



Exhaust Manifold Developmental Activates in Compression Ignition Engine

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Abstract: *Developmental practices of internal combustion engine for exhaust manifold have been reviewed in this paper.*

Keywords: *exhaust manifold, diesel engine and parameters etc.*

I. Introduction

Atul A. Patil, L.G. Navale, V.S. Patil [1] presented in their technical paper more amount of air pollution was due to emissions from an internal combustion engine. Exhaust system plays a vital role in reducing harmful gases but the presence of after treatment systems increases the exhaust back pressure. To analyse the exhaust energies available at different engine operating conditions and to develop an exhaust system for maximum utilization of available energy at the exhaust of engine cylinder was studied. Design of each device should offer minimum pressure drop across the device, so that it should not adversely affect the engine performance. This paper deals with the exhaust system designed and through CFD (Fluent) analysis, a compromise between two parameters namely, more maximisation of brake thermal efficiency with limited back pressure was aimed at. In CFD analysis, three exhaust diffuser system (EDS) models with different angles are simulated using the appropriate boundary conditions and fluid properties specified to the system with suitable assumptions. The back pressure variations in three models are discussed in. Finally, the model with limited backpressure was fabricated and Experiments are carried out on single cylinder four stroke diesel engine test rig with rope brake dynamometer. CFD analysis of exhaust diffuser systems and the performance of the engine are discussed.

K.H. Park, B.L. Cho, K.W. Lee, K.-S. Kim and Y.Y. Earmme [2] presented in their technical paper designing the exhaust manifold, a designer usually has to perform the fatigue analysis of each candidate of the exhaust manifold, and to decide whether or not it is satisfactory. In each case, the elasto-plastic stress analysis by F.E.M. is required, which is very time-consuming considering the pre-processing and post-processing of the F.E.M data. In this study, a thermal stress index (TSI) is proposed for a practical application to the early stage of designing the exhaust manifold. Although this index, a ratio of the elastic effective stress to yield stress, does not predict quantitatively the expected fatigue life, it is believed that this index can be relatively easily evaluated, and its merit lies in the quick estimation of the effect of the design parameters at the development stage with comparing the nonlinear fatigue analysis.

Jeremy Decker [3] presented in their technical paper the exhaust process of an internal combustion engine, gas exits under high pressure as critical flow. Conversely, exhaust ports are often physically tested under steady, low pressure airflow and inconsistencies frequently occur between test results and engine performance. Modifications are often made using traditional intake port improvement techniques that may have a negative impact on high pressure, compressible flow within the port. This research focused on the question of whether downstream exhaust port geometry can negatively affect port efficiency during low valve lift, critical flow. Typical engine analysis assumes critical flow through the entire valve curtain area with no downstream effects on flow rates or coefficients. A chamber was constructed to use compressed gases to test the critical flow performance of two Chevy SB2.2 cylinder head ports. A Weld Tech ported cylinder head was chosen based on discussions with port designers indicating the final design was modified to increase port volume and diameter which increased engine performance, but resulted in reduced flow under low pressure, steady airflow. One port was modified to decrease port volume and increase steady flow coefficients to mimic these conditions as described by designers. Then, compressed carbon dioxide and nitrogen were used as testing fluids to investigate the low lift critical flow performance of the original and modified ports. These results were compared to those obtained from steady flow, low pressure testing using air. The use of the products of lean hydrogen combustion was also investigated, but ultimately deemed infeasible with the envisioned testing apparatus. Through modifications the port volume was reduced 4.7% and steady, low pressure flow coefficients were improved by 7.2% at 0.050" valve lift and 6.1% at 0.100" valve lift compared to the original port. These improvements were mostly gained through pressure recovery. Using the compressed gas chamber, the measured effective critical flow coefficients averaged over 20

to 90 lb/in² were decreased 2.8% and 3.2% at 0.050" lift using nitrogen and carbon dioxide, respectively. At 0.100" lift, the effective critical flow coefficients averaged over 20 to 70 lb/in² were decreased 0.1% and 0.14% using nitrogen and carbon dioxide, respectively. Critical flow coefficient results indicated a dependence on upstream pressure and downstream port geometry, which could contribute to the inconsistencies in steady flow testing and engine performance. Engine Analyzer software was also used to demonstrate the benefits of increased exhaust flow path diameter on predicted power at high engine speeds and the beneficial translation to racing engines. These improvements were the result of reduced back pressure, increased scavenging, and decreased pumping losses.

