International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-3, February 2013

Automotive Radiator Performance – Review

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Abstract— Automotive engine cooling system takes care of excess heat produced during engine operation. It regulates engine surface temperature for engine optimum efficiency. Recent advancement in engine for power forced engine cooling system to develop new strategies to improve its performance efficiency. Also to reduce fuel consumption along with controlling engine emission to mitigate environmental pollution norms. This paper throws light on parameters which influence radiator performance along with reviews some of the conventional and modern approaches to enhance radiator performance.

Index Terms—Automotive engine cooling system, Performance, Radiator

I. INTRODUCTION

Automotive engine cooling system takes care of excess heat produced during engine operation. It regulates engine surface temperature for engine optimum efficiency. Most automotive engine cooling systems consist of the radiator, water pump, cooling fan, pressure cap and thermostat. Radiator is the prime component of the system.

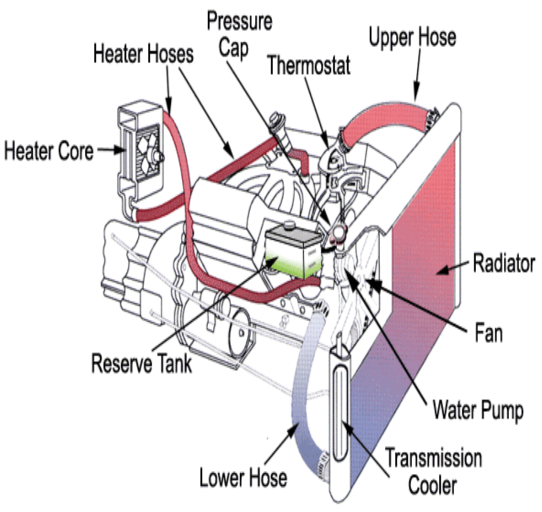

Fig.1 Schematic layout of Engine Cooling System

Radiator is a heat exchanger that removes heat from engine coolant passing through it. Heat is transferred from hot coolant to outside air. Radiator assembly consists of three main parts core, inlet tank and outlet tank. Core has two sets of passage, a set of tubes and a set of fins. Coolant flows through tubes and air flows between fins. The hot coolant sends heat through tubes to fins. Outside air passing between fins pickups and carries away heat.

Performance of engine cooling system is influenced by factors like air and coolant mass flow rate, air inlet temperature, coolant fluid, fin type, fin pitch, tube type and tube pitch etc. While designing cooling system three worst conditions considered based on above parameters.

High altitude : At high altitude, air density becomes low and hence affects air mass flow rate.

Summer conditions : During summer surrounding air is hot i.e. air inlet temperature is more.

Maximum power : Engine condition producing maximum power like when vehicle is climbing uphill, maximum heat rejection is required during this condition.

To compensate all these factors radiator core size required may be large.

II. LITERATURE REVIEW

C. Oliet, A. Oliva, J. Castro, C.D. Pe´rez-Segarra studied different factors which influence radiator performance. It includes air and coolant flow, fin density and air inlet temperature. It is observed that heat transfer and performance of radiator strongly affected by air and coolant mass flow rate. As air and coolant flow increases cooling capacity also increases. Fig.2, Fig.3

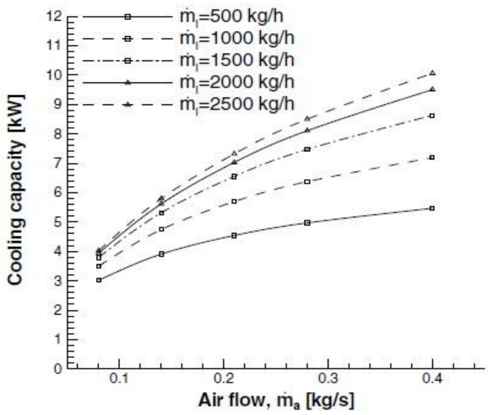

Fig.2 Effect of Air Flow on cooling capacity

Manuscript published on 28 February 2013.
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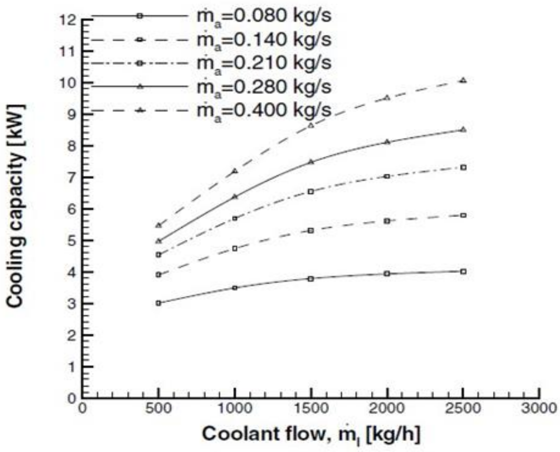

