Generating Simulation data of CNG Genset Engine to Predict various blends of HCNG for Achieving CPCB IV Emission Norms

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Abstract: *The necessity to meet strict emission regulations and increase internal combustion engine fuel economy has resulted in the creation and application of multidimensional models to study and comprehend the process of combustion. The fundamental knowledge of the engine combustion subprocesses, specifically turbulence, chemistry, and their interactions, is still far from perfect. Therefore, it is required to make assumptions, the validity and accuracy of which can only be determined by comparison with measurements The current work involves modeling an existing CNG engine using the 1D simulation tool GT-SUITE, validating the model at baseline. Creating a 1D engine model with real engine data as input and producing simulation results is the first step. Later, based on simulation outputs, the data will be used as input in 3D simulation software for predicting emissions results. Current scope deals with testing the CNG Genset Engine while capturing engine parameters which in turn will used as input to simulation tool for predicting Power, Torque, BSFC etc., and comparing with Measured vs Simulated data. The input for simulation tool are of different fuel-air equivalency ratios on optimal spark advance, peak in-cylinder pressure, and peak in-cylinder temperature. This effort is meant to serve as a first step toward generating a variety of viable ideas that will aid in enhancing the engine's present power output. To provide experimental results, actual experiments will be conducted. The accuracy of the simulation model will be verified to be within 10%. The engine model that has been validated is currently being utilized in a simulation to investigate how changing the fuel-air equivalency ratio affects the best spark advance, maximum in-cylinder pressure, and power output for a particular HCNG blend.*

Introduction

Natural gas has shown to be a challenging substitute fuel for the expansion of environmentally friendly Genset engines during the last few years. Natural gas heavy-duty transport as well as passenger vehicles are very common, although Genset engines using natural gas are still in their infancy as a technology. Natural gas offers advantages in automotive technology as a fuel source for large-scale applications since it has socioeconomic advantages over fossil fuel-fueled engines. Hydrogenated fuel has enormous potential to reduce emissions and maximize combustion efficiency in natural gas engines. At Standard Temperature Pressure(STP) conditions, hydrogen and natural gas mix evenly since they are both gaseous. Compared to natural gas, hydrogen has a higher stoichiometric laminar flame speed in air.

Engine Model Development

Using all the necessary templates, a six-cylinder naturally aspirated CNG engine is modelled in GT-POWER and utilized for baseline validation using test data. The outcomes of using HCNG as fuel rather than CNG will be simulated using the verified model in Stage II of the project. Experiments are used to further validate this simulated results. The impacts of several engine parameters, such as Power, Torque and BSFC on engine performance are then further studied using the validated model.

The standard species included in the GT library in typical proportions by volume, such as methane, ethane, propane, n-butane, and nitrogen vapor, were used to characterize CNG in this model [1]. The final 1D Engine model is shown in Fig.1.

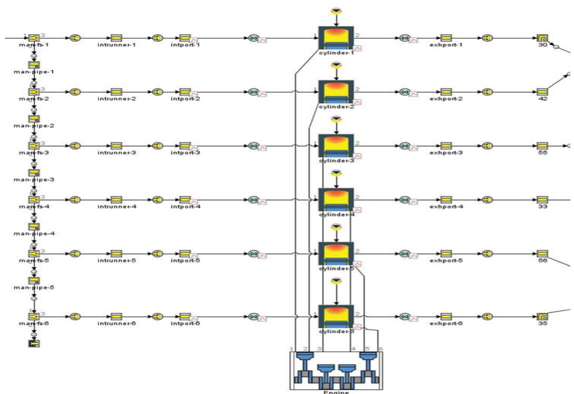

Fig.1 Complete engine 1D simulation model

Given that the simulation will employ a variety of HCNG mixes in this model, the user can define any fuel by utilizing the "Fluid Mixture" template and selecting from the standard fuels found in the GT library or by combining two or more species found in the GT library

Prior Research and Proof Of The Best HCNG Blend

Several HCNG engine blends were assessed by Munshi et al. [8] for heavy-duty applications. According to test data, the highest average NOx reduction in HCNG is found at 25% hydrogen by volume. According to Shioji M. et al. [5], a higher compression ratio results in faster combustion and more heat loss into the chamber wall, which makes it impossible to expect an improvement in thermal efficiency under conditions of higher hydrogen and equivalency ratios.

