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An Investigation on the Efficiency of the CNG Engine's Intake Manifold and Injection Systems

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ABSTRACT

Variations such as piston, exhaust, and manifold were prerequisites in the internal-combustion engine to achieving effective torque, power, and productivity. The reduction of toxic gas emissions is another benefit. Engine performance was improved due to these variables. The intake manifold's primary function is to ensure that the air-fuel mixture is distributed uniformly throughout the cylinders of the engine. The development of an intake manifold and an investigation into the effects of CNG SPFI performance variables such as injection position and air-fuel ratio. Deflection and stress have been measured in a variety of systems. The air-fuel mixture's homogeneity index was also tested by moving the injection point in an examination of computational fluid dynamics. In addition, the k turbulence approach was used to show the impact of turbulence on the aircraft. In this case, the engine's performance was anticipated using 1D experimentation software, and the results were compared to those obtained by simulation.

Keywords: *SPFI; Fuel Injection; CFD; Injection Locality; Manifold.*

1.0 Introduction

The area of the motor between the cylinders and the choke body is known as the internal manifold in interior ignition motors. Its primary function in a multi-chamber engine is to evenly distribute the airflow among all of the chambers and to provide a consistent fuel-air mixture. Air entering the motor chambers in large streams has a significant impact on volumetric productivity. We have two different types of fuel injection methods: MPFI (Multi Point Fuel Injection Indicated System) and SPFI (Single Point Fuel Injection Indicated System). The SPFI is a technique for placing a single injector—or a group of injectors—in a single, essentially uniform spot on the internal manifold. To improve the constancy of the air-fuel mixture in this framework, the infusion area assumes a crucial role. Maji Three-dimensional continuous flow in two different types of channel complex has been theoretically replicated by using the optional Lagrangian - Eulerian (ALE) method [1-3]. The inner manifold plan is chosen while mass stream paces are compared. The study analysed the air-fuel stream of a long and short sprinter internal manifold with variable plenum chambers. The study examined the effects of admission sprinter length and breadth on a four-stroke and single-cylinder IC Engine demonstration, and the results were validated using GT-Power game programming. Internal manifold structure and valve port effect volumetric efficiency and stream power, according to [4-5]. On CFD analysis, Using the rapid flash start engine's entrance valve,

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study polyhedral matrix dependability and work size. Work in developed a winding internal manifold model to forecast gas flow in the admission arrangement of a single chamber IC Engine. The interior manifold affects motor volumetrics and appearance. The study in adjusted the entrance sprinter breadth and valve timing of a complex framework [6-7]

In order to investigate the effects of admission sprinter width and time on the motor execution, research using the engine reproduction software Ricardo Wave has been done. The results are compared with those from skeleton dyno tests. The research looked into how volumetric proficiency was affected by entrance length for different engine speeds [8-9]. On the basis of consumption of sophisticated and contrasted test data, It has been established that a one-dimensional simulation can accurately forecast the weight wave at two distinct sites. The investigation on the liquid stream that was conducted for the course during the intake complex with several different cross areas of the choke body was described in the work that is found. The idea of the stream at the valve as well as a relative reading of the weight and speed range are both developed here. [10-13].

2.0 SPFI Manifold System Simulation and Modeling

This component controls internal manifold pressure and deformation. The automobile box complex is rebuilt to get the internal manifold data base. Using CATIA software, the H4TC CNG Engine SPFI's internal manifold architecture is modified. Plenum, center, and choke body are made individually and assembled by relating imperatives and resilience’s. In the complicated box framework. The infusion point is 175 mm from the chokes body [14-15]. Produced to meet 3.65-liter volume standards. To increase consistency list, the inner complex is rebalanced with a mixed region 160mm, 230mm, 150mm, 130mm, and 180mm from the gag body. The intake system feeds air and fuel to a chamber-mixing engine component. The affirmation complex plenum [16] promotes this combination. It's rectangular, 2.70 litres, 660 mm long, and 120 mm wide. The plenum and stifle body are the focus. It's 60mm wide. The gag body regulates engine air-fuel flow. Single point fuel infusion area affects air-fuel mixture. 175mm longer than the choke body, the system has 15.5 mm deltas [16-18].

