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Research Article

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Experimental Analysis of Heat Transfer from Engine Cylinder to Water Jacket with Porous Media

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Abstract—

Engine heat transfer and cooling is always been a crucial area of interest for improvement of engine performance. Engine cooling system plays an important role to maintain operating temperature of engine. The coolant circuit initiates by picking up heat at water jacket. Temperature of engine cylinder is very high. This temperature transfer from engine cylinder to water jacket through conduction and convection. Introduction of porous media in water jacket affect the heat transfer in water jacket. This extensive research is carried out to study heat transfer from water jacket of an engine experimentally. The research covers many individual topics which include heat transfer at water jacket, flow through porous media and heat transfer from engine cylinder to water jacket.

Keywords— Heat Transfer, Water Jacket, Porous Bed, Engine Cylinder, Water Flow

I. INTRODUCTION

IC engine heat transfer analysis improving the removal of excess heat from engine thermal system and leading to improvement of engine thermal efficiency has been considered as one of scientific challenge for decades. IC engine is an important prime mover used in various fields mainly in automotive and power generation. In early days of IC engine development, power output and efficiency were main focus of researchers. Heat in commercial engine has to travel through engine components leads to increase its temperature. This percentage of heat loss through engine cooling varies according to various engine and cooling system parameters. Engine cooling system is crucial to ensure engine could operate at its optimum temperature. However it is always being neglected. Moreover the experimental investigations are performed through the temperature measurement of the coolant in the jackets inserting various thermocouples in various points. In an actual sense, the heat transfer and temperature distribution is varied in every point of cooling jacket. Controlling the cooling rate or heat transfer rate through putting the steel balls in engine water jacket is totally new concept. In a piston cylinder assembly, there is high temperature in piston cylinder. Now cylinder is cooled by water flowing through engine jacket. Heat transfer takes place from piston to water. When steels balls are inserted in engine cylinder jacket as a porous media, what will be the effect on heat transfer and cooling rate? In recent years considerable interest has been generated in the study of flow in porous media. The porous medium consists of spherical balls which are closely packed and fluid passes through spherical balls. The fluid flows through interconnected pores. The known solutions are useful in understanding the flow and heat transfer phenomena. The heat transfer and other phenomena in porous media have become hot topics of research during the last few years. The heat transfer through porous media is much different from the classical principals of heat and thermodynamics. Use of engine cylinder jacket creates a curiosity in the field of porous media. Till today flow through porous media in engine cylinder jacket is not studied.

A heating element is inserted in between the engine cylinder in order to produce the engine cylinder temperature artificially. Introduction of this heating element in engine cylinder is never used before. During flow of fluid the acceleration forces are involved and relation between flow rate and pressure drop through porous bed in engine jacket is not linear, hence considered as non Darcian flow. The small scale experimental set up supported with the software's are efficient to measure the parameters for analysing the heat transfer and cooling rate through engine jacket. The parameters like temperature can be recorded accurately with the variation of various parameters. It will be more interesting to record the temperature when the flow passes through porous media introduced in engine cylinder jacket. A schematic figure of engine cylinder jacket with porous media is shown in figure 1.

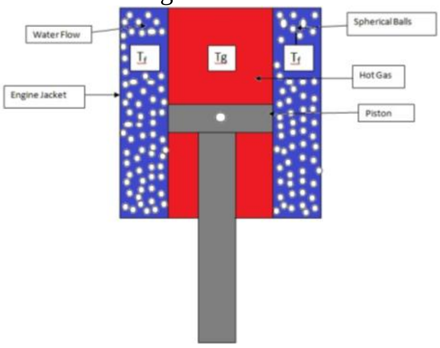

FIG. 1 ENGINE CYLINDER JACKET WITH POROUS MEDIA

II. LITERATURE SURVEY

Various researchers threw lights on this area. Yongping Chen et.al. (**2014**) developed A theoretical model of liquid flow through porous media and numerically analysed to investigate the role of pore structure on liquid flow behaviours in porous media.

