# Analysis of Causes of Engine Overheating due to Cooling System Failure Using Pareto Principle

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***Abstract*** **-** *Cooling system plays an important role to control the temperature of the engine. The overheating of the engine can be prevented by using an efficient cooling system and assists the vehicle running at its optimal performance. The failure of cooling system component results in overheating of an engine. This paper presents the study conducted to find out the causes of engine overheating because of cooling system failure through Pareto analysis, cause and effect diagram is prepared to classify the causes into sub causes and the thermal analysis of the cylinder liner is done using Ansys two different materials gray cast iron and aluminium alloy 6061 were used.*

**Keywords**- *Cooling system, cylinder liner, Engine overheating, Thermal analysis, Pareto analysis*

## I. INTRODUCTION

Although engines have improved a lot, they are still not very efficient at turning chemical energy into mechanical power. Most of the energy in the gasoline (perhaps 70%) is converted into heat, and it is the job of the cooling system to take care of that heat. The primary job of the cooling system is to keep the engine from overheating by transferring this heat to the air, but the cooling system also has several other important jobs [5].

In the case of Internal Combustion engines, combustion of fuel and air takes place inside the cylinder of the engine and hot gases are generated. The temperature of the gases generated will be around 2300-2500°C. This is a very high temperature because of which the oil film between the moving parts will burn and may result into seizing or welding of the same.

So for the engine to work more efficiently the temperature must be reduced to about 140-200°C. Too much cooling will tend to reduce the thermal efficiency of the engine so, the objective of the cooling system is to keep the engine cool and maintain it in it in most efficient operating temperature.

When it is cold It has been noted that the engine is quite inefficient and hence the cooling system is designed in a manner to prevent cooling when the engine is warming up and till it attains to maximum operating temperature, then it starts cooling.

Pareto analysis is a statistical technique in decision making that is used for the selection of a limited number of tasks that produce significant overall effect. It is one of the most commonly used, and easy to implement method [8]. The results of a Pareto analysis are typically represented through a Pareto chart. The chart represents the various factors under consideration in ranked order. The presentation of this chart is in the form of a bar graph in descending order and helps to predict easily which factors are vital few by providing a clear indicator through superimposing a line graph that cuts an 80 percent cumulative percentage and also helps in determining those factors which have least amount of benefits and vice-versa. In this paper the data collected regarding the causes of engine overheating are studied and critical causes were identified using pareto analysis. it helps to identify different defects and classify them according to their significance.

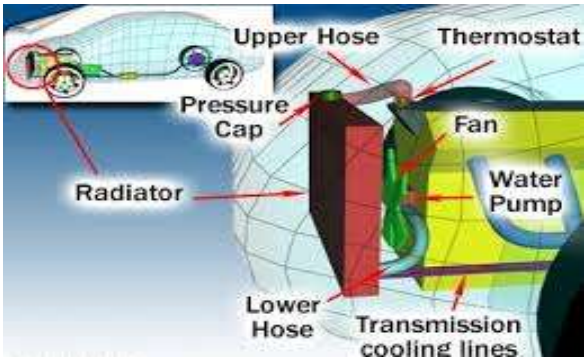



***Fig*** 1.1 The Basic Parts of the cooling system

## II. TYPES OF COOLING SYSTEMS

There are mainly two types of cooling systems : Air cooled system, and Water cooled system.

### 2.1 AIR COOLING SYSTEM

In small engines say up to 15-20 kW generally Air cooled system is used and also in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air.

Advantages of Air Cooled System

Following are the advantages of air cooled system:

(a) The system is light due to absence Radiator/pump
(b) There are no leakages in case of air cooled engines.
(c) Coolants are not required.
(d) Where if water is used it may freeze This system can be used in those cold climates.

Disadvantages of Air Cooled System

(a) Comparatively it is less efficient.
(b) air cooled systems are used where the engines are exposed to air directly.

### 2.2 WATER COOLING SYSTEM

In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc.the heat of combustion is absorbed when the water is circulated through the jackets. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. Through the water jackets The cooled water is again recirculated.

