A Review Paper on Design and Analysis of Cooling System of Formula Student Car

B. Praveen Kumar[1], E. Nikhil Reddy[2], K. Ravi Kumar[3], B. Chandrashekar Reddy[4], S. Venkat Dilip[5]

[1]*Assistant Professor, Department of Mechanical Engineering, Guru Nanak Institute of Technology, Hyderabad, India.*

[2,3,4,5]*B. Tech Student, Department of Mechanical Engineering, Guru Nanak Institute of Technology, Ibrahimpatnam, Hyderabad, India.*

ABSTRACT- This study takes a look at the design process of the cooling system of the Formula Student vehicle. The vehicle was built keeping in mind all the rules and regulations of the Formula Student Competition. Among numerous rules, one rule was to use air and plain water as the only coolant for radiator and no other substance. Though the car is dynamically fit and performed decently during the event, there was a heating issue in the engine which needed to be solved. The problem has been approached using both theoretical and simulation models. Firstly, Number of Transfer Units method will used to calculate the effectiveness of the radiator and later the rate of heat transfer is calculated. Various parameters like core size, mass flow rate of water and air, fan configurations etc., are taken into consideration. Ansys software will be used to perform full body analysis to study the positioning of the radiator on the race car. The results obtained from these models will be validated experimentally on the vehicle using data acquisition. Temperature sensors will be placed at the inlet and outlet of the radiator to record the data. The study not only results in designing an efficient cooling system but also laying out a systematic approach for further development.

Keywords- Cooling System, Formula Student, FSAE, Sidepods, Radiator, Ansys.

1. INTRODUCTION

Internal combustion engine cooling uses either air or liquid to remove the waste heat from an engine. For small or special purpose engines, cooling using air from the atmosphere makes for a lightweight and relatively simple system. Cooling system works by passing liquid continually through the passages in the engine block. Powered by the water pump, the coolant is pushed through the engine block. As the solutions travels through these passages, it absorbs heat from the engine. Most internal combustion engines are fluid cooled using either air (a gaseous fluid) or a liquid coolant run through a heat exchanger (radiator) cooled by air.

The radiators are used in water cooled petrol and diesel engines to keep water circulation in the cylinder heads of engines at relatively constant temperature and thus prevent overheating of the engine. In Formula car, the engine is placed at the rear side, so the radiator section needs to be located near to it. Due to this less amount of air flow to the radiator can be seen as compared to the vehicle with radiator at front. So, there is a need of designing a air duct that directs and increases the flow of air at the radiator core such that proper cooling of the engine can be obtained. And to maintain the optimum working temperature inside the engine.

2. LITERATURE SURVEY

C. M. De Silva et al. [1] This paper attempts to critique differing aerodynamic sidepod designs and their effect upon radiator heat management. Various features from inlet size, sidepod shape and size, presence of an undertray, suspension cover, gills and chimneys are analysed for their effects.

Rishabh Bahuguna et al. [2] This paper brings forth a detailed study on the intricate design of the cooling system. In this paper Pressure distribution and velocity distribution were also obtained along the length of the sidepod for different velocities of the car.

Sachin R Kamath et al. [3] In this paper CFD is used as a tool for this study and simulation based on the complete race car 3D model is carried out for different cases. Further, Wind Tunnel Experiment is carried out to validate these results.

Antonio J. Torregrosa et al. [4] In this paper, a methodology for the design process of engine cooling systems is presented, which is based on the interaction among three programs: a code developed for radiator sizing and rating, a 3D commercial code used for the air circuit modeling, and a 1D commercial code used for the modeling and simulation of the complete engine cooling system.

Ram Bilas Prasad et al. [5] have done detailed analysis and improvement in cooling system by performing thermal analysis and a suggestion for improving the cooling efficiency of an engine is also mentioned. The results are verified after conducting several experiments on the SAE Supra Vehicle.

Lisa Van Den Berg, Brandon Lofaro. [6] In their paper presented a process of designing cooling system to a formula student team, focusing more on testing and analysis. Wind tunnel testing is done to ensure the design is safe, before installing it onto the car.

