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PERFORMANCE COMPARISON OF SINGLE POINT AND MULTI POINT FUEL INJECTION ENGINE MANIFOLD SYSTEM

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Abstract: Intake manifold of IC Engine plays a very crucial role to improve the performance of the engine. The main function of intake manifold is to evenly distribute combustion mixture to each intake port. The aim of this paper is to investigate the performance of the engine by using single point fuel injection system and multi point fuel injection system, Also to investigate the effect of intake manifold systems on the performance of the engine. For that the two intake manifold systems have been taken into consideration for evaluation. To simulate 1D model SI Wiebe Combustion Model and Woschni Heat Transfer Model is used. The 1D analysis of the engine with SPFI manifold system is done by using 1D Simulation software. The result of 1D analysis is evaluated by using test cell results. Then the 1D Simulation of new MPFI System is carried out using same software and finally the comparison of results of MPFI system and experimental results are evaluated.
Keywords: IC Engine, 1D Analysis, SPFI, MPFI

1. INTRODUCTION

In IC engine to improve the performance and reduce emission gases the engines breathing ability plays a very crucial role. In plenum of the intake manifold two waves are formed (compression and rarefraction) during induction process. These two waves affect more to improve the breathing ability of the engine. This theory is known as intake tuning theory. So the selection of intake manifold plays a very crucial role to improve homogeneity of the air-fuel mixture. There are basically two types of intake manifold systems Single point intake manifold and Multi point intake manifold systems.

V.S Midhun et.al [1] have discussed the methodology to convert the diesel engine into CNG engine to meet Euro v emission norms. The CFD Analysis of Single point fuel injection and multi point injection systems have been carried out. The researchers have worked to get the optimum engine performance, injection timing, and volumetric efficiency. The performance of the engine have been estimated by using 1D analysis and the CFD Analysis have been done to check the homogeneity of Air-Fuel mixture. Ishant Gupta et.al [2] have done theoretical study of multi point fuel injection system. The study shows that how the injection system impacts on the power output, fuel efficiency, Emission, Performance, smooth operation and maintenance cost of the engine. The researchers have briefly discussed the different components of the MPFI system. Researchers have discussed the advantages of MPFI system over different injection system.

Luiz Otavio Ferrao Texeira Alves et.al [3] have elaborated the effect of intake runner length and diameter on the performance of the four stroke single cylinder engine. 1D analysis was carried out by using 1D simulation software GT-Power and optimization software mode frontier. The runner length and diameter have been calculated by using Helmholtz resonator theory and intake tuning theory. M.A Cevin et.al [4] have discussed the effect of intake plenum length and volume on the performance of the spark ignition engine. The engine test has been carried out with different plenum volume to design a new variable length intake manifold plenum. The evaluation of performance of the engine is carried out by consideration of brake torque, brake power, thermal efficiency, and specific fuel consumption. According to the researchers the engine plenum length must be extended for low engine speed and shortened for high engine speed.

Harishchandra Jagtap et.al [5] have predicted the performance of the engine by using two different intake manifold runner length. The performance prediction of engine is done by using AVL Boost 5.1 1d simulation software. The uniformity index of the mixture is evaluated by using CFD analysis. Researchers found that the engine with short runner manifold gives better volumetric efficiency than the long runner manifold and the CFD distribution fluid flow is more uniform for short runner manifold. Dileep Namdeorao Malkhede et.al [6] have investigated the effect of intake length on volumetric efficiency for high range of engine speed. For that 1D model of the engine were developed and analyzed by using 1D simulation software. The results of 1D model were compared with Experimental result. From this study it is found that the volumetric efficiency changed. Helmholtz resonator theory and the acoustic theory have been used to calculate optimum intake length.

