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Study of Design Improvement of Intake Manifold of Internal Combustion Engine

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ABSTRACT: For a better performance of an internal combustion engine, design of intake manifold is one of the important factor. It is required that equal mass of air fuel mixture is delivered to each cylinder of the engine. Unequal distribution of charge reduces the efficiency of the engine. Presented study aims at the design modification of the intake manifold so that almost equal velocity can be obtained at the end of each runner. For the study purpose Intake manifold of Maruti Wagnor was used. Experimental study was conducted on the manifold and variation in outlet velocity and outlet pressure was recorded at different inlet velocities. Further, three dimensional drawing of the intake manifold was made and CFD simulation was conducted using ANSYS FLUENT. Two models were studied by making some modifications in the actual manifold and thus an improved manifold design was suggested. Results show that nearly equal velocity was obtained at all the runner outlet and flow velocity at outlet 1 increased by 16%, and velocity in other outlets improved by approximately 5% to 7% as compared to actual model.

Keywords: Intake Manifold, Computational Fluid Dynamics (CFD)

1. INTRODUCTION:

In an automobile, engine is one of the main component. Continuous research is going to make the engine more and more efficient and use of alternate fuels. The major challenge faced is to reduce the global carbon emission and to reduce the oil consumption. Now a day compressed natural gas (CNG) is widely used in the automobiles. Efficiency of an engine working on CNG is very less. When compared to the gasoline, it is seen that the average torque and power losses of CNG is in range of 1.6 to 21.6% and 3 to 19.7% respectively [1]. The efficiency of an engine depends on many factors, design of intake manifold (IM) being one of them. The function of the IM is even distribution of a uniform mixture of fuel and air to all the cylinders. Even distribution is essential for a better performance and optimal efficiency. Design of the IM is thus very important for better engine performance. Length of the runner, diameter of the runner, plenum volume, smoothness of the joints, shape of the runners are the some of the factors which are considered during the design of the IM.

Computational Fluid Dynamics (CFD) is very helpful in predicting the flow pattern inside the cylinder and the IM. Using the CFD can reduce the design modification time. To analyze the physical phenomena which is involved in change of kinetic energy, renormalization group theory (RNG k- ε) turbulent model is used [2]. For an automobile different IM are used as per requirement and then the modifications are done as needed. But some general modifications are preferred for a good IM design. For the IM of a diesel engine, profile near the corners are made smooth so that reflecting shock waves at high velocity can be avoided. Some improvements in the plenum can also be made so that the flow can be easily directed into the runners [3]. With increase in the plenum volume, the runner outlet vacuum decreases which leads to increase in efficiency and improved engine performance [4]. Improvement in the engine performance occurs with variation in the plenum length. At the low engine speeds, plenum length needs to be extended whereas at the high engine speeds, it needs to be shorten [5]. Design of the venture also effect the performance. It was seen that as the throat velocity was increased, break power was also increased [6]. According to the work of Tsogtjargal G. et al. out of IM of length reduced by 5cm, increased by 10cm and increased by 20cm, manifold with increased length showed the reduced fuel consumption at ideal conditions. In the straightway, IM increased by 10cm showed least fuel consumption, whereas in the traffic jam condition, simple runner gave the best results [7]. For the high speeds, runners with small pipe length and large diameter gives best results and at low speeds, large pipe length and small pipe diameter gives best results. On the same time, pipe diameter and length do not have significant influence on the specific fuel consumption and engine thermal efficiency [8]. For an engine with benefits of both, the two IM can be merged to form duel intake manifold [9]. Out of the spiral, helical, helical-spiral combined IM configurations, helical IM has highest volumetric efficiency, whereas Spiral-Helical combined manifold has 10% higher efficiency than Spiral manifold. At TDC of compression, helical-spiral combined intake manifold delivers higher mean swirl velocity [10]. With the introduction of helical grooves inside IM there was 25.6% gain in thermal efficiency, 23.5% and 13.6% reduction in specific fuel consumption and in ignition delay respectively, 26.9% reduction in smoke emission, 6.6% reduction in NO_x formation, 15.6% reduction in hydrocarbon emission and 36.47% reduction in carbon monoxide emission [11]. Introducing the helical threads inside the IM also effect the engine performance. Experiment performed with the 4mm width threads with pitch varied from 10mm to 25mm in steps of 5mm showed that better performance, as compared to other modified IMs, was obtained with IM with threads of 10mm pitch. There was a reduction of 12.5% and 0.3% in hydrocarbon emissions and carbon monoxide emission respectively [12]. Out of the IM with internal acme threads, buttress threads, knuckle threads all having a pitch of 2 mm and normal IM, there was an increase of 14.5% in brake thermal efficiency, reduction of 11.62% in bsfc and increase of 9.72% in volumetric efficiency as compared to normal manifold when buttress threaded manifold used. For normal manifold, knuckle, acme and buttress threaded manifold exhaust gas temperature observed was 223 ^{0}C, 232 ^{0}C, 238 ^{0}C and 247 ^{0}C respectively [13]. For this study, intake manifold of a naturally aspirated, four-stroke petrol engine was selected. Flow pattern inside the intake manifold was studied using the CFD for the modification of the design of the intake manifold.

