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DESIGN AND OPTIMISATION OF A VARIABLE LENGTH MANIFOLD SYSTEM FOR ENHANCED ENGINE PERFORMANCE

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ABSTRACT

This paper presents a novel Variable Length Intake Manifold System (VLIMS) designed to enhance the performance and efficiency of internal combustion engines, with a focus on production vehicles. Unlike conventional cast intake manifolds that restrict geometric flexibility, VLIMS dynamically adjusts intake runner lengths to optimise torque and power across the entire RPM range. By incorporating advanced mechanisms for runner length control and smooth plenum movement, the system ensures uniform airflow while minimising eddy formation and resonance. The use of lightweight, nylon-filled polymers not only reduces production costs but also improves combustion efficiency through better swirl and air-fuel mixing. Modelling and simulation conducted in SolidWorks and GT-Suite validate the feasibility of VLIMS, demonstrating significant improvements in engine efficiency and fuel economy. Tailored for a KTM 390 engine, this system addresses the demand for a cost-effective, high-performance intake manifold solution suitable for mass production.

Keywords: Variable Length Intake Manifold, Engine Performance Optimization, Airflow Dynamics, Computational Fluid Dynamics (CFD), Cost-Efficient Design.

I. INTRODUCTION

Our product Variable Length Intake Manifold System is made as a result of tuning of the conventional intake manifold for better performance of the engine. It consists of a single runner and plenum which has a curved bulb shape. There is an input for the plenum. The air moves across the inner volume of the plenum and passes through the curved runner. It has another concentric tube to increase the length of the runner. The length is changed using a rack and pinion system placed on top of the runner. The inner runner tube is connected to the engine and its position is fixed. When we require an increase in length, the plenum moves backwards. To make this movement smooth and constrained, we have attached two dampers on either side of the plenum.

Dimensions

- Plenum length - ~380mm
- Inlet- 48mm
- Runner length - 314mm
- Runner outlet - 42mm
- Damper - 100mm

In a variable length intake manifold, runner length has to be optimized for a particular environment and engine. For our intake manifold we took two extreme points on the rpm band and then calculated the optimum runner length. This runner length optimization was done on gt-suite. Variable intake system is used to optimize power and torque for the engine and performance and to create better fuel consumption that makes it more efficient than the basic intake system. This is because the variable intake is operating as a 2 switch device for an engine. It has a particular setting for a given rpm usage and an alternate setting for a different rpm usage. In general a long intake manifold produces a higher torque at low engine rpm and a short intake manifold produces the same high torque at higher engine rpm. It is also designed to improve engine performance by avoiding the phenomena like formation of eddies and non uniform flow of individual runners. Air flow inside the intake manifold is one of the important factors, which governs the engine performance. Hence the flow phenomenon inside the intake manifold is fully optimized to produce more engine power with better combustion. This system will also affect the swirl pattern. Swirl pattern is very useful in the combustion

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process. A good swirl pattern will help the process to achieve complete combustion than it also will help to minimize the engine knocking.

Objectives

The main objectives for this project are to achieve the following-

- To propose a new design of variable intake system.
- To test the proposed design in terms of its performance and effect.
- To optimise torque and power.
- To maintain a good swill pattern and uniform air flow inside the manifold.
- To avoid the formation of eddies and resonances in airflow.

II. LITERATURE REVIEW

Anil Kumar. D.B, Dr. Anoop Kumar Elia

In this they did a computational study of low-pressure steady state through the intake manifold. It was a three-dimensional flow study within the manifold runners and it was simulated using CFD and the code Fluent. They carried out analysis for every runner for both the designs. We know that a duly designed intake manifold is essential for the optimal performance of an internal combustion engine. The simulation was done and it was observed that the pressure drops at the 4th runner through the plenum chamber due to the sharp bend at the region of runner 4 inlet and the plenum where the flow doesn't smoothly enter runner 4. While no such thing happens for the optimized intake manifold. While looking at the velocity streamline result it was observed that eddies formation takes place at the 4th runner while smoothening the curve at the 4th runner in the optimized intake manifold system reduced the eddies formation.

