implemented. This procedure is followed by using mathematical calculations and relations for naturally aspirated CNG engine and given targeted data for turbocharged CNG engine. Also, 1-D simulation work is to be carried out on software known as GT-POWER to compare and validate the results for naturally aspirated engine & predict the performance for turbocharged CNG engine.

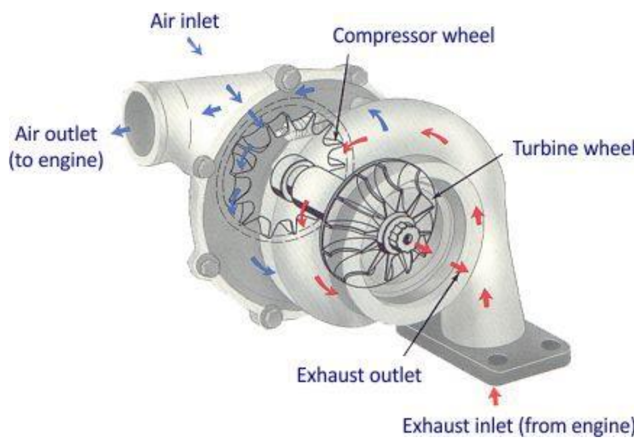


Fig. 1.Turbocharger construction and flow of gases

For simulated turbocharged CNG engine, optimization of engine parameters is carried out to achieve targeted results. Using these calculated and optimized results and inferences, the solution to the problem statement is concluded.

A turbocharger mainly consists of two main sections - the turbine and the compressor. The turbine consists of turbine wheel and the turbine housing whose purpose is to guide the exhaust gases into the turbine wheel. The kinetic energy of the exhaust gases gets converted into the mechanical after striking it on turbine blades. The exhaust outlet helps the exhaust gases to exit from the turbine. The compressor wheel in turbocharger is attached to a turbine with the help of steel shaft and as the turbine turns the compressor wheel, it draws the high-velocity, low pressure air stream and convert it into high-pressure, low –velocity air stream. This compressed air is pushed into the engine with the more quantity of fuel and hence produce more power.

III. MATCHING AND SELECTION PROCESS

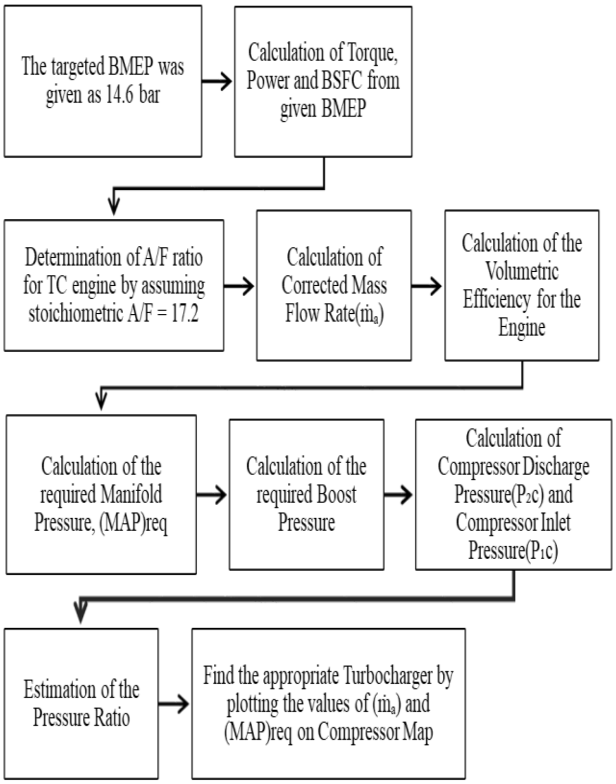


Fig. 2. Matching and Selection Process

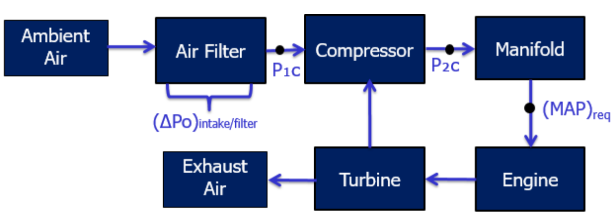


Fig. 3. Air Flow in a Compressor

$P_2c = (MAP_{req}) + (\Delta P)_{loss} = 14.91 + 0.21(\text{assume}) = 15.12$ psi

