ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.5

Concept Generation for High Efficiency Radiator Design

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Abstract:
Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The majority of radiators are constructed to function in automobiles, buildings, and electronics. The radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for engine cooling. So here are some techniques for the concept generation of high efficiency radiator.

Keywords: Idea generation, Concept generation, new idea.

I. INTRODUCTION

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The majority of radiators are constructed to function in automobiles, buildings, and electronics. The radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for engine cooling.

Customer Requirements / Engineering Specifications

The dissipating a larger amount of heat to the air (147 kW), a smaller size (10-15% smaller in volume), lower inlet fluid temperature (to 85°C), and alternate placement options are the customer requirements. However, the primary requirement is the increased dissipation of heat. From the customer requirements, the following items listed below in Table 1 to be the engineering specifications.

Table.1. Engineering Specifications

Dissipate 147 kW of heat total
Decrease inlet fluid temperature to 85°C
Decrease thermal resistance of air side by 5%
Decrease total resistance of system by 5%
Increase convective heat transfer coefficient of air by 5%
Minimize frontal area 10-25%
Minimize weight 10-20%
Minimize flow rate 5-10%

These are the some specifications which we have to consider while designing the new product and these specifications will be helpful in generating the new product concepts.

Concept generation

In order to begin the design process, I began by breaking down the functions of the radiator. I did this in the Function Analysis System Technique (FAST) diagram shown in chart below.

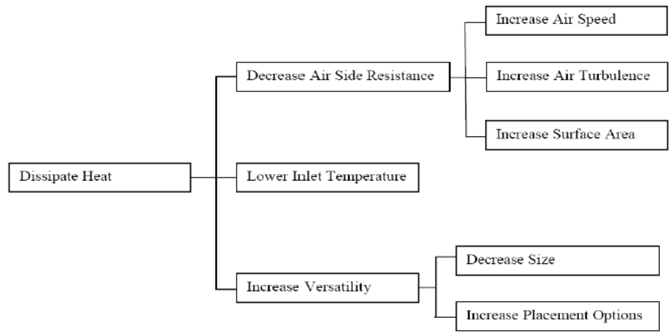


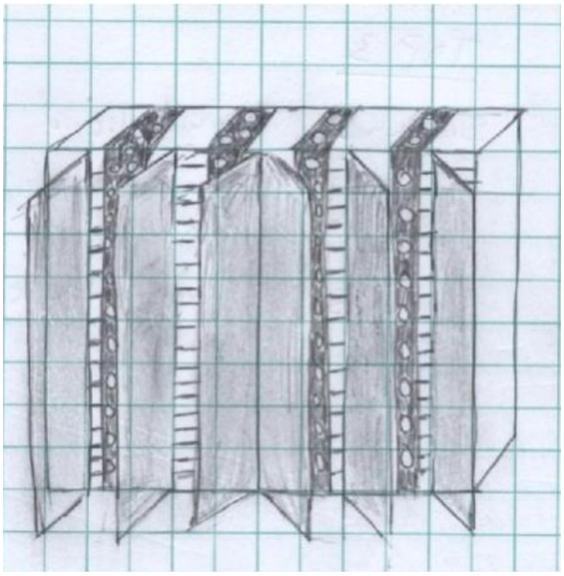
Chart.1.Decomposition Chart

Concept evaluation and selection

The five design concepts are listed below.

Design Concept 1:

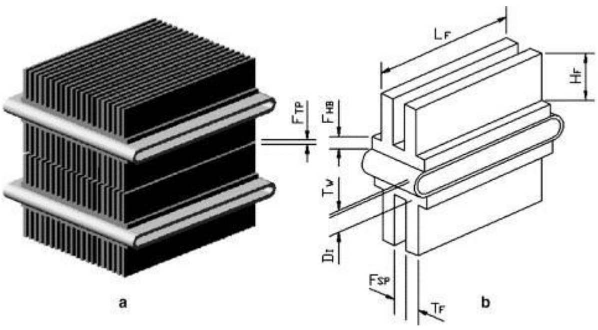
Shown in Figure below, incorporates the use of golf ball type dimples on the surface of the coolant tubes. By creating a rough surface, these dimples aid in increasing the air turbulence. By increasing the air turbulence, the convection coefficient increases. Therefore, the resistance due to the air-side convection should reduce. In addition to the dimples, this design also incorporates the use of air scoops that channel the incoming air into the radiator. This aids in increasing the velocity of the air. With the increased air velocity, the convection coefficient associated for the air is increased. By increasing this value, the thermal resistance associated with the air is decreased. Also included in this design is increased tube width and fin thickness. By increasing these dimensions, more surface area is exposed to the incoming air. Due to the increased exposure, the thermal resistance associated with the air is decreased. The air is decreased. This design also used carbon foam fins which replaced the aluminum fins used on current radiator designs. The carbon foam also increases the surface area exposed to the air. This is mainly due to the fact that the carbon foam is porous and allows the air to flow thru it in addition to allowing the air to flow around it.