Jagadish Bayas, Nilam P Jadhav

In this, after reviewing work of different authors, it was concluded that the intake geometry makes a considerable impact on engine performance. The main impact is on the volumetric efficiency of the engine which ultimately affects the torque & power produced at different engine speeds. Longer intake manifolds give higher torque at lower RPMs while shorter intake manifold tends to give peak torque at high engine RPM.

Jinamin Xu

In this paper, three different kinds of intake manifold were designed and a three- dimensional flow field numerical simulation for them was conducted using FLUENT software. The flow characteristics of the intake manifold were analysed and the intake unevenness of the intake manifold was calculated. The results showed that the inlet end arranged in the middle of the intake manifold can reduce the non-uniformity of intake system as the pressure loss and flow uniformity of intake manifold are two major evaluation indicators, and the scheme 3 (the one with the inlet end in the middle) meets these two design specifications. And it can improve the engine intake and combustion quality.

Shrinath Potul, Rohan Nachnolkar, Sagar Bhave

In this paper, they investigated the effects of intake runner length on the performance characteristics of a four-stroke, single-cylinder and spark-ignited engine with electronically controlled fuel injector. It was found out that the engine performance can be increased by using intake plenum length that can be varied continuously, the rpm at which peak torque occurred changed greatly with intake pipe length, for shorter plenum lengths the torque curve was flatter while as the length was increased the torque output curve peaked more and more.

III. METHODOLOGY

Work carried out for the completion of the project

Researched about various topics in different fields and selected one.

Researched about the conventional intake manifold system and variable length intake manifold system and wrote a literature review of that.

Made a 3D model of our variable length intake manifold system usingSolidworks and Kissoft.

Did a velocity streamline simulation in the Solidworks software

Compute everything in a final report file for our project.

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About the problem

Conventional intake manifolds used in our vehicles have fixed air flow geometry and a static intake manifold. The static intake manifold can be optimized for only a specific rpm and this rpm corresponds to maximum torque rpm of a given engine. But in real life, the working conditions vary depending upon the usage of the vehicle. It also causes less fuel efficiency as compared to the variable intake manifold. Therefore the standard system is not that efficient. Since the engine operates over a large speed range, it is beneficial to develop a method to vary the distance covered by air inside the manifold. This will broaden the torque curve and the engine will be able to maintain high power across a wide rpm range. During high rpm, a short runner is preferred and during low rpm, a long runner is preferred for high power output.

There are many ways of making a variable intake manifold. A commonly used variable intake consists of 2 pipes inside a runner for high and low rpm usage. The flow in this system is controlled by valves. The problem with this system is that the pulsating nature of the airflow produced through the intake manifold and runner due to valve opening and closing results in resonances in the airflow at certain speeds.

The variable length of the manifold will create better fuel efficiency and create more torque and power. Besides that, the new design of variable intake may create better fuel consumption and also performance of the system. Better swirl pattern will be achieved with the right shape of the manifold that will depend on its shape and angle.

