Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Experimental Investigation on Heat Transfer of Water in Engine Cylinder Jacket with Porous Media

***Mahesh Kumar and Beant Singh**

* I.K.Gujral Punjab Technical University, Jalandhar, Punjab, India
Email: Mahesh.mechlect@gmail.com, Mob.+91-9896047065
Punjab College of Engineering and Technology, Lalru(Mohali), Punjab, India
Email: Beantsingh7@yahoo.co.in Mob. +91-9357135278

ABSTRACT

The flow of water and heat transfer somewhere directly or indirectly affects the performance of an engine. An experimental test rig of water cooled four stroke diesel engine with steel balls is standardized in an electronics environment. In this paper heat transfer rate is estimated in a water cooled engine using porous media and compared with heat transfer rate without using porous media. For achieving better result, the experiment is performed at different discharge. A 6-channel temperature acquisition system using MAX6675 with K type thermocouples and Arduino UNO R3 micro controller is developed for the temperature acquisition process. The result revealed that adding porous media with water in water cooled engine effectively boosted the heat transfer rate of engine. The temperature difference between inlet and outlet of water jacket was merely improved in case of coolant flow but increased tremendously with steel balls porous bed. Further findings reflected the effect of discharge rate of coolant on heat transfer of engine. If discharge of coolant is increased, the further enhancement of heat transfer took place. This experiment can be used to improve design of water jacket and to enhance efficiency of diesel engine. Experiment can be performed with porous bed of different material, different engine speed and different coolant discharge in the future.

KEYWORDS: Diesel Engine, Heat Transfer Increment, Engine Cooling, Porous Media, Cooling Jacket, Arduino UNO R3

***Corresponding author:**

Mahesh Kumar

I.K.Gujral Punjab Technical University,

Jalandhar, Punjab, India

Email: Mahesh.mechlect@gmail.com,

Mob.+91-9896047065

1. INTRODUCTION

Generally, old conventional methods of engine cooling and hence increasing heat transfer rate are not so much in use in present scenario. Few years back, great emphasis has been created in the research area of porous media because of its natural occurrence and importance in both geophysical and engineering environments. The exploratory research on heat transfer by using porous bed has gained attention due to its large utilization in a lot of sectors e.g geothermal engineering, civil engineering, agricultural engineering, heat exchanges and Biomedical engineering. The porous media is heterogeneous system of solid and liquid in which the solid (like spherical beads) are closely packed in porous bed and fluid passes through intervening space between the matrixes. The space between the matrixes is called voids in which the fluid flows. These voids are normally interconnected and the path of fluid keeps changing from one void to another void. Hence the flow through the voids provides intense mixing of the fluid with solid and spreading in longitudinal and transverse directions[1]

To achieve maximum performance from an IC engine, it is important to maintain the temperature of engine cylinder between specific temperatures. It is very important for IC (Diesel) engine at peak load & high speed. It can be achieved by using different techniques like porous media, advanced coolant etc. The concept of increasing heat transfer rate through establishment of porous bed in engine water jacket is growing very much these days now. In engine design, it is very important to check that engine should be work at maximum temperature. However this is ignored time to time. Cooling of engine is very much fundamental component. It consist of a circuit starting from inlet and ends to outlet of water jacket. The coolant flow through the water jacket of engine and carry away the heat generated in the cylinder by the convection process. It is very interesting to know the effect of porous bed on heat transfer in water jacket. This is a major factor to know about. A small scale lab experiment is sufficient to analyze the heat transfer in cylinder jacket by using porous media

Further techniques of data acquisition process using electronic components are boosting up this decade. Some years ago, data acquisition process using DAQ card and LABVIEW software was in much more use. Todays it has been improved in much way. Arduino is replacing DAQ card slowly and slowly. An Arduino UNO R3 board with MAX 6675 microcontroller is extra ordinary electronics component for data acquisition.