Fig.3 Effect of Coolant Flow on cooling capacity

When air inlet temperature increases, heat transfer and thus cooling capacity decreases. Smaller fin spacing and higher louver fin angle have higher heat transfer. Fin density can be increased till it blocks the air flow and heat transfer rate decreases. Fig.4, Fig 5 [1]

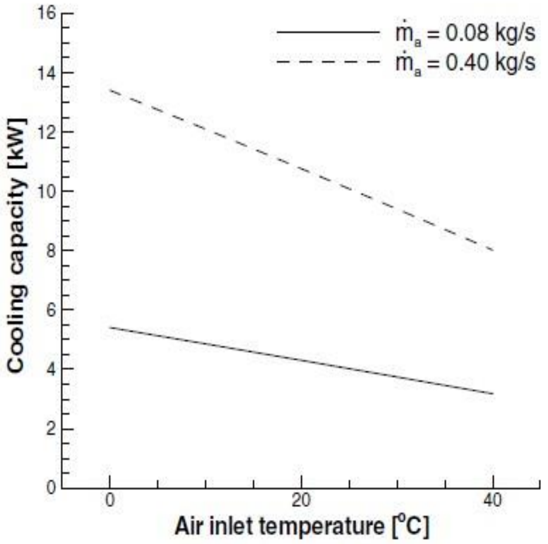

Fig.4 Effect of Air inlet temperature on cooling capacity

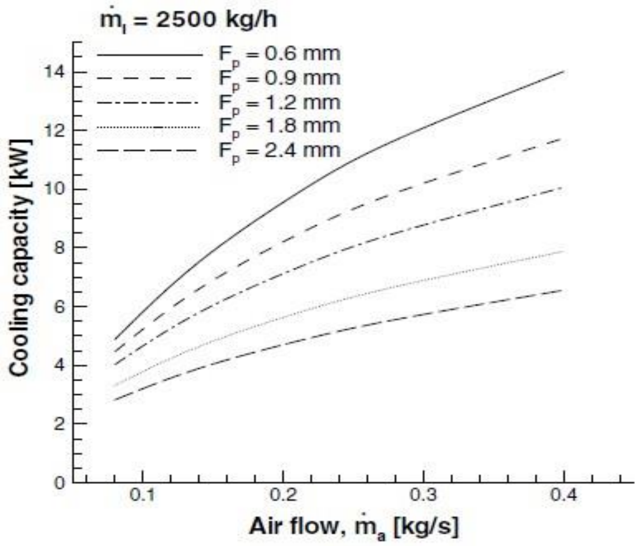

Fig.5 Effect of Fin density (affecting air flow) on cooling capacity

JP Yadav and Bharat Raj Singh in their studies also presented parametric study on automotive radiator. In the performance evaluation, a radiator is installed into a test setup. The various parameters including mass flow rate of coolant, inlet coolant temperature; etc. are varied. Following remarks are observed during study :

Influence of coolant mass flow cooling capacity of the radiator has direct relation with the coolant flow rate. With an increase in the value of cooling flow rate, there is corresponding increase in the value of the effectiveness and cooling capacity.

Influence of coolant inlet temperature with the increase in the inlet temperature of the coolant the cooling capacity of the radiator increases. [2]

Mazen Al-Amayreh in his study, tested the thermal conductivities of ethylene glycol + water, diethylene glycol + water and triethylene glycol + water mixtures, measured at temperatures ranging from 25°C to 40°C and concentrations ranging from 25 wt. % glycol to 75 wt.% glycol. Increasing the concentration of glycol leads to decrease of thermal conductivity. Increasing the temperature of mixture resulted in slight increase in thermal conductivity. [3]

The various techniques are used to enhance the performance of automotive engine cooling system. It may be either conventional or modern approach. Conventional approach relies on fin, tube and fan design optimization. Modern techniques are based on new technologies like nano-technology, heat load averaging capacity or actuator based engine cooling system. This paper reviews some of the conventional and modern approaches focusing on radiator performance enhancement.

