Design, Fabrication and Investigation of Compact Heat Exchanger

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Abstract: **The demand for greater compactness & higher performance is increased along with vehicle comfort & fuel economy. This paper discusses necessity of engine cooling systems in the automobile &components of engine cooling system. Analytical calculations are made for sizing of radiator for given heat load &application, 3 to 5 KW to be more specific. Aerodynamic drag reduction is desirable to minimize vehicle fuel usage, yet a practical requirement of vehicle design is adequate airflow through the radiator to ensure adequate engine cooling under all operating conditions. Therefore, it is important to optimize the cooling air flow through a vehicle's radiator without detriment to aerodynamic drag. This is an attempt of a analytical approach for design and sizing of a Heat exchanger and also offers a starting point for future research in the design of Automotive cooling system. Today's automobiles are getting equipped with high powered engines. The process of equipping such automobiles with this has necessitated the need for improving the cooling efficiency of its radiators. The present work aims on studying and analyzing the thermal behavior of automobile radiators.**

Keywords: Heat Exchanger, Radiator, Automobile, Thermal Characteristics.

I. INTRODUCTION

Modern automotive internal combustion engines generate a huge amount of heat. This heat is created when the gasoline and air mixture is ignited in the combustion chamber. This explosion causes the piston to be forced down inside the engine, levering the connecting rods, and turning the crankshaft, creating power. Metal temperatures around the combustion chamber can exceed 538°C. In order to prevent the overheating of the engine oil, cylinder walls, pistons, valves, and other components by these extreme temperatures, it is necessary to effectively dispose of the heat. Approximately 1/3 of the heat in combustion is converted into power to drive the vehicle and its accessories. Another 1/3 of the heat is carried off into the atmosphere through the exhaust system. The remaining 1/3must be removed from the engine by the cooling system. These improvements can be used to remove engine heat with a reduced size cooling system. Smaller cooling system leads to use of smaller and lighter radiators which in turn will lead to better performance and increased efficiency.

A. Problem Statement:

Improving the heat transfer rates by designing a compact heat exchanger.

B. Objectives:

Generally, the thermal resistance of the air-side is the major part of the total thermal resistance of the air-to-water cross-flow heat exchanger, and it plays the leading role in the performance of heat exchangers.

- To evaluate the key parameters of heat transfer and fluid flow, including the heat transfer coefficient, Nusselt number, Reynolds number, friction factor, effectiveness, and NTU.
- To design a radiator rig which is more compact but still having sufficient cooling capabilities.

C. Methodology:

- Selection of coolant depending on the fluid characteristics.

1. Mono-ethylene Glycol (50%) + Water (50%).
2. VG-60 Oil.

- Literature survey to find out details and data about radiator i.e. radiator specifications.
- Design the radiator.
- Fabrication of radiator based on the acquired results.
- Consider the different shapes of fins louvered or straight fins.
- Perform different test on it and optimize the results.

II. AUTOMOBILE COOLING SYSTEM:

A water-cooled engine block and cylinder head have interconnected coolant channels running through them. At the top of the cylinder head all the channels converge to a

ISSN : 2454-9150 Special Issue - AMET-2019

single outlet. A pump, driven by a pulley and belt from the crankshaft, drives hot coolant out of the engine to the radiator, which is a form of heat exchanger. Unwanted heat is passed from the radiator into the air stream, and the cooled liquid then returns to an inlet at the bottom of the block and flows back into the channels again.

Usually the pump sends coolant up through the engine and down through the radiator, taking advantage of the fact that hot water expands, becomes lighter and rises above cool water when heated. Its natural tendency is to flow upwards, and the pump assists circulation. The radiator is linked to the engine by rubber hoses, and has a top and bottom tank connected by a core a bank of many fine tubes. The tubes pass through holes in a stack of thin sheet-metal fins, so that the core has a very large surface area and can lose heat rapidly to the cooler air passing through it. On older cars the tubes run vertically, but modern, low-fronted cars have cross flow radiators with tubes that run from side to side.

In an engine at its ordinary working temperature, the coolant is only just below normal boiling point. The risk of boiling is avoided by increasing the pressure in the system, which raises the boiling point. The extra pressure is limited by the radiator cap, which has a pressure valve in it. Excessive pressure opens the valve, and coolant flows out through an overflow pipe. In a cooling system of this type there is a continual slight loss of coolant if the engine runs very hot. The system needs topping up from time to time. Later cars have a sealed system in which any overflow goes into an expansion tank, from which it is sucked back into the engine when the remaining liquid cools.

