A Review Paper on Effect of Exhaust Manifold on Performance of CI Engine

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Abstract

The combustion process in the internal combustion engine is varying cycle to cycle while changing load, speed, etc. It is difficult to achieve better fuel economy and reduce pollution emissions. Literature shows that design of a taper, straight and lower thermal inertia exhaust manifold gives better mass conservation, fuel economy and engine efficiency. Back pressure on engine having a strong influence on engine efficiency and need to be minimized by using divergent shape exhaust manifold. Main objective of this invention is to improve the scavenging process to clean the cylinder from exhaust gases for fill up maximum volume of fresh air to increase volumetric efficiency and finally increase overall efficiency of an engine.

***Keywords**- Tapered pipes; Impulsive flow; Exhaust manifold; Convergent-divergent nozzle, CI engine.*

I.   INTRODUCTION

To improve the design of exhaust system for fulfill the requirement of consumer is more engine power and eco-friendly. So, adequate design of exhaust manifold geometry is necessary for improving gas exchange process. Exhaust manifolds are generally made of simple cast iron or stainless steel which collect engine exhaust gas from cylinder and deliver it to the exhaust pipe. Exhaust manifolds are too large will cause the exhaust gas to expand and slow down, decreasing the scavenging effect and that are too small will create exhaust gas flow resistance which reducing power and dilute the incoming intake charge. Exhaust temperature of CI engine are lower due to their greater expansion ratio and are generally in the range of 200°C - 600°C.

II.   LITERATURE REVIEW

Atul A. Patil, et al. [1] Work on Design and construction of the diffuser type exhaust manifold having different half cone angle i.e. $\theta_1=22.5°$, $\theta_2=25°$, $\theta_3=30°,\theta_4=45°,\theta_5=60°$, $\theta_6=75°,\theta_7=90°$. They have carried out experimental work at engine output condition is 5 kg load and 1500 rpm constant speed and found the result of fuel consumption rate is inversely proportional to the diffuser volume of exhaust manifold. Pressure at outlet of diffuser type exhaust manifold is directly proportional to the diffuser volume of exhaust manifold, which reduces the back pressure. For, using θ_1 to θ_7 diffuser half cone angle: Brake thermal efficiency increase from 15 % to 30 % and fuel consumption rate decrease from 0.81 kg/h to 0.74 kg/h respectively.

F. Payri, et al. [2] carried out different taper pipe configurations were constructed in order to see the mass Conservation of steady flow conditions through tapered ducts. A taper pipe having different cone angle values are 3°, 6.3° and 9° tested with impulsive flow test rig which helps to analyze the fluid-dynamic behavior of different taper pipe. It is known that tapered duct calculation causes mass conservation problems, which can be increased with the consideration of pulsating flow, typical in automotive engines. Mass conservation problem is improved in 9° convergent divergent pipe compared to other configuration duct.

Masahiro Kawasaki, et al. [3] were taken exhaust manifold equally divided into three segment. In this work they were designing the pipe radius of exhaust manifold, in

1st case: radius of exhaust pipe vary from 83% to 122% of original radius from first segment to third segment of an exhaust manifold. Their result achieve higher charging efficiency (that indicates power) than conventional exhaust manifold. In 2nd case: The pipe radius of exhaust manifold r_0 will vary from 90% to 120% of the original radius from first segment to third segment of an exhaust manifold. First part radius (r_0), second parts radius (ar_0) increasing by factor a will vary from 1.06 to 1.18 and third parts radius (br_0) increasing by factor b will vary from 1.35 to 1.45. Their results suggest that less gas interaction and the higher charging efficiency achieve in second case compared to first case.