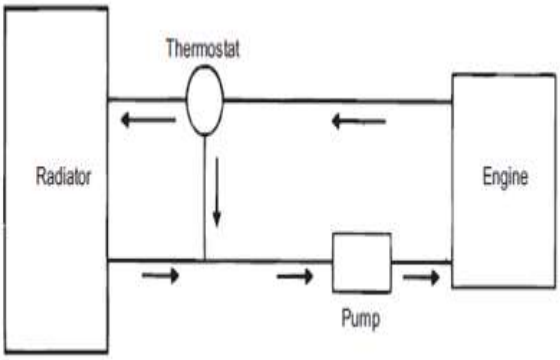



***Fig*** 2.2.1 Components of water cooling system

Water cooling system mainly consists of :
(a) Radiator,
(b) Thermostat valve,
(c) Water pump,
(d) Fan,
(e) Water Jackets, and
(f) Antifreeze mixtures.

(a)Radiator

It mainly consists of an upper tank and lower tank and between them is a core. The upper tank is connected to the water outlets from the engines jackets by a hose pipe and the lover tank is connect to the jacket inlet through water pump by means of hose pipes.

When the water is flowing down through the radiator core, it is cooled partially by the fan which blows air and partially by the air flow developed by the forward motion of the vehicle. the radiators are generally made out of copper and brass and their joints are made by soldering.

(b) Thermostat Valve

It is a valve which prevents flow of water from the engine to radiator, so that engine readily reaches to its maximum efficient operating temperature, it automatically begins functioning After attaining maximum efficient operating temperature

(c) Water Pump

The circulating water is pumped by it. Impeller type pump will be mounted at the front end. the pump casing comprises of enclosed shaft on which impeller is mounted . The pump casing has inlet and outlet openings. The pump is driven by means of engine

output shaft only through belts. When it is driven water will be pumped.

(d) Fan
It is driven by the engine output shaft through same belt that drives the pump.

(e) Water Jackets
Cooling water jackets are provided around the cylinder, cylinder head, valve seats and any hot parts which are to be cooled. Heat generated in the engine cylinder, conducted through the cylinder walls to the jackets. The water flowing through the jackets absorbs this heat and gets hot. This hot water will then be cooled in the radiator.

(f) Antifreeze Mixture
The ideal antifreeze solutions should have the following properties:
(a) It should dissolve in water easily.
(b) It should not evaporate.
(c) in cooling system It should not deposit any foreign matter.
(d) It should be cheap and easily available.
(e) It should not corrode the system.

Advantages of Water Cooling System
(a) Cooling is uniform in cylinder, cylinder head and valves.
(b) By using water cooling system Specific fuel consumption of engine is improved .
(c) Engine need not to be provided at the front end of moving vehicle if we employ water cooling system.

Disadvantages of Water Cooling System
(a) It depends upon the supply of water.
(b) Water pump requires considerable power for circulating water.
(c) If the water cooling system fails then it will result in severe damage of engine.

## III. DATA COLLECTION

The data regarding the causes of engine overheating is collected from the mechanics, the data of 25 engines were collected. The causes related to the engine overheating due to inefficient cooling system were identified.

***Table*** 3.1 Causes of engine overheating

| Sr.no | Engines | Causes of overheating | Sub Causes |
|---|---|---|---|
| 1 | Cummins | Radiator | Damaged cores |
| 2 | Cummins | Fan | Loose belt |
| 3 | Tata 709 | Water pump | Damaged o ring |
| 4 | Cummins | Fan | Fan blade |
| 5 | Tata 1109 | Coolant | Improper concentration |
| 6 | Tata 1210 | Radiator | Damaged cores |
| 7 | Cummins | Fan | Loose belt |
| 8 | Hino | Coolant | improper Level |
| 9 | Tata 1612 | Gasket | Installation |
| 10 | Tata 709 | Coolant | Improper concentration |
| 11 | Tata 1613 | Gasket | Thickness |
| 12 | Cummins | Coolant | improper Level |
| 13 | Hino | Coolant | Improper concentration |
| 14 | Tata 2515 ex | Radiator | loose hoses |
| 15 | Hino | Fan | Fan blade |
| 16 | Tata 608 | Coolant | Improper concentration |
| 17 | Cummins | Radiator | loose hoses |
| 18 | Tata 909 | Coolant | improper Level |
| 19 | Cummins | Fan | Loose belt |
| 20 | Hino | Radiator | Damaged cores |
| 21 | Tata 1612 | Coolant | Improper concentration |
| 22 | Cummins | Coolant | improper Level |
| 23 | MAN | Gasket | Thickness |
| 24 | Cummins | Radiator | Damaged cores |
| 25 | Tata 1612 | Radiator | Damaged cores |

