Review of Method of Testing of Heat Dissipation Performance of Radiator

[1]Pratibha R. Walunj, [2]Nitin Korde, [3]Rahul Dhanore

[1]ME Heat Power GHRCOEM, Ahmednagar,
[2]Dept. of Mechanical Engg, GHRIOT, Pune
[3]Dept. of Mechanical Engg, GHRCOEM, Ahmednagar
Email: [1]pratibhawalunj15@gmail.com, [2]nitin.korde@raisoni.net, [3]rahul.dhanore@raisoni.net

Abstract—This review specifies the method of test for accessing the heat transfer efficiency of radiator used in road vehicles. The efficiency of cooling arrangement of an internal combustion engine when fitted with the radiator may be judged mainly by its heat transfer performance. The principle behind the assessment of heat transfer performance of radiator makes use of a wind tunnel arrangement with provisions for measuring the pressure and temperature of both air and the coolant, flow rate in front and rare of the radiator.

Index Terms— Flow Rate, Heat Dissipation Rate, Pressure Drop

I. INTRODUCTION

The proposed work is related to the method of testing of radiator of IC engine automobiles. The radiator is nothing but the type of heat exchanger which is used to cool down the coolant used in IC engines of automobiles. In radiator, the air is used as the heat transfer medium as it is freely and abundantly available, without any disposal issues. In automobile radiator, the air is induced naturally because of motion of vehicle. The heated air is sucked out by using fan. There are various types of radiators are available in market according to their size, shape and heat transfer capacity. For all the types of radiators it is very important to check out whether the respective radiator is correct option for respective application or not. For the selection of correct radiator, heat transfer performance is the main criteria. Hence, in this paper we are proposing the method of testing of heat transfer performance of radiator.

II.TERMINOLOGY USED

For the purpose of this review, the following definitions should apply,

A. Heat Dissipation Rate of Coolant (Qw)

The heat dissipation rate of coolant is the quantity of heat which coolant loses under test conditions, and it is expressed by the unit of kilojoules per second (KJ/s).

B. Heat Dissipation Rate of Air (Qa)

D.Flow Rate of Coolant (mw)

The flow rate of coolant which passes through radiator is expressed in kilograms per second (Kg/s).

E. Flow Rate of Air (ma)

The flow rate of air which passes through radiator is expressed in kilograms per second (Kg/s).

F. Upstream End

It is the area before the radiator which permits air to enter into the radiator.

G. Downstream End

It is the area after the radiator which permits air to exit away from the radiator.

H. Coolant side Pressure Loss (Pw)

The difference of static pressure between the coolant side inlet and outlet of the radiator measured under test conditions and it is expressed by the bar.

I. Air side Pressure Loss (Pa)

The difference of static pressure between the air side inlet and outlet of the radiator measured under test conditions and it is expressed by the bar.

III. REQUIREMENTS FOR TESTING

1. The test room conditions should be steady and at normal ambient temperature and humidity. The air flow should be steady without large fluctuations.

2. The water used for test purposes must be clear without any suspended impurities.

3. The radiator inlet temperature should be maintained at +/-5 ºC to the exhaust temperature of coolant from engine at the dissipation rate.

4. The temperature should be recorded at the steady state conditions and the variation of +/- 2 ºC in the coolant inlet temperature is permissible between successive readings.

5. The measuring equipment should be calibrated before start of the test.

6. The test must be maintained at steady atmospheric conditions.

The heat dissipation rate of air is the quantity of heat which air receives under test conditions, and it is expressed by the unit of kilojoules per second (KJ/s).

C.Inlet Temperature Difference (ITD)

The difference between inlet temperatures of engine coolant and air is expressed by the unit of degree Celsius (ºC).

IV. TESTING AND MEASURING EQUIPMENTS

The thermal performance of radiator could be experimentally investigated in workshop at VRDE, Ahmednagar. The radiator will be placed at throat section of venturimeter shaped connecting tube. The typical testing arrangement is shown in **Fig. 1**.