Figure 1: Core in the Intake Manifold

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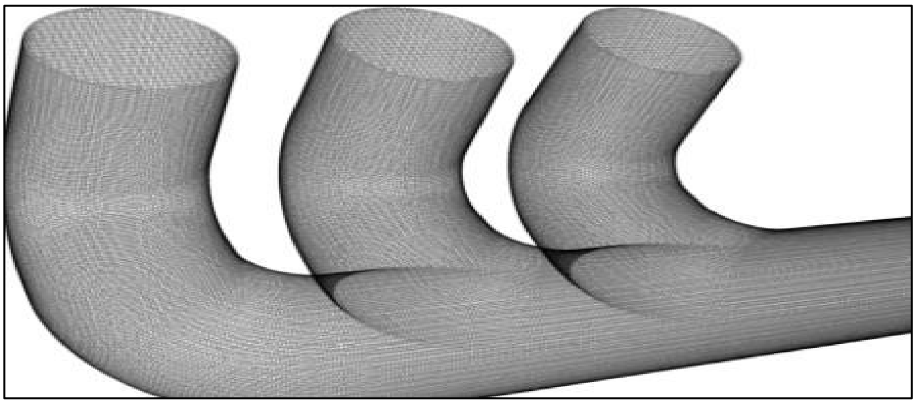
Figure 2: Intake Manifold Mesh Geometry

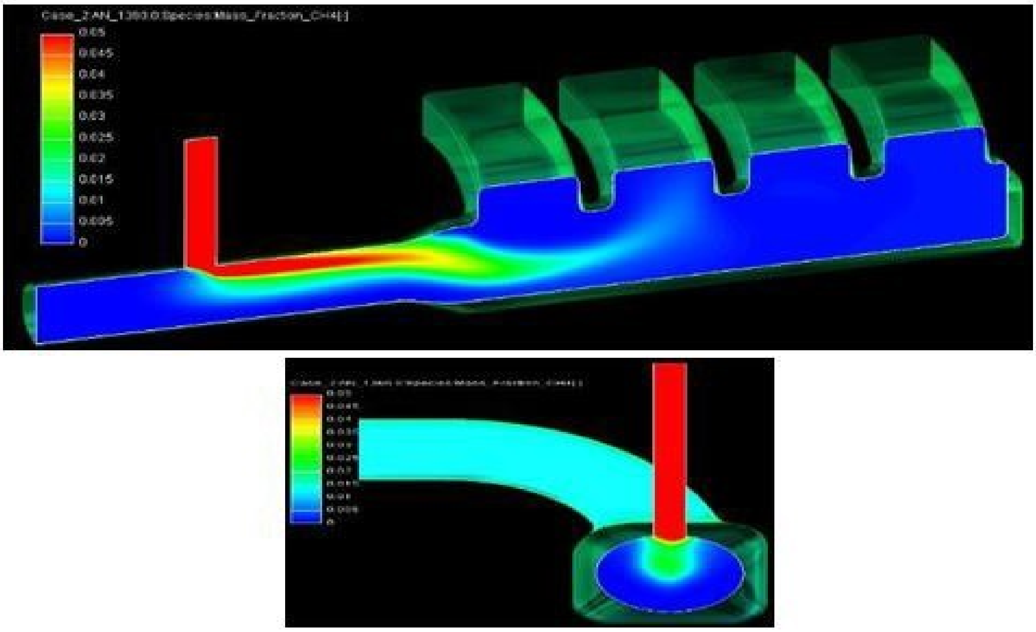


Because of its hygienic geometry for missing lines, hole filling, and other issues, CAD model has been saved as a STP file and imported into ANSYS. The tetrahedral component has a minimum size of 0.6433mm and a maximum dimension of 82.34mm, which coincides with the hygienic calculation.