This work will raise the concept of increasing heat transfer rate using porous media and data acquisition using Arduino micro controller. It will allow the establishment of relation between data acquisition and heat transfer rate in further study of heat transfer research area.

2. LITERATURE SURVEY

Many researchers explained a lot of new concepts about engine cooling and heat transfer rate.

Bin Chen and Li Zhang[2] investigated the effect of increasing specific heat and influence of charge cooling of water injection in a TGDI engine. They concluded that charge cooling has a smaller impact to increase to increasing specific heat on the variation of in cylinder temperature and pressure. Mashadi and Kakaee[3] established low temperature rankine cycle to increase the waste heat recovery from the internal combustion engine cooling system. Experimental study of pyrolysis combustion coupling in a regeneratively cooled chamber was carried out in order to check two parameters i.e. Heat transfer and coke formation by Taddeo L[4] He observed that combustor heat exchange efficiency increases with fuel mass flow rate. Experimental investigation of two phase flow and heat transfer performance in a cooling gallery under forced oscillation was carried out by Xeoli Yu and Dong Yi[5]. Their result showed that heat transfer in turbulent flow was quite stronger than in transition flow. Azzam S[6] performed experimental investigation of the impact of geometrical surface modification on spray cooling heat transfer performance in the non-boiling regime. Aqiang and Jie[7] evaluated mass injection cooling on flow and heat transfer characteristics for high temperature inlet air in a MIPCC engine. Jindong Z[8] investigated improvement of desorption efficiency using engine cooling water in natural gas vehicle tank. He concluded that using the engine cooling as the heating source of heating jacket can greatly improve desorption performance of gas tank in natural gas vehicle. Large eddy simulation of transpiration cooling in turbulent channel with porous wall was carried out by Xuefeng and Guangbo[9]. He concluded that transpiration cooling process can take a large amount of energy away from the wall thus achieving high efficiency. Xiao and Zhao[10] numerically investigated transpiration cooling for porous nose cone with liquid coolant. Transpiration cooling for additive manufactured porous plates with partition wall was done by Gan and Zhang[11]. K Anirudh and S Dhinakaan[12] investigated the effect of Prandtl number on the forced convection heat transfer from a porous square cylinder.

3. EXPERIMENTAL APPARATUS AND PROCEDURE

The experimental set up consists of following part: A 5 HP four stroke water cooled diesel engine, A Centrifugal Pump, A discharge measuring Rotameter, A Temperature Acquisition System and a water tank of 1000 litre capacity as shown in Figure 1. The description of main parts of experimental set up is given below:

Fig.1. Schematic diagram of Experimental Set up

3.1. Diesel Engine

A four stroke diesel engine is used for the experiment. The specification of engine is as given below:

No of Cylinder	1
Rated Speed	1500 RPM
Rated Output	3.7 kw
Break Horse Power	5
Specific fuel consumption	245 g/kw-hr
Fuel Oil	H S Diesel
Cooling type	Water Cooled

Table 1 Specification of Diesel Engine

3.2. Centrifugal Pump

A 1 HP centrifugal pump is used in order to pump the water from the storage tank. This water is supplied to the water jacket of engine for cooling purpose.

3.3. Rotameter

A panel mount rotameter is used for measuring the discharge as shown in Figure 2. This rotameter gives the reading of discharge in LPM and LPH.

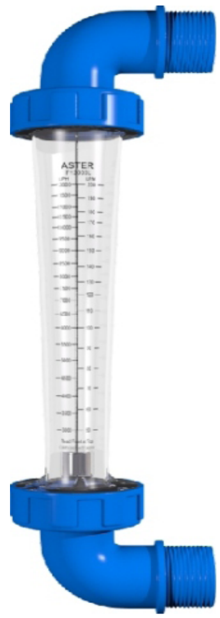


Fig.2. Panel Mount Rotameter

3.4. Temperature Acquisition System

The material used for temperature acquisition is an Arduino UNO R3 board and 6 MAX 6675 temperature sensors with K type thermocouples as shown in Figure 3.