In their experimental work, Thipse S. S. et al. [2] found that from the perspectives of fuel efficiency, power production, and pollution compliance, CNG injection engines outperform CNG carbureted engines. Compared to CNG carbureted engines, CNG injection exhibits an 8% decrease in fuel consumption and an 11% increase in power. It is significant to remember that the phenomena of hydrogen embrittlement do not affect engine components when hydrogen blends up to 30% by volume with CNG. As a result, no significant changes to the fuel system or engine components are envisaged. Additionally, it increases engine efficiency, which reduces fuel usage and emissions of hydrocarbons. Retarding the ignition timing is necessary to enhance the flame speed of HCNG engines; this results in reduction of NOx emissions.

In their study, Das L M, et al. [6] referred to the HCNG system as Hydrogen Added Natural Gas(HANG). The HANG system uses natural gas with added hydrogen. It has been stated that the lean misfire limit for a CNG-fueled engine can be increased from 1.20 to 1.46 by adding 15% of hydrogen on an energy basis. The HANG system showed a notable increase in power production and brake thermal efficiency.

Experimental Setup

Test data using CNG as the fuel was produced using the CNG engine test equipment. The experimental setup shows that the engine intake manifold received the mixture of air and compressed natural gas [2]. CNG was stored at a pressure of 200 bars. Fig. 2 depicts the schematics of the experimental setup.

For the test, a six-cylinder NA CNG-powered engine was employed. Tests of 3 Mode Test Cycle for Genset engines were conducted with CNG fuel across the whole engine test cycle range. The CNG 1D model was then validated using CNG test data by conducting 3 Mode Test cycle data.

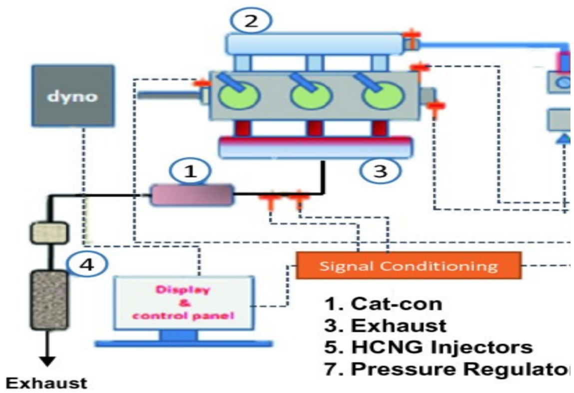

Fig.2 Typical schematic of test setup

Validation of Baseline Model

Prior to the validation of the standard CNG engine, it was required to optimize the spark advance for the specified engine specs at each chosen engine speed. In order to determine the ideal spark advance at each chosen 3 Mode Genset Cycle engine. Power, Torque, BSFC and Volumetric Efficiency was chosen as the dependent variable. The spark timing that produces the most braking torque at a given 3 Mode Cycle is the ideal spark.

Forecast Using CNG Fuel:

The "fuel object" attribute in the fuel injector object of the 1D model was changed for the prediction of the CNG Engine performance.

A. Comparison of Measured data v/s Simulated data of CNG fuel for Genset Engine Performance

There is a variety of software available that can simulate the process involved in your research work and produce the best possible result. GT Power is one example of such software. Once these GT Power files are uploaded into software, you can get simulated results which simplifies the process for doing optimization in developing a new engine or meeting regulation targets.

Fig.3 show comparison of Measured data v/s Simulated data with CNG fuel for Power

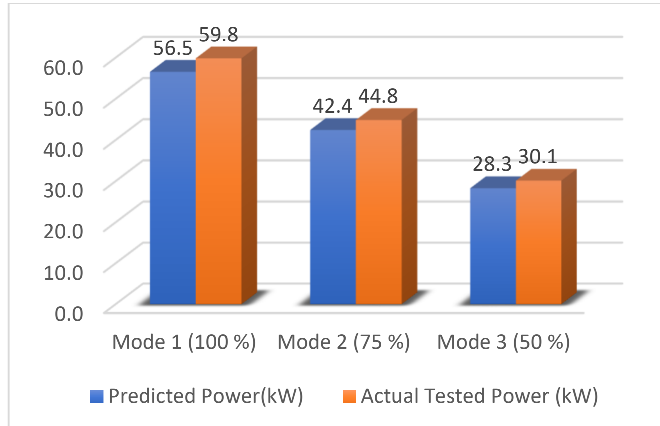

Fig.3 Power (kW)

Fig.4 shows comparison of Measured data v/s Simulated data with CNG fuel for Torque