A Kalpakli, et al. [4] carried out experiment on straight pipe and 90° bent pipe whose inner diameter is 40.5 mm and curvature radius of R_c =51 mm. In this experiment, maximum mass flow rate of air is 0.5 Kg/s having pressure is 6 bar. Rotating valve generates pulses where the rotation rate is set by a frequency controlled AC motor. Time resolved stereoscopic particle image velocimetry measurements to obtain snap shots of velocity field after a 90° bend pipe. They examine the behavior of flow structure and observed the vortex pattern at the center of pipe in downstream. Mass flow rate in bent pipe and straight pipe Vs. pressure ratio when pulsation frequency 40 Hz is shown below in figure.1.
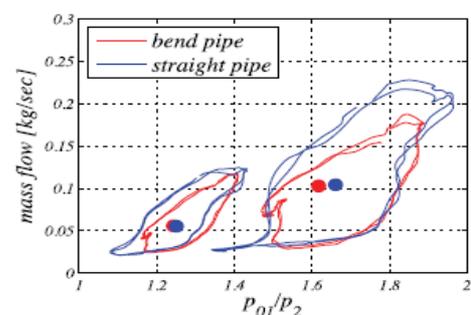

Figure 1. Mass flow rate Vs Pressure ratio [4]

J. Galindo, et al. [5] carried out experimental work on dual wall air gap exhaust manifold and conventional exhaust manifold. In this test, exhaust manifold having higher thermal inertia (stainless steel) or lower thermal inertia (cast iron) with external insulation. The experimental results of mass flow rate in lower thermal inertia part is 140

kg/h and higher thermal inertia part is 130 kg/h. Engine torque in lower thermal inertia part is 200 Nm and higher thermal inertia part is 190 Nm. Non insulated, lower thermal inertia manifold deliver 1.7% more energy compared to higher thermal inertia part. Finally they concluded that dual wall air gap exhaust manifold improve transient performance of an engine due to saving exhaust energy by reducing heat loss to increase catalyst temperature by 50 °C, increase torque 6.6 % and volumetric efficiency.

Moh'd Abu Qudais. [6] Introduce a theoretical model for predicting the instantaneous exhaust gas temperatures and velocities of a single cylinder diesel engine. It includes modelling of non-instantaneous combustion, heat transfer and variable specific heat to get continuous change in the gas state throughout the cycle. Also, cylinder volume, mass of charge and internal energy of the gas is found at any instant in the cycle. Finally, they concluded that experimentally results are approximately same to the results obtained from modelling is shown in below figure.2. Based on this agreement, the model can be used to predict the instantaneous exhaust velocity and temperature of many engines over wide ranges of operating condition.
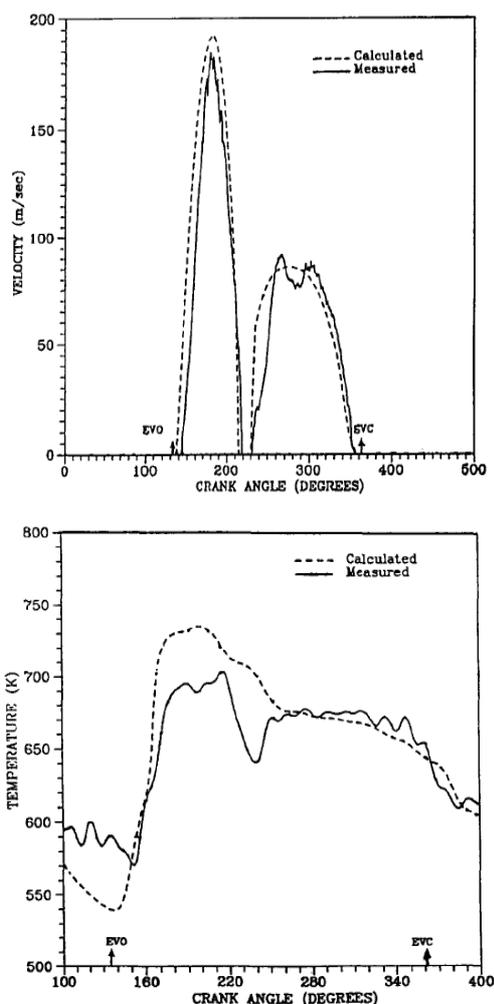

Figure 2 Velocity and Temperature Vs Crank angle [6]