Taner Gocmez and Udo Deuster[4] presented in their technical paper exhaust manifold cracks from Thermomechanical Fatigue (TMF) are often seen on highly loaded engines, due to increasing marketplace demands for performance and emissions. A constant search for higher strength materials is needed, due to maximum gas temperatures that in some instances are already above 1000°C. The use of virtual prototypes for creating a development strategy for testing will reduce expense and time as opposed to using physical prototypes. The design and analyses engineers are assisted through advanced simulation technologies, which help locate critical areas during the early phases of development so that local structural weaknesses can be removed. A variety of studies have been published over the last few decades regarding the identification of these critical areas, which include considering kinematic and isotropic hardening, creep in material modeling and consideration of plasticity, creep and oxidation in lifetime modeling. This study focuses on the development of a reliable approach to predict failure of exhaust manifolds and on the removal of structural weaknesses through the optimization of design. The failure modes for TMF cracks, vibration and exhaust manifold gaskets are emphasized. The resulting optimization used both manual and automatic methodologies, which highlight the correlated advantages and disadvantages of the proposed design. Examples of the applications show that automatic shape optimization is a powerful tool in the development of exhaust manifolds, which face ever decreasing development time. Engineering expertise is still needed required to fully utilize this technique, because the results strongly depend on defining the problem. The optimization of cast and fabricated manifolds (single or dual wall design) requires different techniques, due to the production restrictions. The locations where failures occur, on both the exhaust manifolds (cast or fabricated) and exhaust manifold gaskets, are predicted with high degree of accuracy. This study also shows an optimization package, which provides practical solutions to engineering problems through the removal of local structural weaknesses on highly loaded exhaust manifolds.

S. N. Ch. Dattu. V, Pradeep Varma. M, Shyam Sundar. B[5] presented in their technical paper the designing of exhaust manifold is a complex procedure and is dependent on many parameters viz. back pressure, exhaust velocity, mechanical efficiency etc. As a part of thermal analysis how the temperature distribution, thermal gradient, heat flux varies from material to material is going to study in both the existing & modified geometries and results were compared by using ANSYS.

Atul A. Patil, L.G. Navale, V.S. Patil [6] presented in their technical paper the global warming and air pollution are big issue in the world. The more amount of air pollution was due to emissions from an internal combustion engine. Exhaust system plays a vital role in reducing harmful gases, but the presence of after treatment systems increases the exhaust back pressure. This paper deals with the exhaust system designed and through CFD (Fluent) analysis, a compromise between two parameters namely, more maximization of brake thermal efficiency with limited back pressure was aimed at. In CFD analysis, two exhaust diffuser system (EDS) models with different angles are simulated using the appropriate boundary conditions and fluid properties specified to the system with suitable assumptions. The back pressure variations in two models and the flow of the gas in the substrate are discussed in. Finally, the model with limited backpressure was fabricated and Experiments are carried out on single cylinder four stroke diesel engine test rig with rope brake dynamometer. The performance of the engine and the exhaust diffuser systems are discussed.

Atul A. Patil, L.G. Navale, V.S. Patil [7] presented in their technical paper exhaust system development requires minimum fuel consumption and maximum utilization of exhaust energy for reduction of the exhaust emissions and also for effective waste energy recovery system such as in turbocharger, heat pipe etc. from C.I. engine. To analyze the exhaust energies available at different engine operating conditions an exhaust system developed for maximum utilization of available energy at the exhaust of engine cylinder is studied. Design of each device should offer minimum pressure drop across the device, so that it should not adversely affect the engine performance. Back pressure acting on engine is the most important controllable factor which basically deteriorates the engine and emission control performance. So numbers of methods to increase the performance of the CI engine have been established. A better method of utilising the exhaust is achieved in this paper which uses the exhaust gases from an optimal sized engine currently used, to convert available Kinetic energy and enthalpy of exhaust gases into the pressure after treatment of exhaust gases. This pressure is used and sent through diffuser which reduces the back pressure.