2. DESIGN MODELLING AND MESH GENERATION:

Using a 3-D CAD designing software the modelling of the intake manifold was done for the CFD analysis. After the modelling, this geometry was imported into the ANSYS workbench and fluent meshing was done.

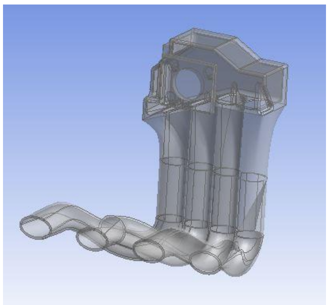
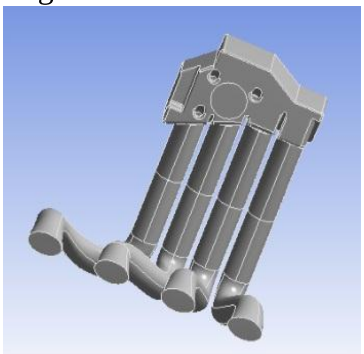
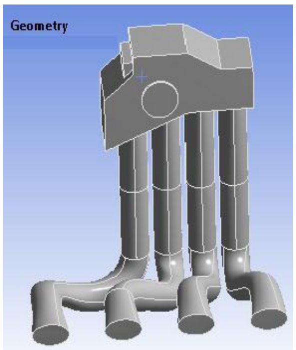


Fig 1: Actual 3-D Model

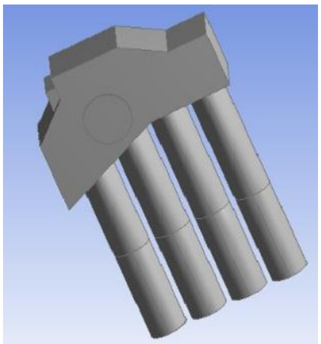
For the study three models were developed, Moodel-1 (actual model), Model-2 (without internal projections) and Model-3 (without internal projections at plenum and without curve at the end of runners). The actual model has the final mesh of 2673528 elements. Figure 1 shows the actual 3-D model and figure 2 shows the flow volume model of all the three models used for the study.



Model 1



Model 2



Model 3

Fig 2: Flow volume model of three different models studies

3. EXPERIMENTAL SETUP:

For the experimental purpose, pressure taps were attached at the runner outlets so that pressure can be measured at the outlets. The inlet condition was varied by regulating the blower and air at different inlet velocities was introduced in the IM. Air velocity at different outlet was recorded with the help of anemometer and the pressure difference between inlet and outlet of the manifold was recorded with the help of U-tube manometer. The intake manifold used to conduct study is shown in figure 3 and the experimental setup is shown in figure 4.