$\therefore P_2c = 1.042$ bar (gauge pressure) + 1(absolute pressure)

$\therefore P_2c = 2.042$ bar

IV. SIMULATION FOR NATURALLY ASPIRATED 6-CYLINDER CNG ENGINE MODEL

GT-Power is an effective tool used in industry to perform 1-D simulations. The simulation work is done in 1-D simulation tool known as GT-SUITE. The 6-cylinder naturally aspirated and turbocharged CNG engine model is built in GT-ISE.

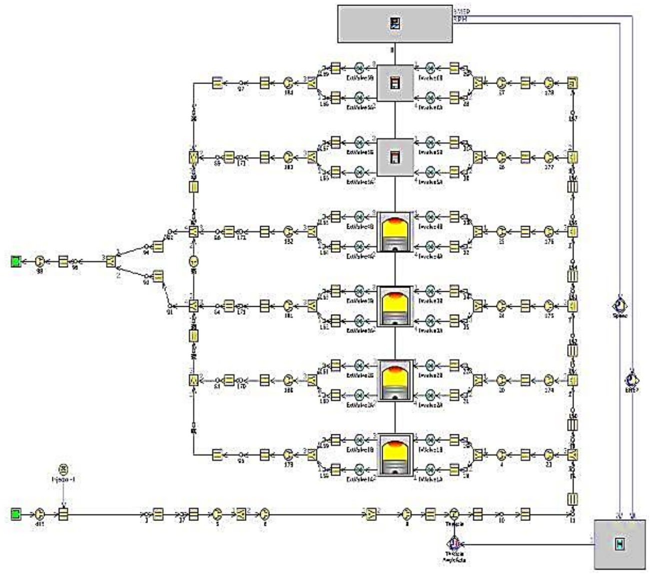


Fig. 4. 1-D Naturally Aspirated 6- Cylinder CNG Engine Model

The above model shows 6-cylinder Naturally Aspirated CNG engine. Model shows various engine components linked with each other.

Main components of naturally aspirated engine are engine crankcase, engine cylinders, inlet and exhaust valves, throttle valve, air inlet port and exhaust port, pressure sensors, temperature sensors, speed sensors etc.

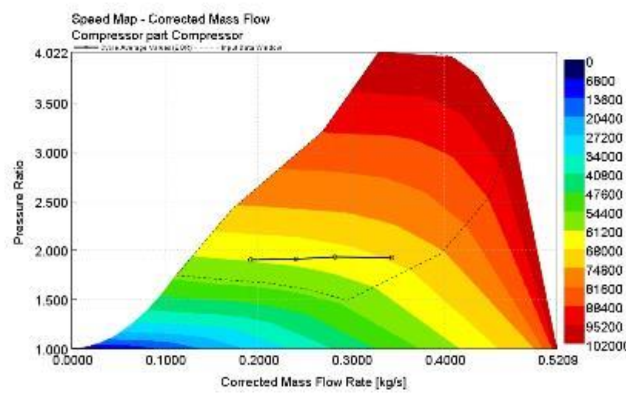
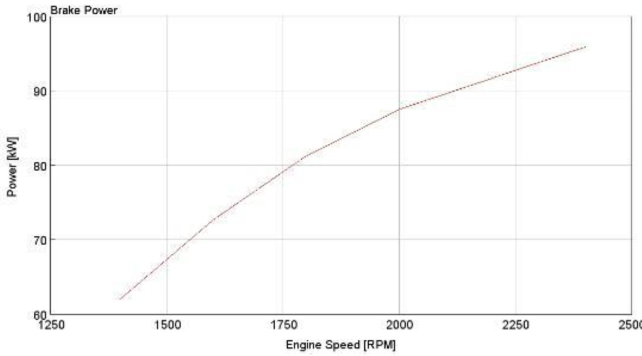