Fig.3. Arduino UNO R3 board and MAX 6675 temperature sensor with K type thermocouple

An Arduino UNO is a type of micro controller board system which is based on the microcontroller ATMega328P. The technical specifications of ARDUINO R3 are shown in table 2 [13].

Microcontroller	ATMega 328 P
Operating Voltage	5V
Input Voltage	7-12 V
Digital I/O pins	6
DC current per I/O pins	20 mA
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
Length	68.6 mm

Width	53.4 mm
Weight	25 gm

Table 2 TECHNICAL SPECIFICATIONS OF ARDUINO UNO R3

Figure 4 shows the development of a temperature acquisition system.

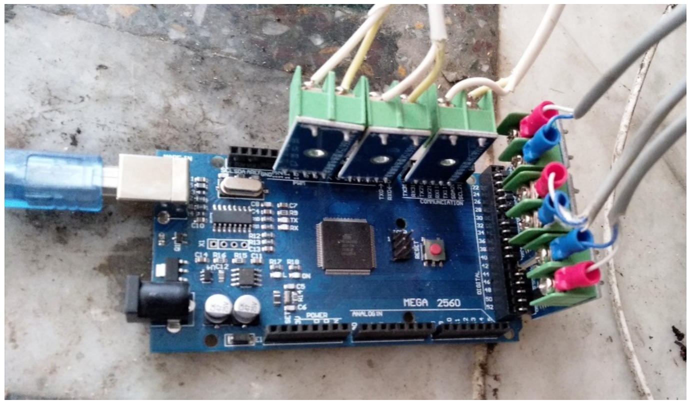


Fig.4. Development of Temperature Acquisition System

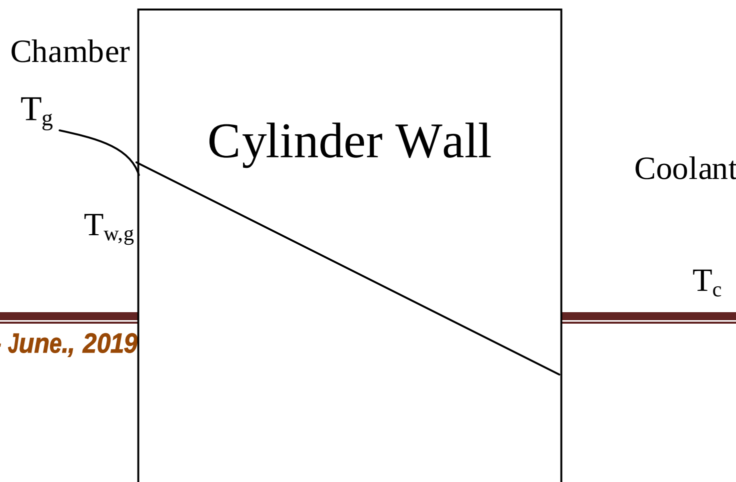
4. METHODOLOGIES

Methodologies in the form of equations based on cooling system of automobile were presented[14]. The coolant side convective coefficient (h_c) was calculated with the measurement of gas temperature (T_g), gas side wall temperature ($T_{w,g}$),coolant side wall temperature($T_{w,c}$) and coolant temperature (T_c) as shown in equation (1).

$$\mathbf{h_c} = \frac{hg(Tg - Tw,g)}{(Tw,c - Tc)} \quad (1)$$

Measurement of coolant side wall temperature ($T_{w,c}$) and coolant temperature(Tc) are measured by Max 6675 with K type thermocouples inserted in the engine water jacket on different points.

Figure 5 described the path of heat flow across wall of combustion chamber and its thermal resistance.