Dr. Vikas J. Patel Dr.S.A.Channiwala [8] presented in their technical paper increasing worldwide demand for energy and the progressive depletion of fossil fuels has led to an intensive research for alternative fuels which can be produced on a renewable basis. Hydrogen in the form of energy will almost certainly be one of the most

important energy components of the early next century. Hydrogen is a clean burning and easily transportable fuel. Most of the pollution problems posed by fossil fuels at present would practically disappear with Hydrogen since steam is the main product of its combustion. This Paper deals with the modeling of Suction and Compression Processes for Hydrogen Fuelled S.I.Engine and also describes the safe and backfire free Delayed entry Technique. A four stroke, Multicylinder, Naturally aspirated, Spark ignition engine, water cooled engine has been used to carrying out of investigations of Suction Process. The Hydrogen is entered in the cylinder with the help of Delayed Entry Valve. This work discusses the insight of suction process because during this process only air and Hydrogen enters in to cylinder, which after combustion provides power. Simulation is the process of designing a model of a real system and conduction experiment with it, for the purpose of understanding the behavior of the design. The advent of computers and the possibilities of performing numerical experiments may provide new way of designing S.I.Engine. In fact stronger interaction between Engine Modelers, Designers and Experimenters may results in improved engine design in the not-to-distant future. A computer Programme is developed for analysis of suction and Compression processes. The parameter considered in computation includes engine speed, compression ratio, ignition timing, fuel-air ratio and heat transfer. The results of computational exercise are discussed in the paper. Ashwani Kumar, Arun Kumar, Arpit Dwivedi and Pravin P Patil [9] presented in their technical paper was design and analysis of 4-stroke 4- cylinder exhaust manifold. A new material 321-Austenitic Stainless steel has been selected for exhaust manifold. Thermal, Static structural and Modal Analysis is performed to check the high temperature Strength. The first five orders vibration mode of the ExhaustManifold is obtain using ANSYS as an analysis tool. The parameter used for the simulationis exhaust gas temperature. A maximum exhaust gas temperature of 800 OC is applied to theexhaust manifold for thermal analysis. The structure of exhaust manifold was modelled

using SOLIDEDGE software. Finite element modelling and analysis were performed using ANSYS 14. The natural frequency and Vibration mode of the exhaust manifold are obtained and its vibration characteristics are analyzed. The analysis method in the paper present satisfactory results of stresses and can effectively solve the problems of the

optimization design for different materials and vibration safety examination of exhaust manifold. The analysis show that the natural frequency of vibration varies from 63 Hz to 519 Hz. The simulation results were compared with experimental results presented in literature. External excitation on the exhaust manifold must be avoided to coincide with these natural frequencies, in order to prevent the fracture

Thomas Cornelio, Michael R. Schloder and Michael O'Neill[10] presented in their technical paper result of the wide range of operating environments, component parts of automotive and commercial engine exhaust systems require a unique combination of material properties that are not easily met using existing wrought, cast, or powder metallurgy alloys. Alpha Sintered Metals (ASM) now offers a new Powder Metal (PM) alloy with improved hot oxidation properties that not only supplements the application of traditional stainless steel alloys but also enhances the service life reliability of these components for elevated exhaust temperature applications. ASM's new alloy named Alphaloy, demonstrates material property advantages for several critical exhaust system attributes. The test results of studies comparing Alphaloy to other traditional materials exhibit improved performance relative to hot oxidation resistance, tensile strength and machinability while maintaining consistent performance for thermal expansion, atmospheric corrosion and weldability. Alphaloy's excellent resistance to degradation from thermal cycling offers dramatic performance improvement over 400 series stainless steel materials. The paper also reviews and discusses some current exhaust industry practices that promote improved sealing and longer useful life requirements. Furthermore, progressive emission reduction initiatives will increase demand for PM flanges in fabricated manifolds, complex diesel after treatment systems such as Diesel Oxidation Catalyst (DOC) and Selective Catalytic Reduction (SCR) and new cooled Exhaust Gas Recirculation (EGR) systems. Alphaloy's unique combination of physical and mechanical properties is ideal for many of these applications.