Farouk, Abdelrahman et al. [7] Study concerns many parameters to have a complete overview on the radiator operation. These parameters include the heat rejected from the engine to the cooling water as a function of crank shaft rotational speed, the mass-flow rate of air through the radiator core as a function of the car speed, static pressure drop of the air across the radiator core at varying air mass-flow rates.

Paul Eric Korczak [8] This thesis gives simple and cost effective method for analyzing the heat carrying capacity of the cooling module on the Formula SAE vehicles was developed. Simple fixtures were designed and built in order to equip the Formula SAE car with sensors able to acquire the necessary data in order to calculate the heat carrying capacities of the air flowing through the heat exchanger and the water flowing through the engine.

Kuntzer, G. et al. [9] The paper presents a method of evaluating heat exchangers and to predict the heat generated by the engine. In order to get the data needed for the analysis, some experimental measurements are made, the water pump flow rate are measured and temperature sensors are added to both, cold and hot, fluids. The air velocity profile through the radiator core showed to be a very important factor in this situation, trying to predict it, CFD simulations have been used. Evaluating the methods, comparisons are performed looking for the best approximation with real case. Realizing that the actual cooling system is not the ideal, some modifications are proposed looking for reliability and mass reduction.

Naushad Ansari et al. [10] This article proposes a change in the design of radiator fins to improve the overall cooling efficiency of such systems. As radiator fins are instrumental in the heat transfer process, a design change in them results in substantial changes in the output efficiency results. The central concept that is utilized is to increase the surface area of the fins, which would increase the rate of heat loss from the pipes.

Murat Cetrez et al. [11] Presented here is the cooling system development of Ford Transit vehicle with 200 PS five cylinder engine by Ford Otosan engineers. After 140 PS Ford four cylinders engine, 200 PS engine was developed, completely new and more powerful cooling system was required. CFD studies were carried out to decide about the cooling pack details. UH3D CFD model was developed. Based on given radiator, condenser and fan performance data, engine heat rejection, coolant flow rate, top hose temperature were determined. CAE studies were done for different radiator sizes, different bumper slots and different fan sizes. Based on CFD studies it was decided what to test in the wind tunnel. Vehicle tests were done to verify cooling pack performance.

A.V. Gritsenko et al. [12] This article describes the calculation of the liquid cooling of an electric drive. This paper brings forth a detailed study of the intricate design of the cooling system. The problem is approached using both theoretical and simulation models. The results are validated experimentally on a vehicle using data acquisition. The study outcomes include designing an efficient cooling system as well as laying out a systematic approach for further development.

JP Yadav, Bharath Raj Singh. [13] A complete set of numerical parametric studies on automotive radiator has been presented in detail in this study. The modeling of radiator has been described by two methods, one is finite difference method and the other is thermal resistance concept. In the performance evaluation, a radiator is installed into a test-setup and the various parameters including mass flow rate of coolant, inlet coolant temperature; etc. are varied. A comparative analysis between different coolants is also shown.

Shreyas Padmaraman et al. [14] In this work, an attempt is made to develop a simple yet reasonably accurate analytical model to calculate the effectiveness of a radiator. The model is then applied to predict the operating temperature of the engine at varying load conditions. Experimental investigations were performed using a customized radiator test rig to replicate the field test conditions.

Oduro, Seth & Ampofo, Joshua. [15] The paper studies the effect of clay soil blocking the heat transfer area of the radiator on the engine coolant temperature by developing a mathematical model. The results of the study indicated that the percentage area covered resulted in a proportional increase of the inlet and outlet temperatures of the coolant in the radiator. The mathematically model developed also predicted the experimental data very well.

Carles Oliet et al. [16] This paper presents a set of parametric studies performed on automotive radiators by means of a detailed rating and design heat exchanger model developed by the authors. This work provides an overall behaviour report of automobile radiators working at usual range of operating conditions, while significant knowledge-based design conclusions have also been reported. The results show the utility of this numerical model as a rating and design tool for heat exchangers manufacturers, being a reasonable compromise between classic ε − NTU methods and CFD.