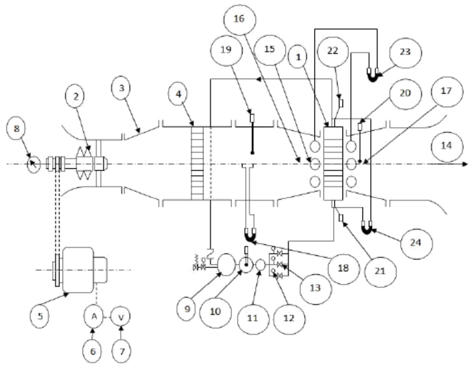

Fig. 1: Experimental Setup

The **Fig. 1** contains: 1)Test Radiator 2)Fan 3)Body Of Wind Tunnel 4)Rectifying Lattice 5)Shunt Motor 6)Ampere Meter 7)Voltmeter 8)Speed Counter For Fan 9)Hot Coolant Tank 10)Supplementary Hot Coolant Tank 11)Coolant Pump And Motor 12)Coolant Flow meter 13)Coolant Flow Adjusting Valve 14)Wind Direction 15)Connecting Tube 16)Upstream End 17)Downstream End 18)Liquid Column Gauge (Water) For Air Flow meter 19)Thermometer For Inlet Air Temp 20)Thermometer For Outlet Air Temp 21)Thermometer For Inlet Coolant Temp 22)Thermometer For Outlet Coolant Temp 23)Liquid Column Gauge (Water) For Air Side Pressure Loss 24)Liquid Column Gauge (Mercury) For Water Side Pressure Loss.

The test apparatus is broadly divided into waterside circuits and airside circuits.

A. Waterside Circuit:

The waterside circuit shall be equipped with separators in order to prevent mixing of air and vapor in the waterside circuit of the radiator. The hot water tank shall be so designed as to prevent air and vapor locking. The water pump may be connected to either side of inlet pipe or the outlet pipe of the radiator. Care shall be taken to avoid any cavitations. The rate of heat rejection by hot water tank shall be enough to maintain heat dissipation rate and shall be adjustable in all ranges of heat dissipation.

B. Airside (Wind Tunnel) Circuit:

The flow passing through radiator shall be adjustable. The arrangement shall include fan, throttle devices such as orifice, shutter, cone etc. The connecting tube between main body of wind tunnel and the radiator shall be interchangeable to take of variations in size and shape of radiator. The shape of the connecting tube shall be such that the front of the radiator receives a uniform parallel flow of air. All joints shall be totally airtight. An alternate suction type arrangement with wind tunnel is also permissible when mutually agreed between the manufacturer and the purchaser.

C. Measuring Equipments:

1. Water Flow Meter: The water flow meter used shall have an accuracy of +2% of maximum scale.

2. Air flow Meter: The air flow meter used shall be based on pitot tube or orifice or nozzle. The minimum scale for liquid column shall be 1 mm on 30˚ inclined type manometer or that having a vertical column.

3. Pressure Gauges: For waterside the liquid mercury column gauge shall have minimum 1mm accuracy. For the airside to measure pressure loss, the liquid column shall have at least 1mm accuracy. For measuring atmospheric pressure, a Fortin's barometer is recommended.

4. Thermometers: For measuring the thermometers used shall have at least +/- 0.1˚C accuracy for waterside and 1˚C accuracy for the airside. For room temperature and humidity, a wet and dry bulb thermometer shall be used.

D. Tests:

The airside circuit will be completed by connecting the radiator and wind tunnel with the connecting tube. The waterside circuit of the test apparatus will be connected to the inlet and outlet pipes of the radiator. When radiator will reach the stable conditions with specified rate of air and water flow, the heat transfer and pressure loss tests shall be conducted. The following will be measured:

1) Atmospheric pressure and humidity
2) Inlet and outlet coolant temperatures
3) Inlet and outlet air temperatures
4) Rate of air and coolant flow
5) Wind velocity
6) Pressure loss-Coolant and air side

Flow measurements shall be after stable conditions are reached. When Pitot tube will be used for air flow, only the control air velocity may be measured and the ratio of mean to centre velocity shall be used for computing the rate of air flow. The air flow is to be measured in the air inlet side.

E. Pressure Loss Measurements:

1. The pressure loss measurement of waterside s to be made at the position as near as possible to the end of inlet and outlet pipe of radiator.

2. The pressure loss measurement of airside is to be near the radiator at the upstream and downstream end both locations being equidistant from centerline of the radiator core.

Temperature of coolant shall be measured as accurately as possible, near the inlet and outlet pipe of the radiator. Inlet and outlet air temperatures, each may be measured at nine places covering entire core surface and the mean temperature shall be calculated. The point of location of thermometer shall be such that it does not receive radiant heat from the radiator.

