ISSN(Online): 2319 - 8753
ISSN (Print) :2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

A Review on Heat Transfer Analysis in Automotive Exhaust System

Mahesh S. Vasava [1], P. V. Jotaniya [2]

P.G. Student, Department of Mechanical Engineering, L. D. College of Engineering, Ahmedabad, Gujarat, India[1]

Assistant Professor, Department of Mechanical Engineering, L. D. College of Engineering, Ahmedabad, Gujarat, India[2]

ABSTRACT: The automotive exhaust system is exposed to high temperature as the hot gases from combustion chamber passes through it. The uniform distribution of heat is needed to enhance life of exhaust system components. Heat transfer studies in the exhaust system is necessary to understand the physical phenomena takes place in it which is required to design purpose of exhaust system. Higher performance of engine can be achieved by normal operating condition which can be limited by controlling exhaust system temperature. This article is providing a detail review on heat transfer analysis in automotive exhaust system.

KEYWORDS: Heat transfer, Automotive exhaust system, Engine performance, Emission.

I. INTRODUCTION

Internal combustion engine is an important prime mover used in the various field like automotive, power generation and industry application. Heat transfer affects the performance, emission and durability of the engine as well as the design, material choice and fatigue life of vehicle components. Engine heat transfer and cooling is necessary for improvement of engine performance. Measuring the exhaust gas temperature from automotive exhaust system is useful to understand the engine processes. The exhaust gases coming out from engine are at very high speed and at high temperature. Exhaust system of an automobile from which exhaust gases coming out from combustion chamber have silencer which is integral part of exhaust system. High temperature in exhaust system leads to thermal, vibration and fatigue failures causing the cracks in silencer. So it is necessary to study the heat transfer analysis for hot section of exhaust system for better performance of automobile.

Thermal mass and external insulation to exhaust system is main factor which affects the inlet gas temperature of catalytic converters. Under normal operating conditions, catalytic converters are most effective to reduce air pollution from internal combustion engines. The exhaust gases flowing through the exhaust system need to be cooled before reaching the catalytic converter to increase performance of catalytic converter. The heat transfer analysis in automotive exhaust system is necessary because their importance in the design and optimization phases of exhaust after-treatment system. Heat loss between the engine out and before the catalyst converter will determine the energy gain of the catalyst thus affect the temperature rise of the catalyst which affect catalyst life time.

A significant number of researches have been done for exhaust manifold, exhaust piping and catalytic converter packaging design for automotive exhaust system to improve performance based on heat transfer analysis of exhaust system. The resulting heat transfer expression based on experiments and mathematical modelling used in computational models for the design of exhaust system parts and optimization phases to facilitate the selection of suitable material and designed system for better performance.

ISSN(Online): 2319 - 8753
ISSN (Print) :2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

II. LITERATURE SURVEY

Durat et al. (2014) carried out CFD and experimental analysis on thermal performance of exhaust system of a spark ignition engine. An experimental study was carried out to compare the CFD and heat transfer analysis of gas flow in the exhaust pipe. In the experiments the temperatures at inlet and outlet of the exhaust pipe were measured and the study 3-D transient CFD analysis has been performed for the whole exhaust pipe. The results in CFD analysis was in good agreement with those of experimental data. Also, an optimum catalyst location was determined by the CFD analysis performed in transient regime.

Ghazikhani et al. (2014) have been researched the exergy recovery from a Direct injection diesel engine. Investigation performed for turbocharged diesel engine at various engine speeds and torques. For this, a double pipe heat exchanger with counter current flow is used in the exhaust of engine. As an important outcome, by increasing the load and engine speed, the recovered exergy increased. The reduction of brake specific fuel consumption (bsfc) due to the use of recovered exergy from exhaust has also been studied in the study. The results show that by using recovered exergy, bsfc decreased approximately 10%.

Liu et al. (2014) studied the compatibility of automotive exhaust thermoelectric generation system, catalytic converter and muffler. The research work tried to vary the installation position of thermoelectric generator and proposed three different locations. They identified the three positions for installation of thermoelectric generator as (i) location at the end of exhaust system (ii) location between catalytic converter and muffler and (iii) location at upstream of catalytic converter and muffler. Simulation and experiment were developed to compare thermal uniformity and pressure drop characteristics over the three operating cases. From the simulation and experiment, heat exchanger in case (ii) location between catalytic converter and muffler obtained more uniform flow distribution, higher surface temperature and lower back pressure than in other cases. At the same time, the catalytic converter and muffler could keep normal working in case location between catalytic converter and muffler, providing a theoretical and experimental basis for the exhaust gas waste heat recovery system.