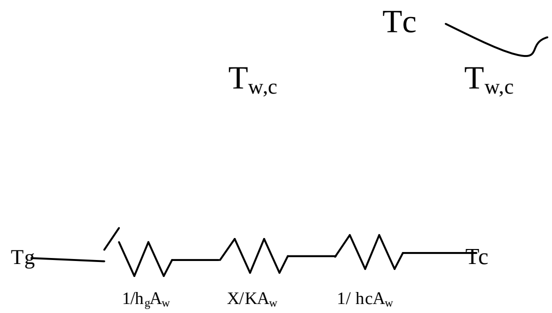


Fig.5. Temperature and thermal resistance concept at water jacket

T_g = Gas Temperature

$T_{w,g}$= Gas side wall temperature

$T_{w,c}$ = Coolant side wall temperature

T_c = Coolant Temperature

h_g = Gas side convective coefficient

h_c = Coolant side convective coefficient

A_w = Cylinder Wall Area

Krisztna Uzuneanu[15] gave equations for heat transfer in cylinder head wall as:

(a) Heat Transfer Flow in the Cylinder Head Wall:

$$q = \frac{Tg - Tc}{\frac{1}{\alpha gw} + \frac{\delta 1}{\lambda 1} + \frac{\delta 2}{\lambda 2} + \frac{1}{\alpha c}} \qquad (2)$$

(b) Inner temperature of cylinder head wall with carbon soot layer:

$$T_{w1} = Tg - \frac{q}{\alpha gw} \qquad (3)$$

(c) Inner Temperature of cylinder head wall without carbon soot:

$$T_{w2} = T_{w1} - q\frac{\delta 1}{\lambda 1} \qquad (4)$$

(d) Cylinder Head Wall to Cooling Fluid:

$$T_{w3} = T_{w2} - q\frac{\delta 2}{\lambda 2} \qquad (5)$$

Where Tg = Mean Temperature of the gases (K)

Tc = Cooling Fluid Temperature (K)

αgw = Gas Wall Heat Transfer Coefficient (W/m^2K)

$\lambda 1$ = Thermal Conductivity of Carbon Soot (W/mK)

$\delta 1$ = Thickness of Carbon Soot Layer (m)

$\lambda 2$ = Thermal Conductivity of Cylinder Head Material (W/mK)

$\delta 2$ = Thickness of Cylinder Head Wall (m)

αc = Wall-cooling fluid heat transfer coefficient (W/m^{2}K)

Heat Transfer Rate in a steady flow[16] is calculated as:

$$Q = m\ (i_{out}-i_{in}) \tag{6}$$

Where m = Mass Flow Rate (Kg/s)

i_{out} = Outlet Enthalpy(kJ/kg)

i_{in} = Inlet Enthalpy(kJ/kg)

To determine the heat transfer coefficient, the LMTD was obtained using the following relations:

$$\text{LMTD} = \frac{\Delta Tin - \Delta Tout}{\ln\left(\frac{\Delta Tin}{\Delta Tout}\right)} \tag{7}$$

Where ΔTin = T_w-T_{in} = Wall Temp-Inlet Temp

$\Delta Tout$ = T_w-T_{out} = Wall Temp-Outlet Temp

5. DATA ANALYSIS

Graph of change in temperature of water passing through water jacket at 1 LPM is shown in figure 6. It is shown that after 90 minutes temp of water become constant. Here T1 and T6 are inlet and outlet temperature of water jacket respectively. T2 to T5 are the temperatures of points in water jacket at equal distance. It is shown that the gap between T1 and T6 are approx. 20°C.