M.A.Hazrat et. al**.(2013)** did steady state analysis of coolant temperature distribution in a spark ignition engine cooling jacket. Amit V. Paratwar et. al**.(2013)** carried heat transfer as well as flow analysis of existing cooling jacket of 6 cylinder turbo after cooled medium duty diesel engine. Gazy F. Al-Sumaily et. al.**(2013)** reviewed simulating steady and pulsatile forced convective flows over a circular cylinder placed in a porous medium filled channel

S.C.Pang et. al.**(2012)** studied Air flow and coolant flow circuit in vehicle's cooling system. Mehmet Turgay Pamuk et. al. **(2012)** studied experimentally heat transfer in porous media under oscillating water flow.

Shohel Mahmud et. al.**(2011)** modelled a simplified porous medium thermoacoustic system to observe its energy interaction characteristics and identified its operating conditions mainly as a function of porous medium Darcy number.

According to Demuynck et al, (**2009**) Various types of engine geometry and fuels, operation principle, high temperature and high speed of both the crank shaft as well as the pistons inside the cylinder etc are the challenging factors in developing globally acceptable model for engine heat transfer, i.e. effective thermal management system.

Torregrosa et al., (**2008**) analysed both experimentally and theoretically the engine as well as the vehicle thermal system management, reduction of emissions and fuel demand per crank shaft rotation and load governance.

Borman and Nishiwaki, (**1987**) did Theoretical analysis of heat transfer from combustion chamber to the surrounding areas i.e. water jackets in both the cylinder blocks and cylinder heads require appropriate solution of continuity, momentum and energy equations.

Liquid cooling system of an internal combustion engine is sometimes dealt as the channel flow system and heat transfer coefficient for convective mechanism is calculated through those equations (Cengel, 2002; Dittus and Boelter, 1930; Heywood, 1988; Ozisik, 1980; Rohsenow and Griffith, 1955; Sieder and Tate, 1936).

III. PROBLEM FORMULATION

The literature survey for various aspects of flow, heat transfer in engine jacket and porous media is presented. The experimental study on heat transfer through engine jacket with porous media is scare. First of all, Heat transfer through engine jacket is calculated without using porous media. Then flow rate is changed and again new Heat transfer through engine jacket is calculated without using porous media. Then spherical steel balls are inserted in engine jacket and heat transfer is calculated. Figure 2 illustrated the heat flow path across engine wall.

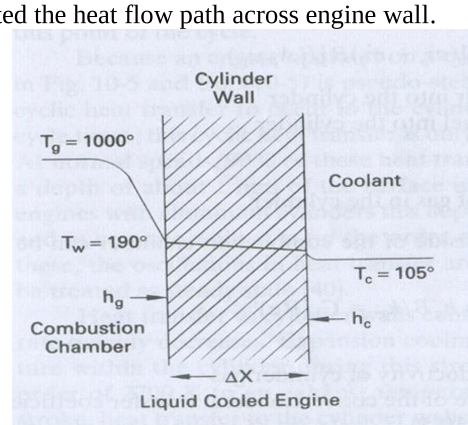

Fig. 2 Heat Flow path across engine wall

According to KRISZTINA UZUNEANU and TANASE PANAIT in Recent Advances in Fluid Mechanics and Heat & Mass Transfer,

A) Heat Transfer from gas to wall occurs due to convection and radiation.

1) Convective Heat Transfer

$$q_{conv} = \frac{\dot{Q}_{conv}}{A} = h_{gc}\left(T_{gas} - T_{wall}\right)$$

2) Radiation Heat Transfer between cylinder gas and combustion chamber walls is

$$q_{rad} = \frac{\dot{Q}_{rad}}{A} = h_{gr}\left(T_{gas} - T_{wall}\right) = \frac{\sigma\left(T_{gas}^4 - T_{wall}^4\right)}{\frac{1-\varepsilon_g}{\varepsilon_g} + \frac{1}{F_{1-2}} + \frac{1-\varepsilon_w}{\varepsilon_w}}$$

B) Further heat transfer from inner wall to outer wall will occur due to conduction

$T_{wall-inner} - T_{wall-outer} = Q_{\text{conduction}} \times \ln(D_o/D_i)\ /\ (2\times\pi\times k\times l)$