Dattatray et al. (2013) studied the thermal analysis for motor bike exhaust silencer for ensuring reduction in hot spot through design improvement. They design the silencer made with hot spot reduction and made improvement in the life of the components of exhaust system. They used high temperature heat resistance powder coating for mufflers of automobile application with enhanced aqueous corrosion, high temperature corrosion which started from the generation of the hot spot at front end of muffler. They analysed the modified design of silencer for heat transfer and proposed best suitable solution for reduction in hot spots in the exhaust sub-system.

Saider et al. (2012) studied the various technologies to recover exhaust heat from internal combustion engine. The focus of the study is to review the latest developments and technologies on waste heat recovery of exhaust gas from internal combustion engine. This research includes thermo electric generators, organic Rankine cycle, six stroke cycle internal combustion engine and new development in turbocharger technology.

Petkovic et al. (2011) carried out experimental verification of developed mathematical model of the heat transfer in exhaust system. They developed 1-D mathematical model of unsteady heating up of the exhaust system parts. Experimental investigations carried out to measure temperature at various locations on the exhaust pipe for different gas flow rates. The gas was air supplied by a compressor. They reported that comparison between modelling and experimental results showed good agreement.

Martins et al. (2011) studied the internal combustion engine cooling at different operating condition by means of heat pipes for recovery of thermoelectric exhaust energy. They used thermoelectric generator for exhaust system at the hot source that is exhaust pipe for electric generation in automotive application.

Jayanth et al. (2010) studied the heat transfer in two stroke internal combustion engines. The research work carried out for reducing short circuiting of fresh charge by admitting cooled exhaust gas to pass through reed valves fitted at the upper end of the transfer passage in a crank case scavenged two stroke engines. A heat exchanger was fabricated in order to cool the exhaust gas at a temperature of about 400^{o}C to avoid the pre-ignition inside the engine cylinder. They reported that in complete or partial filling up of transfer port by air/cooled exhaust gases which scavenges the burnt products and avoids the loss of fresh A/F (Air-fuel ratio) mixture during scavenging. Hence it results in improvement of specific fuel consumption and reduction of hydro carbon emissions.

Obodeh et al. (2009) reported the performance of two stroke motorcycle with tuned adjustable exhaust pipe. Manifold temperature and pressure were measured for one cylinder two stroke motorcycle. The testing considered of three measurement series. In the first, the temperatures along the length of designed exhaust pipes were measured and optimum length determined by charging efficiency as a criterion. The exhaust pipe with optimum length was used in the second test while the third test used the original equipment manufacturer exhaust system. They reported that the tuned exhaust system was found to have good impact on the specific fuel consumption lowered by 12%. The major engine out emission hydro carbon and carbon monoxide were reduced by a minimum of 27.8 and 10.7% respectively.

Sorin et al. (2008) presented a study estimating the instantaneous character of heat transfer coefficient in exhaust pipes for the continuous and intermittent flows. The authors concluded that, transient solution of the heat transfer equations was necessary to find out the instantaneous character of heat transfer coefficient.

Kar et al. (2004) studied the method of measuring the instantaneous exhaust gas temperature by thermocouples. Thermocouples do not measure the instantaneous exhaust gas temperature because of their limited dynamic response. A thermocouple compensation technique has been developed to estimate the time constant *in situ*. This method has been commissioned in a simulation study and a controlled experiment with a reference temperature. The studies have shown that the signal bandwidth has to be restricted, since noise will be amplified in the temperature reconstruction. The technique has been successfully applied to some engine exhaust measurements.

Zidat et al. (2003) studied a basic heat transfer analysis to assess and rank the relative impact of thermal mass, external heat insulation and internal gas flow on the exhaust manifold outlet temperature. Using a simple heat balance in the exhaust manifold, the importance of exhaust gas flow is highlighted. They reported that an increase in wall thickness will increase the mass and the external heat transfer (through the increase of the external diameter) but will not change the internal heat transfer. An increase in the internal diameter will decrease the internal heat transfer and will also increase the mass and the external heat transfer. Finally the air gap case will reduce the external heat transfer and will increase the overall mass of the exhaust manifold. The effect of changes in internal heat transfer is more than ten times the effect of mass or external insulation changes during the first 15 seconds of a cold start.

Kandylas et al. (1999) studied the heat transfer in automotive exhaust pipe for steady state and transient heat transfer measurements in automotive exhaust systems and analysed by means of computer model covering all exhaust piping configurations like single wall, double wall with insulation. They optimized the exhaust manifold, downpipe design, position of catalytic converter in gasoline engine, position of particulate trap in diesel engines, exhaust manifold material and pipe insulation. In this paper, transient heat transfer in automotive exhaust systems was examined and a computer-aided approach to exhaust system temperature response optimization was employed in the study of real world design situations.