V. CALCULATIONS

From the results obtained, the heat dissipated from the waterside shall be calculated and this value shall be judged by heat received on airside simultaneously. The air velocity on the upstream side shall also be calculated.

1. Heat dissipated on waterside shall be calculated by the following formula:

Qw = mw*Cpw*(Th1-Th2) …………………. (**Eq. 1**)

Where,

Qw = Rate of heat dissipated on the waterside, (KW) mw = mass flow rate of coolant, (Kg/s)

Cpw = Specific Heat of Water, (KJ/KgK) Th1 = Inlet temperature of coolant, (˚C) Th2 = Outlet temperature of coolant (˚C)

2. Heat received on airside:

Qa = ma*Cpa*(Tc2-Tc1) ….………… (**Eq. 2**)

Where,

Qa = Rate of heat dissipated on the airside, (KW) ma = mass flow rate of air, (Kg/s)

Cpa = Specific Heat of air, (KJ/KgK) Tc1 = Inlet temperature of air, (˚C) Tc2 = Outlet temperature of air, (˚C)

3. Using orifice rate of air can be calculated by,

$Qa = 3600*\alpha*\beta*mo*((2*g*px)/K)^{1/2}$ ………(**Eq. 3**) Where,

α = Flow coefficient

β = Correction coefficient by expansion of air mo= Area of opening of orifice, (m^2)

px = Pressure difference immediately in front and behind the orifice, (mm Aq)

K = Weight of air per unit volume immediately in front of orifice,(Kg/m^3)

g= Acceleration due to gravity, (9.8 m/s^2)

Vwf = Qa/(F*3600) ……………………. (**Eq. 4**) Where,

F= Front side area, (m2)

For design of connecting tube the following correlations are to be used (**Fig. 2**),

In the case of the transition from rectangular shape to circular shape as well as the transition from a circular shape to a rectangular shape, the rules described in the following equations applies,

For reducing tube (m≤1): L/D≥1.8*[(1/m1/2)-1] + [0.4*(a/b)]…… (**Eq. 5**)

For expanding tube (m≥1): L/D≥4*[1-(1/m1/2)] + [0.4*(a/b)]…… (**Eq. 6**)

For reducing tube (m≥1): L/D≥1.8*[1-(1/m1/2)] + [0.4*(a/b)]…… (**Eq. 7**)

For expanding tube (m≤1):

L/D ≥ 4*[(1/m1/2)-1] + [0.4*(a/b)]…… (**Eq. 8**)

Where,

m= area ratio = [(π*D2) / (4*a*b)] ..…. (**Eq. 9**)

L = Length of connecting tube, m

D = Inside diameter of measuring duct, m a = length of long side of rectangle, m

b = length of short side of rectangle, m

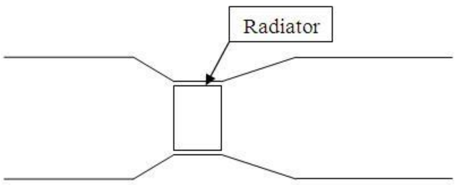

Fig. 2: Connecting Tube

VI. SUMMARY

From the measured properties like temperatures of coolant at inlet and outlet, temperatures of air at inlet and outlet, flow rates of both coolant and air, pressure drops of air and coolant the heat transfer performance can be evaluated. And it is the only criteria for testing of the radiator. The method of testing explained above can be used for any other type of heat exchanger.

REFERENCES

[1] Ramesh K Shah and, Dusan P. Sekulic, “Fundamentals of Heat Exchanger Design,” John Wiley & Sons, Inc., pp. 1-209, 378-418, 2003.

[2] JP Yadav and, Bharat Raj Singh, “Study on Performance Evaluation of Automotive

Radiator," S-JPSET:ISSN: 2229-7111, vol. 2, 2011.

[3] Bureau of Indian Standards "Internal Combustion Engines-Radiators-Heat Dissipation Performance-Method of Test," UDC 621.43:629.113, 1993.

[4] Matthew Carl, Dana Guy, Brett Leyendecker, Austin Miller and, Xuejun Fan, "The Theoretical and Experimental **4.** Air velocity of Front side area (Vwf) can be calculated, Investigation of the Heat Transfer Process of an Automobile Radiator," ASEE-GSAC, 2012.

[5] Pawan S. Amrutkar, Sangram R. Patil and, S. C. Shilwant, "Automotive Radiator-Design and Experimental Validation," IJAUERD, ISSN: 2277-4785, 2013.

◈◈◈