Jose Manuel Lujan, et al. [7] introduces a model of exhaust systems in two-stroke gasoline engine which accounts the effect of exhaust manifold length and flow velocity fluctuation. The experimental facility measured engine performance with different load, speed and their

result show that, exhaust pressure evolutions always follow described pattern (see figure 3) if synchronized properly, help to extract exhaust gases from the cylinder and retain fresh mixture before closing the exhaust port. Trapping efficiency values are in the range between 0.5 and 0.8. From modeling result, scavenging efficiency is 3% more and trapping efficiency is 12% more than experimental result.
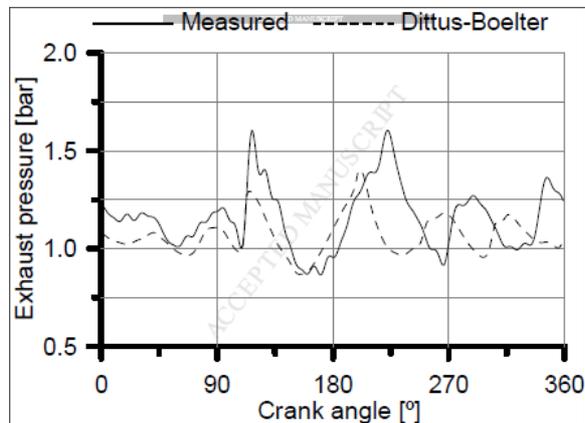

Figure 3 Exhaust pressure Vs Crank angle [7]

Ali Hocine, et al. [8] development of a numerical model allowing us to study heat transfer and gas flow behavior in exhaust manifold with or without post injection. This model use for calculate precisely the instantaneous mass flow rate and the temperature of the exhaust gas when leaving the combustion chamber. They analyze the sonic blockage of valve at the section of minimum area due to large pressure difference between the cylinder and the exhaust manifold (M = 1). A unity of the Mach number is reached at the throat since the beginning of the valve opening and then Mach number decreases is shown in below figure .4. The heat release to the exhaust gases with post injection is 25% to 35% more than without post injection. The heat release to the water coolant with post injection is 10 to 15% more than without post injection.
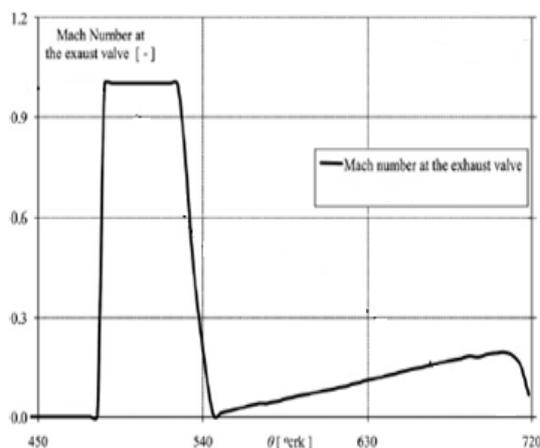

Figure 4. Mach number at Exhaust valve [8]

Anthony Sorin, et al. [9] were taken a conventional exhaust manifold for the experimental study of continues and intermittent gas flow interaction in engines. The heat transfer in the exhaust pipe can be modeled base on one-dimension conduction equation in the solid part and one-dimension energy equation in the gas flow. The following experiment was carried out for an average mass

airflow of 11 g/s. The thermal excitation period was set to 0.08 s which corresponds to a camshaft speed of 750 Rpm. The heat transfer fluctuation varies 30 % to 60 % of mean value and result show that, heat transfer coefficient of intermittent gas flow is 30% more than continuous flow.

