Low Engine Speed Torque Improvement in Natural Gas Engine using Turbocharging: An Experimental Observations

P. J. Suple*, C. R. Sonawane*, S. S. Thipse^, J. P. Mohite#, N. B. Chougule#

*Symbiosis Institute of Technology, Mechanical Engineering Dept., Pune, India
^Automotive Research Association of India, Pune, India
#Tata Motors, Pune, India

Abstract

Diesel engines have always been at the heart of automotive prime movers, mainly for the road based commercial vehicles since a long time. For about past twenty years, many cities have insisted on using natural gas powered vehicles with an aim of reducing air pollution. Thereafter, natural gas based engines have experienced rapid development and adoption of newer technologies, with an objective of reducing engine emissions and be able to meet target emission limits. With requirements for enhanced comfort features for e.g. air conditioner, pneumatic door and shock absorbers, other electric appliances, etc. in the commercial passenger vehicles such as school, staff and mass transport vehicles mass transit vehicles etc. and restrictions of maximum vehicle speed for safety purposes, such natural gas powered vehicle require higher traction at slow engine speeds. The objective of this paper is to evaluate and summarize various approaches, strategies, and technologies developed for enhancing the torque of engine. Most of these are applicable to full range of engine speed. Integrating them for improving torque at slow engine speeds is core objective here. Experimental result of a specimen CNG engine are presented here which shows an enhancement in the torque as well as engine power at slow engine speed region with turbocharged configurations.

Keywords: Compressed natural gas engine, slow speed torque, turbocharged natural gas engine

Nomenclature

CNG compressed natural gas
OEM original equipment manufacturer
IMEP indicated mean effective pressure
BMEP brake mean effective pressure
DI direct injection
Nm newton meter, unit of torque
Rpm/RPM rotations per minute, unit of speed
BSFC brake specific fuel consumption
g/kwh gram per kilowatt hour
EGR exhaust gas recirculation
kW kilowatt
TDC top dead center
ATDC after top dead center
SOI start of injection
SI spark ignition
VGT variable-geometry turbine
NA Naturally aspirated
TC Turbocharger
MSR Measured
SIM simulated

1. Introduction

One finds all sorts of vehicles in cities. Considering energy consumption, it is seen that the share of personal means of transport far exceeds that of public transport. [1]. Demand always existed for trucks to be powered by alternate fuels, with economic benefits in operating them as compared to conventional fuels [2]. Heavy duty, mass transport buses, operating on natural gas will next milestone in reducing emissions. [3]. In emerging markets, worldwide, OEM's shall be integrating platform technology, in which minor changes to base product will help to meet very large market requirements [4]. Share of small and light commercial vehicle will expand for coming years [5]. These will derive more from global powertrains scenario and be using alternate fuels, advanced transmissions etc. [6]. Natural gas has helped to lower air pollution and has enhanced outlook of green mobility [7]. Various aspects such as aspects such as economics, ease of design and control, combustion, performance etc. are promising when considering natural gas as an alternate automotive fuel [8]. Although natural gas still needs a lot of development on infrastructure, availability etc. the number of vehicle operating on natural gas will increase over a period of time. Newer technologies such as compression ignition, new on-board CNG storage systems etc. will be seen on urban transport bus [9]. Bio-methane can also be used instead
of natural gas as an automotive fuel, however, it first needs to be treated to enhance methane content and then compressed to enhance energy content to make practical sense for on-vehicle storage [10].

In 2010-2011, commercial vehicle production in India registered a growth of about 23% in at a compounded annual growth rate of about 9.3%. These numbers take into account hundreds of vehicle variants across different platforms. The operation cost of these vehicle will be an important factor that shall determine market share and many OEMs shall have to provide natural gas operated variants of their popular vehicles [11]. With a compulsion of using natural gas for commercial vehicles in major metros across country, the number of these vehicles is bound to increase. In addition, regulations on powertrains, safety standards are issued known as bus body code, that mention various different criteria and specifications that must be met for enhanced passenger safety and comfort [12]. As vehicle evolve, it shall underline OEM’s actions to provide powertrains with alternate fuels, thanks to Government’s stress on natural gas policy in India; manufacturers now offer their popular vehicle variants in natural gas option across the country [13].

2. Changes to engine for slow speed torque improvements

Specimen engine, available for purpose of testing and co-relation is a six cylinder naturally aspirated engine, powering buses for city mass transport of passengers. Brief aspects are highlighted in table 1.

<table>
<thead>
<tr>
<th>Specifications of base engine</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Bore x Stroke</td>
<td>97 x 128</td>
</tr>
<tr>
<td>Number of cylinder</td>
<td>6 Cylinder, Inline</td>
</tr>
<tr>
<td>Firing order</td>
<td>1-5-3-6-2-4</td>
</tr>
<tr>
<td>Rated speed</td>
<td>2500 RPM</td>
</tr>
<tr>
<td>Swept volume</td>
<td>5.7L</td>
</tr>
<tr>
<td>Aspiration</td>
<td>Natural</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>12.5:1 +/- 1</td>
</tr>
</tbody>
</table>

2.1 Relation between different means and engine output

Various means of improving engine output are categorized by nature that they affect engine running. Table 2 provides a short outline of different means used by different researchers. This also highlights the understanding among various means and engine output.

2.2 Simulation and engine testing

The engine is virtually simulated by representing it in a suitable model. Refer figure 2. The outcome of this model is then compared to engine performance from actual testing. This is done to assess the accuracy of model against the actual engine.

Fig. 2. Base natural gas engine as modeled in software

Actual performance parameters and virtual model performance parameters should be as close as possible. This assures that the virtual model is alike the specimen engine. One dimensional model of specimen engine was thus made using same configurations as that of specimen engine. The simulation results are then compared with actual results.

Fig. 3. Comparing simulated and actual engine combustion pressure

Improving slow speed torque needs changes to engine components. Because natural gas engines are based on diesel engines, there are practical constrains. Figure 1 indicates engine output and other crucial parameters, recorded during full open throttle performance test.

2.1 Relation between different means and engine output
The above figure 4 shows engine performance at different speeds. As slow speed torque droops, it suggests that many parameters are to be optimized on engine and controller. Selection of appropriate turbocharger and other related hardware to deliver optimal output is a major subject, requiring detailed approach considering the slow speed requirements that shall provide desired benefits.

### 3. Conclusion

It is observed that there is enhancement in engine output with help of turbocharger. As turbocharger helps to draw more air into the engine, it assists in burning more fuel, thus liberating more heat. Going forward, the approach will be restricted to improving engine output at slow speeds than full operating range.

### References