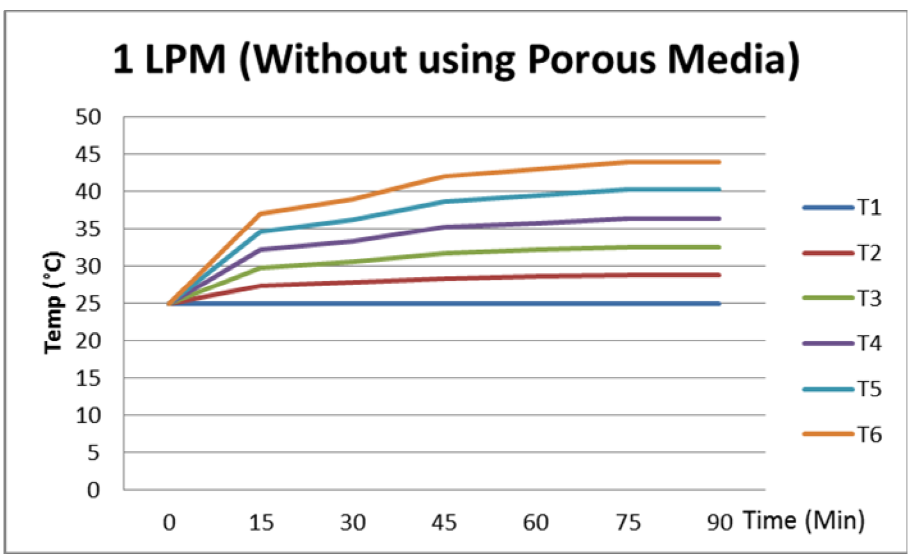


Fig.6. Time vs Temp Graph (1LPM)

Time vs temperature graph at 2 LPM without using porous media is shown in Figure 7.

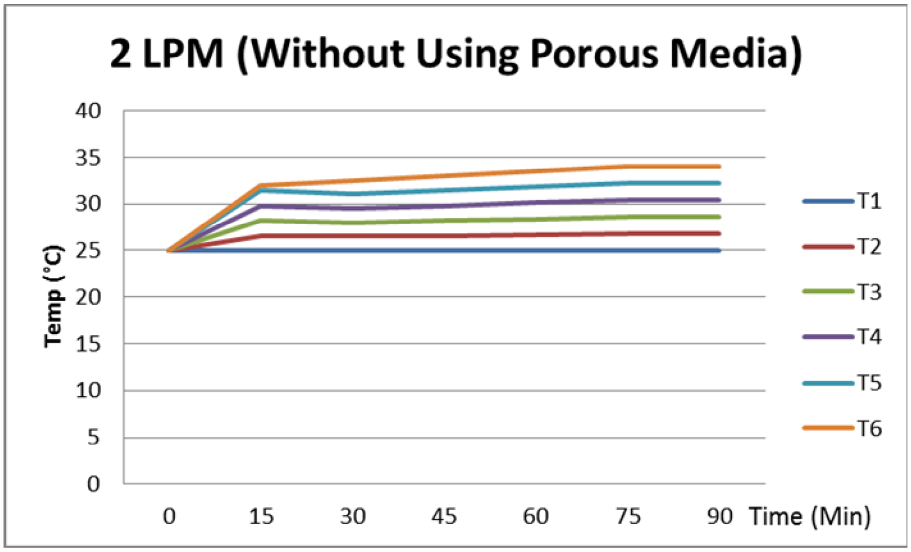


Fig.7. Time vs Temp Graph (2LPM)

Steels balls are used as the porous media in the water jacket. The steel balls were of 10 mm diameter as shown in Figure 8. Approximately 775 balls were used to make porous bed in water jacket.

Fig.8. Steel Balls used as Porous Media

At 1 LPM discharge, time vs temp graph is shown in Figure 9. It is clear from the graph that as compared to 1 LPM without using porous media, the temp reduces in case of porous media.