Morinaka et al. (1986) studied a water-cooled-engine cooler of the divided type for vehicles like auto bikes, auto tricycles, and four wheel buggies. The cooler has two radiators for cooling the water-cooled engine, these radiators being inclined with respect to the direction of progress of the vehicle such that their axes extending at right angles to their front intersect with each other at a forward position of the radiator.

III. CONCLUSION

The present review paper gives the analysis of the heat transfer in automotive exhaust system. It is found that the heat transfer in exhaust system plays a key role for the design of exhaust system components. Hot spot and corrosion on exhaust pipe and silencer can be controlled by exhaust system temperature. Back pressure in exhaust pipe can be controlled by limiting exhaust temperature which can be improved the silencer and exhaust pipe efficiency. By controlling the exhaust gas temperature, catalytic converter life span can be improved. So it is conclude from the above literatures, the heat transfer in exhaust system directly affects the performance and the emission characteristics of the internal combustion engine. For improvement in the performance of an engine, it is necessary to control the temperature in automotive exhaust system.

REFERENCES

[1] Balashanmugam, P., Elakiya, E., and Sharma, S., “Performance analysis on a turbocharged two wheeler engine”, International Journal of engineering research and science and technology, Vol. 2(4), pp.29-41, 2013.
[2] Dattatray, D. G., Shinde, V. B., Kulkarni, S. S., “Thermal analysis for motor bike exhaust silencer for ensuring reduction in hot spots through design enhancement”, International Journal of Advanced Engineering Research and Studies, Vol. II/ IV, pp.134-137, 2013.
[3] Durat, M., Parlak, Z., Kapsiz, M., Parlak, A., “CFD and experimental analysis on thermal performance of exhaust system of a spark ignition engine”, Journal of Thermal Science and Technology, Vol. 33(2), pp.89-99, 2013.
[4] Ghazikhani, M., Hatami, M., Ganji, D., Mofid, G., Behravan, A., Gholamreza, S., “Exergy recovery from the exhaust cooling in a DI diesel engine for BSFC reduction purposes”, Energy, Vol. 65, pp.44-51, 2014.
[5] Gogineni, P., Gada, V., Suresh Babu, G., “Cooling Systems in Automobiles and Cars”, International Journal of Engineering and Advanced Technology, Vol. 2(4), pp.688-695, 2013.
[6] Jayanth, T., Arun, M., Murugan, G., Mano, R., Venkatesan, J., “Modification of Two Stroke I.C Engine to Reduce Emission and Fuel Consumption”, International Journal of Engineering and Technology, Vol. 2(1), pp.42-47, 2010.
[7] Kandylas, I. P., Stamatelos, A. M., “Engine exhaust system design based on heat transfer computation”, Energy Conversion and Management, Vol. 40, pp.1057-1072, 1999.
[8] Kar, K., Roberts, S., Stone, R., Oldfield, M., “Instantaneous Exhaust Temperature Measurements Using Thermocouple Compensation Techniques”, SAE paper 2004-01-1418.
[9] Liu, X., Deng, Y. D., Chen, S., Wang, W. S., Xu, Y., Su, C. Q., “A case study on compatibility of automotive exhaust thermoelectric generation system, catalytic converter and muffler”, Case Studies in Thermal Engineering, Vol. 2, pp.62–66, 2014.
[10] Martins, J., Brito, F. P., Goncalves, L. M., Antunes, J., “Thermoelectric energy recovery with temperature control through heat pipes”, SAE paper 2011-01-0315.
[11] Obodeh, O., Ogbor, A. D., “Improving the performance of Two-stroke Motorcycle with tuned adjustable exhaust pipe”, Journal of Applied sciences, engineering and technology, Vol. 1(2), pp.59-65, 2009.
[12] Morinaka, M., Komuro, K., “Water-cooled engine cooler for vehicle”, United state Patent, Patent number 4632206 (1986).
[13] Petkovic, S., Pesij, R., Lukic, J., “Experimental verification of mathematical model of the heat transfer in exhaust system”, Thermal science, Vol. 15(4), 1035-1048, 2011.
[14] Saidur, R., Rezaei, M., Muzammil, W. K., Hassan, M. H., Paria, S., Hasanuzzaman, M., “Technologies to recover exhaust heat from internal combustion engines”, Renewable and Sustainable Energy Reviews, Vol. 16, pp.5649–5659, 2012.
[15] Zidat, S., and Parmentier, M., “Exhaust Manifold Design to Minimize Catalyst Light-off Time”, SAE paper 2003-01-0940.