The radiator needs a constant flow of air through its core to cool it adequately. When the car is moving, this happens anyway; but when it is stationary a fan is used to help the airflow. The fan may be driven by the engine, but unless the engine is working hard, it is not always needed while the car is moving, so the energy used in driving it wastes fuel.

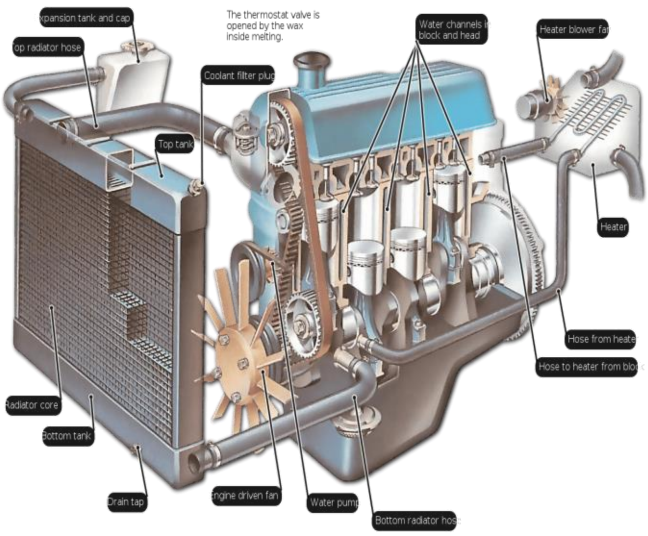

Fig 1: Components of Engine Cooling System

III. RADIATOR SPECIFICATIONS OF 1000CC AUTOMOBILE:

- AIR INLET TEMPERATURE= 25-35^0 C (Generally ambient)
- COOLANT INLET TEMPERATURE= 83-89^0 C
- COOLANT OUTLET TEMPERATURE= 73-79^0 C
- MASS FLOW RATE OF COOLANT= 0.05-0.15 KG/SEC
- VELOCITY OF AIR DEPENDS UPON THE FAN AND ALSO ON THE VELOCITY OF AUTOMOBILE.

IV. EXPERIMENTAL SETUP

The coolant enters the radiator in hot condition. The radiator distributes the hot coolant into its branched tubes where the coolant transfers its heat to the surroundings through the fins. The coolant leaves the radiator at a temperature just above the optimum temperature. This coolant is stored in the oil storage tank. From the storage tank the oil is taken through the engine's coolant jackets (here the engine is replaced by heater coils). As a result, the coolant carries away the excess heat from the engine. This coolant in hot condition is taken to the radiator and the cycle continues.

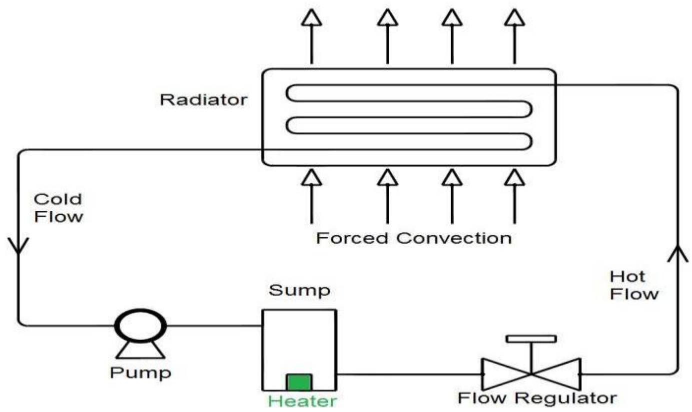

Fig 2: General Layout Of Cooling System

V. DESIGN

From the chart of typical values of overall heat transfer coefficient, we know that for air cooled heat exchanger value of overall heat transfer coefficient (U) ranges from 300-450 W/m^{2}K. So here we assume it to be equal to 300W/m^{2}K.