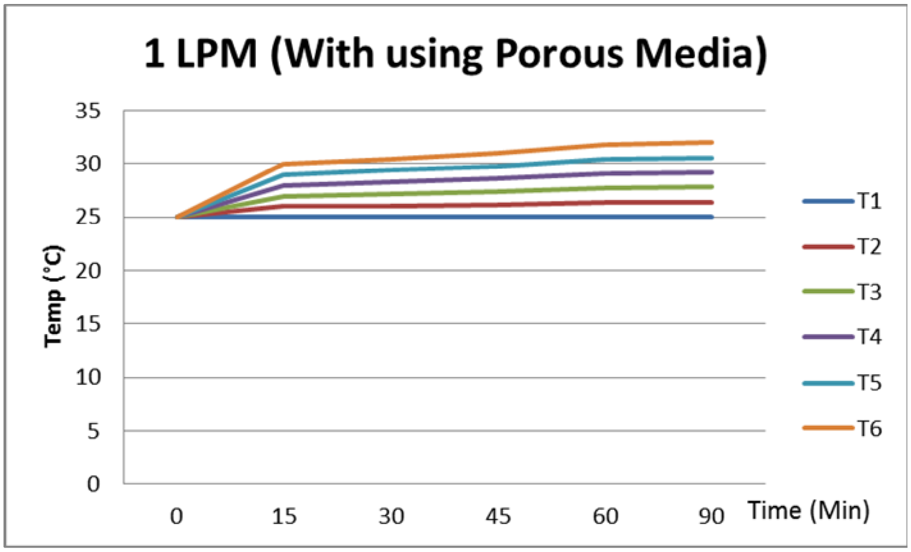


Fig.9. Time vs Temp (1 LPM)

2 LPM discharge is shown in figure 10 with porous media. As compared to without using porous media, the temperature difference again reduces in the approximately same proportion.

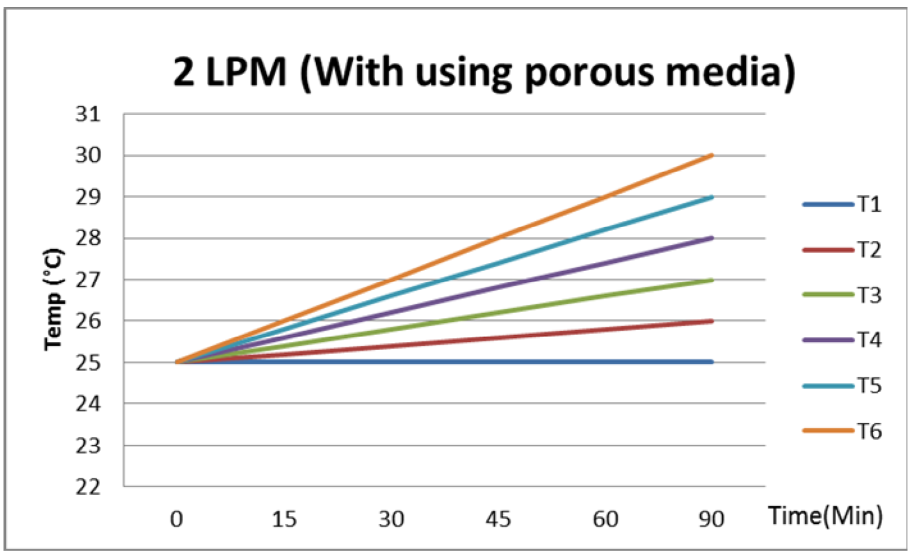


Fig.10. Time vs Temp (2 LPM)

6. RESULT AND DISCUSSION

In this work, it is clear from the figure 6-10 that firstly, temperature difference reduces when discharge is enhanced from 1 LPM to 2 LPM. Secondly, when porous media is used in the water jacket along with water, temperature difference between inlet and outlet of water jacket reduces. The effect of use of porous media is shown clearly. It is well known that heat transfer rate is inversely proportional to the temperature difference. So by using porous media heat transfer rate is enhanced. The heat transfer rate at different experiment is compared and shown below:

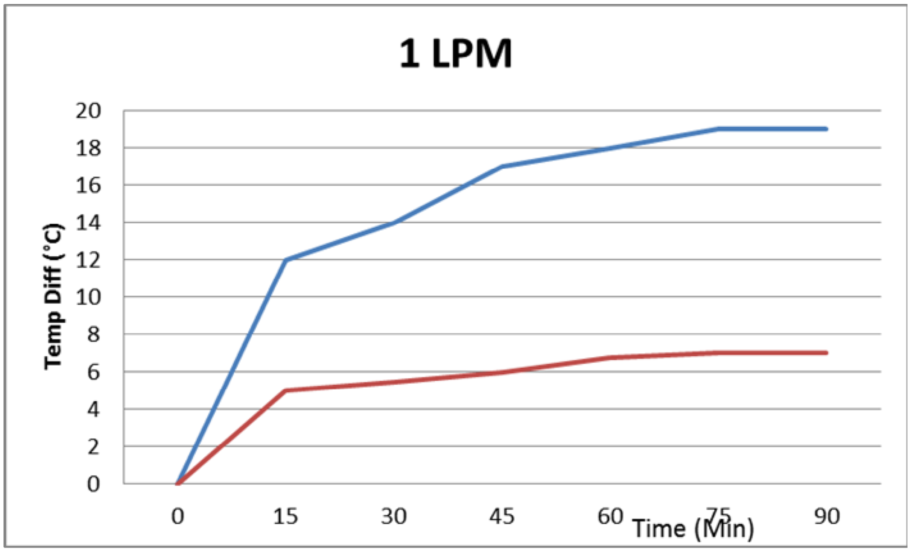


Fig.11. Time vs Temp

In the figure 11, the temperature difference vs time graph is shown for 1 LPM. The blue line show the graph for temperature difference without using porous media and red line show the graph for temperature difference with using porous media. It is clear from the graph that temperature difference decreased when porous bed is used in cylinder water jacket and hence heat transfer rate is increased.

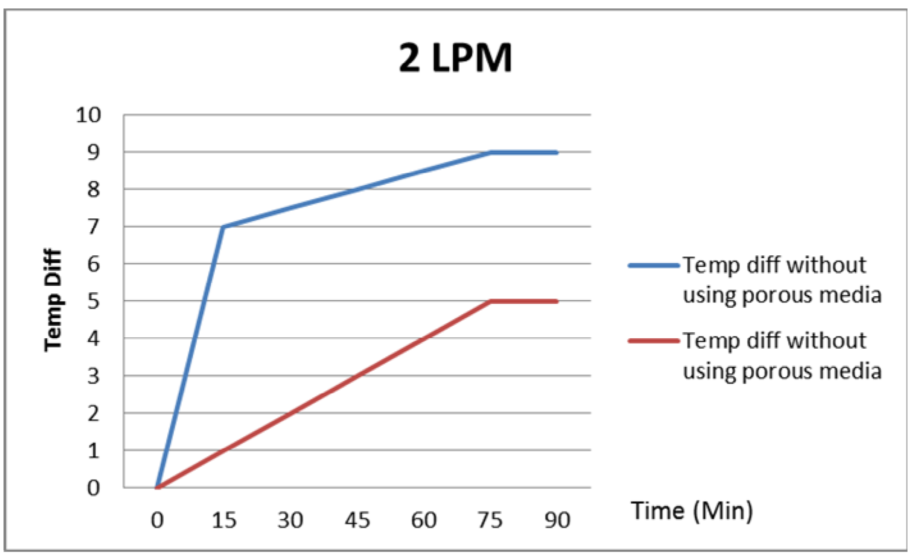


Fig.12. Time vs Temp

When graph of 2 LPM is drawn, it is clear that again temperature difference is decreased by use of porous bed and simultaneously heat transfer rate is increased.

So result showed that heat transfer rate increased with porous media filled in water jacket of the engine. This result is very similar as given by Mahdi and Mohammad[17].