Fig 3: Intake manifold Figure

Fig 4: Experimental setup

4. RESULTS AND DISCUSSION:

4.1. Experimental results:

Air was introduced in the intake manifold at the different velocities and corresponding velocities at all the runners were recorded. On the same time, pressure drop was also recorded with the help of the U-tube manometer. Figure 5 shows the anemometer data and figure 6 shows the pressure at the outlet of different velocities.

From the Bernoulli Theorem we know that pressure and velocity are inversely proportional. Thus from the graphs we can conclude that velocity in the outlet 1 is minimum and at outlet 4 it is maximum. By temperature variation test it is noticed that the density change is very small and remain almost equal to the standard density of air at NTP.

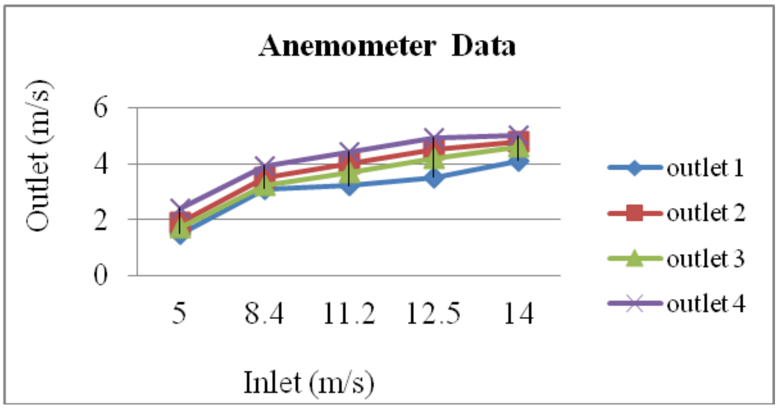


Fig 5: Velocities at outlets with variable inlet velocities

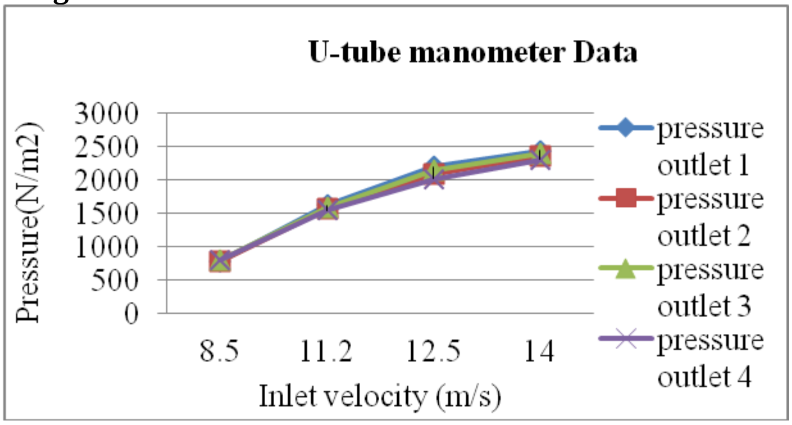


Fig 6: Pressure at outlets on variable inlet velocities

Destructive test was performed for the study of internal geometry of intake manifold. It was seen that there were many hidden projections inside the manifold which causes restriction to the flow and thus leads to uneven distribution at the outlets. Figure 7 shows these hidden projections which were not visible at first.

