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A review paper on exhaust manifold

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ABSTRACT

The design and operational variables of exhaust systems are decisive to determine overall engine performance. The best engine overall performance can be obtained by proper design of the engine exhaust systems. Using this engine model, the effects of the parameters of the exhaust systems on the engine performance are obtained. In particular, the following parameters are chosen: diameter of the exhaust manifold, exhaust pipe lengths, and geometry of pipe junctions. This investigation helps to find the optimized size of exhaust pipe system which can be used further designing as well as the manufacturing of exhaust manifold.

Key words- *Exhaust Manifold, IC Engine, CFD, Simulation.*

1. INTRODUCTION

The Exhaust manifold of an engine is an important component which has a considerable effect on the performance of the I.C engine. The exhaust manifold operates under high temperature and pressure conditions, which collects exhaust gases from the engine and passes it to the atmosphere. Their design usually has to be performed by trial and error method through many experiments and analysis. This designed and analyzed model can be used in different vehicles of designing competition like Supra SAE-India, FSB, FSG etc. for getting better performance with the same engine.

2. LITERATURE REVIEW

Mohd Sajid Ahmed [1] identifies the optimum exhaust manifold for 4-Stroke Inline 4 cylinder engine. Different manifolds are analyzed with the help of CAE software & flow of exhaust is observed. In this research, five variants of exhaust manifold based of modeling viz. convergent inlet pipe, divergent-straight-convergent, reduced the convergent length and increased divergent length, reduced divergent length, and increased convergent length, identical convergent and divergent and reduced straight length.

Benny Paul [2] performed the CFD analysis on exhaust manifold on a diesel engine. The Reynolds Averaged Navier Strokes with RNG k-ε turbulence model was used for simulation. Helical-spiral manifold geometry creates higher velocity component inside the combustion chamber. *STAR-CD* was used for the research work & the meshes were generated in *Gambit.*

Masahiro Kanazaki [3] was able to successfully optimize the manifold. Divided Range Multi-objective Genetic Algorithm was used. The three-dimensional manifold shapes are evaluated by the unstructured, unsteady Euler code with the empirical engine cycle simulation code. The two objective functions for the optimization was i) maximizing exhaust gas temperature at the end of exhaust pipe ii) maximize the charging efficiency.'

Xueyuan Zhang [4] had conducted a thermo-fluid-solid analysis of exhaust gases. Welding residual stress effects on modal analysis and thermal stress. The operating condition of 302 kg/hour flow rate of exhaust gas at 870˚C was considered by the authors. By using boundary conditions for FEA solver the welding residual stress in the manifold

M. Usan [5] applied different optimization techniques for the exhaust system to increase the power & efficiency. The optimization was in terms of Geometry, Structural, cost, and CFD. One Dimensional CFD simulations were carried out using AVLBOOST with the engine torque and catalytic converter inlet temperature over the engine rpm was being estimated. This approach features a multi-disciplinary optimization in engineering software framework.

O. Chiavola [6] investigated the overall performance of IC engine via Intake & Exhaust system. There are two different approaches i) Time Domain Non-linear Model, ii) Linear Acoustic Method. Ruggerini RDM 901 single cylinder 4-Stroke diesel engine is compared with the experimental measurement & computed pressure in the manifold Complex components and multi-dimensional analysis is time-consuming and cost requirement is more for mesh generation & computation.

Ugur Kesgin [7] had performed a study on the design of the exhaust system of a stationary natural gas engine, Elongation of the exhaust pipe from 62mm up to 1500mm brings an efficiency increase of 0.38% points. Also, a diffuser shaped T junction in the exhaust system increase the efficiency from the one-dimensional simulation as well as three-dimensional simulations is around 0.3%.

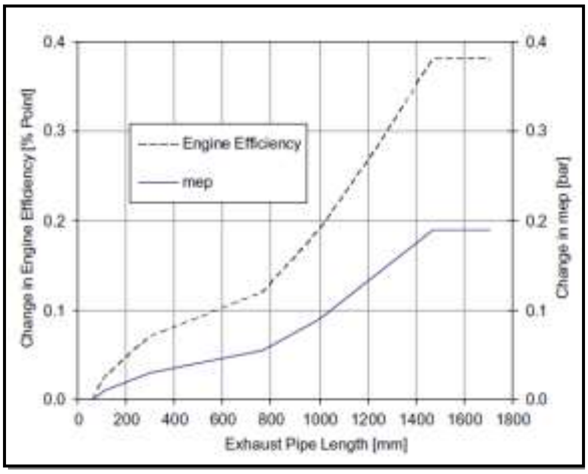

Fig.1: Effect of the length of the exhaust pipe on the engine efficiency and mean effective pressure (mep)

Guoquan Xiao [8] had performed Transient simulation of heat transfers for exhaust system, with the periodic pulsating movement of the exhaust gas the heat transfer characteristics velocity and temperature were obtained and analyzed, and the transient mean value was compared with the steady results, at 10% pulsating exhaust gas velocity and 1% pulsating exhaust gas temperature condition, the transient mean surface heat dissipating capacities of exhaust gas system components are 11.6% up.

