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Design & Development of the Cooling System for Genset Application

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ABSTRACT

Diesel Genset radiator is key component of engine cooling system. Radiator thermal analysis consist of sizing and rating of heat exchanger. Radiator size mainly depends on heat rejection requirement. Heat transfer calculations are important fundamentals to optimize radiator size. Genset manufacturers use 1-D simulation software to decide radiator size. This paper focuses on thermal analysis of radiator theoretically using LMTD method and its validation by simulation and actual testing approach.

Keywords: Diesel Genset radiator, Heat transfer, Rating, Simulation, Sizing

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I. INTRODUCTION

Diesel Genset radiator is key component of engine cooling system. Coolant surrounding engine passes through radiator. In radiator coolant gets cooled down and re-circulated into system. Radiator sizing is important factor while designing cooling system. Radiator size depends on heat load as well packaging space availability and directly to material cost. Heat load depends on heat rejection required to keep engine surface at optimum temperature. Generally LMTD or ε-NTU method is used to do heat transfer calculations of radiator. Both methods have its own advantages and preferred according to data availability. Diesel Genset is stationary application and all inlet and out let temp range is known. When radiator inlet and outlet temperature are known LMTD gives faster solution. When any of the temperature is unknown LMTD method undergoes iterations to find solution. In this case LMTD method is better. In this paper LMDT method is described to do heat transfer calculations.

II. HEAT TRANSFER CALCULATIONS

Purpose of thermal analysis of radiator is to determine heat transfer surface area (sizing) and performance calculation to determine heat transfer rate (rating). It is necessary to find out amount of heat transfer, outlet temperatures of both fluids are known. Here approximate size is assumed according to space availability. Based on this size heat transfer rate is calculated which should fulfill the requirement. Radiator size and heat transfer rate finalized accordingly. Coolant side heat transfer coefficient calculations and mathematical expressions are taken from references [1,2,3,6]

Basic equation for heat exchanger design

2.1. Overall heat transfer coefficient

The basic heat exchanger equation is applicable for tube type. When the overall heat transfer coefficient is constant then the basic design becomes.

$$Q = U \times A \times F \times LMTD \tag{1.1}$$

Where Q is the total heat load to be transferred
U is the overall heat transfer coefficient referred to the area,
A is heat transfer area
LMDT is the logarithmic mean temperature difference and
F is the correction factor for multiple tube side passes

U is most commonly refer to Ao the total outside tube heat transfer area, including fins,

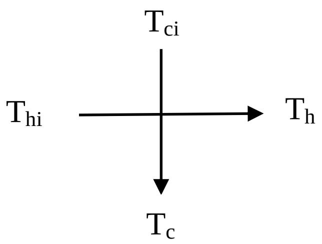
$$U = \frac{1}{\frac{1}{h_o} + Rf_o + Rf_{in} + \frac{\Delta Xw Ao}{kw Am} + Rf_{in}\frac{Ao}{Ai} + \frac{1}{h_i} \times \frac{A_o}{A_i}} \quad (1.2)$$

Where h0 and hi are the inside and outside film heat transfer coefficient, respectively Rfo and Rfi are the inside and outside fouling resistance, ΔXw and kw are the wall thickness (in the fin section) and the wall thermal conductivity , and R_{fin} is the resistance to heat transfer due to the presence of the fin (Fins and tube are all one pice of metal) there is no need of include contact resistance.
The mean wall heat transfer area Am is given with sufficient precision as

$$A_m = \frac{\pi L}{2} \times (d_i + d_r) \quad (1.3)$$

2.2 Mean temperature difference, F factor

The MTD is related to the Logarithmic Mean Temperature Difference (LMDT) by the equation $MTD = F \times LMTD$
Where LMTD is always defined as for countercurrent flow arrangement.



$$LMTD = \frac{\emptyset_1 - \emptyset_0}{In(\emptyset_1 - \emptyset_0)} \quad 1.4$$

$\emptyset_1 = (T_{hi} - T_{ci})$, $\emptyset_0 = (T_{ho} - T_{co})$

Where T_{hi} and T_{ci} are the inlet temperature and T_{hi} and T_{ci} are the outlet temperatures of hot and cold fluid

The value of F depends upon the P and R values
$R = (T_{hi}-T_{ho}) / (T_{co}-T_{ci})$
= (Range of hot fluid) / (Range of cold fluid)
$P = (T_{co}-T_{ci}) / (T_{hi}-T_{ci})$ = (Range of cold fluid) / (maximum temp difference).

III. ANALYTICAL APPROACH

Actual thermal analysis is performed first theoretically and then by simulation approach for following requirement. It includes heat rejection requirement, space available under hood to mount radiator on genset base. Heat transfer requirement is decided as per engine specification, engine operating conditions and genset operating conditions. Cooling system design should fulfill all these requirements.
Following parameters are considered for analytical approach. First radiator core size is assumed and heat transfer calculations done.