IV. MODELING AND ANALYSIS

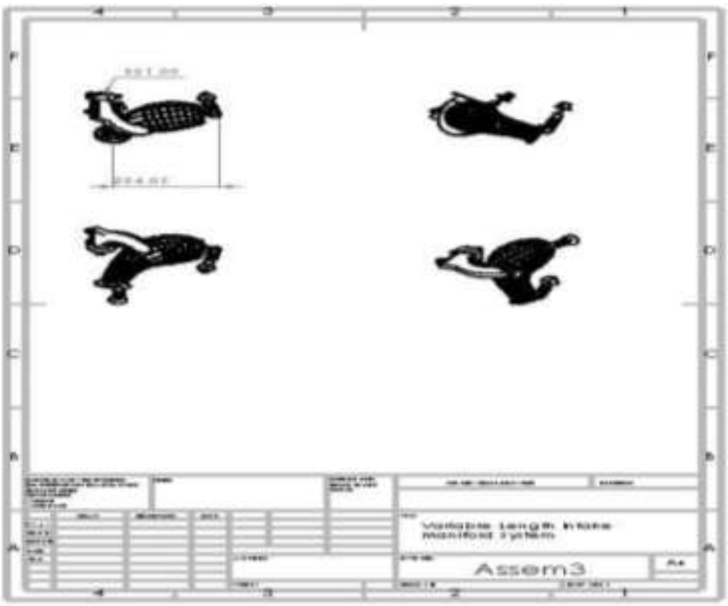

Figure 1: 2D view of the variable intake manifold based on ktm390

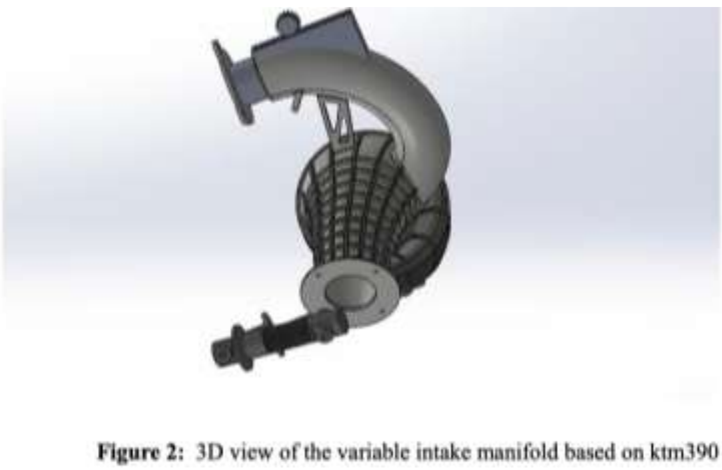

Figure 2: 3D view of the variable intake manifold based on ktm390

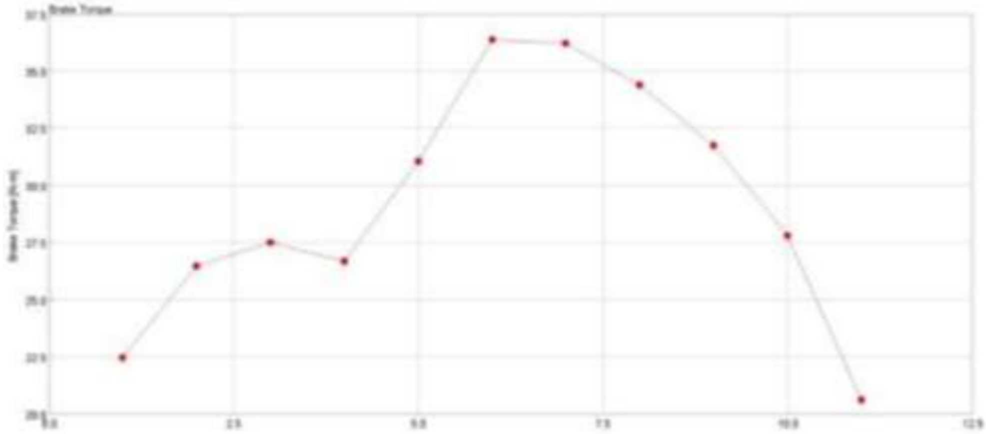

Figure 3: Short runner torque vs RPM graph

Time schedule

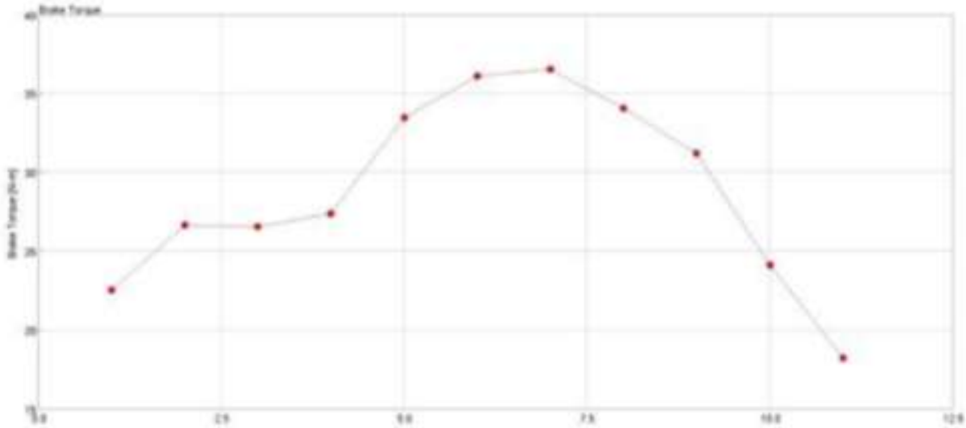

Figure 4: Long runner torque vs RPM graph

Cost Analysis

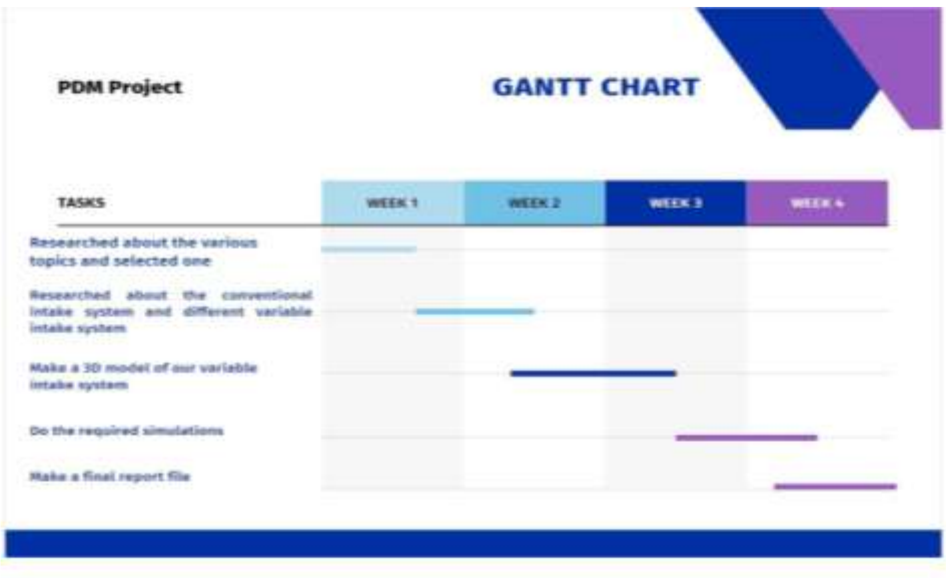

Figure 5: Gantt chart

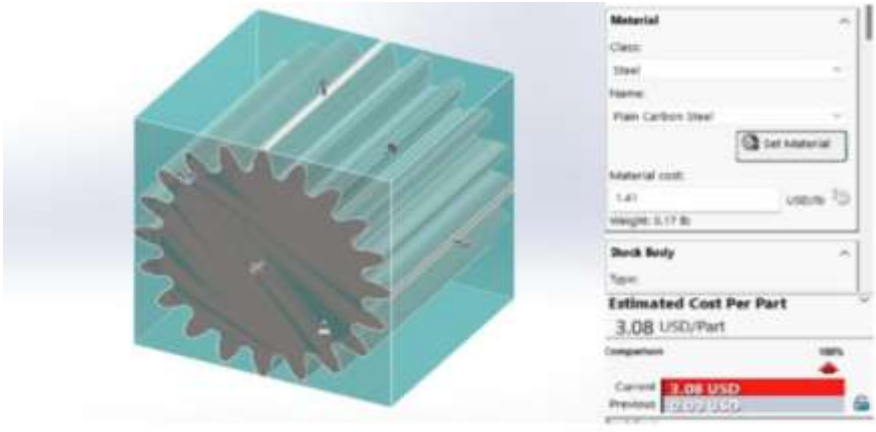

Figure 6: Cost Analysis of pinion gear in Solidworks

We came upon an estimated cost after extensive market research.A conventional intake manifold system costs around 5000 to 10000 Rs depending on the model and the material it's been made of.

The intake manifold has conventionally been manufactured from aluminium or cast iron, but the use of composite plastic materials has been gaining popularity in recent years (e.g. in most Chrysler 4-cylinders, Ford Zetec 2.0, Duratec 2.0 and 2.3, and GM's Ecotec series.)