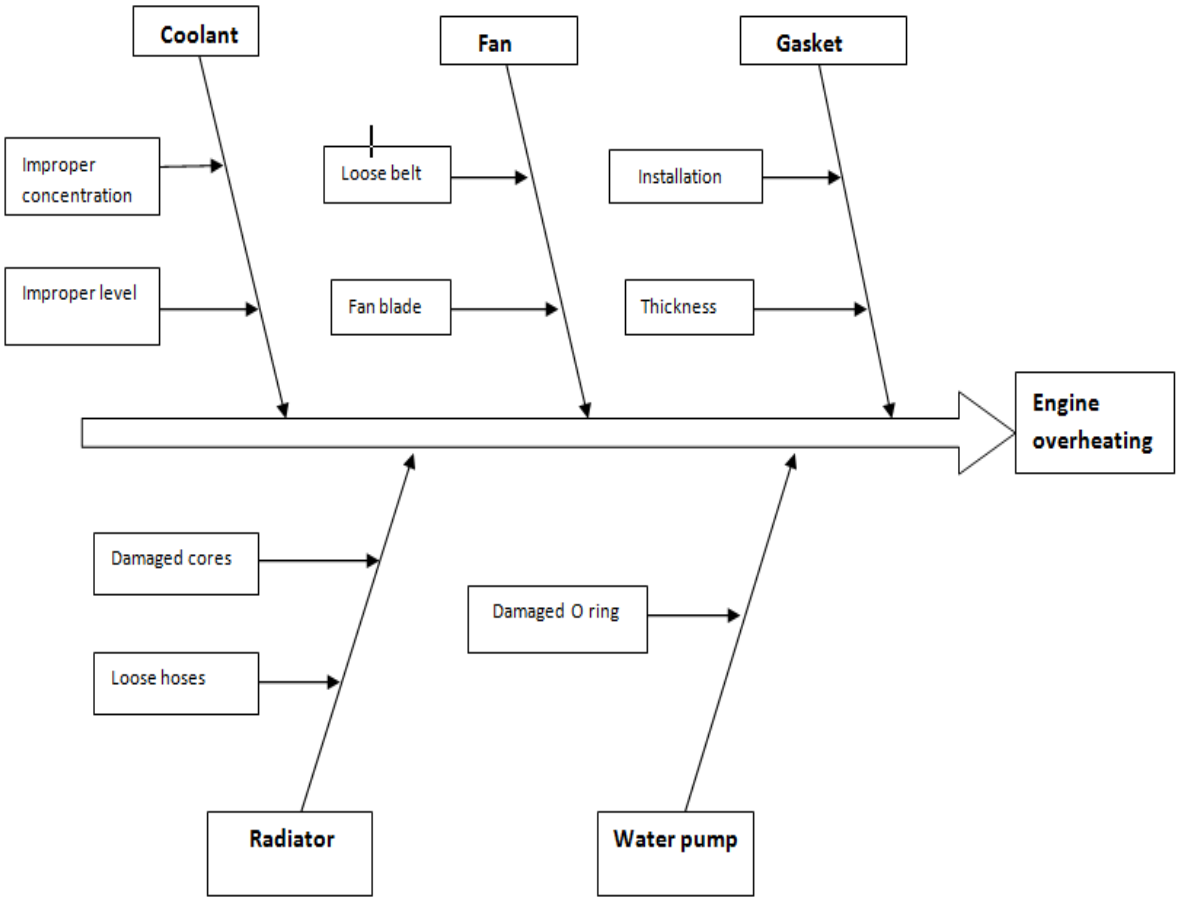



***Fig*** 3.1 cause and effect diagram of engine overheating

## IV. ANALYSIS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user designated size) called elements. The software implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand.

### A THERMAL ANALYSIS OF CYLINDER LINER

The analysis of the cylinder liner is done with two different materials. And the type of the analysis is Thermal Analysis.

The Required data is taken for the Analysis:

Table 4.1 materials for analysis

| SR. NO | COMPONENT | MATERIAL |
|---|---|---|
| 1 | LINER | Gray Cast Iron |
| 2 | LINER | Aluminium Alloy 6061 |

**Aluminum Alloy 6061**

Table 4.2 properties of cylinder liner

| **Bounding Box** | |
|---|---|
| Length X | 108.97 mm |
| Length Y | 108.97 mm |
| Length Z | 203.2 mm |
| **Properties** | |
| Volume | 1.9905e+005 mm³ |
| Mass | 1.5625 kg |

Generate Mesh

Meshing is done by using size controls command of lines, the line of specimen is divided to get a good mesh. After that mesh area is selected as shown.