3.0 Configuration of the SPFI in 3D CFD Simulations

In the CNG gulf and air bay, mass flow rates and weight conditions are measured. Air gulf and CNG channel specify the weight and temperature of the immediate environment. The margin for 3D CFD Flow rates of 0.09638 kilograms per second (in air) are combined with a temperature of 300 degrees Celsius, a pressure of 0 pounds per square inch (in CNG), and a mass-flow rate of 0.09638 kilograms per second (in CNG). the engine's inlet mixture pressure is 3600 psi

Figure 3: Using 3D CFD to Model the SPFI Configuration



Using CNG and air in conjunction with an injector angle of 90 degrees would be ideal. The engine supplies the required energy.

Figure 4: When Cylinder 4 is Operational

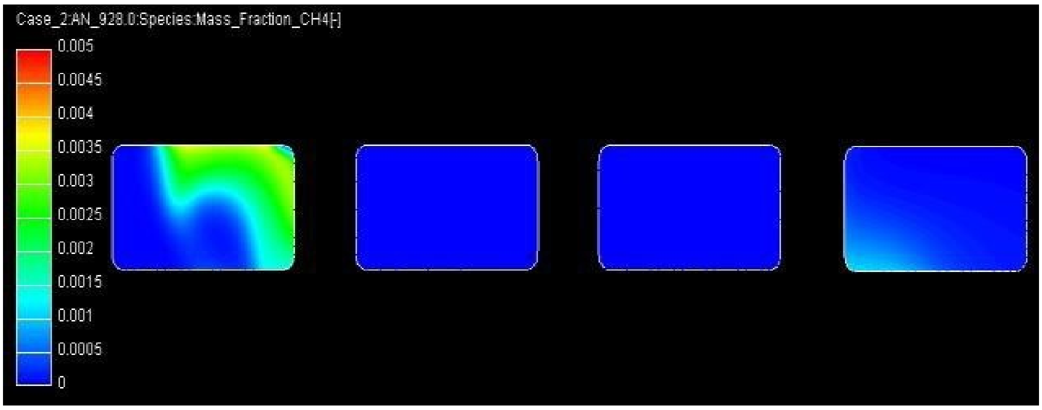


Figure 5: When Cylinder 3 is Operational

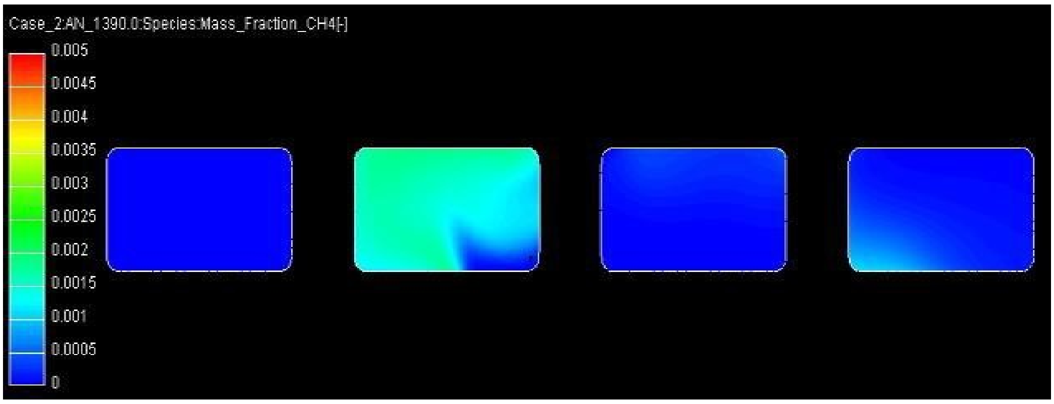
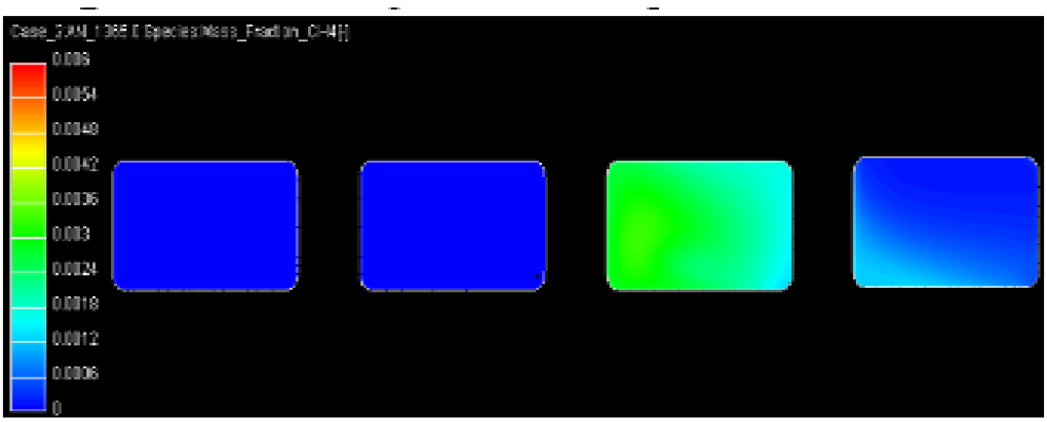