And so we have decided on using nylon-filled polymers to make our intake manifold system. Using plastic will save weight and cost, and conducts heat much more slowly than aluminium and cast iron. This will help lower the temperature of the incoming air for a denser, more powerful air/fuel mixture.

The cost of our variable length intake manifold system has been estimated to be around 2000 to 3000 Rs.This price was reached on by looking into different manifold systems that were made by the same material as we have suggested. Manifold systems such as MANIFOLD INTAKE (Rs.2,724.00), MANIFOLD ASSY, INTAKE (Rs, 2,522.00), MANIFOLD COMPAINTK (Rs. 2,847.00) etc.

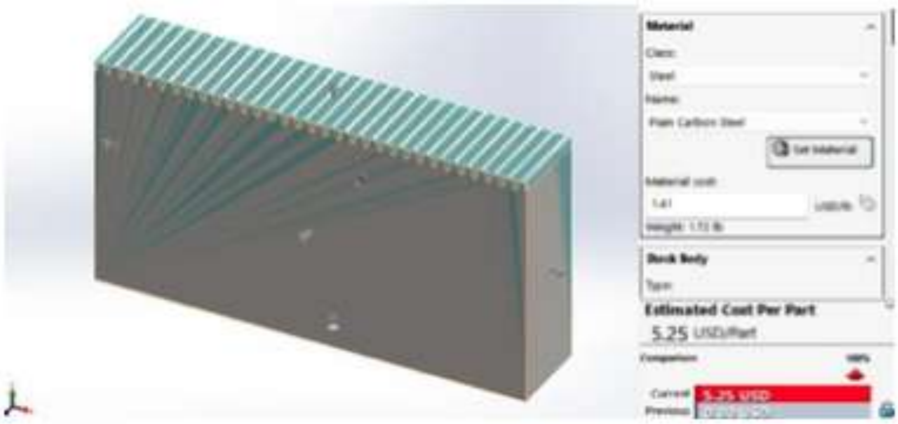

Figure 7: Cost analysis of rack gear in Solidworks

We also found an estimated cost of our intake system:-

- The volume for our design was found out to be 692.892 cc from theSolidworks software.
- The density of the material (PA12) that we recommend to use is 1.01g/cc.
- So, the mass of our design is 692.892 * 1.01 = 699.82092 g.
- The cost of Black Nylon powder 3D printing material was found out to beUS$ 45/kg.
- So, the cost is 0.69982092 * 45 = 31.49194 US
- As of 3 Dec, 3:10 pm UTC 1 United States Dollar equals 75.24 Indian Rupees

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- Therefore, the cost in Indian Rupees is = 2369.45367 Rs
- Now, the cost of the dampers was found out to be $17.99 which is 1353.56 Rs
- And, the cost of rack and pinion was found out in the Solidworks and it was 3.08 USD and 5.25 USD respectively. Now, this is equal to 626.749 Rs
- Hence, the total cost is (31.49194 + 17.99 + 3.08 + 5.25 =) 57.81194 USD and in Indian Rupee it is 4349.77 Rs.
- The cost we have got in Indian rupee is not an accurate depiction of the cost as the cost of the different items we found on the internet were from an American market point of view. If the item is to be made in India and all the rest of the materials procured for designing of this product is also made in India then the estimated amount would be in the range of 2000 to 3000 as mentioned before.
- To get an estimate of where our product is in the price range, we looked in different websites and it was mentioned that the estimated parts cost ranges anywhere from 50$ to 100$ in an American Market and,
- Due to the fact that our variable length intake manifold system optimises power and torque for the engine performance and creates better fuel consumption. Therefore it becomes far more cost-efficient than the conventional manifold intake system.

V. RESULTS AND DISCUSSION

A CAD Model was made in Solidworks and did the geometrical optimisation in Fusion 360. The model consists of the plenum, runner, rack and pinion system andtwo dampers.