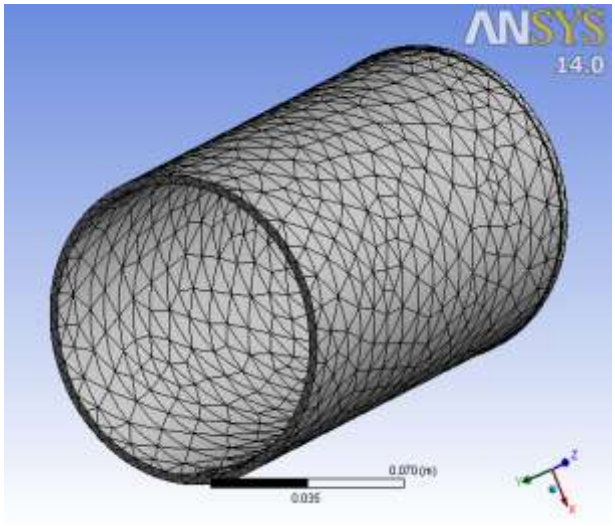
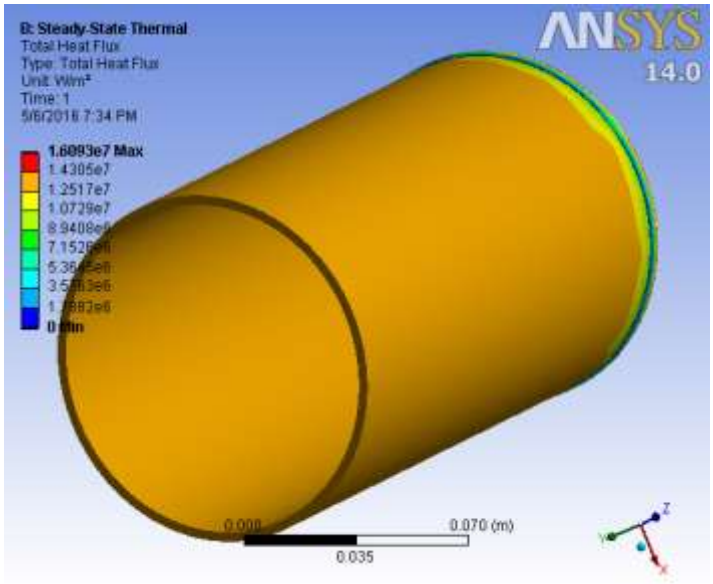



Fig 4.1 Meshed model of aluminium cylinder liner

Apply Loads

Loads – Define Loads – Apply – Thermal – Temperature




**Temperatures** Inside liner=700ºc Outside liner=40ºc

Fig 4.2 total heat flux of aluminium cylinder liner

**Gray cast iron**

Table 4.3 properties of cylinder liner

| **Bounding Box** | |
|---|---|
| Length X | 108.97 mm |
| Length Y | 108.97 mm |
| Length Z | 203.2 mm |
| **Properties** | |
| Volume | 1.9905e+005 mm³ |
| Mass | 0. kg |

Repeat the meshing procedure for Gray cast iron cylinder liner

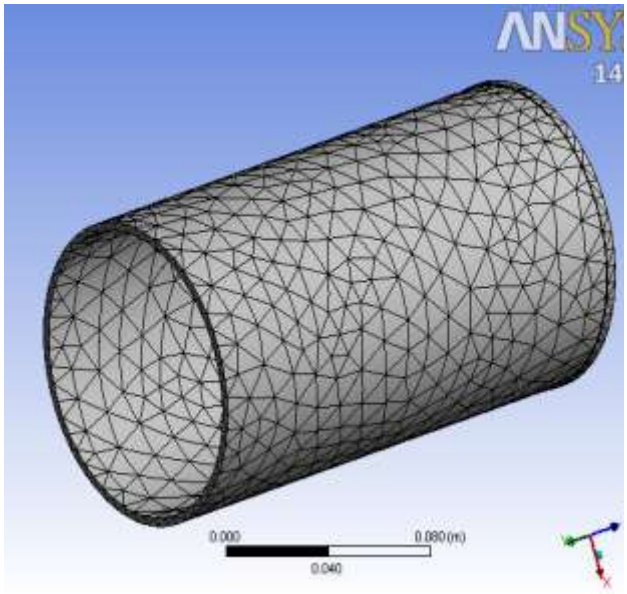



Fig 4.3 Meshed model of gray cast iron cylinder liner

Apply Loads
Loads – Define Loads – Apply – Thermal – Temperature
**Temperatures** Inside liner=700ºc Outside liner=40ºc

