Experimental Investigation of Automotive Exhaust System using Liquid Jet Cooling Device

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Abstract— Liquid jet cooling device is designed for automotive exhaust system cooling. It is a simply a heat exchanger designed for automotive exhaust system. This device can be fitted with exhaust pipe near manifold to control the temperature of exhaust system. Liquid jet cooling device has cylindrical housing to hold a quantity of cooling water and a nozzle at entrance to create liquid jet and bubble generators to produce small bubbles. Experimental investigation of liquid jet cooling device is carried out to study the axial distribution of temperature in cooling device as well as automotive exhaust pipe and effect of gas holdup on temperature distribution has been investigated. It has been reported from experimental research that using liquid jet cooling device higher heat transfer between exhaust pipe and cooling water is obtained.

Key words: Heat transfer; liquid jet cooling device; gas holdup; automotive exhaust system

I. INTRODUCTION
The automotive exhaust system is exposed to high temperature as the hot gases passes through it. The uniform distribution of heat is needed to enhance life of exhaust system components. Controlling the exhaust gas temperature, higher performance of the engine can be achieved. An exhaust gas cooling device for automotive exhaust system includes a nozzle, bubble generator and a cylindrical housing to hold a quantity of cooling medium. The present cooling device has advantages of simple in construction, less costly and effective cooling to exhaust system. This device is more efficient and more economical to use as it cooling down entire exhaust system and so heat related stress due to mechanical expansion and contraction of mechanical parts can be minimized. Higher temperature in exhaust system leads to thermal, vibration and fatigue failures causing the cracks in silencer. So it is necessary to cool down the exhaust system. Catalytic converters are most effective to reduce air pollution from internal combustion engines under normal operating conditions. The exhaust gases flowing through the exhaust system need to be cooled before reaching the catalytic converter to increase performance of catalytic converter. A significant number of researches have been done for cooling of exhaust manifold, exhaust piping and catalytic converter for automotive exhaust system to improve performance based on heat transfer analysis of exhaust system. Robert Wassmur [10] investigated the method and arrangement for cooling an exhaust system of a vehicle having an internal combustion engine. The arrangement includes a controller for detecting an elevated temperature condition of the exhaust system and detecting a predetermined engine operating status. Bradley J. Shaffer [11] proposed the design for an exhaust manifold cooling for an internal combustion engine having a turbocharger, an exhaust manifold and heat exchanger. Martins et al. [5] 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.

II. EXPERIMENTAL SETUP AND PROCEDURES

Experiments were carried out using liquid jet cooling device which was fitted with the existing exhaust system. Experimental investigation done by the method mentioned in the research by Petkovic et al. [9]. Temperature at various locations of exhaust system is measured by K type thermocouple which is fitted with exhaust system at location ‘3’ and ‘4’ and at location ‘1’ and ‘2’ of cooling device. Water in cooling device is provided from storage tank by pump and flow rate is adjusted by rotometer. Pressure drop in liquid jet cooling device is measured by ‘U’ tube manometer. Before starting the engine, water is pumped from the storage tank and allowed to emerge from the device. Water jet is created by means of providing nozzle in the entrance of the device. The purpose of the jet is to create turbulence in water so higher heat transfer rate between exhaust pipe and cooling water could be achieved. The axial temperature distribution was measured for cooling device and exhaust pipe as steady state flow of water is maintained in the device. For specific speed of engine the temperature at the location ‘1’ and ‘2’ of cooling device and the location ‘3’ and ‘4’ of exhaust pipe is noted at specific time. Same experiment was carried out for various flow rate of water in the device. Experiments were carried out at room temperature and exhaust gas temperature was also being measured during the experiments. Gas holdup is measured by pressure drop measurement technique. Gas holdup is an important hydrodynamic parameter which affects the heat transfer and mass transfer rate and it is a basic measure in gas-liquid contacting devices. Gas holdup is a ratio of gas phase volume to the...
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Manometer ports are provided to measure pressure drop between two ports. This pressure drop is used to measure local gas hold up. Local gas hold up is given by,

$$\varepsilon_g = 1 - \frac{\Delta p}{g \cdot z \cdot \rho}$$  \hspace{1cm} (1)

$\Delta p$ = Pressure drop, N/m² and
$z$ = Distance between manometer two port, m
$g$ = acceleration due to gravity, m/s²
$\rho$ = Density of liquid

Temperature distributions in cooling device and in exhaust pipe at axial locations $T_1$, $T_2$, $T_3$ and $T_4$ were investigated for the different coolant flow rate at different speed of two wheeler engine of single cylinder type, 99.35 cm³ displacement having compression ratio 9.3:1 and effects of local gas holdup on temperature distribution has been studied.

### III. RESULT AND DISCUSSION

#### A. Axial temperature variation in automotive exhaust pipe and liquid jet cooling device

Experimental investigations were carried out for various engine speeds for superficial liquid velocity. Temperature distributions were measured in axial position of automotive exhaust pipe.

From experimental analysis it is found that increase in cooling water flow rate would be lower the outlet exhaust pipe temperature. So increase in liquid coolant velocity in liquid jet cooling device enhanced the heat transfer between exhaust pipe and cooling device. This is due to the more turbulence created in the cooling water which is improved the heat transfer between exhaust systems and cooling water.

#### B. Effect of cooling water flow rate on gas hold up:

Experimental investigations of liquid jet cooling device shows that the increase in cooling water flow rate would be increased the gas hold up and so higher the heat transfer between cooling water and the exhaust pipe. This can be possibly due to more turbulence in bubble column device. It is also reported that increase in liquid coolant velocity, the heat flow rate between exhaust system and cooling water increased. It is also reported from
experimental investigation that the use of liquid jet cooling device lower the temperature of exhaust gases and silencer.

![Fig 8 Effect of cooling liquid flow rate on gas hold up](image)

Increase in cooling liquid flow rate would be increased gas hold up to certain instant and again increased. This is the transition zone in the liquid jet cooling device in which homogeneous to heterogeneous regime takes place. At lower liquid flow rate it is in homogeneous regime and at higher flow rate more turbulence in water leads to breakup and formation of the small bubble and eddy takes place which leads to heterogeneous regime. In this regime this cooling device gives improved heat transfer.

IV. CONCLUSIONS

The experimental analysis of liquid jet cooling device gives the important of heat transfer analysis 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. Many researchers have concluded that 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. Experimental analysis of liquid jet cooling device is carried out for automotive exhaust system. It is found from experiments that such device is very important to control and regulate the exhaust gas temperature as well as exhaust system temperature to improve exhaust system or exhaust system components life span.

REFERENCES