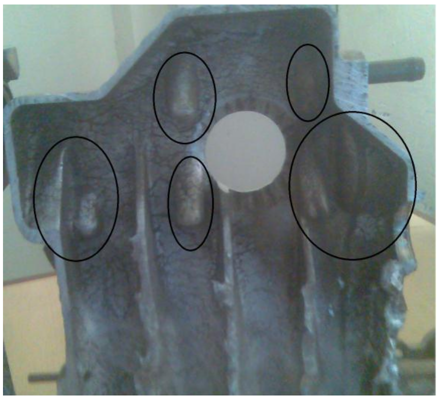


Fig 7: Hidden Projections

4.2. CFD results:

CFD analysis was done on all the three models to find the velocity and pressure variation between the different outlets at given inlet velocity. The CFD simulation results of the actual model were verified by comparing with the experiment results. Velocity vector view of actual model at inlet velocity of 18m/s is shown in figure 8.

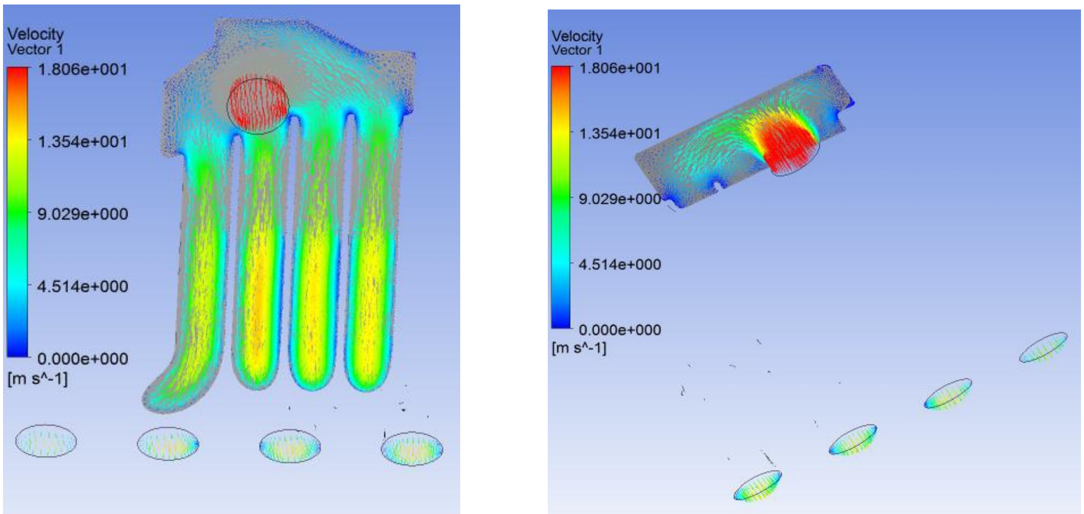
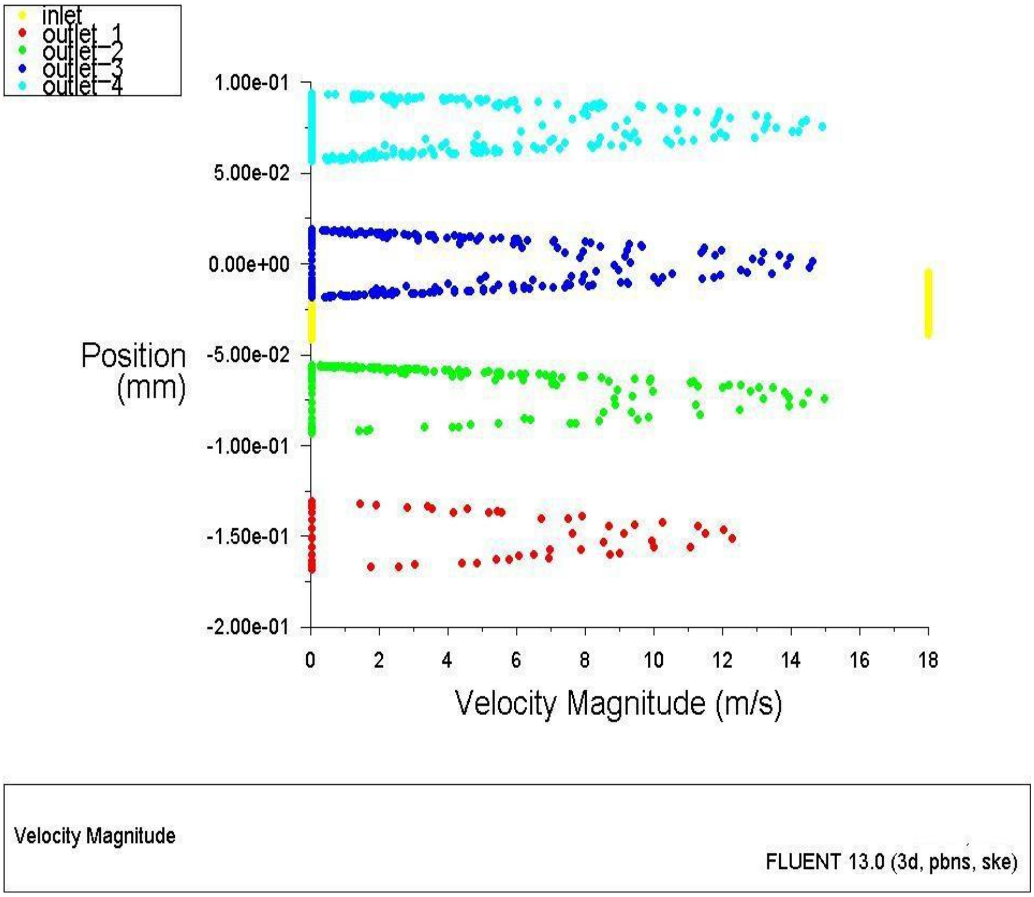
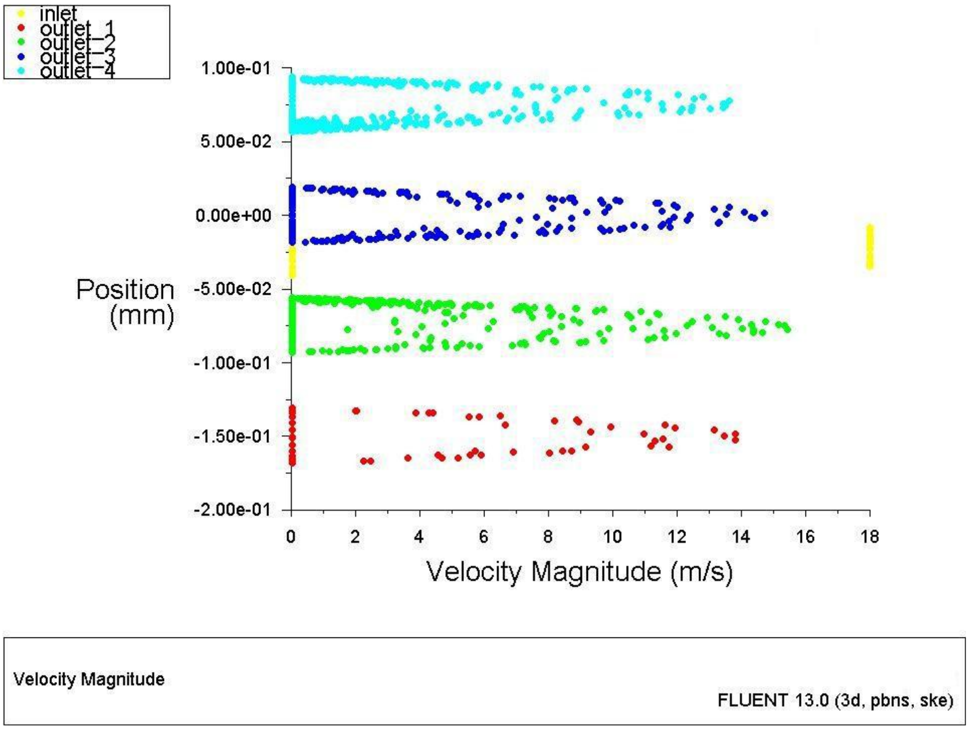


