Performance Analysis of Liquid Jet Cooling Device for Automotive Exhaust System Cooling

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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 which is used to control the temperature of automotive exhaust system, as it is necessary to control the temperature of automobile engine and automotive exhaust gases. This device can be fitted with exhaust pipe near manifold to control the temperature of exhaust system. Performance analysis of liquid jet cooling device is carried out for heat transfer rate between cooling water of liquid jet cooling device and the exhaust pipe. The experimental study is carried out for superficial liquid coolant velocity in the range between 0.016 m/s and 0.032 m/s and the speed of engine set for 1500, 2000 and 2200 RPM. It has been investigated from the experimental research that using liquid jet cooling device, higher heat transfer rate between exhaust pipe and cooling water is obtained for increasing the superficial liquid coolant velocity for each run of the engine which controls the exhaust system temperature.

***Key words*:** Heat transfer; liquid jet cooling device; heat transfer rate; 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. 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. So it is necessary to cool down the exhaust system. 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.

Ghazikhani et al. [10] 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. Liu et al. [15] 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 location at the end of exhaust system, location between catalytic converter and muffler and 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. Jayanth et al. [5] investigated 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.

The present research has been intended in the cooling of exhaust system, exhaust gases and engine by providing liquid jet cooling device to exhaust pipe for a two wheeler vehicle in which the cooling efficiency can be enhanced by permitting more turbulence in cooling water of liquid jet cooling device. Liquid jet cooling device comprises of two sections namely inlet section and outlet section. Inlet section of liquid jet cooling device has a nozzle from which cooling water flow into the device main housing. Small bubble generators are provided in the main housing of liquid jet cooling device to produce bubbles and turbulence. The cooling device is fabricated such that it can easily installed on exhaust pipe. The flow of coolant water is maintained from top to bottom of the device.

II. EXPERIMENTAL SETUP AND PROCEDURES

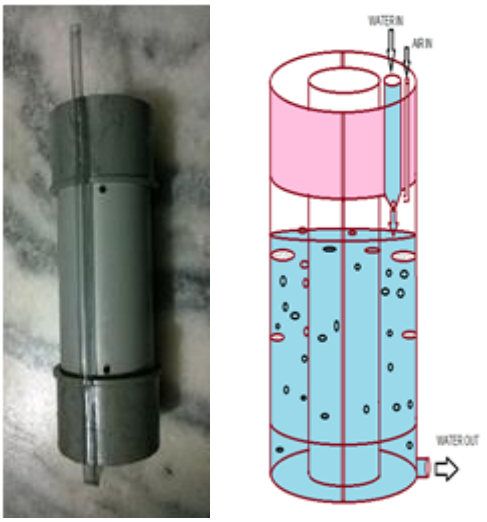

Fig. 1: Schematic view of liquid jet cooling device

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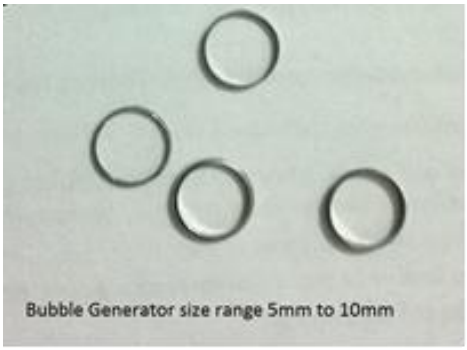

Fig. 2: Bubble generators

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. [11]. 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 specific flow rate of coolant water is adjusted. Temperature of coolant water in storage tank also measured. 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'.

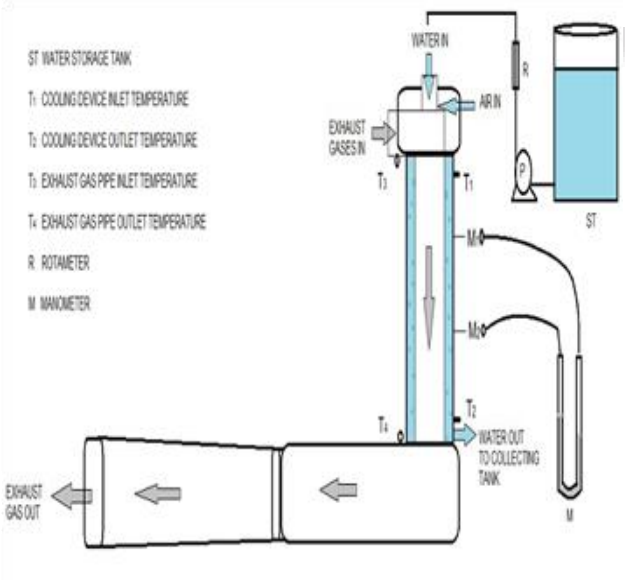

Fig. 3: Schematic diagram of experimental set up

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 in liquid jet cooling device 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 total volume of phase. Manometer ports are provided to measure pressure drop between two ports of liquid jet cooling device.