F. Payri, et al. [10] there works on modelling of exhaust system based on linear acoustic theory to estimate the mass velocity and pressure distribution along the exhaust system. The model was validated by comparison with experimental result at selected points in the exhaust system. A simple four-in-one manifold, Instantaneous pressure time histories were recorded at points A, B and C which is 150mm, 1545mm and 1590mm away from end of exhaust manifold respectively. Sound pressure level Vs frequency at A, B, C points is shown in below figure 5.They also concluded that, modelling and experimental result shown good agreement in pressure and mass velocity distribution.
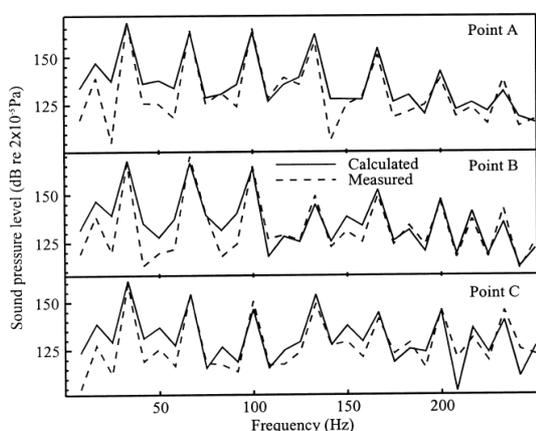
Figure 5 Sound Pressure Level Vs Frequency [10]

I.P. Kandylas, et al. [11] carried a different exhaust manifold like four into catalyst, four into two into one, four into one configuration with single wall or double wall air gap. Experimentally data from steady state and transient heat transfer in automotive exhaust systems are analyze at different velocity by taking all exhaust pipe configurations. The highly unsteady, pulsating nature of the flow in exhaust manifold increase heat transfer rates observed in exhaust systems. Their results imply that the enhanced heat transfer rates are also observed in the absence of pulsations. Four into catalyst, double wall manifold give improvement in performance compared to four into one single wall manifold show in below figure 6.
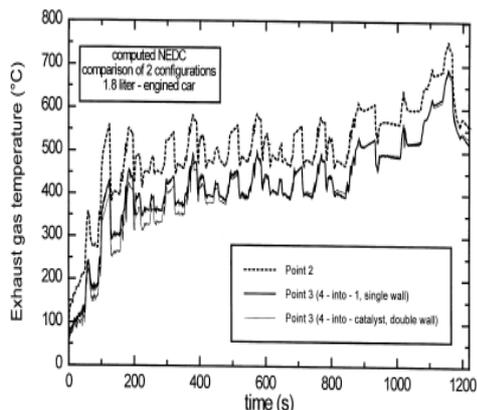
Figure 6 four-into-catalyst, double wall Vs four into one single wall.[11]

H. Bartlett, et al. [12] create a simulation model for analysis of variable geometry, exhaust gas systems by giving variable input signal like pressure, velocity, mass flow rate, speed. They were study the effect of pulsating gas stream generated by varying pulse time through a vehicle exhaust and silencer. Simulation studies were carried out over a speed range of 375 to 7500 rpm for varying lengths of exhaust pipe. Their result show that the maximum flow rate of the exhaust gas is depend on the engine speed and the ratio of the exhaust pipe length (L_1) to the silencer length (L_2). They were concluded that a ratio of exhaust pipe length to silencer length ($\frac{L_1}{L_2} = \frac{4}{1}$) would give optimum performance over speed range is 750-3750 rpm.

Cristiana Delprete, et al. [13] A commercial cast iron exhaust manifold of a diesel IC engine has been purchased and dissected to measure geometrical dimension for Solid works 2009 CAD software. The model calibration has been carried out from literature experimental data of commercial exhaust manifolds of similar geometry and material. Implementing several multi axial design base models are available (Kandil Brown Miller, Fatemi Socie) and strain based models (Von Mises, ASME Code and Sonsino Grubisic). The ASME code gives higher fatigue life, while the Sonsino Grubisic and the Fatemi Socie models provide the most optimistic life. The Kandil Brown Miller model which gives the most conservative life prediction which takes into account both shear and normal strain acting on the critical plane for ductile material.

S. Jerez, et al. [14] Make a mathematical modelling for the behaviour of unsteady one dimensional flow of a perfect gas in a tapered duct with friction and heat transfer. A model that can produce an impulse test rig has been used to obtain the numerical results. The numerical results show that error on mass conservation has been observed when the section of the duct is constant. The CE-SE (space time conservation element and solution element) method, highly accurate numerical solutions have been obtained for various flow problems involving discontinuities, shock waves, non-smooth changes of surface area and their interactions in tapered duct. A semi-implicit CE-SE technique improves the mass conservation under pulsating flow in tapered duct.

