Significance of Intake Manifold Material on Engine Performance

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Abstract

The breathing process in the engine is important for power production and it is controlled by the suction manifold. The movement in the suction manifold is considered as pipe flow where in the frictional losses will be more. The finishing and surface roughness of the material are important and can be attained by the manufacturing process. This project intends to compare the performance of an engine with three different intake manifolds with different materials. The materials are PA6GF30, PA66GF30 and AlSi8Cu3. The original engine manifold is made up of AlSi8Cu3. The manifold of other two materials is prepared to the required dimensions and conducted the performance analysis on the engine by keeping other parameters as constant. The results have shown better improvement in the power and torque developed with Intake manifold material of PA6GF30. The brake specific fuel consumption decreases for PA6GF30 manifold for all loads when compared to PA66GF30 and AlSi8Cu3 manifolds. The volumetric efficiency and air flow rate increases for PA6GF30 manifold for all loads when compared to PA66GF30 and AlSi8Cu3 manifolds. The results show the suitability of PA6GF30 material for manifold in order to get better performance..

Keywords: *PA6GF30; PA66GF30; $AlSi_8Cu_3$; Performance; BSFC; Volumetric Efficiency*

1. Introduction

The efficiency improvement of diesel engine is tremendous importance since they are used widely all over the world. The most important component of diesel engine is cylinder in which the method of fuel compression at greater hotness, i.e., the air – fuel (A/F) blend explosion is done. Diesel engine is working on the model of diesel thermodynamic cycle for the burning of the fuel where the air fuel mixture is burned at higher pressure and temperature [2]. Air Intake Manifold (AIM) is a vital portion of the engine for the suction of air into the engine. Distributing the air evenly to every intake port in the cylinder head is the primary function of AIM [3].

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The requirements of AIM include supplying an adequate quantity of oxygen to confirm complete combustion, preparing adequate amount of Exhaust Gas Recirculation (EGR) diluent to regulate combustion temperature, controlling the temperature and pressure of the charge, imparting exact bulk motion and kinetic energy to the charge for supporting mixing and combustion products and reducing the size and attentiveness of impurities present in the air. Through a chamber present in the suction slot of AIM, certain feeding for each pipe to the cylinder is taken place. Fixed air flow is used for the designing of the standard AIM. Volumetric efficiency has the impact on the size and shape of the AIM [4]. AIM has to provide as much air as possible for its given volume (volumetric efficiency) [5]. Engine efficiency is also affected by AIM design. AIM improves the performance of the engine by providing sufficient air volume to the combustion chamber [6].

In general, the AIM performance test is done by direct engine running and prototypes. Plan and construction of AIM uses Additive Manufacturing (AM) which require less cost and time in comparison to other methods [7-11].

If lighter material is used in the AIM, it will result in better overall efficiency of the engine. A Ford study [12] found that a particular lightweight nylon option as AIM material has many benefits, i.e., environmental health, conservatory gases, packaging volume and energy ingestion. It gauged aluminum air intake manifold (AIM) with thermoplastic polymer aluminum, by the nylon 66 arrangements bound with fibrous glass of 30% and became used by Du Point. The nylon products have the advantages on environmental issues, i.e., mechanical properties, energy consumption, greenhouse gases and landfill volume. The output shows that the acidity is relatively equal to the binary blending materials.

The results directed the variation of the plenum length with respect to engine speed and it should be higher for low speed and vice versa for getting higher burning rate. This regulates the intake plenum length for the particular operation of an engine. Injecting ethanol through exhaust during suction has a positive effect on emissions and increases the apparent heat release rate in Diesel engine [13].

The experiments carried out by Ceviz and Akın [14] for imitation of turbocharger improved engine performance by designing a manifold variable length plenum. Poor combustion during a higher load causes the smoke to its extreme in a marine diesel engine with controlled air injection due to improper air fuel ratios [15]. The consequence of intake air temperature and the impact of alternate materials for air intake on the ethanol fuelled diesel engine were analyzed [16].