K. S. Umesh, V. K. Pravin & K. Rajagopal[11] presented in their technical paper exhaust manifold was one of the most critical components of an IC Engine. The designing of exhaust manifold is a complex procedure and is dependent on many parameters viz. back pressure, exhaust velocity, mechanical efficiency etc. Preference for any of this parameter varies as per designers needs. Usually fuel economy, emissions and power requirement are three different streams or thought regarding exhaust manifold design. This work comprehensively analyzes eight different models of exhaust manifold and concludes the best possible design for least emissions and complete combustion of fuel to ensure least pollution.

Raja A, Ramanathan A R and Vaidyanathan S [12] presented in their technical paper diesel engine exhaust system retrofit capable of suppressing the wave that offends the exhaust gas flow has been introduced in the vicinity of the exhaust port of a single cylinder naturally aspirated four stroke 7 HP 1500 rpm direct injection diesel engine and experimented. The retrofit considerably reduces the smoke, hydrocarbon, carbon monoxide and oxides of nitrogen levels while improving the thermal efficiency moderately (1% to 3%). The impact of retrofit on smoke and oxides of nitrogen are pronounced at higher loads. While the influence of retrofit on UBHC reduction is more or less uniform with increasing load, that on carbon monoxide is pronounced at lower loads. Exhaust gas temperature, cylinder peak pressure and peak heat release rate decline with the use of retrofit. Retrofit of area

factor 7 (area factor is the ratio of flow dissipation area with retrofit to that with conventional straight exhaust pipe) is found better than those with 4 and 8.

Sweta Jain, AlkaBani Agrawal [13] presented in their technical paper the Sequential Coupled Thermal - Structural Analysis to investigate the associated thermal stresses and deformations under simulated operational conditions close to the real situation on different materials. Analysis carried out by reference environmental testing conditions; in different ambient temperatures on different materials i.e. cast iron, structural steel. The finite element analysis software ANSYS Workbench 14.0 used to calculate the linear steady state temperature distribution under the thermal field & structural analysis. Thermal analysis calculates the temperature distributions and related thermal quantities in an exhaust manifold. Structural analysis takes inputs from thermal analysis to calculate deformation, stress and strain. FEM analysis is done by using tetrahedral element of first order and convergence test is performed for structural load. The purpose of this analysis is to ensure the appropriateness of material for the defined design from the view point of serviceability of the exhaust manifold. Selected details and results of the overall investigation are presented and discussed within the framework of this paper.

Christoffer Blomqvist[14] presented in their technical paper to increase the engine efficiency in terms of fuel consumption and lower emissions have lead to higher demands on materials. In this thesis five different thermal barrier coatings applied using air plasma spraying to three materials commonly used for exhaust application are evaluated. This thesis work was done at Scania CV in Södertälje with main focus on evaluation during thermal cycling. The goal of this thesis is to evaluate the coatings and correlate their behaviour to their characteristic microstructure. The coatings were evaluated through their stability in thermal conductivity, fracture toughness, hardness, porosity and failure modes. The parameters were obtained using laser flash, Vickers indentation, Vickers indentation fracture toughness and microscopic evaluation methods. The evaluation shows that conventionally used zirconia based materials exhibits low thermal conductivity, high hardness, and stable fracture toughness compared to other evaluated materials. One material that can be applicable in diesel exhaust application is mullite, which showed similar performance to zirconia based materials. For the use of TBC together with SiMo51 a different bondcoat than conventional NiCrAlY needs to be evaluated.

Gopaal, MMM Kumara Varma, Dr L Suresh Kumar[15] presented in their technical paper exhaust manifold in the engines 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. Their design usually has to be performed by trial and error through many experiments and analyses. Therefore, an automated design optimization would reduce technical, schedule, and cost risks for new engine developments. This paper deals with the various factors that are to be considered in the design of the exhaust manifold. It tries to explain the effect of various factors during the Finite Element Analysis.