Sr. No	Parameter	Radiator Core	CAC Core
1	Core Height	900	900
2	Core Width	595	290
3	Number of rows	2	1
4	Total nos. of tube	98 (per row 49)	16
5	Tube c/s length	32	74
6	Tube c/s width	2	8
7	Tube thickness	0.29	0.5
8	Tube pitch	12.7	18.6
9	Fins per cm	15	8
10	Fin thickness	0.12	0.12
11	Total no of fins	602	513
12	Lower angel	2.5	3
13	Lower pitch	1.49	1.75

IV. SIMULATION APPROACH

One-dimensional simulation software is used to design and perform thermal analysis of cooling system. The cooling system is represented as a network of various parts like pipes, heat source etc. Inputs include fluid flow rates and temperatures, core dimensions, fins and tubes details like thickness, thermal conductivities, number of tubes etc. It is also possible to specify different coolant types or other system combinations or different concepts and compare them with each other. System can be analyzed at constant or variable operating conditions. Cooling system performance can be estimated independent of the vehicle measurements, earlier in development phase. Analysis accuracy can be increased by incorporating Computational Fluid Dynamics results into cooling system 1-D model design. Simulation software offers great saving in terms of cost and development time while designing cooling systems

Following parameters and steps followed.

Steps: 1. Heat source is selected as a radiator. Core dimensions specified.

2. Input and output nodes set for air and coolant inlet and outlet parameters.

3. Air and coolant flow direction given through network lines

4. 50% / 50% water and ethylene glycol coolant is selected accordingly its thermo-physical properties like inlet temperature, viscosity, density etc. prescribed.

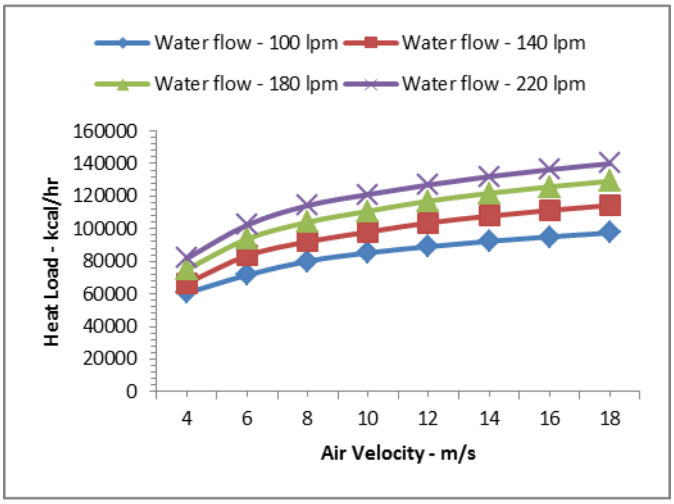


Fig. 1.1 Heat rejection V/s mass flow rate

On the basis of data obtain from theoretical calculation, Simulation done by using KULE software. Fig 1.1 shows the heat rejection value at different air and coolant flow rate.

V. EXPERIMENTAL APPROACH

Cooling test is conducted on first proto type radiator sample, it is manufacture base on theoretical calculated design confirmation and performance simulated by using KULE simulation software.

5.1 Reason for going for Open genset trail.

By keeping the open set trail results as reference normally our GOEM's & our team start design the Acoustic canopy. In open set trail using Duct at various restrictions we capture CFM & temperature at all the major points. So when the temperature rises beyond our designed spec than it shows the restriction created by duct is more. Temperature rises due to lack of proper cooling in the sense very less flow of air inside the system. With the obtained result we can easily predict the amount of air flow/restriction required the system when it is inside the canopy.

- According to the airflow required proper cut-outs will be provided at the fresh air entry & hot air exit when we design Acoustic canopy.
- Open set trail also helps us in adding restriction inside the canopy to reduce noise.

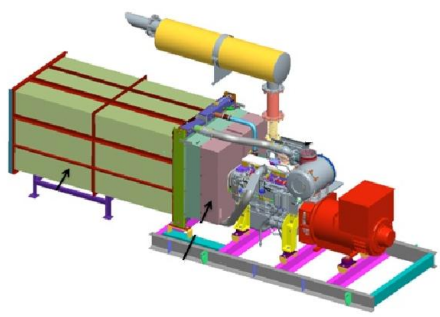


Fig 1.2 Open genset test setup

In terms of restriction we are adding pressure inside the system which ultimately increases the engine parameter temperatures like Coolant/CAC/LTA & Exhaust etc.

Table No. 1.1 Cooling performance result summery

	LAT at % Loading					
Restriction (Inchs)	**0%**	**25 %**	**50 %**	**75 %**	**100 %**	**110 %**
0"	85.5	76.8	74.6	66.1	68.5	65.1
0.25"	79	75	69	66	66	62.7
0.5"	77.8	73	68	65	64	61
0.75"	75.8	70	65	62	61	58.7
1"	73	69	62	59	57.9	54
Enclosed	82	74.2	62.5	55.8	50.7	48.6

VI. RESULT AND DISCUSSION

From results of KULE analysis and experimental test, cooling system design using LMTD method is meet the genset performance criteria .Through this project cooling system design is done for the 45 degree limiting ambient temperature and simulate through soft analysis and validated with experimental test.
Radiator core area calculated by LMTD method and simulation on KULE software very close and same performance observe in experiment test. it passed the objective of the project and gives the 52.9 degree limiting ambient temperature.& 15.8 degree IMTD which suffice the requirement .LAT was Calculated by Considering water tank Temp as 107 for Prime 200 kVA genset Rating.

VII. CONCLUSIONS

In this dissertation, cooling system is design for genset to operate at 45 deg ambient temperate condition. Amount of heat rejected through radiator core is simulated at different mass flow rate for both the fluid by using KULE simulation software. Because of genset heavy duty operating cycle, radiator performance to be validate with experimental test. Comparison of simulation and experimental result shows that both result closely match with each other and meet engine cooling requirement on all load condition. Thus theoretical thermal analysis of radiator using LMTD method is validated using simulation approach. Core dimensions are fixed from these results and to be used while designing radiator

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