Figure 6: When Cylinder 2 is Operational

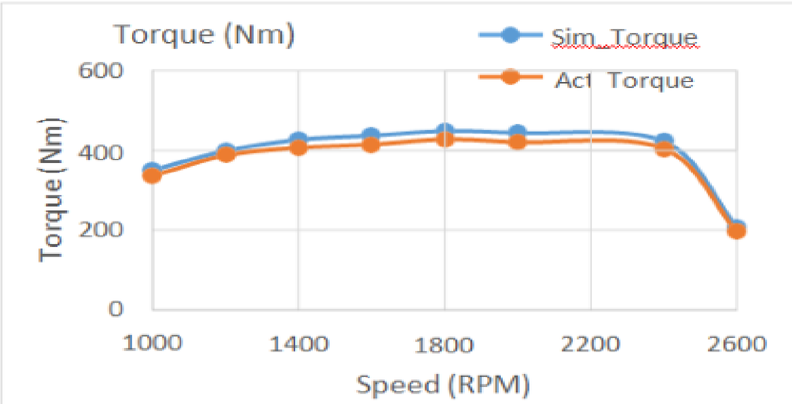


The stream that comes out of sprinter exits nos. 1, 2, and 3 is distributed uniformly across the entire cross section. Sprinter 1 has experienced very little flow through it as a direct result of its location in proximity to the air intake. Throughout the top portion of the entire run, there has been a buildup of flow at outlet 4, which is located at the very end. In this particular instance, it is believed that the sudden fixation with approaching stream and through math is to blame for the fact that it does not get at the inward corners of cross area at all. The fact that runner4 is located near the air filtration indicates that there is sufficient flow.

4.0 CFD Analysis of SPFI Configuration

Before conducting a 1D investigation into a turbocharged 4 cylinder SPFI CNG motor complex, there are a number of conditions that need to be satisfied first. Some examples of these requirements are an engine chamber calculation, a valve timing profile, an ending request, fuel properties, a choke body trademark, a turbocharger map and characteristics, an inlet stream profile and coefficient, a delta pipe width for the motor complex, and so on. The performance of a motor is assessed over a speed range of 1000 to 2600 revolutions per minute using GT Power's SPFI framework and a genuine motor mounted in a motor test cell. The whole findings are listed below.