Fig. 5. Compressor Speed Map

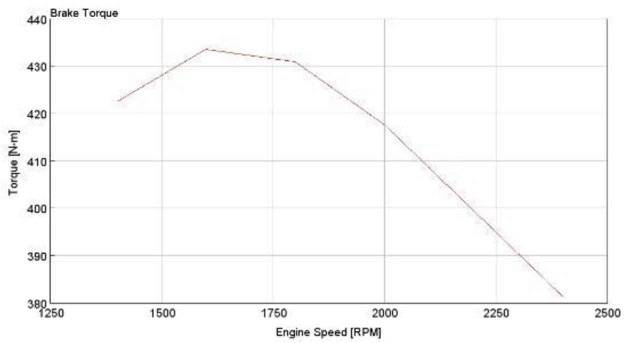
The black horizontal line just below pressure ratio of value 2 shows that the compressor speed varies between 61200 rpm to 68000 rpm at full loads.

However, for part loads the pressure ratio will decrease leading to drop in compressor speeds.

Thus we can conclude that the compressor is working within safe limits.

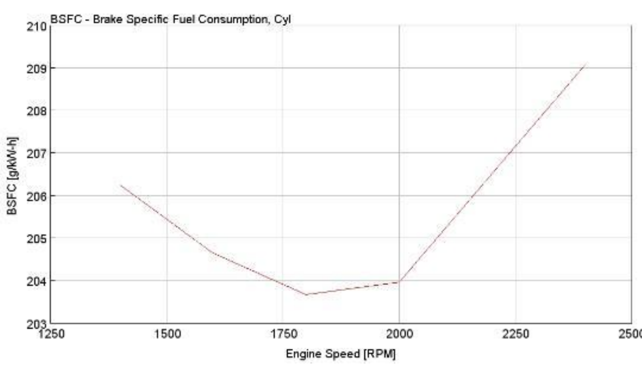


The figure shows the graph of Power Vs Engine Speed. The Power obtained is around 95 to 96 kW @ engine speed of 2400 rpm.



The figure shows the graph of Torque Vs Engine Speed. Here, the Torque obtained @ 1400 rpm is 430 Nm. Maximum Torque obtained is around 434 Nm in the engine speed range of 1400 – 2000 rpm.

At 2400 rpm the Torque obtained is around 382 Nm.



The figure shows the graph of BSFC Vs Engine Speed. At maximum speed of 2400 rpm the BSFC obtained is around 209.02 g/kW-hr.

At 1300 rpm where maximum Torque, the BSFC obtained is around 206.03 g/kW-hr.

To validate these results let's compare and analyse the results obtained from experimental setup and simulated results from GT-POST.

Table.1. Validation for Naturally Aspirated Engine

Parameters	Experimental Results	Simulated Results
Maximum Power (kW)	96 kW @ 2400 rpm	96 kW @ 2400 rpm
Maximum Torque (Nm)	430 Nm @ 1400 – 2000 rpm	434 Nm @ 1400 – 2000 rpm
BMEP (bar) @ Maximum Torque i.e. 430 Nm	8.9 bar	8.9 bar
BSFC(g/kWhr) @ Rated Speed i.e 2400 rpm	210.31 g/kWhr	209.02 g/kWhr

From the above table, it can be seen that experimental and simulated values are approximately similar.

The difference between the values of engine parameters is within the range of 5% and so the simulated results are correct. Therefore, the naturally aspirated 6-cylinder CNG engine is validated.

V. CONCLUSION

- After carrying out the numerical and experimental analysis on 6-cylinder CNG NA and TC engines, the following conclusion has been drawn,
- Boost pressure is a function of compressor speed which is directly dependent on throttle opening angle.
- With the help of compressor maps turbocharger is selected for required power output. It is also concluded that there is improvement in rated power and torque for modified engine as compared to base NA engine.
- Turbocharging by using exhaust gas energy that would otherwise be lost improves engine efficiency.
- The volumetric efficiency at 1300 rpm for NA engine is 74% and for TC engine is 115% this means the volumetric efficiency increases by 35% for TC engine, whereas the volumetric efficiency at 2400 rpm for NA engine is 68% and for TC engine is 112% this means the volumetric efficiency increases by 39% for TC engine.

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