Janne Kemppainen. [17] The aim of this bachelor's thesis is to document the primary design of the liquid cooled cooling system for a Formula Student race car and to get acquainted with the basics of a modern liquid-cooled cooling system. The physics in the cooling is presented with the working principle of the cooling system itself. Finally, the primary design of a liquid-cooled cooling system for a Formula Student race car is presented with a brief summary of the results. Another aim of this thesis is also to provide a comprehensive but brief package of information regarding the cooling system and its design especially for the new members of Formula Student Oulu (FSO) to help in the continuity of development and to ease the familiarization of the subject.

REFERENCES

[1] C. M. DE SILVA, M. NOR AZMI, T. CHRISTIE, E. ABOU-SABA, A. OOI, 2011, Computational flow modelling of Formula-SAE sidepods for optimum radiator heat management. Journal of Engineering Science and Technology, Vol. 6(1), pp. 94-108.

[2] Bahuguna, R., Prasad, T., Khanna, R., Kumar, A. et al., "Design and Development of Cooling System for a Formula SAE Race Car," SAE Technical Paper 2018-01-0079, 2018.

[3] Kamath, Sachin & P, Prajwal & S N, Shashank & Damodaran, Vinay & R, Anand & Kulkarni, Prakash. (2013). CFD and Experimental Optimization of Formula SAE Race Car Cooling Air Duct. 10.4271/2013-01-0799.

[4] Torregrosa, Antonio & Olmeda, Pablo & Garcia-Ricos, Antonio & Natividad, Jordi & Romero, Carlos. (2010). A Methodology for the Design of Engine Cooling Systems in Standalone Applications. SAE Technical Papers. 10.4271/2010-01-0325.

[5] Ram Bilas Prasad, Navendu Singh, Rahul Singh, Shubham Sahai, Avanish Kumar Singh. Cooling Performance Analysis and Improvement in the Cooling System of SAE-Supra Vehicle.

[6] Lisa van den Berg, Brendon Lofaro, 2014, "Formula SAE Cooling System Design", Mechanical Engineering Department, California Polytechnic State University, San Luis Obispo, pp. 1-141.

[7] Farouk, Abdelrahman & Amin, Amin & Ali, Ehab & Abdullah, Abdullah & Mohamed, Tariq & Team, ZUFS & Abdel Gawad, Ahmed. (2021). Study of the Performance of an FSAE Cooling Radiator.

[8] Paul Eric Korczak. (2009). Cost Effective Method For The Evaluation Of A Formula SAE Engine Cooling System.

[9] Kuntzer, G., Martins, M., Bayer, F., Soliman, P. et al., "Development of a FSAE Racecar Cooling System," SAE Technical Paper 2015-36-0409, 2015.

[10] Mittal, A., Misra, A., Sharma, A., Gupta, A. et al., "Design and Analysis of Modified Radiator Fins to Improve Overall Cooling Efficiency," SAE Technical Paper 2020-01-2029, 2020.

[11] Çetrez, M., Balta, B., and Edege, T., "Cooling System Development of Light Commercial Vehicle," SAE Technical Paper 2009-01-1467, 2009.

[12] Gritsenko, A.V. & Alferova, Irina & Pakhomeev, N.. (2021). The Development of a Liquid Forced Cooling System in a Racecar. 10.1007/978-3-030-54814-8_44.

[13] Yadav, Jp & Singh, Prof Bharat Raj. (2015). Study on Performance Evaluation of Automotive Radiator. SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology. 2.10.18090/samriddhi.v2i2.1604.

[14] Padmaraman, Shreyas & Mathivanan, Nagarathnam & Ponangi, Babu. (2021). Heat Dissipation Characteristics of a FSAE Racecar Radiator. International Journal of Heat and Technology. 39. 1667-1672. 10.18280/ijht.390531.

[15] Oduro, Seth & Ampofo, Joshua. (2012). Effect of Radiator Fins Blockage by Clay Soil on the Engine Cooling Temperature. International Journal of Engineering and Technology (IJET). 2. 1002-1010.

[16] Oliet, Carles & Oliva, A. & Castro, Jesús & perez-segarra, carlos-david. (2006). Parametric studies on automotive radiators. Applied Thermal Engineering. 2033-2043. 10.1016/j.applthermaleng.2006.12.006.

[17] Janne Kemppainen, "Designing a cooling system for a formula student race car", University of Oulu, Degree Programme of Mechanical Engineering, Bachelor's thesis 2020, 49 p.