Simon Martinez-Martinez [9] CFD analysis had performed to estimate the performance of the exhaust manifold while placing the catalytic converter near to it (Close-Coupled Catalytic Converter). They considered three types of manifolds: i) Cast Manifold ii) 4-2-1 Manifold iii) L-Shape Manifold. All the three types of manifolds had almost same uniformity index but the losses in each manifold are different.

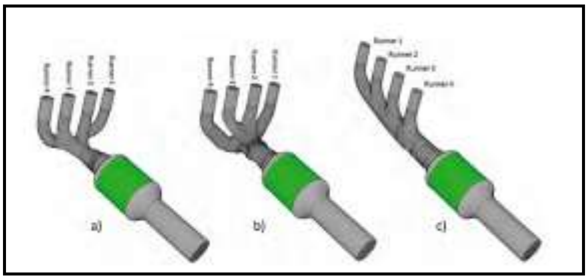

Fig.2: a) cast manifold, b) 4-2-1 manifold and c) L-shaped manifold.

Dr. Gangadhar Vvrls [10] had designed the exhaust manifolds using different parameters like back pressure, exhaust velocity, mechanical efficiency etc. also analyzed and compared the modified model with an original model having different material, heat flux. The obtained result indicates that the modified model has 63% more heat transfer, 2.3% more mass flow rate than the original, and has 20.37% less pressure than the original. Also defined the maximum recommended back pressure limits.

Table 1: Back Pressure Limits

Engine Size	Back Pressure Limit
Less than 50 KW	40 kpa
50-500 KW	20kpa
500 KW and more	10kpa

3. CRITICAL REVIEW

Flow distribution in the exhaust manifold is highly dependent on header shape and flow rate. The optimization can be carried out in many ways like Geometry, structural, cost, fluid dynamics. Simulation can be calculated by numerically i.e. CFD methods for flow loss coefficient in manifolds. Range Multi-objective Genetic Algorithm used to optimize the exhaust manifold. The exhaust manifold also goes under thermal expansion due to the high temperature of the exhaust gas which is exposed to the vibration caused by the IC engine. Exhaust manifold performance also depends upon back pressure, exhaust velocity, bending angle of the pipe. Smooth flow will be obtained by Long Bend Centre Exit which will ultimately provide the better performance. L-shape manifold and 4-2-1 manifold have almost similar flow uniformity Index (0.96) but the losses in the L-shaped manifold are 50% more than that of the 4-2-1 manifold. The back pressure which is built-up in exhaust manifold is creating a power loss of 1-2 hp will be neglected and a further increase in power output will be obtained.

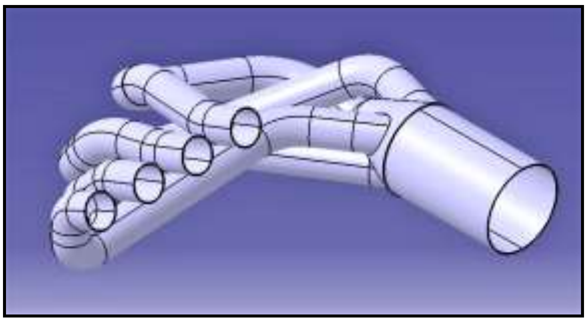

Fig.3: CAD Model of Exhaust Manifold

4. CONCLUSION

In the summary, it can be concluded that the flows can be simplified by using CFD techniques. The flow of exhaust depends on the runner length, bending angle of the pipe thus, by iteration method in ANSYS FLUENT optimized angle will denote the flow with least obstruction. The iteration method is time-consuming so the CFD analysis can be done with the help of MATLAB software. Further modification of Helmhotz (Runner length of the manifold) i.e. modified runner length can be obtained which is the indication of an increase in power output. The designed model of the manifold will be especially for an application like Formula Student Vehicle.

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