The input air is given by the intake manifold to the engine is important because the output power is mainly depends on the input. The size, shape, material and manufacturing are the parameters to be studied to get higher intake. The thermal conductivity of the intake manifold material shows a vital character in the engine performance since it increases the temperature of the intake manifold. When the temperature of the manifold rises, it decreases the density and in turn the volumetric efficiency decreases.

The current work deals with the performance of an engine for various intake manifold materials of PA6GF30, PA66GF30 and $AlSi_8Cu_3$.

2. Material and Methods

The specifications of the engine and the properties of materials and manufacturing of manifolds are discussed here.

2.1. Engine Specifications

The specifications of the engine are 4 cylinder turbo charged diesel engine with 16.5 as compression ratio, 85mm as bore, 96 mm stroke, 2.2 liter as displacement volume, 103 kW (140 HP) as maximum power and 255 Nm as maximum torque at rated speed of 3750 rpm. The air intake manifold is made of PlasticAmide6 with Glass Fiber 30% (PA6GF30).

2.2. Properties of Materials

The air intake manifold is fabricated using PA6GF30 and PA66GF30. Polyamide 6 (PA6) is also recognized as polycaprolactam or Nylon and one of the most commonly used polyamide worldwide. Ring-opening polymerization of caprolactam is used for manufacturing PA6. The melting temperature of PA6 is 223°C. The one of the most widespread engineering thermoplastics is Polyamide 66 (PA66) and is widely applied as a reserve to metal in several places. PA66 is manufactured by polycondensation of hexamethylenediamine and adipic acid. The melting temperature of Polyamide 66 is 255°C. The benefits of PA66 matched to PA6 are absorbing marginally less moisture, greater modulus, sound wear resistance and enhanced short term heat resistance. The advantages of PA6 related to PA66 are better ductility (due to greater toughness), enriched long term heat resistance, superior impact resistance in small temperatures, good surface quality and improved creep resistance, healthier UV-resistance (depends on modification) and lesser cost. The mechanical and physical properties of both are compared with AlSi8Cu3 and are given in Table 1. The properties are shown lower young’s modulus, elongation, bending strength, impact strength, specific heat, melting temperature and density for PA6GF30 material. This recommends this as suitable manifold material. Further advantages of lower in weight, price, production cycle time, friction, air pressure loss and high thermal insulation were observed with the plastic material related to that of Aluminum. The equivalent characteristics of Aluminum solid are obtained through mixing plastic grades with glass fiber.

Table 1. Properties of Manifold Materials

Quantity	PA6GF30	PA66GF30	AlSi8Cu3
Young's modulus (MPa)	7500 - 9500	6000 - 15000	70000-75000
Tensile strength (MPa)	130 - 190	160 - 160	140-160
Elongation (%)	6 – 7	3 – 6	10-30
Bending strength (MPa)	270 - 270	130 - 300	607
Impact strength (J/cm)	1.2 - 1.7	1.1 - 1.1	1.1-1.3
Thermal expansion (e^{-6}/K)	20 – 30	25 - 30	26-30
Thermal conductivity (W/m.K)	0.23	0.67	0.7
Specific heat (J/kg.K)	1380	270	554
Melting temperature (°C)	260	255	660
Service temperature (°C)	-40 – 120	-40 - 80	-40-100
Density (kg/m^3)	1400 – 1400	1370 - 1370	2740

3. Experimental Setup

The engine is loaded with the eddy current dynamometer and burette setup is used to measure the fuel consumption. The engine speed is varied and the parameters measured are volumetric efficiency, power, air flow rate, brake specific fuel consumption and torque. Fig. 1 shows the experimental setup. Range, accuracy and percentage of uncertainties of different instruments used are shown in Table 2.