M_w=Mass of Water = 0.15 kg/s
T_{hi}=Temp. of coolant at inlet =85℃
T_{ho}=Temp. of coolant at outlet =77℃
T_{ci}=Temp. of water at inlet =30℃
T_{co}=Temp. of water at outlet =40℃
C_{pw}=Heat capacity of water = 4.197 KJ/KgK

Cpa=Heat capacity of air = 1.001 KJ/KgK

δa = 10292Kg/m3

Using Energy balance equation,

$(MCp\Delta T)w = (MCp\Delta T)$

So outlet temperature of air is calculated

We know that,

$q = m_W * Cp_W * \Delta T_{wq}$

$= 0.15*4.197*8$

$= 5.0364$ KW

$5.0364 = 0.5*1.005 * \Delta T_a$

$\mathbf{\Delta T_a = 10^oC}$ **Tco= 40°C**

$\Theta_1 = T_{hi} - T_{co} = \mathbf{45^oC}$

$\Theta_2 = T_{ho} - T_{ci} = \mathbf{47^oC}$

$LMTD = \Theta_1 - \Theta_2/\ln(\Theta_1/\Theta_2) = \mathbf{46^oC}$

Ma = **0.5 kg/sec**

$P = T_{co} - T_{ci}/T_{hi} - T_{ci} = \mathbf{0.182}$

$R = T_{hi} - T_{hi}/T_{co} - T_{ci} = \mathbf{0.8}$

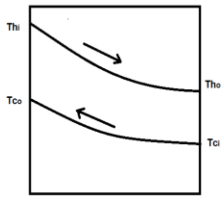

Fig 3: LMTD Of Counter Flow Heat Exchanger

Using the values P&R calculating correction factor (F) from standard chart

F=0.91

LMTDcorrected = F * LMTD

$= 0.91*46^oC$

$\mathbf{= 41.4\ ^oC}$

Assuming U= 300W/m^{2}k

But considering fouling resistance to be **0.000352**

The overall heat transfer coefficient U comes as **271 W/m^{2}k**

5.0364= 271*A*41.4°C

A=0.4489m^2

We know that

A = n*P*L

Assume length we can calculate no of tubes (n)

Assuming length to be **300mm**, and cross-sectional area to be rectangular with dimensions **20*3mm^2**

The number of tubes yielded are <u>**32.23** </u>which are approximated as<u> **35**</u>**.**

VI. Schematic Of Test Rig

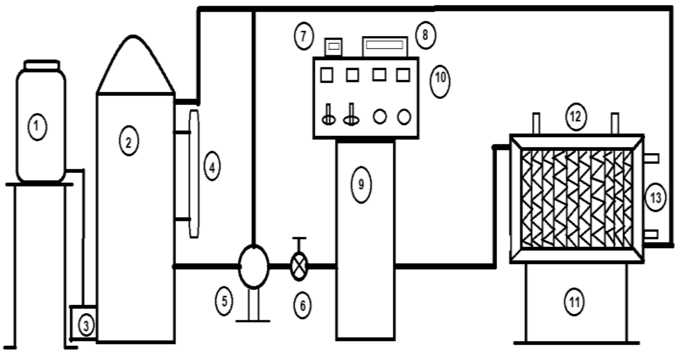

Fig 4: Block Diagram Of Test Rig

1) Diesel Tank
2) Boiler
3) Boiler Hearth
4) Manometer
5) Pump
6) Regulating Valve
7) Pressure Drop Indicator
8) Flow Meter
9) Control Panel
10) Temperature Indicator
11) Wind Tunnel Fitted with Radiator
12) Water Temp Sensors
13) Air Temp and Pressure Sensors.

VII. Observation Table

According to above calculations we have manufactured compact heat exchanger. One test has also been performed on the radiator. The observations are as follow:

Water flow rate (m3/hr)	Air Vel. (m/s)	Tho	Thi	Tco	Tci	ΔPair (MPa)
1.13	6	72.5	81	40	30	4.14
	7	75	83	42	30	4.06
	8	76.7	83.7	42	30	4.02
	9	77	84	42	30	3.96
1.57	6	78.6	83.2	42	30	3.79
	7	78.5	82.5	42	30	3.81
	8	78	82.1	42	30	3.81
	9	77.5	81.5	42	30	3.83
2.08	6	77.8	81.6	42	31	3.56
	7	78.3	`82.3	42	31	3.54
	8	77.9	81.3	42	31	3.56
	9	77.5	80.9	43	31	3.59
2.5	6	77.1	79.6	42	31	3.92
	7	77.3	79.9	43	31	3.9
	8	77.8	80.8	44	31	3.83
	9	77.7	80.7	44	31	3.84

VII. CONCLUSION

By going through the given observations and comparing with existing data it can be concluded that by compacting the size of radiator it is possible to improve the performance of heat exchanger in terms of heat transfer rate. It has further scope for microchannel heat exchanger where hydraulic diameter reduces to micron scale and hence can obtain improved performance.

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