Bayas Jagadishsingh G et.al [7] have designed the intake manifold runner length by using Chrysler ram theory and Helmholtz resonator theory. The analysis of the engine has been carried out using 1D CFD Code lotus engine simulation. From this study it is concluded that intake tuning method closely predict the intake length required to obtain maximum volumetric efficiency and significant improvement in performance of the engine obtained using variable intake length. L.J.Hamilton et.al [8] have evaluated the testing of various intake runner lengths and cross section geometries on a Honda CBR 600 gasoline engine. The effect of Air-Fuel mixture is evaluated by adding 180 degree bends to the intake runner. The short length intake runners of 0.25 to 0.45 have evaluated to identify the better runner length intake manifold. The intake tuning theory was used to calculate better runner length. Then the CFD Analysis of the same manifold systems has been done. The result of CFD analysis has been evaluated with experimental result. Chawin Chantharasenawong et.al [9] have estimated the performance of racecar engine for different runner length. The runner length have been determined from the wave equation over different range of engine speed. Computer simulation has been performed to determine the pressure of Air-Fuel at the engine entry with various runner lengths. Finally the simulation results have been compared with chassis dynamometer test. Shashank Ghodke et.al [10] have evaluated the effect of runner diameter valve timing on the engines volumetric efficiency. 1D simulation has been done of the engine dynamometer. Test was carried out using engine simulation software Ricardowave. The simulation results are validated by using chassis dynamometer test. Researchers have concluded that when only runner diameter varied the improvement in volumetric efficiency found appx 8.5% and when valve timing varied the improvement was seen 3%.

This paper aims to study effect of different intake manifold systems on the performance of the IC Engine. Another application of this study is to compare the Performance of the engine with two different intake manifold systems. Performance of the engine is simulated by using engine software GT-Power. The results of GT-Power are validated with Experimental results. The work has been carried out on a 6 cylinder NA Engine with 6 Liter capacities.

2. 1D SIMULATION OF NA CNG SPFI ENGINE

This section deals with the estimation of the engine performance by using Single point fuel injection manifold system. The data of the engine is obtained by existing CNG SPFI engine. In order to simulate the engine performance the 1D Analysis is done for different speed range. To simulate the performance of the engine the software GT-Power is used. GT-Power is a effective tool used in industry to perform 1D simulation so the benchmarked data is used to prepare GT-Model. The six cylinder NA CNG engine is used for performance analysis. GT-Power can be used to predict either steady-state conditions or transient behavior of engine system. It is used to predict engine volumetric efficiency, power, torque, flow rate and flow velocities in all passages, pressure and temperature of the gases in each component of the system. SI Wiebe Combustion Model is used. GT Power is effective tool used in industry to perform 1D simulation so the benchmarked data is used to prepare GT-Model. Figure shows the 1D model which is used for simulation of SPFI Engine to validate Engine power, Engine torque and break specific fuel consumption of the engine. The intake manifold details are also given so the précised performance of the engine is traced. The model now can used to predict engine performance for engine.

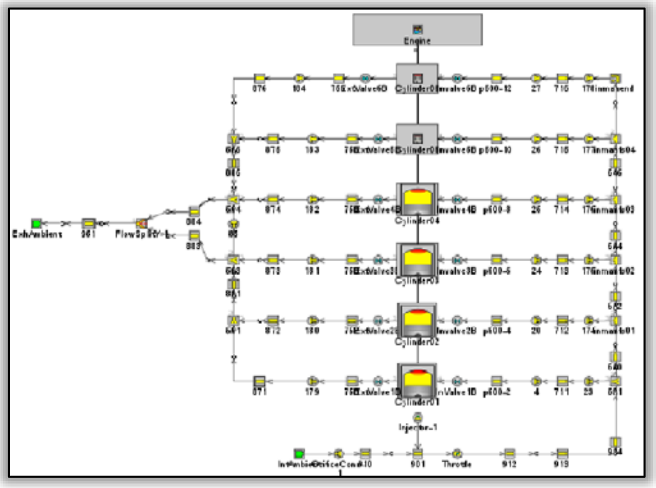

Figure 1. 1D Analysis of Existing SPFI System

3. EXPERIMENTAL ANALYSIS

For vehicle with gross vehicle weight less than 3.5 Tons can be tested directly on the chassis dynamometer for Engine performance parameters measurement and for vehicle with gross vehicle weight more than 3.5 Tons need to have their engines removed and tested on the engine dynamometer.

The Engine is tested in the test cell which fully facilitated by the equipment's. The CNG Engine is coupled with a dynamometer for load application. A dynamometer is a machine used to measure torque (N-m) and rotational speed (rpm) from which power produced by an engine can be calculated. A dynamometer absorbs the power developed by the engine under test. The dynamometer must be able to operate at any speed and load. The prime mover to any level of torque that the test requires a dynamometer is usually equipped with some means of measuring the operating torque and speed. The power absorbed by dynamometer is generally dissipated to the ambient air or transfer to cooling water. Test bed operation is control by AMA i60-04 [AVL] software.