III. CONCLUSION

Exhaust manifold design depends on surface smoothness and shape. So, construction of an exhaust manifold with less complexity may reduce back pressure and gives better mass conservation. Back pressure on engine is ultimately reduces the scavenging effect and volumetric efficiency. Finally we concluded that Design of an exhaust manifold with smooth surface, straight having lower thermal inertia to achieve better fuel economy and efficiency.

REFERENCES

[1] Atul A. Patil, L.G. Navale, V.S. Patil, "Experimental Investigation and Analysis of Single Cylinder Four Stroke C.I. Engine Exhaust System" International Journal of Energy and Power (IJEP) Volume 3 Issue 1, February 2014.

[2] F. Payri, J. Galindo, J.R. Serrano, F.J. Arnau, "Analysis of numerical methods to solve one-dimensional fluid dynamic governing equations under impulsive flow in tapered ducts" International Journal of Mechanical Sciences 46 (2004) 981–1004.

[3] Masahiro Kawasaki, Masashi Marikina, Shigeru Obayashi and Kazuhiro Nakahashi, "Exhaust manifold design based on engine cycle simulation" Parallel Computational Fluid Dynamics - New Frontiers and Multi-Disciplinary Applications.(2003)

[4] A Kalpakli, R orlu, N Tillmark, P H Alfredsson. "Experimental investigation on the effect of pulsations on exhaust manifold related flows aiming at improved efficiency" KTH CCGEx, Department of Mechanics, Royal Institute of Technology, Sweden.

[5] J. Galindo , J.M. Lujan , J.R. Serrano , V. Dolz , S. Guilain, "Design of an exhaust manifold to improve transient performance of a high-speed turbocharged diesel engine" Experimental Thermal and Fluid Science 28 (2004) 863–875.

[6] Moh'd Abu Qudais. "Instantaneous Exhaust Gas Temperature and Velocity for a Diesel Engine" Applied Energy, Vol. 56, No. 1, pp. 59-70,1997.

[7] J. Lujan, H. Climent, P. Olmeda, V.D. Jiménez, "Heat transfer modelling IN exhaust systems OF high-performance two-stroke engines", Applied Thermal Engineering(2014),doi:10.1016/j.applthermaleng.2014.04.045.

[8] Ali Hocine, Bernard Desmet, Smail Guenoun, "Numerical study of the influence of diesel post injection and exhaust gas expansion on the thermal cycle of an automobile engine" Applied Thermal Engineering 30 (2010) 1889-1895.

[9] Anthony Sorin , François Bouloc , BrahimBourouga , Pierre Anthoine, "Experimental study of periodic heat transfer coefficient in the entrance zone of an exhaust pipe" International Journal of Thermal Sciences 47 (2008) 1665–1675.

[10] F. Payri, A.J. Torregrosa, R. Payri, "Evaluation through pressure and mass velocity distributions of the linear acoustical description of I. C. engine exhaust systems" Applied Acoustics 60 (2000) 489-504.

[11] I.P. Kandylas, A.M. Stamatelos, "Engine exhaust system design based on heat transfer Computation" Energy Conversion & Management 40 (1999) 1057-1072.

[12] H. Bartlett, R. Whalley, "Modelling and analysis of variable geometry exhaust gas Systems" Applied Mathematical Modelling 22 (1998) 545-567.

[13] Cristiana Delprete, RaffaellaSesana, Andrea Vercelli, "Multiaxial damage assessment and life estimation: application to an automotive exhaust manifold" Procedia Engineering 2 (2010) 725–734.

[14] S. Jerez, J. V. Romero and M. D. Rossello, "A Semi-Implicit Space-Time CE-SE Method to Improve Mass Conservation through Tapered Ducts in Internal Combustion Engines" Mathematical and Computer Modelling 40 (2004) 941-951.

[15] V. GANESAN, I C Engines, McGraw-Hill Education (India) PVT Limited (2008)