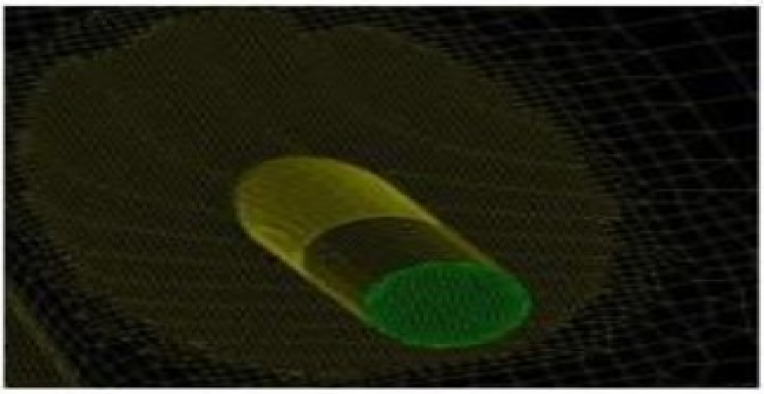
Figure 7: 1D CFD Analysis



4.1 Coordinated MPFI MANIFOLD simulation and modelling

Injector rails are used to accept CNG from the motor in this type of injection system. The MAP sensor is used to approximate the load on the engine in these frameworks, which are based on the rule of velocity thickness.

Figure.8: The MPFI System's Mesh Geometry



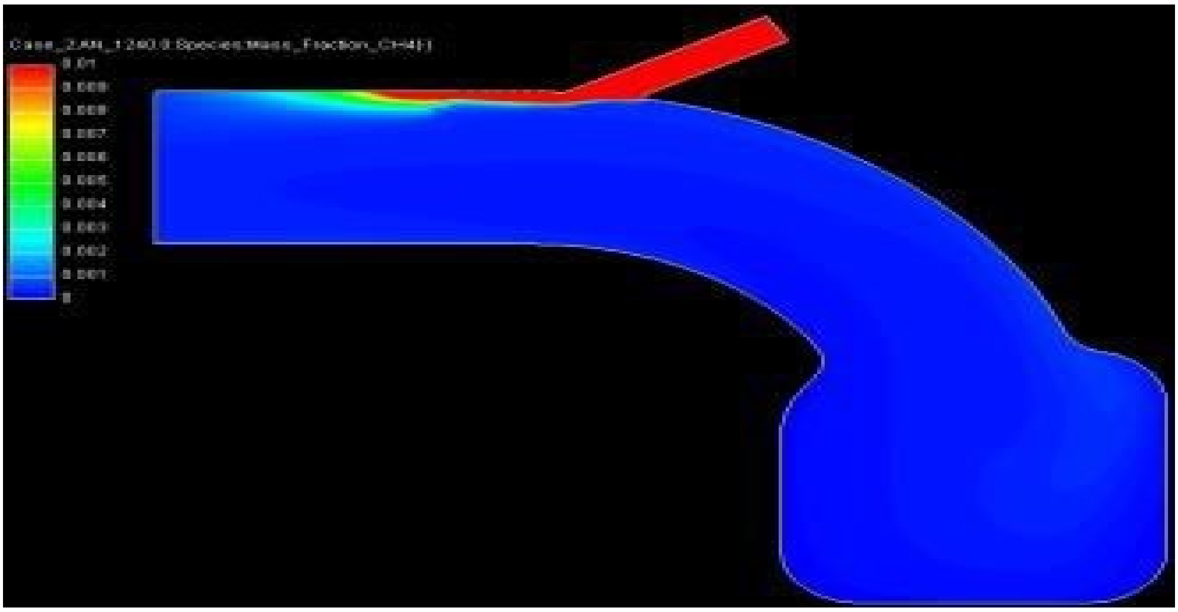
The characteristics of a fuel-air mixture admitted through a port are influenced by a number of factors. Aside from air speed and weight distribution, choppiness valves, and so forth, what affects fuel vaporization most clearly is temperature profile in the entrance port. The internal manifold plenum facilitates the flow of this mixture. There are two plenums, each measuring 65 80 millimeters in width and height, and they have a combined volume of 2.65 litres. The plenum is located in the middle of the choke body. A mixture of air and fuel is sent into the plenum through this port It's made from molded square channels. An engine's amount of Air-Fuel is measured by the choke body, which is in charge of that function. It has a diameter of 55 mm. An internal manifold Fuel and air mixtures are delivered to the combustion chambers via runners, an internal manifold component.

The computation is coincided by the tetrahedral component, which comprises a minimum size of 0.5mm and a maximum size of 40mm for the component. When it comes to the most fundamental part of the computation, the smaller the size of the meshing that is created. Reasonableness and the type of investigation are taken into consideration in order to make the selection of the sort and size. The Fit Intake system is a complicated architecture that consists of 174012 elements and 928472 nodes.