The test cell is equipped with the conditioning air system needed as per the testing standards for carrying out the testing as per standard atmospheric conditions. The test bed is also having heat exchanger for cooling purpose. Engine in the bed is connected with intercooler, fuel tank. The engine is controlled by Engine controlled unit and control panel. Engine performance is assessed for speed range of 1000 to 2400 rpm. For the same speed range Power and Torque is recorded and plotted for SPFI Fuel injection system. The curve obtained for SPFI is validated using Experimental results.

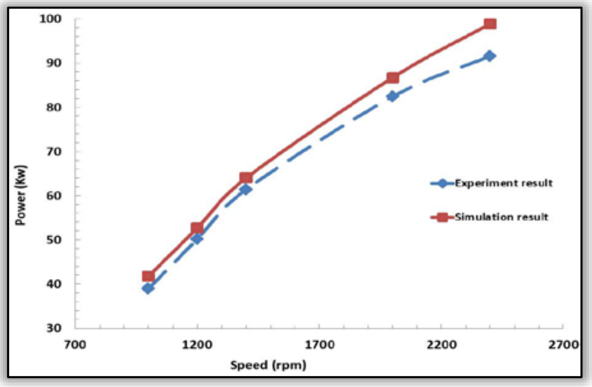

Figure 2. Power Comparison for Experimental and 1D of Existing SPFI System

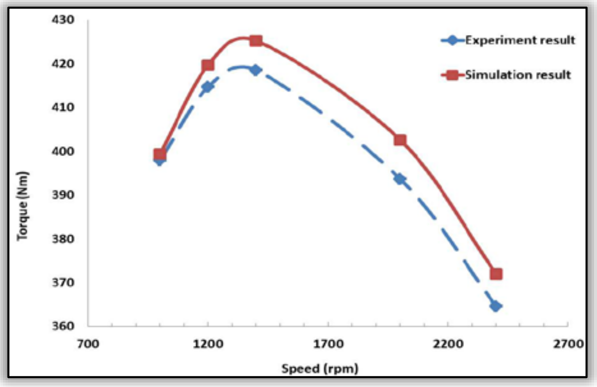

Figure 3. Torque Comparison for Experimental and 1D of Existing SPFI System

Figure 2 shows the normalized brake power of the engine from the speed range of 700 to 2700 rpm by Experimental and simulation method. Improvement in the power is observed especially when speed of the engine get increased. It is observed by both the method that power increases for the engine from the speed range of 700 to 2700 rpm.

Figure 3 shows the normalized brake torque of the engine from the speed range of 700 to 2700 rpm by Experimental and simulation method. Here the peak torque is 425 Nm at 1400 rpm.

4. PERFORMANCE PREDICTION FOR CNG MPFI ENGINE

In the Multi point fuel injection system the injector injects the fuel into the admission valve of each and every cylinder individually. The Engine control unit has total command of how much fuel is to be injected. This technique provides uniform fuel to each cylinder so that the engine gets better power and higher output from each one of them. So there are many advantages of MPFI over SPFI Have studied in this paper. So the new MPFI system has been designed to check the performance of the engine. The new MPFI System is designed for the same engine.

The Performance of the engine is totally depending on the Air and fuel motion inside the intake manifold. So to get the best performance design of intake manifold plays a crucial role. The flow resistance will get reduce and breathing ability will improve if the intake manifold design would be proper.

The flow distribution in manifolds is totally depends on the manifold volume, design of the manifolds runner, and total inlet flow pressure in the manifold. The intake manifold system is having complex structure and it consist of Air-fuel mixture with different velocity magnitude and pressure magnitude. To find out the type of flow in manifold. It is necessary to calculate the Reynolds number and Mach number. Calculated Reynolds no is greater than 4000 so the flow is turbulent. Calculated Mach number is less than 0.8 so the flow is subsonic.

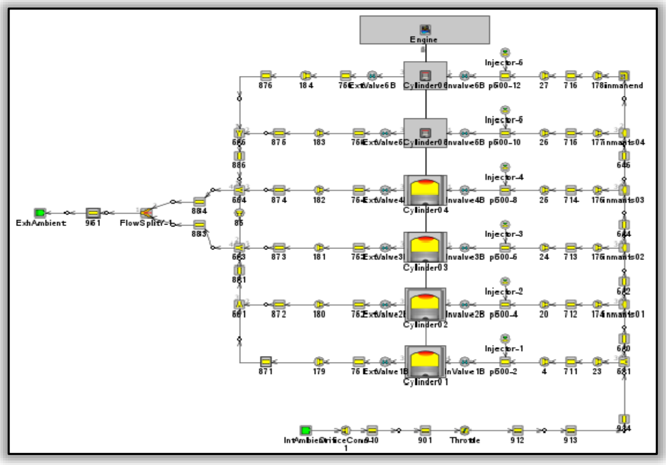

Figure 4. 1-D Analysis of MPFI CNG Engine

Too small throat causes air flow restriction at the throat which is undesirable for better mixing fuel and air. The mass flow rate of engine for maximum speed of 2400 is given. Maximum mass flow rate of engine was used to find the pipe size. The gas was assumed to be incompressible fluid where the Mach number is less than 0.1.