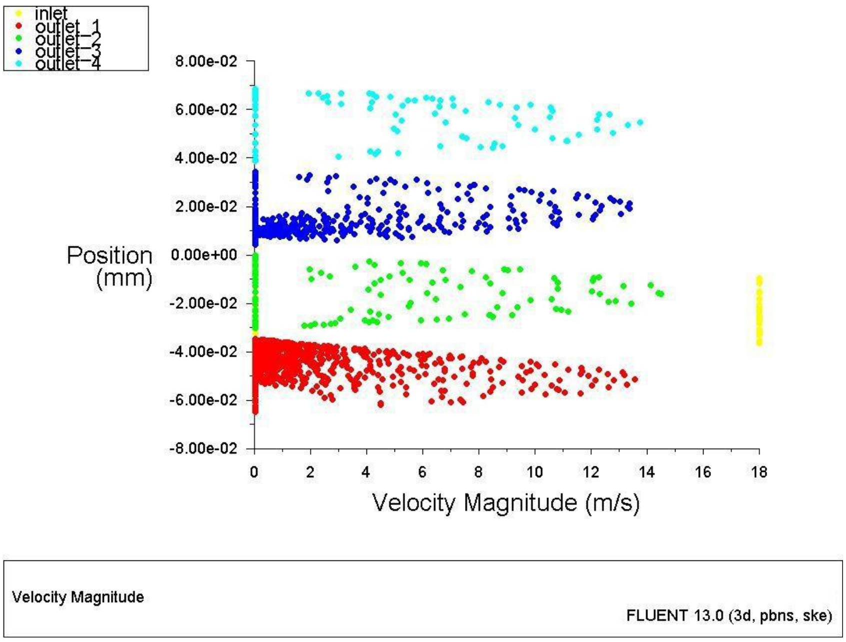
Fig 8: Velocity Vector (Model-1, 18m/s)



(a) Model-1



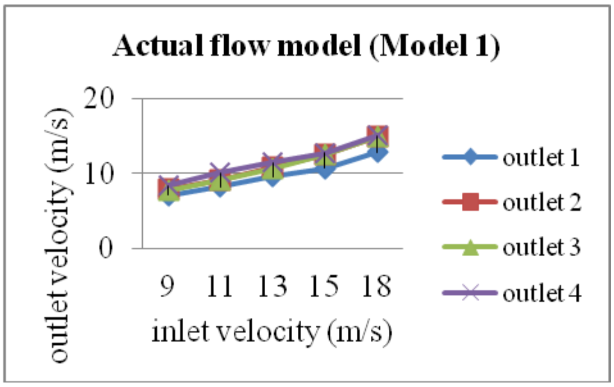
(b) Model-2



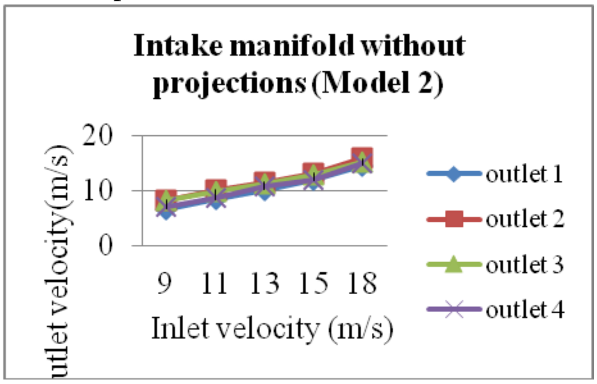
(c) Model-3

Fig 9: Velocity profile at different outlets (18m/s)