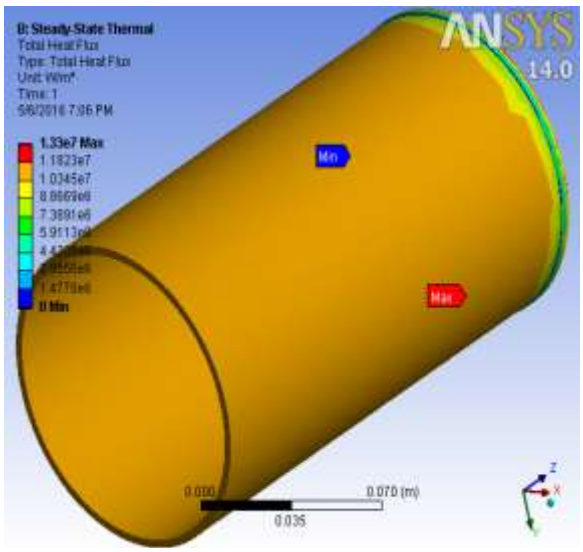



Fig 4.4 total heat flux of gray cast iron cylinder liner

## V. RESULTS

The causes of the engine overheating data is analyzed using pareto technique and based on the Pareto principle of 80/20 rule it is found that the major causes of engine overheating were coolant, radiator and fan since marker line cuts the cumulative percentage line at 80%.so the L.H.S shows the critical causes

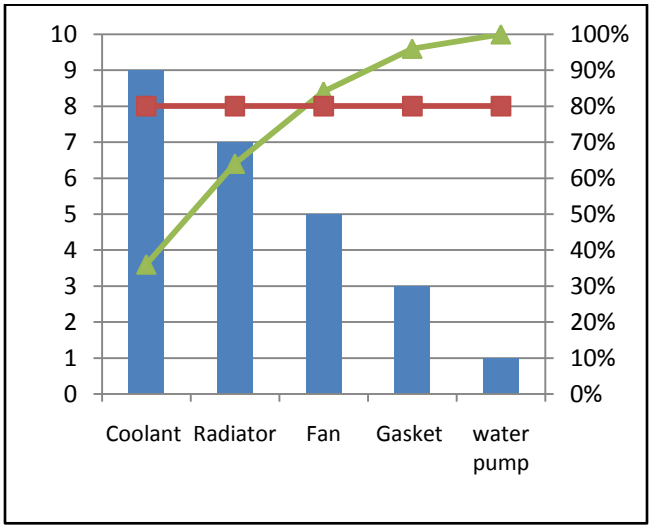



Fig 5.1 pareto analysis

Table 5.1 critical causes of engine overheating

| Sr.no | Cause | Contribution |
|---|---|---|
| 1 | Coolant | 36% |
| 2 | Radiator | 28% |
| 3 | Fan | 20% |

In ansys Using thermal analysis two different materials gray cast iron and aluminium alloy 6061 were studied the result of which are shown

Table 5.2 Total heat flux of liner material

| Liner Material | Inside Temperature | Outside Temperature | Total heat Flux |
|---|---|---|---|
| Gray cast iron | 700°C | 40°C | 1.33e7 w/mm$^2$ |
| Aluminium alloy 6061 | 700°C | 40°C | 1.60e7 w/mm$^2$ |

## VI. CONCLUSION

Using Pareto technique the causes of overheating in 25 engines were studied in which cooling system is considered it is found that coolant, radiator and fan were the critical causes of overheating. In engines it is found that the coolant level was below the limit and coolant is not being used in proper concentration. Radiator cores were found to be damaged and because of loose hoses water was not properly circulated through radiators. In some engines fan belt is found to be loose and broken fan blades were also observed. In ansys the thermal analysis is done using two different materials it has been seen that the total heat flux is more in aluminium alloy 6061 than gray cast iron since the heat flux is more therefore the rate of heat transfer will be more it is recommended to use aluminium alloy 6061 as liner material.

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