Rajesh Bisane, Dhananjay katpatal [16] presented in their technical paper after treatment system design should be done in such a way that considering the complete system objectives. Energy efficient exhaust system development requires minimum fuel consumption and maximum utilization of exhaust energy for reduction of the exhaust emissions and also for effective waste energy recovery system such as in turbocharger, heat pipe etc. from C.I. engine. Traditional manifold optimization has been based on tests on Exhaust system. This trial & error method can be effective but is very expensive & time consuming. Beside this method cannot provide any information about the actual flow structure inside the system. This vital information can be obtained using 3-D CFD analysis. The design engineers can study the flow structures & understand whether a particular system performs correctly or not.

Mohd Sajid Ahmed, Kailash B A, Gowreesh[17] presented in their technical paper exhaust manifold was one of the important components of internal combustion engine which plays a major role in the improvement of fuel consumption of the engine. Combustion efficiency of the engine can be improved by improving the exhaust manifold design in internal combustion engine. Performance of the engine increases if the exhaust manifold is of a good condition. The designing of exhaust manifold is a complex procedure and is dependent on many parameters. Better the exhaust manifold design better is performance of the engine. The major work was to improve the design to lower the backpressure in the exhaust manifold which increases the performance of the engine. Computational fluid dynamics (CFD) was one of the most popular and current running software which was mostly used in automobile industries in order to reduce the cost which was spent in design and analysis of various models in the fluid flow field. In the present work, analysis was carried out for different shape of exhaust manifolds using CFD software. To achieve the optimal geometry for the low backpressure and high exhaust velocity, five different models were designed and comprehensively analyzed with the help of velocity contours and pressure contours. Using the commercially available software the flow through exhaust manifold is done. Comparison was done for five different models using the velocity contour and pressure contour and best possible model for lower backpressure and high exhaust velocity was suggested.

Julia H. Buckland Mrdjan Jankovic J. W. Grizzle J. S. Freudenberg [18] presented in their technical paper feedforward A/F control in turbocharged gasoline engines with variable valve timing requires knowledge of exhaust manifold pressure, P_e . Physical conditions in the manifold make measurement costly, compelling manufacturers to implement some form of on-line estimation. Processor limitations and the calibration process,

however, put constraints on estimator complexity. This paper assesses the feasibility of estimating P_e with an algorithm that is computationally efficient and relatively simple to calibrate. A traditional reduced order linear observer is found to perform well but has too many calibration parameters for practical implementation. Using the performance of the observer as a benchmark, static estimation is explored by parameterizing the equilibrium values of P_e with both the inputs and the outputs of the system. This nonlinear static estimate, combined with simple lead compensation, yields a practical observer implementation

KS Umesh, VK Pravin, K Rajagopal [19] presented in their technical paper in internal combustion engines, volumetric efficiency was one of the prime factors in determining how much power output an engine can generate as compared to its capacity. The purpose of this research work was to investigate using CFD whether design of exhaust manifold has any impact on volumetric efficiency of the multi-cylinder SI engine and if any verify those results obtained through CFD analysis via actual experiments. The scope of the research is further stretched to investigate whether exhaust geometry has any impact on mechanical efficiency of the multi-cylinder SI engine. Flow of the exhaust gases through exhaust manifold is simulated using ANSYS FLUENT V12.0 using pressure and velocity parameters as boundary condition. The analysis has been carried out on two designs an existing one and a modified one and results are subsequently compared. It was observed that the volumetric efficiency improved drastically upon modification in exhaust geometry. Physical models of the same these two systems were subsequently manufactured and exhaustive experiments were carried out on them. The results obtained through CFD analysis were experimentally confirmed.

Vivekanand Navadagi, Siddaveer Sangamad [20] presented in their technical paper exhaust manifold was one of the critical components of IC engine for improving the volumetric efficiency. The volumetric efficiency of the engine can be increased by reducing the backpressure in the exhaust manifold. This work analyzes the flow through two different models of exhaust manifold using CFD. The design of exhaust manifold was modified to get optimal geometry. The analysis results of two models are compared for back pressure. By comparing the results of two models the decrease in back pressure was found which ensure improvement in volumetric efficiency of the engine.

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