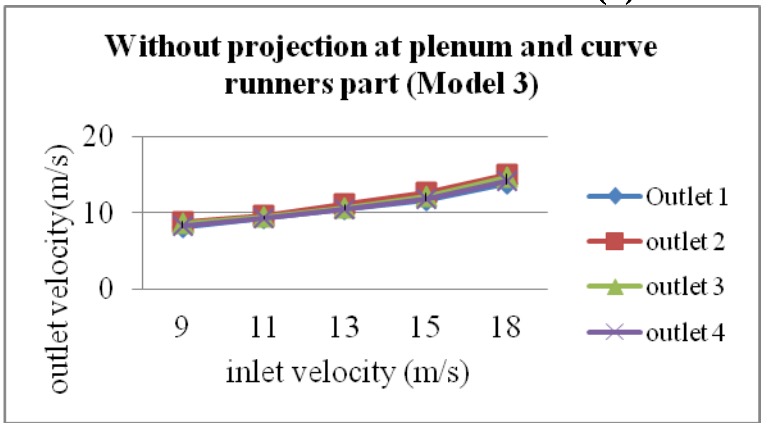
Velocity profile at the different outlets, as obtained from fluent, for all the three models at 18m/s inlet velocity are shown in figure 9. Three graphs shown in figure 10 shows the variation of outlet velocities with respect to variation in inlet velocity for all the three IM models. From all these graphs we can conclude that outlet velocities of runner 2 and runner 3 is almost equal and variation can be seen in runner 1 and runner 4. This can be validated with experimental results too for model-1.



(a) Model-1



(b) Model-2



(c) Model-3

Fig 10: Velocities at outlets at different inlet velocities

To study the design modification, the outlet velocities for all the three models are examined carefully. Figure 11, 12, 13 and 14 shows the variation in each outlet velocity of all the three models at different inlet velocities.