Figure 8: 3D view of the variable intake manifold based on ktm390

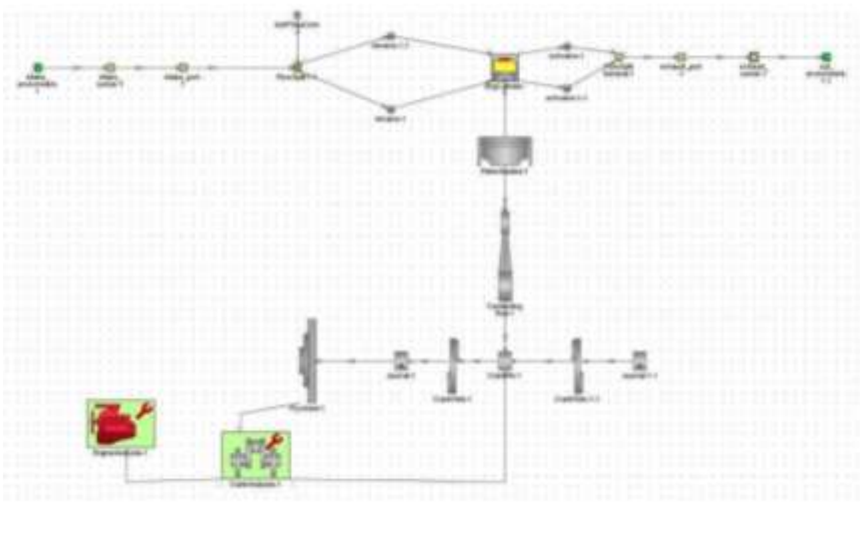

Figure 9: The runner length optimization was done using this engine model in Gt Suite.

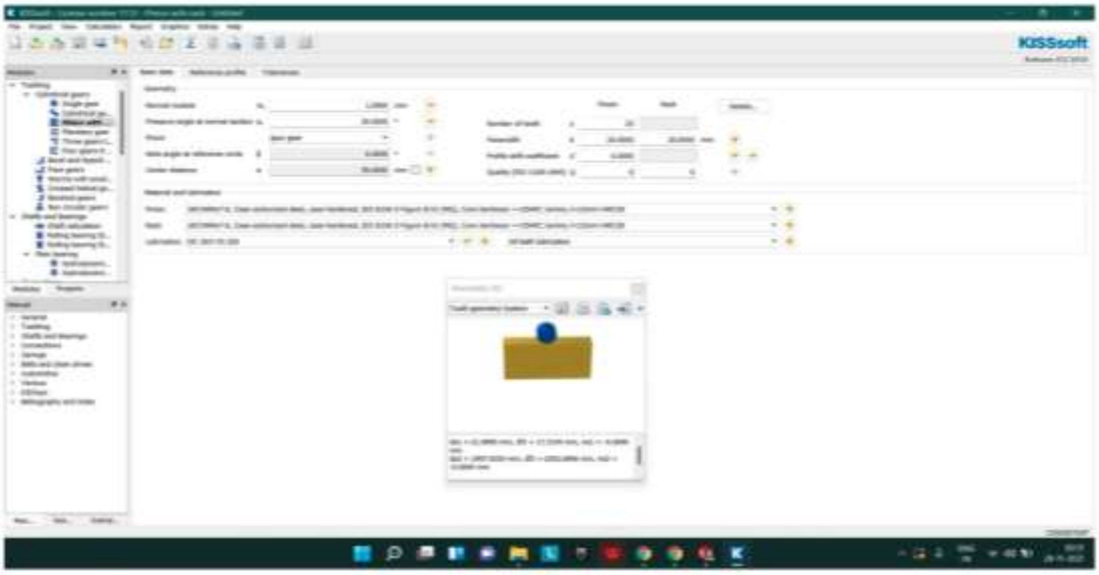

Figure 10: The values for the rack and pinion were obtained from Kisssoft.