P. K. Trivedi, N. B. Vasava illustrated the effect of Tube pitch for best configured radiator for optimum performance. Heat transfer increases as the surface area of the radiator assembly is increased. This leads to change the geometry by modifying the arrangement of tubes in automobile radiator to increase the surface area for better heat transfer. The modification in arrangement of tubes in radiator is carried out by studying the effect of pitch of tube by CFD analysis using CFX. Results Shows that as the pitch of tube is either decreased or increased than optimum pitch of tubes, the heat transfer rate decreases. [4]

Pitambar Gadhve and Shambhu Kumar described use of dimple surface to improve forced convection heat transfer. Heat transfer enhancement is based on principle of scrubbing action of cooling fluid inside the dimple. Surface dimples promote turbulent mixing in flow and enhance heat transfer. An experimental set up has been designed and fabricated to study effect of dimpled surface on heat transfer in rectangular duct. Results compared with flat surface tube and found heat transfer enhancement over the later one. [5]

P. Gunnasegaran, N. H. Shuaib, and M. F. Abdul Jalal in their study numerical simulations on fluid flow and heat transfer characteristics over louver angle fin Compact Heat Exchangers are reported. A computational domain from the fluid inlet to outlet is solved. The impacts of using variable louver angles (+2°, +4°, −2°, −4°, and uniform angle 20°) and louvered fin with variable fin pitches (1 mm, 2 mm, and 4mm) on both thermal and hydraulic of CHE are presented. The Nusselt number is higher for increased or decreased louver angle compared to uniform louver angle. The variable louver angle patterns and louver fin with smaller pitch applied in CHEs could effectively enhance the heat transfer performance with moderate degradation of pressure drop penalty compared to plain fin surface of CHE. [6]

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Prof. D. K. Chavan, Prof. Dr. G. S. Tasgaonkar explained conventional radiator size is rectangular which is difficult for circular fan to cover whole surface area. It creates lower velocity zones at corners giving less heat transfer. Author has proposed to eliminate corners and develop circular shape radiator which is compact, more efficient and leads to minimum power consumption to drive a fan and maximum utilization of air flow. [7]

Considering limitations of conventional techniques to improve cooling system performance various new technologies are adopted. Research is going on to stabilize the results.

K.Y. Leong, R. Saidur, S.N. Kazi, A.H. Mamun described use of nanofluid based coolant in engine cooling system and its effect on cooling capacity. It is found that nano-fluid having higher thermal conductivity than base coolant like 50%/50% water and ethylene glycol. It increases heat transfer. So for same heat transfer, radiator core area can be reduced compared to base one. It finds better solution to minimize area. Thermal performance of a radiator using nanofluid is increased with increase in pumping power required compared to same radiator using ethylene glycol as coolant. [8]

John Vetrovec carried work on engine cooling system with heat load averaging capacity using passive heat load accumulator. Heat load accumulator is phase change material which stores heat generated during peak and dissipates stored heat during reduced heat load condition. This is achieved by sacrificing phase change of PCM from solid to liquid or vice versa. This leads to compact heat exchanger for same heat rejection. Also it reduces load on cooling system. System can handle high transient loads and permits faster warm up during cold engine start. [9]

M.H. Salah, P.M. Frick, J.R. Wagner, D.M. Dawson discussed about hydraulic actuated cooling system. Actuators can improve temperature tracking and reduce parasitic losses. Actuator based engine cooling system uses controller to control coolant pump and radiator fan operating conditions. It provides power to system component as per requirement. Thus it regulates power consumption of system component with cooling capacity. A nonlinear back stepping robust controller is used to regulate engine coolant temperature in hydraulic based thermal management system. Proposed controller maintained the coolant temperature to its set point with system improvement. Use of this system offers greater power density with compact in nature. [10]

III. FUTURE SCOPE

Engine cooling system can contribute in some of the engine aspects like reduction in fuel consumption thus minimizing exhaust and fuel emission. This can be achieved by keeping engine at optimum thermal operating conditions. Also thermal load on engine, engine components, lubricating fluid can be reduced. Effective engine cooling system can help to shorten engine warm up period during cold start and heat loss recovery to improve driving comfort. Reduction in weight and required space to fit system on a vehicle is the most challenging task in developing cooling system. Also efforts to be taken to implement use of emerging technologies like nano-technology and to stabilize the results of these systems. In short, future challenges include developing more compact, light weight, improved performance and economical engine cooling system.

IV. PROPOSED WORK

The proposed work is concerned with developing excel sheet to calculate heat rejection. Few input parameters will give exact idea regarding heat rejection. Sheet will help to estimate effect of varying tube and fin density, coolant flow rate etc. on heat rejection. Theoretical calculation of radiator core size and heat rejection for a given engine inputs. Validation of core size by simulation software and comparing theoretical heat rejection with simulation results. Optimizing core size as per heat rejection requirement. 3D modeling of radiator components header, tubes, fins and tanks. Finite element analysis of radiator to test its robustness for thermal and pressure loads. Prototype development to validate the radiator performance.

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