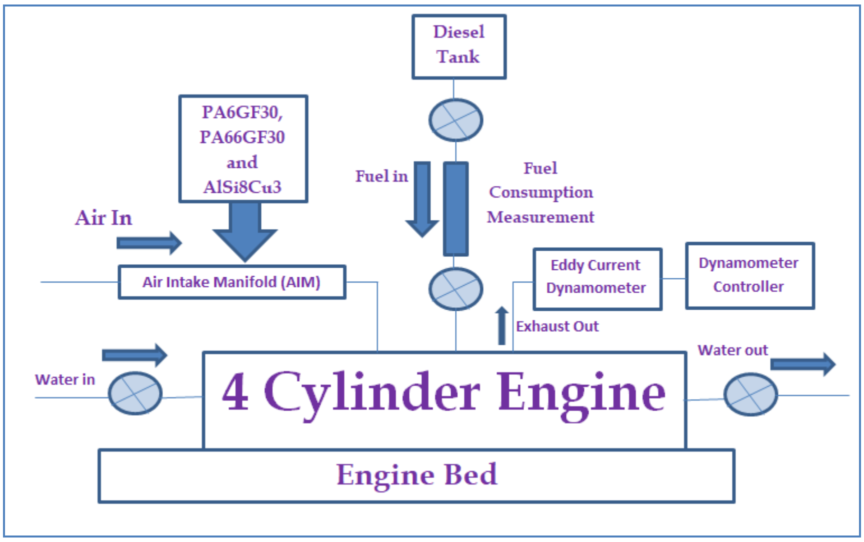

Figure 1. ***Experimental Setup***

Table 2. ***Accuracy and % of uncertainties of Instruments***

S. No.	Instruments	Accuracy	% of uncertainties
1	Exhaust gas temperature indicator	+1 to -1	+0.15 to -0.15
2	Speed measuring unit	+10 rpm to -10 rpm	+0.1 to -0.1
3	Load Indicator	+0.1 kg to 0.1 kg	+0.2 to -0.2
4	Burette for fuel Measurement	+0.1cc to -0.1 cc	+1 to -1
5	Digital stop Watch	0.6 s to -0.6 s	+0.2 to -0.2
6	Manometer	+1 mm to -0.1 mm	+0.1 to -0.1

4. Results and Discussion

The various results derived during the experiment are discussed here.

4.1. Power Vs. Speed

The variations of power with the increases in engine speeds for various AIM materials are shown in Fig 2. Increases in power are obtained for various speeds of the engine after the changes in intake manifold materials are used. PA6GF30 shows the higher increase in power when compared with PA66GF30. The maximum rise in power of 26.9% is obtained for PA6GF30 when related with $AlSi_8Cu_3$ at 2250rpm. The maximum increase in power of 8.46% is obtained for PA66GF30 when compared with $AlSi_8Cu_3$ at 4000 rpm. The properties of PA6GF30 aids in higher increases in power when compared with remaining materials. The reason for the increase of power for PA6GF30 plastic intake manifold are higher air flow rate, uniform air flow rate, improved design for plastic AIM, no restriction, high volumetric efficiency and less density of AIM material.

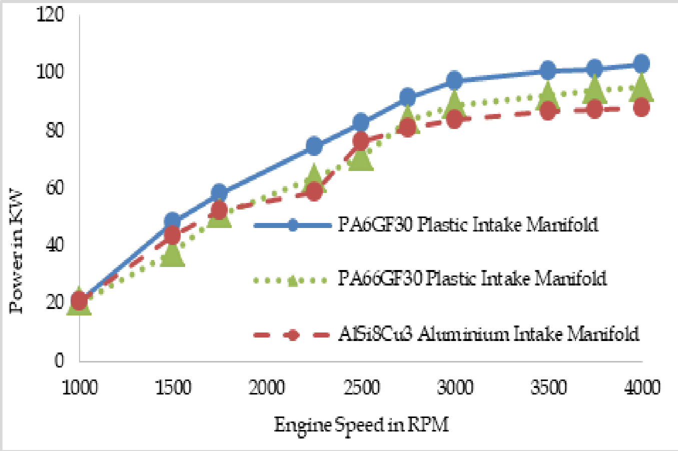

Figure 2. Variation of Power against Engine Speed

4.2. Torque Vs. Speed

The variations of torque with the increases in engine speeds for various AIM materials are shown in Fig 3. Increases in torque are obtained for various speeds of the engine after the changes in intake manifold materials are used. PA6GF30 shows the higher increase in torque when compared with PA66GF30. The maximum increase in torque of 18.76% is obtained for PA6GF30 when compared with $AlSi_8Cu_3$ at 3500rpm. The maximum increase in torque of 17.34% is obtained for PA66GF30 when compared with $AlSi_8Cu_3$ at 3500 rpm. The properties of PA6GF30 aids in higher increases in torque when compared with remaining materials. The reason for the increase of torque for PA6GF30 plastic intake manifold are higher air flow rate, uniform air flow rate, improved design for plastic AIM, no restriction, high volumetric efficiency and less density of AIM material.