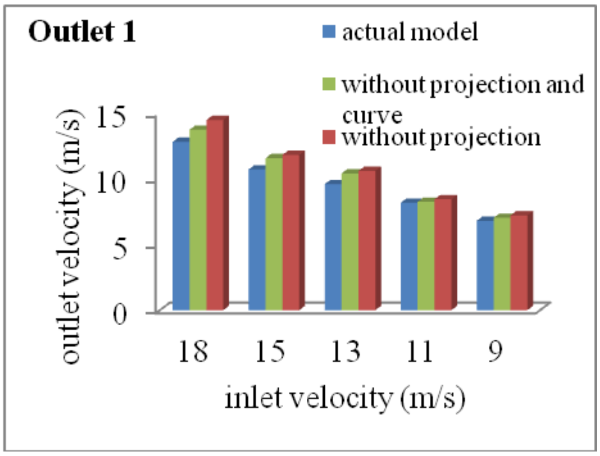


Fig 11: Outlet verses Inlet velocities at outlet-1

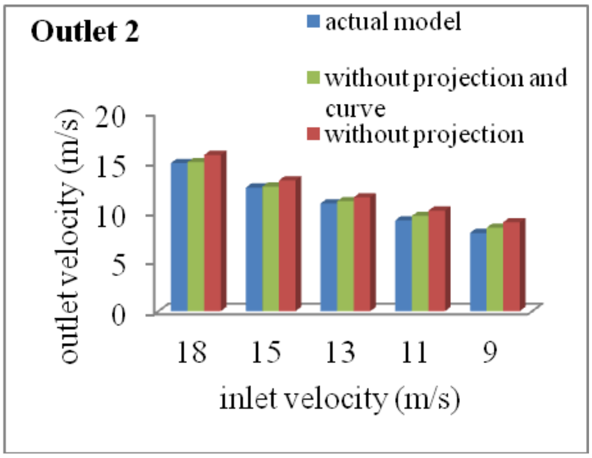


Fig 12: Outlet verses Inlet velocities at outlet-2

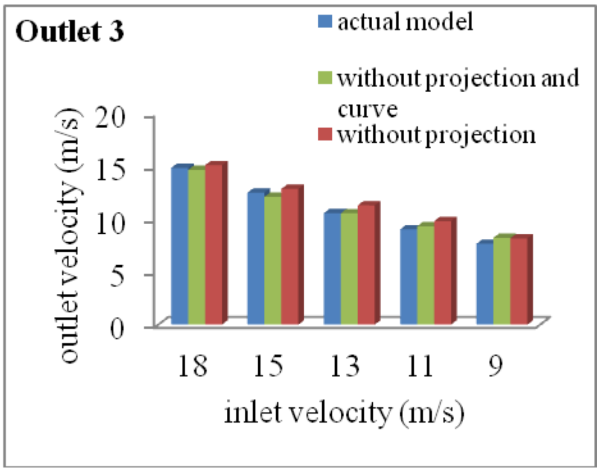


Fig 13: Outlet verses Inlet velocities at outlet-3

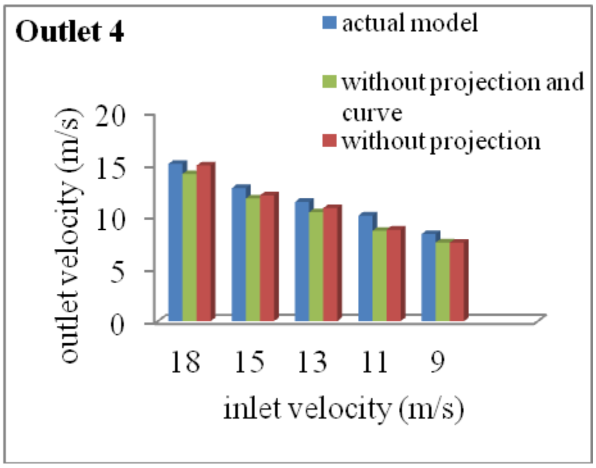


Fig 14: Outlet verses Inlet velocities at outlet-4

Outlet 1: At outlet 1 it is seen that actual model shows the least velocity as compared to the two modified models. It can be also seen that for actual model, outlet 1 has lowest velocity out of all four outlets. Thus it can be concluded that the projections at runner 1 has actual bad design.

Outlet 2 and Outlet 3: It is observed that velocity at outlet 2 and outlet 3 have nearly equal velocity for model-1 and model-3 but have slightly higher velocity for model-2. This is because there is no projections inside plenum and curves design at the end is good. The other reason for equal velocity is their position which is just below the inlet of IM. Thus it is seen that the position of the runners is also important factor in designing the manifold.

Outlet 4: It is observed that at the outlet 4, actual model shows more velocity than the modified designs. This may be due to the projection of depth cut above the runner 4. Thus it can be concluded that this inside projection of deep cut plays an important role for a good manifold design.

From the above discussion it is noticed that the model is good at the curve designing part and depth cut above the runner 4, which help in equal velocity at the outlets, whereas there are some bad design projections at runner 1.

5. CONCLUSIONS:

From the above study it may be concluded that:

i. The model has good design of runners and the curves at the end are helpful in achieving the equal velocity at outlet.

ii. Position of the runners with respect to the inlet also plays an important factor.

iii. Faulty design of the plenum is the reason for the variation of outlet velocity.

iv. Inside projections near the runner 1 causes restriction to the passage of flow, which leads to low velocity and high pressure loss at outlet 1 in actual model.

v. Intake manifold geometry with plenum chamber free from unwanted projections and depth cuts show good result. It is seen that there is an increase of 16% in flow velocity at outlet 1, and velocity in other outlets improved by approximately 5% to 7%. In modified design nearly equal velocity is obtained at all runner outlets as compared to actual intake manifold.

NOMENCLATURE:

IM	-Intake Manifold	bsfc	-Break Specific Fuel Consumption
CFD	-Computational Fluid Dynamics	CNG	-Computational Fluid Dynamics
3-D	-Three Dimensional	CAD	-Computer Aided Design

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