The benefit of this design is that all of the changes to the current radiator design help to reduce the thermal resistance associated with the air. This is either done by increasing the surface area exposed to the air or increasing the convection coefficient

Design Concept 2

There are several ways to improve the current radiator design. This showed that one way to decrease the thermal resistance associated with the air is to change the type of fin material used. Instead of using aluminum fins, fins constructed of carbon-foam were used. The fins were constructed out carbon-foam that had a porosity of 70%, a thickness of 0.762 mm, and a height of 8.725 mm. The fin density was set to 748 fins/m. The carbon-foam fins can be seen in figure below.



It showed that the percentage of thermal resistance associated with air-side convection was reduced to about 60%, therefore the percentage of the thermal resistance associated with the fluid was increased. With the shift in these percentages, the convective benefits of nano fluids would have a more significant

Design concept 3

Figure below, illustrates the refrigeration cycle, which we would use to replace the radiator. This would be an additional refrigeration cycle from the cycle already existing in the vehicle. This would eliminate the dependence on air to cool the coolant. This cycle incorporates the use of a dual fluid heat exchanger. The purpose of the heat exchanger is to remove heat from the engine coolant by adding it to the refrigerant, R-134a. Once this is done, the refrigerant gets compressed in the compressor and then moves on to the condenser. In the condenser, the refrigerant loses the heat it received from the engine coolant. Then, it passes through the expansion valve and then through the evaporator. Once it passes through the evaporator, it enters the heat exchanger and the cycle repeats itself

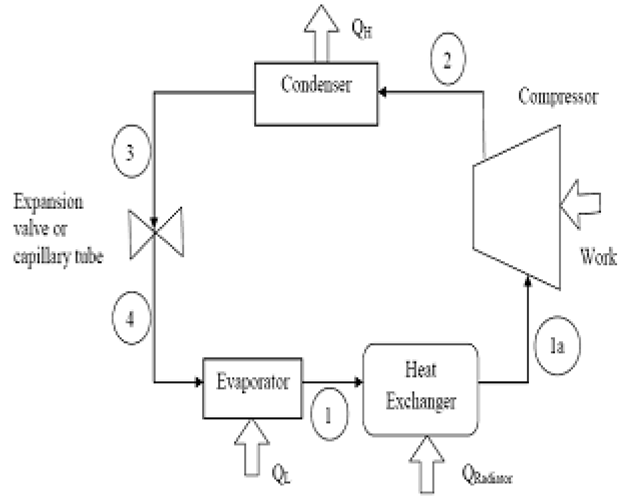


Figure.1.Basic Refrigeration Cycle with Additional Heat Exchanger

One benefit of this design is that it reduces the dependence on the air to cool the engine coolant by using the refrigerant. By using the refrigerant, we would be able to remove more heat from the coolant than by using a liquid-air heat exchanger.

Selected Design Concept

The new design concept is similar to current radiators, but replaces aluminum fins with carbon foam channels. Due to the thermal properties of carbon foam (k = 175-180 W/mK for carbon foam with 70% porosity), along with increasing the amount of heat rejected, we will be able to reduce the overall size of the radiator while simultaneously increasing the surface area exposed to the air, thus reducing the air side resistance. Figure 18 below shows our new design concept. See Figure below

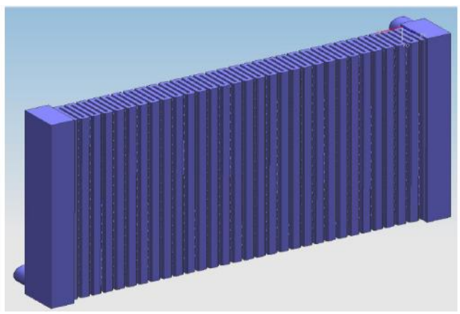


Figure.2. carbon foam radiator concept

The carbon foam has channels in a corrugated pattern. This corrugation channels air into the slots and forces the air through the carbon foam. Also, there are many tubes which are arranged in a parallel design. They provide support for the carbon foam as well as contain the necessary volume of coolant. The end caps are made out of aluminum and also provide structural support and mounting locations. Overall, this design concept is a simple design which will meet most of customer requirements, including dissipating 147 kW of heat with an inlet fluid temperature of 85°C, decreasing the overall volume.

II. CONCLUSION:

Our task was to design a new concept for an automotive radiator. It was required to reject an increased amount of heat

(5%) from current radiator designs while lowering the fluid inlet temperature (10%) For new concept generation of high efficiency radiators design the first step is to collect all the desired technical specifications regarding the product and then to find out whether there is any existing product with desired specifications. If not available then there should some modifications to be done in the existing products like it is done in this study. In the selected product aluminum fins are replaced with the fins made of carbon-foam were used which were helpful in improving heat dissipation rate of the radiator.

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