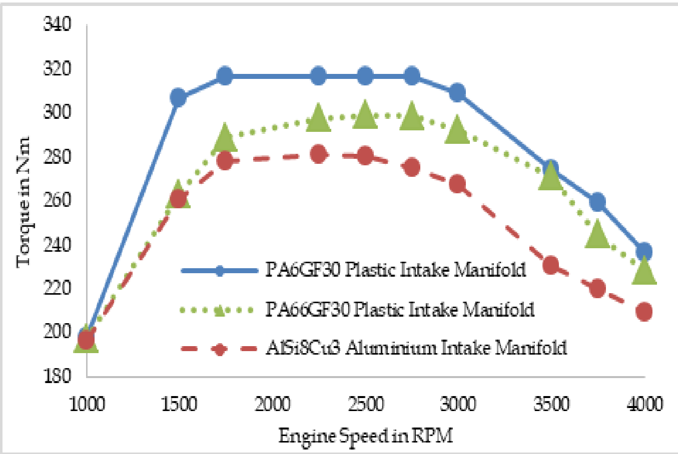

Figure 3. Variation of Torque against Engine Speed

4.3. BSFC Vs. Speed

The variations of the BSFC, with the increases in engine speeds for various AIM materials are shown in Fig 4. Decreases in BSFC are obtained for various speeds of the engine after the changes in intake manifold materials are done. PA6GF30 shows the higher decrease in BSFC when compared with PA66GF30. The maximum decrease in BSFC of 12% is obtained for

PA6GF30 when compared with $AlSi_8Cu_3$ at 1000rpm. The maximum decrease in BSFC of 6% is obtained for PA66GF30 when compared with $AlSi_8Cu_3$ at 1000 rpm. The properties of PA6GF30 aids in a higher decrease in BSFC when compared with remaining materials. The reason for the decrease of BSFC for PA6GF30 plastic intake manifold are higher air flow rate, improved design for plastic AIM, high volumetric efficiency and less density of AIM material.

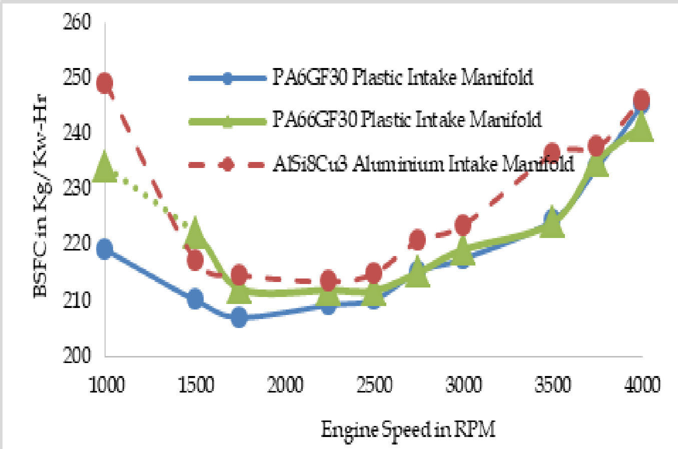

Figure 4. Variation of BSFC against Engine Speed

4.4. Volumetric Efficiency Vs. Speed

The variations of volumetric efficiency with the increases in engine speeds for various AIM materials are shown in Fig 5. Increases in volumetric efficiency are obtained for various speeds of the engine after the changes in intake manifold materials are done. PA66GF30 shows the higher increase in volumetric efficiency when compared with PA6GF30. The maximum increase in volumetric efficiency of 3.9% is obtained for PA66GF30 when compared with $AlSi_8Cu_3$ at 3500rpm. The maximum increase in volumetric efficiency of 2.96% is obtained for PA6GF30 when compared with $AlSi_8Cu_3$ at 1750 rpm. The properties of PA66GF30 aids in higher increases in volumetric efficiency when compared with remaining materials. The reason for the increase of volumetric efficiency for PA6GF30 plastic intake manifold is less density of AIM material.