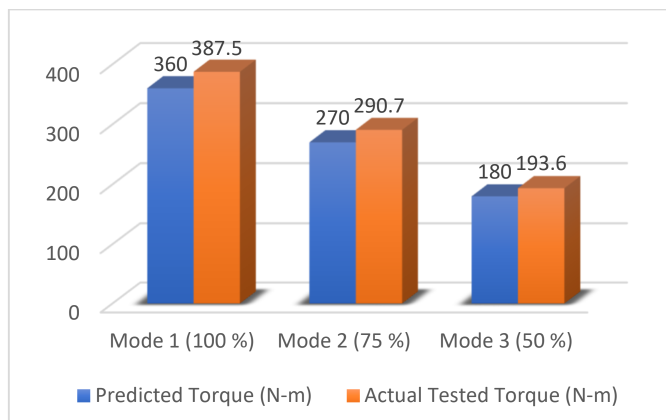

Fig.4 Torque (Nm)

Fig.5 shows comparison of Measured data v/s Simulated data with CNG fuel for BSFC

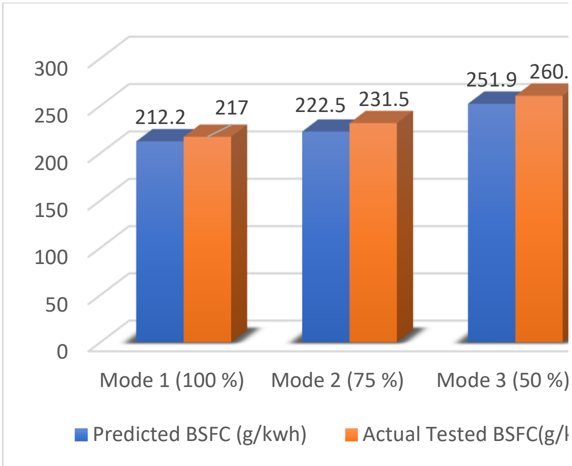

Fig.5 BSFC (g/kwh)

Fig.6 shows comparison of Measured data v/s Simulated data with CNG fuel for Exhaust Temperature

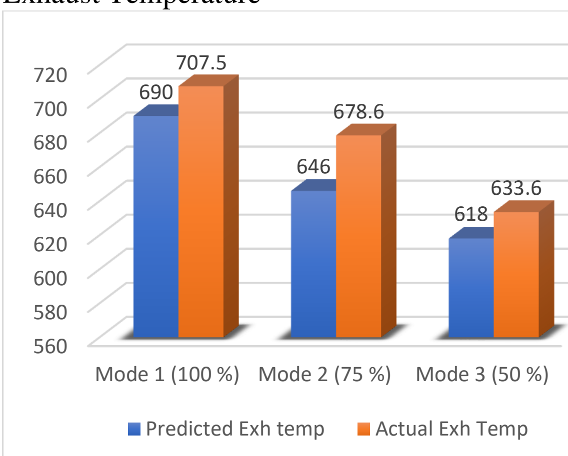

Fig.6 Exhaust Temperature (°C)

Fig.7 shows comparison of Measured data v/s Simulated data with CNG fuel for Volumetric Efficiency (%)

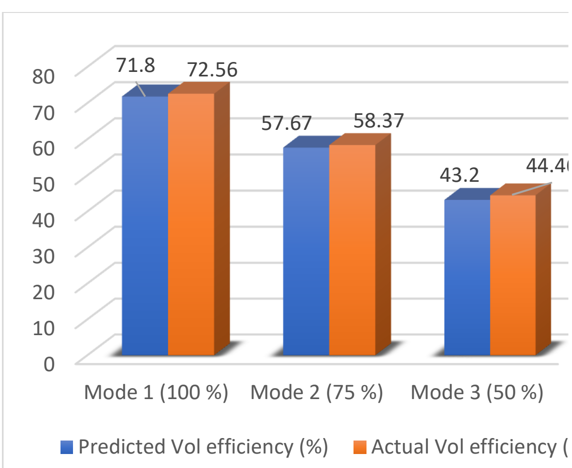

Fig.7 Volumetric Efficiency (%)

Conclusions

- Getting a verified engine model in a chosen 1D simulation tool (GT-SUITE) for CNG was the main goal of this work.
- For a given fuel, the optimum spark advance needs to be slightly advanced for both, rich and lean mixtures as compared to stoichiometric operation.
- The baseline engine model (CNG as fuel) was validated experimentally with the simulation results following the same trend as the experimental results and lie within an accuracy of 5 % (maximum) across the entire speed range.

References

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