4.2 MPFI configuration simulated in 3D CFD modeling

When the CNG injector is positioned at a 30-degree angle, the CNG and air mixture is begun in the top territory and is calculated as the top cross-region since it runs via the internal port. To top it all off, the engine's power has been sufficient.

Figure 9: View from 'Y



The design of the sprinter outlet is actually constant. Sprinters have wave elements within them that act as a funnel, causing the curly form of the racers. There is a 5.98 percent standard deviation in the stream at sprinters 1, 2, and 3 as compared to sprinter number 4. 0.1711Kg/s is the mass flow rate for a major portion of the positive stream during the cycle. Because of the switch from SPFI to MPFI, the reenactment's speed has increased from 0.1678 Kg/s to 0.1756 Kg/s. By allowing CNG to communicate with air that is approaching, SPFI may reduce wind flow.

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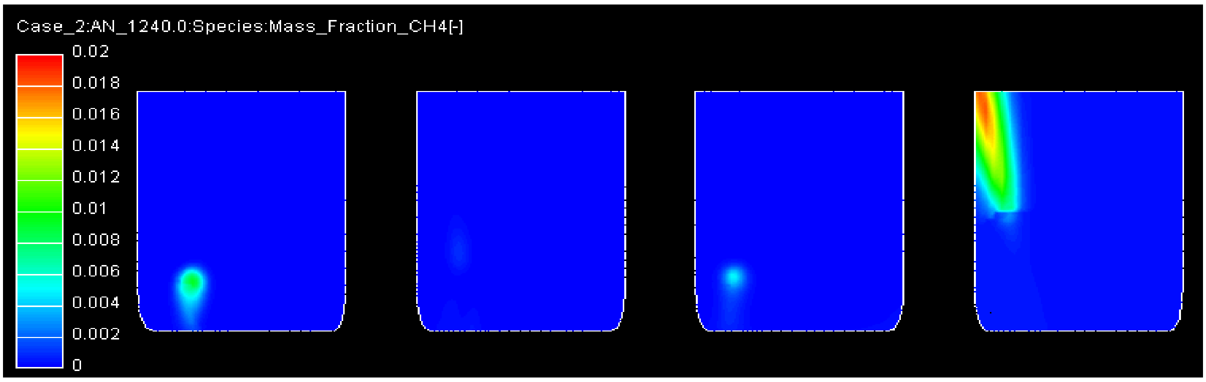
Figure 10: Active when, the Flow in the Runner's Outlet