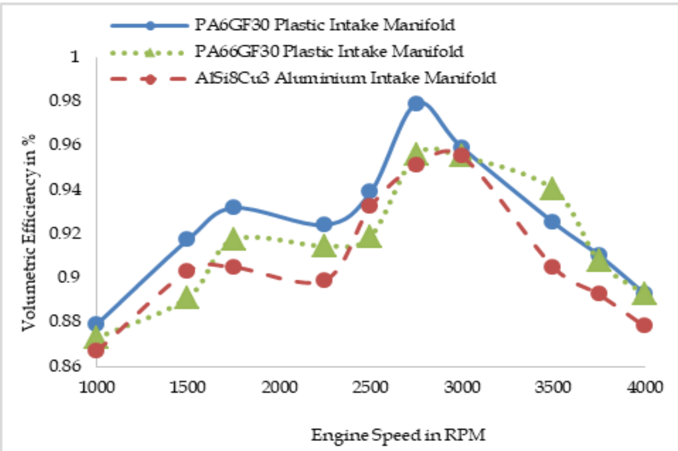

Figure 5. Variation of Volumetric Efficiency against Engine Speed

4.5. Air Flow Rate Vs. Speed

The deviations of air flow rate with the increases in engine speeds for various AIM materials are shown in Fig 6. Increases in air flow rate are obtained for various speeds of the engine after the changes in intake manifold materials are done. PA6GF30 shows the higher increase in air flow rate when compared with PA66GF30. The maximum increase in air flow rate of 31.8% is obtained for PA6GF30 when compared with $AlSi_8Cu_3$ at 2250rpm. The maximum increase in air flow rate of 10.31% is obtained for PA66GF30 when compared with $AlSi_8Cu_3$ at 2250 rpm. The properties of PA6GF30 aids in higher increases in air flow rate when compared with remaining materials, because of lesser density. The reason for the increase of air flow rate for PA6GF30 plastic intake manifold is less density of AIM material.

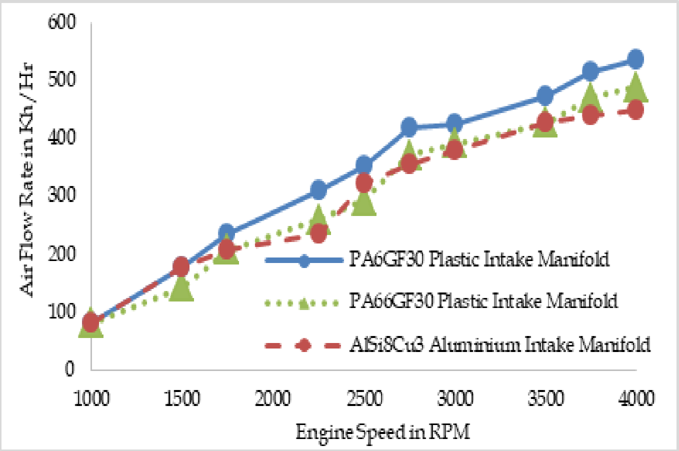

Figure 6. Variation of Air Flow Rate against Engine Speed

5. Conclusions

The performance of an engine for three different intake manifolds with different materials of PA6GF30, PA66GF30 and $AlSi_8Cu_3$ are compared. The results show that PA6GF30 aids in higher brake power, torque, volumetric efficiency and air flow rate when compared with $AlSi_8Cu_3$ at all speeds. Also PA6GF30 result in a reduction in BSFC when compared with $AlSi_8Cu_3$ and PA66GF30. The high specific heat of PA6GF30 results in reduction in temperature inside the AIM which increases the volumetric efficiency. PA66GF30 also shows a slight increase in engine performance when compared with $AlSi_8Cu_3$.

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