7. CONCLUSION

This study analyzed the effect of porous media in the heat transfer rate or temperature difference between inlet and outlet of engine water jacket. The experiment was performed by using water as a coolant and water + steels balls as coolant in the water jacket of engine. The tests were carried out at 1 LPM and 2 LPM. Based upon the experimental results, following conclusions can be drawn:

1. Temperature difference in 2 LPM discharge reduced as compared to the 1 LPM. It is due to the factor that when discharge is increased, more heat is carried out in minimum time. It will result in increase in heat transfer rate in case of 2 LPM discharge.
2. When steel balls were used as a porous media in water jacket, then temperature difference was reduced tremendously. Also it showed a great effect when it was carried out with 2 LPM discharge. Use of porous media resulted in greater heat transfer rate.
3. Enhancement of heat transfer rate depends upon two factors: (1) Discharge of coolant (2) Use of porous media
4. More will be discharge, more heat will be carried out and there will be more heat transfer.
5. Use the porous media, more heat transfer will be there.

ACKNOWLEDGMENT

The authors would like to gratefully thanks the I K Gujral Punjab Technical University, Jalandhar (Punjab) India

CONFLICT OF INTEREST

The authors declare that there is no conflict of interst.

REFERENCES

1. S. Beant, S. Chanpreet experimental study of inter phase heat transfer between solid and liquid phases for cyclic heating - cooling of porous media, thesis, Punjabi University Patiala, 2014
2. Chen Bin, Zhang Li, “Investigating the effect of increasing specific heat and the influence of charge cooling of water injection in a TGDI engine”, Applied Thermal Engineering 2019; 149: 1105-1113.
3. Mashadi B, Kakaee A, “Low-temperature Rankine cycle to increase waste heat recovery from the internal combustion engine cooling system”, Energy conversion and Management, 2019; 182: 451-460.

4. Taddeo L, Gascoin N, “Experimental study of pyrolysis-combustion coupling in a regeneratively cooled combustor: Heat transfer and coke formation”, Fuel 2019; 239: 1091-1101.
5. Yu X, Yi D, “Experimental investigation of two-phase flow and heat transfer performance in a cooling gallery under forced oscillation” IJHMT 2019; 132: 1306-1318.
6. Salman S, Nabeel M, “Experimental investigation of the impact of geometrical surface modification on spray cooling heat transfer performance in the non-boiling regime”, IJHMT 2019; 133: 330-340
7. Lin A, Zhou J, “Evaluation of mass injection cooling on flow and heat transfer characteristics for high-temperature inlet air in a MIPCC engine”, IJHMT 2019; 135: 620-630
8. Zhang J, Tan y, “Investigation of Improvement of Desorption Efficiency Using Engine Cooling Water in Natural Gas Vehicle Tank” Applied Thermal Engg, 2018
9. Xiao X, Zhao G, “Large-eddy simulation of transpiration cooling in turbulent channel with porous wall”, Applied Thermal Engg 2018; 145: 618-629
10. Xiao X, Zhao G, “Numerical investigation of transpiration cooling for porous nose cone with liquid coolant”, IJHMT, 2018; 121: 1297-1306
11. Huang G, Min Z, “Transpiration cooling for additive manufactured porous plates with partition walls”, IJHMT, 2018; 124: 1076-1087
12. Anirudh K, Dhinakaran S, “Effects of Prandtl number on the forced convection heat transfer from a porous square cylinder”, IJHMT, 2018; 126: 1358-1375
13. Arduino UNO Product Manual.
14. Pang S.C. and Kalam M.A., “A review on air flow and coolant flow in vehicles’ cooling system,” IJHMT 2012; 55: 6295-6306
15. Krisztina Uzuneanu and Tanase Panait, International Conference, “Analysis of Heat Transfer in the combustion Chamber of an Internal Combustion Engine using Thermal Networks”, Recent Advances in Fluid Mechanics and Heat & Mass Transfer 2011
16. J.C.Hsieh and B. H. Lee., “Experimental Study of Heat Transfer of supercritical carbon dioxide in silica-based porous media,” Elesvier Energy Procedia 2014; 61: 914-917
17. Mahdi R and Mohammad H, “Review of convection heat transfer and fluid flow in porous media with nanofluid, Renewable and sustainable Energy Reviews, 2015; 41: 715-734