Temperature distributions in cooling device and in exhaust pipe at axial locations T1, T2, T3 and T4 were investigated for the different coolant velocity at different speed of two wheeler engine of single cylinder type, 99.35 cm3 displacement having compression ratio 9.3:1 and performance analysis of cooling device has been studied.

III. RESULT AND DISCUSSION

Experimental investigations were carried out for various engine speeds for specific quantity of fuel. Various superficial liquid coolant velocities adjusted to measure temperature distributions in axial position of automotive exhaust pipe and heat flow rate in cooling device has been investigated. Speed of engine maintained at 1500 RPM, 2000 RPM and 2200 RPM.

1) Variation of Heat flow rate in liquid jet cooling device at different engine speed for 100 ml fuel consumption:

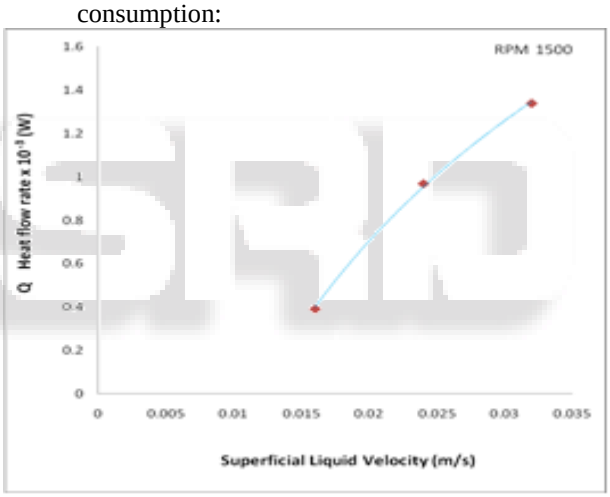

Fig. 4: Variation of Heat flow rate in cooling device at engine speed 1500 RPM, 100 ml fuel consumption

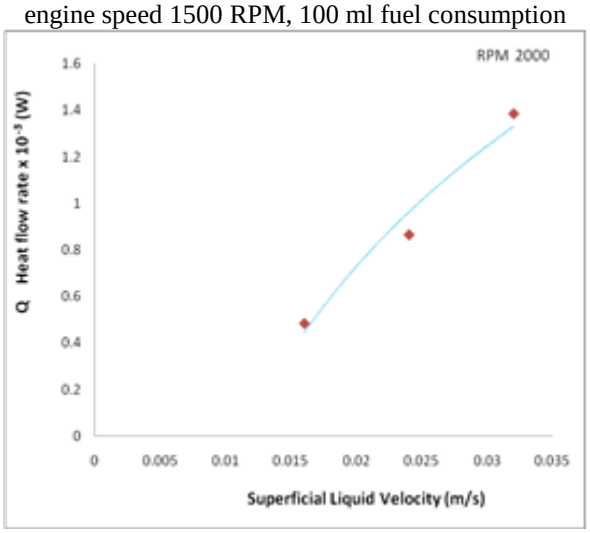

Fig. 5: Variation of Heat flow rate in cooling device at engine Speed 2000 RPM, 100 ml fuel consumption

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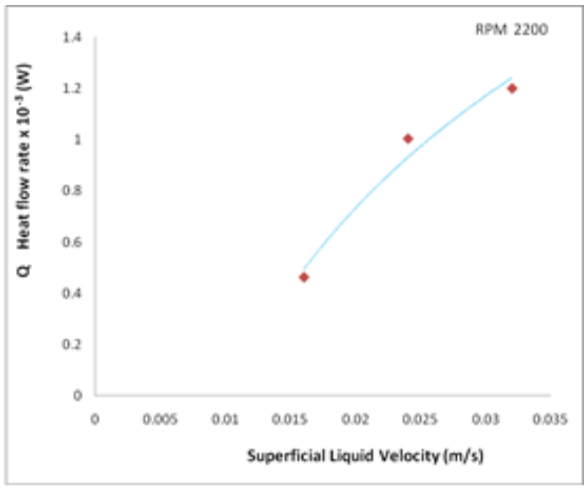

Fig. 6: Variation of Heat flow rate in cooling device at engine speed 2200 RPM, 100 ml fuel consumption

2) Variation of Heat flow rate in cooling device at different engine speed for 200 ml fuel consumption:

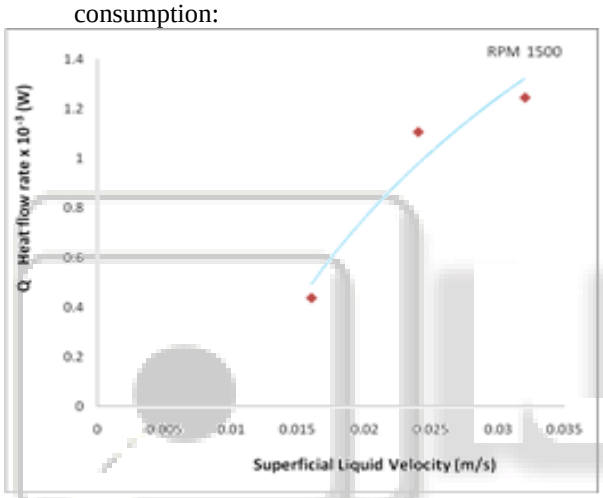

Fig. 7: Variation of Heat flow rate in cooling device at engine speed 1500 RPM, 200 ml fuel consumption

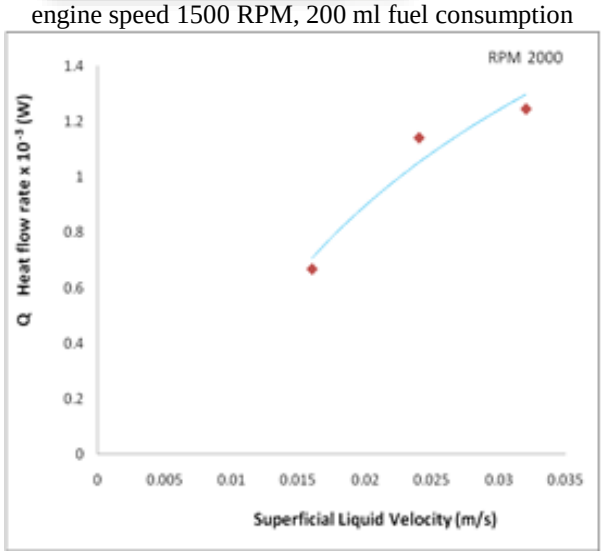

Fig. 8: Variation of Heat flow rate in cooling device at engine speed 2000 RPM, 200 ml fuel consumption

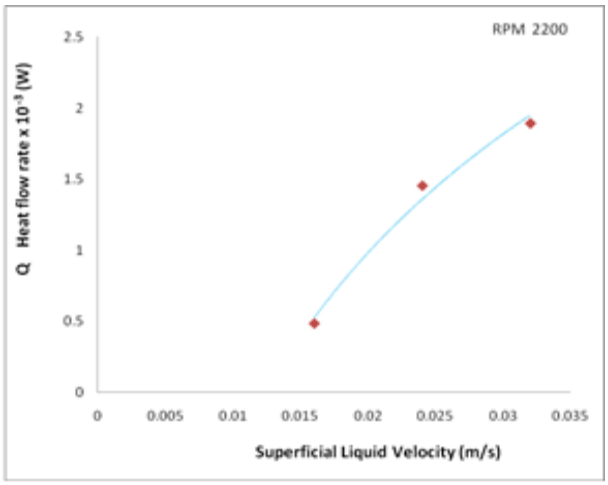

Fig. 9: Variation of Heat flow rate in cooling device at engine speed 2200 RPM, 200 ml fuel consumption

Experimental investigations of liquid jet cooling device shows that the increase in cooling water flow rate would be increased the heat transfer rate between cooling water and the exhaust pipe. This can be due to more turbulence in liquid jet cooling device. It is also reported that increase in liquid coolant velocity, decrease the temperature of exhaust gases and silencer.

For lower superficial liquid velocity, homogeneous regime occurs in liquid jet cooling device and so less turbulence leads to lower heat transfer rate between exhaust pipe water and at higher superficial liquid velocity more turbulence in water leads to breakup and formation of the small bubble and eddy takes place which leads to heterogeneous regime gives improved heat transfer rate.

IV. CONCLUSIONS

The performance analysis of liquid jet cooling device gives the important of heat transfer rate between exhaust pipe and cooling water of liquid jet cooling device in automotive exhaust system. It is found that the heat transfer in exhaust system important 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. Performance analysis of liquid jet cooling device is carried out for automotive exhaust system. It is reported from the experimental investigation that liquid jet cooling device gives more heat transfer rate between exhaust pipe and cooling water. It gives higher efficiency to the engine as it control the temperature of exhaust system component. Fuel consumption is less for the test vehicle which has used exhaust system cooling. It is found from experiments that such device is very important to control and to regulate the exhaust gas temperature as well as exhaust system temperature to improve exhaust system or exhaust system components life span.

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