C) Now heat transfer from outer wall to coolant

$Q_1 = h\times A\times\ (T_{\text{wall-outer}} - T_{coolant})$

D) At last heat transfer from outer wall to spherical balls inserted is given as

$Q_2 = h_b \times A_b \times (T_{\text{wall-outer}} - T_{ball})$

Where σ = Stefan Boltzman Constant
ε_g = Emissivity of gas
ε_w = Emissivity of wall
F_{1-2} = View factor between gas and wall
h = Heat transfer coefficient of cylinder
h_b = Heat transfer coefficient of spherical ball
A = Area of engine cylinder
A_b = Area of spherical ball

IV. MATERIALS AND METHODS

A. Boundary Conditions

Mass flow inlet: 5 L/min)
Pump Capacity: 80 L/min
Coolant inlet temperature: 355 K (i.e. 82°C)
Coolant: Water (Water has higher specific heat capacity than 50/50 EG-H_2O)
Initial Pressure: 1.2 bar (gauge)(i.e. boiling point is > 401 K)
Temperature of combustion chamber: 600 K (i.e. 327°C)
Material of Spherical Balls used: Steel
Wall roughness factor: 1 mm

B. Experimental Set-up

The experimental Set-up of water flowing through water jacket with spherical steel balls placed in it is shown in figure 3.

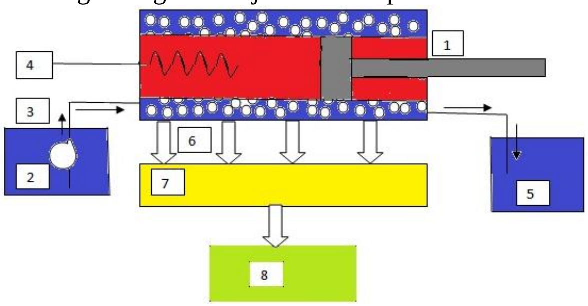

Figure 3 Schematic diagram of water flowing through water jacket with spherical steel balls placed in it

1. Piston Cylinder Assembly with water jacket
2. Water Tank
3. Pump
4. Heating Element
5. Tail Race
6. K-type thermocouple
7. Data Acquisition Card
8. PC

1) Porous Bed in Engine Jacket: Engine Cylinder is most important part of experimental set-up. Engine cylinder is taken from 5 HP four stroke diesel engine. A heating element is inserted in the cylinder with temperature controller to set the temperature of heating element. Four thermocouples are inserted in the engine jacket to measure different water temperature. In first set of experimentation steel spheres are packed in the bed, in second exp spheres of aluminum are packed. The flow rate is adjusted in the rotameter between 5 to 7 liters per minute before starting of experiment and remained constant for the experiment. As the Reynolds Number based on tube radius, its value is above 200 for all experiments. Hence the flow is considered as turbulent flow. The K type thermocouples inserted in bed converts temperature gradient into mille volts (electricity).
2) Data Acquisition Card: Data acquisition card (DAQ card) converts the analog signal into digital signal in PC. AD LINK 2213 DAQ card is used in this experimentation, which has high performance, multifunction card. It can sample up to 16 analog input channels with different gain setting. Multiple DAQ 2213 card can be synchronized interface by (SSI) bus. ADDLINK provides the driver for LAB VIEW software. As per the user guide and instruction manual supplied with card, the DAQ card is installed in PC and 8.2version LAB VIEW software is loaded. The system was programmed as per the requirement of five thermocouples. The set of readings in the digital form is recorded from porous media. DAQ card is sensitive that it records five readings in one second and up to ten decimal numbers.
3) Water Flow: Water flows in direction left to right in engine cylinder at constant flow rate (adjusted in the range 5 to 7 liters per minute) from a constant head tank. A tail race tank is used to collect the used water coming out from the engine cylinder.

V. CONCLUSIONS

In the present work, the experiment is performed to investigate the effect of porous bed on heat transfer from engine cylinder to cylinder jacket. Firstly, experiment is performed without use of spherical balls porous bed. Then the spherical balls are inserted in cylinder jacket. Results are compared in both cases. The differences between the coolant side cylinder walls temperatures measured at different points on the same horizontal line with the help of K-type thermocouple are very small. This indicates that the cylinders show almost identical cooling characteristics in the axial direction. The present model is a step toward analysis of the thermal effects in engines and of cooling systems. The model can be used to study the effects of a number of parameters on heat transfer and wall temperatures for example, the effects of changing the discharge of coolant and of ball shape and wall materials.

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