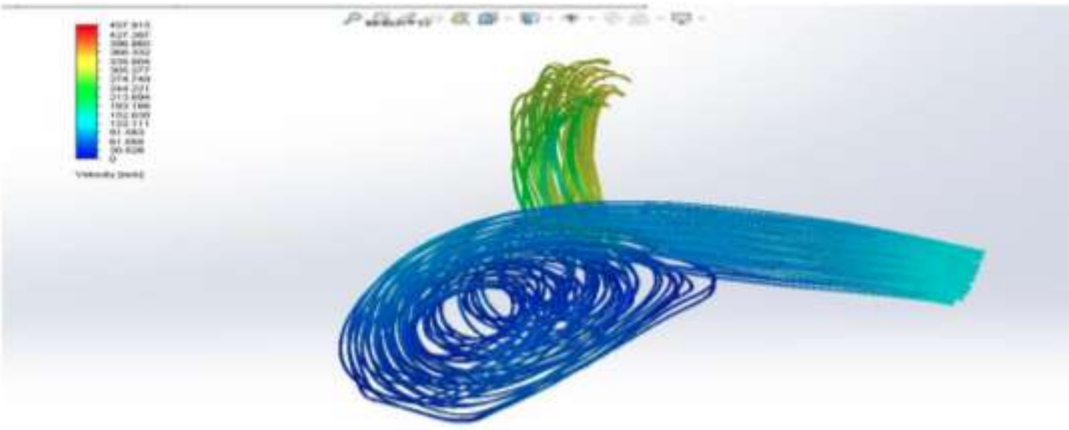

Figure 11: Free-Flow Results of the Variable Intake Manifold Using CFD Analysis

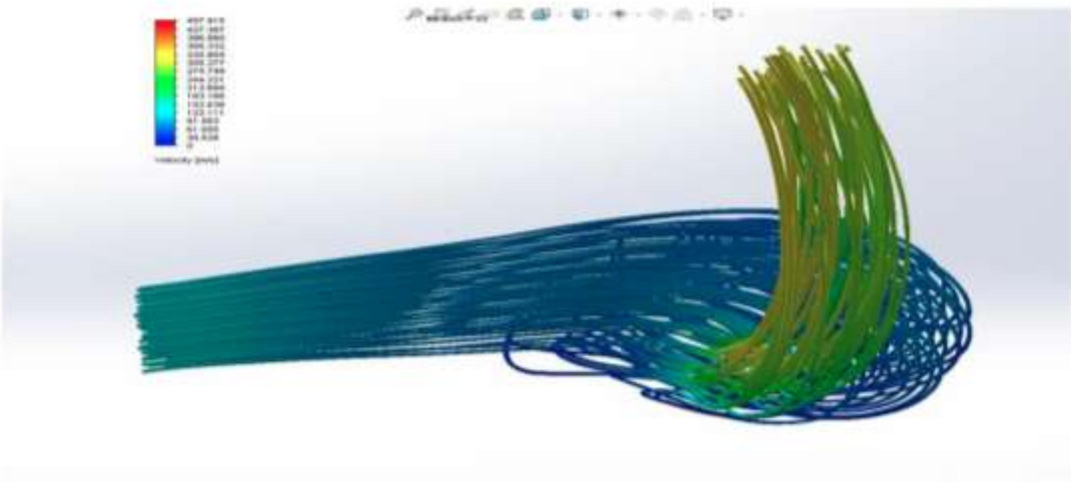

Figure 12: Free-Flow Results of the Variable Intake Manifold Using CFD Analysis

VI. APPLICATIONS

- The variable length intake manifold system is highly efficient.
- It maintains high torque and power in a broad rpm range.
- This system produces a good air/fuel mixture in the engine.
- It improves the fuel efficiency.
- Since producing a VLIMS with a polymer material reduces the overall cost of the product, it can replace the conventional IMS easily.

VII. CONCLUSION

We were successfully able to design a new variable intake manifold system with a reciprocative runner length mechanism. The final design was achieved after several iterations of design and simulation. With this, we got a manifold which produces a smooth uniform airflow which is beneficial for the engine. This design is better than the conventional manifold due to the advantages discussed earlier. It was also able to outperform the variable intake manifold system currently available as there is no formation of eddy currents and resonance. From the cost analysis it is clear that this design is feasible to be mass-produced in the market. Adoption of this system in vehicles will improve the operating conditions and will reduce running and maintenance cost.

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