$$V = MC \tag{1}$$

where, Velocity (V) in (m/s), Mach no M is equal to 0.07 and Speed of sound (C) is equal to 343 m/s.

The mass flow rate (M) at maximum speed of the engine 2400 rpm is equal to 0.09438 Kg/sec, the Area of pipe (A) in m^2 and the Velocity at the inlet (V) is 24.69 m/s. by knowing the mass flow rate and velocity of flow for the engine operation, the initial approximation of the throat size was computed by using equation 2.

$$M = \rho A V \tag{2}$$

With the use of above equations, the inlet pipe and throttle diameter was calculated which is equal to 60 mm.

5. RESULT AND DISUSSION

Figure 5 shows the brake power of the engine for SPFI and MPFI from the speed range of 900 to 2500 rpm. It is observed that power of MPFI increased by 2% compared with SPFI for same Engine. In MPFI system the Engine control unit has total command of how much fuel is to be injected for each cylinder. This gives individual control of the cylinder and hence for each and every cylinder same amount of fuel is delivered. The lambda range is effectively controlled by MPFI System.

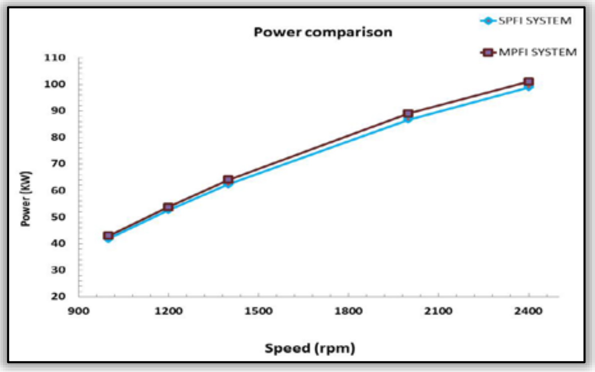

Figure 5. Power Comparison of SPFI and MPFI Systems

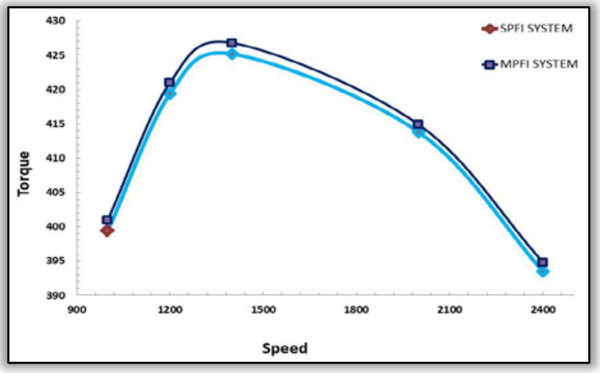

Figure 6. Torque comparison of SPFI and MPFI Systems

Figure 6 shows the Torque of the engine for SPFI and MPFI with speed range of 900 to 2500 rpm. It is observed that for MPFI system torque increased by 2%. The maximum torque obtained for both systems at the speed of 1300 rpm. In MPFI system the Engine control units have total command of how much fuel is to be injected for each cylinder. This gives individual control of the cylinder and hence for each and every cylinder same amount of fuel is delivered. Hence the better torque is observed for MPFI system.

6. CONCLUSIONS

- In this paper detailed study of design of runner volume and plenum volume are carried out.
- Power and Torque was observed for both MPFI and SPFI Engine.
- As Engine speed increased the power and torque increased for both the system but for MPFI system it is higher because of that MPFI system is better than SPFI.
- The Engine control unit have total command of how much fuel is to be injected. This technique provides uniform fuel to each cylinder so that the engine gets better power and higher output from each one of them. Hence for each and every cylinder same amount of fuel is delivered. Vice versa In SPFI system same amount of mixture is not circulated to the all cylinders. Because of this MPFI system gives better engine performance than the SPFI system.

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