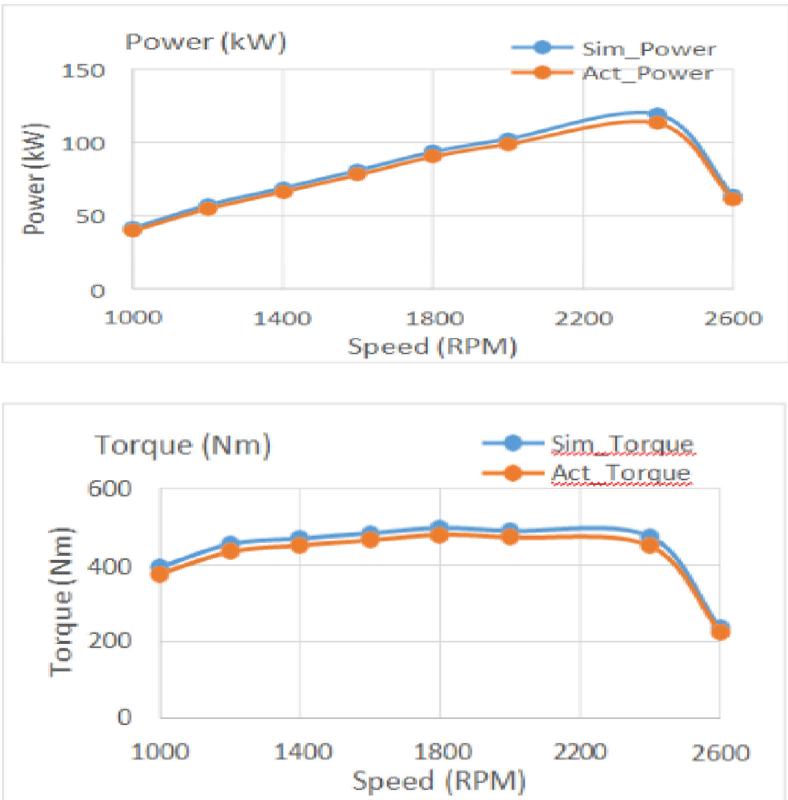


4.3 MPFI configuration 1D CFD analysis

Valve timing, inlet port flow characteristics and turbocharger map and map coordinates are only a few of the variables that go into an engine's cylinder geometry. The modified MPFI system from GT Power and an actual engine in an engine test cell are used to measure engine performance in the 1000-2600 rpm range. The following are the findings:

The modified MPFI system from GT power analysis gives 3.5 to 5 percent more power than the actual engine test results acquired by the engine test laboratory, according to the results of both systems.

Fig.11: Compared to the GT Power Analysis, the MPFI System

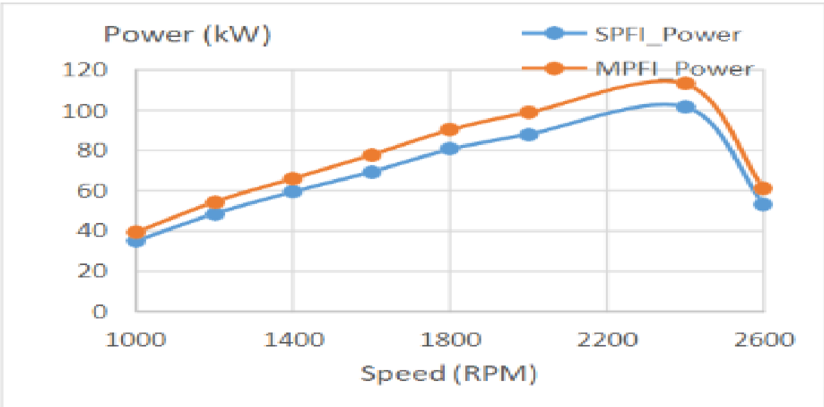


4.4 Comparison SPFI and MPFI CNG engine performance

Using that approach, we were able to compile data on the flow of the air-fuel combination in MPFI and SPFI engines. Compared to SPFI setup, the flow of the Air+CNG mixture is better in the MPFI configuration. Due to air and CNG inflowing close to the internal manifold inlet, SPFI may reduce airflow.

Engine test beds in the lab use the same engines for testing. Engines warm up and perform at full power between 1000 and 2600 revolutions per minute (RPM). The MPFI engine's power and torque are around 10% higher than the SPFI engine, according to the combined findings of the two tests.

Figure 12: Engine Testing in Test Cells as the Basis for Analysis



5.0 Conclusion

The following conclusions have been drawn from research involving 3D CFD analysis, 1D analysis, and intake manifold experimental test data.

- Engine performance can be achieved with a 90°CNG injector position and the air-fuel mix appears to be evenly distributed at each manifold output. Runner 1's distribution flow is significantly lower than that of the other four runners, as they are located far from the air inlet.
- Additionally, the flow of runners out of No. 4 has been concentrated in the upper portion of the segment. For this reason, it hasn't been possible to reach the inner corners or edges of the cross section, because of drift diversion and geometry.
- GT power analysis' modified SPFI system generates 4% to 5% higher power than real engine test results, according to a one-dimensional analysis.
- Using a CNG injector position of 30 degrees, the CNG and air can be combined at the upper portion of the intake port, and it has been anticipated that it will fill the cross-section. Runners 1 through 3 have an average flow variance of 5.98 percent when compared to Runner 4. For the highest portion of positive flow, mass flow over mixture averages 0.1711 kilograms per second (kg/s).

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