

Failure Analysis of Cooling Water Pipe in Diesel Locomotive

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Abstract: The objective of cooling water system is to remove the excess heat from the engine. The working fluid (water) is circulated from the tank to the cylinder liner of each individual cylinder through the cooling water pipe. The working fluid (water) is cooled by circulating it through the radiator and recycled again. When a crack is developed in the cooling water pipe the entire system collapses and the loco gets shut down. The problem identified by us was that the existing cooling water design has more number of bends. Our intension is to analyse the fluid flow pattern in the existing cooling water pipe design and to provide an improved design with less number of bends, better fluid flow pattern and minimum number of failures.

Keywords: Cooling water pipe, working fluid, fluid flow pattern.

1. INTRODUCTION

GENERAL:

In an internal combustion engine heat is the source of energy. When fuel is burnt inside the combustion engine only 35-40% of energy produced is converted to mechanical energy. This is termed as thermal efficiency. The rest of the heat energy is to be conducted and dissipated to the atmosphere by some means nearly 30% of heat is going to atmosphere through exhaust gas. The Components which are having contact with the exhaust gas and heat the engine, we get hot. The components like pistons and bearing metals would become so hot and thus seizure could occur. Therefore this heat must be maintained with fairly close limits to achieve maximum power. Too high the temperature would cause detonation and too cool and engine consumes fuel uneconomically. So, all engines are to be provided with some arrangement of radiating the heat to the atmosphere either directly or indirectly.

METHODS OF COOLING SYSTEM:

There are two methods generally employed for cooling the diesel engine.

1) AIR COOLING:

This method is adopted when the power output is low. E.g.: motorbikes.

2) WATER COOLING:

This is resorted in the heavy vehicles like Trucks and Lorries. Since our diesel engine is a heavy duty engine with enormous horse power output, the cooling water system which is employed to maintain the temperature and cool the components like cylinder liners, cylinder heads and turbo super charger is actually a "circulating water system" assisted by a gear driven water pumps. In addition to cooling of the above components the cooling water helps to cool the hot lube oil returning to the sump before being sent back to the system.

1. The first connection is taken through a flexible water pipe to the turbocharger. The water enters in the turbo inlet casing at the bottom and circulates in its hollow passage to cool the intermediate casing walls between the blower and turbine and bearings, which are in constant connection with the exhaust gases.

Note:

1. From the intermediate casing water enters in the turbine casing through four circular interconnecting passages situated 90 degree apart on the periphery of the casing.

2. The second connection from the three way elbow is taken through a steel pipe to the left bank of the cylinder block. Here water is taken to the aftercooler through a connection and water passes through the tubes of the aftercooler for cooling the super charged air that are passing around the tubes of the after cooler. From the after cooler water return back to the steel pipe through the outlet. Then the cooling water enters the engine block and circulates outside the cylinder liners and cools the cylinder parts.

3. The third connection from the water channels on both dies water is conducted to the individual cylinder heads through water jumper pipes. By flowing into the cavities of cylinder heads, water-cools the cylinder heads. From every cylinder heads, water flows to the common water return headers on the left and right sides through individual raiser pipes. From the water return headers water is made pass through the 'Bubble collector' before reaching the radiators. This has done to break the bubbles formed by the water vapour. Various vent pipes are also provided to prevent steam formation in the system. Right side water return header is connected to the left side radiator and left side water return header is connected to the right side radiator. After passing the tubes of the left radiator water is taken to lube oil cooler. Here water passes through tubes to cool the lube oil, flowing around the water tubes. From the

lube oil cooler water joins with the rightside radiator outlet pipe and flows towards the suction side of the waterpump. The water circulation repeated again and again as described above from the junction of lube oil cooler outlet pipe and right radiator outlet pipe and suction pipe. A pipe is taken out and provided with a valve for draining water as well as filling water by pressure feed. Just before entering the left side radiator a connection is taken to the water temperature manifold, where the temperature switches TS1, TS2 and ETS and water temperature gauge are provided for operating at appropriate temperature. Water entering the radiators is naturally cooled by atmospheric air and thereby air drawn by the rotation of radiator fan.

Two pipes interconnect the expansion tanks that are provided on either side of the radiator compartment. The water in the expansion tank is utilised to supplement the water loss during circulation due to the evaporation or leak. An important safety device is provided in the expansion tank. This is called Low Water Switch (LWS). This is connected to the expansion tank to shut down the engine whenever the water level falls low. The capacity of the cooling water system is 1210 litres.

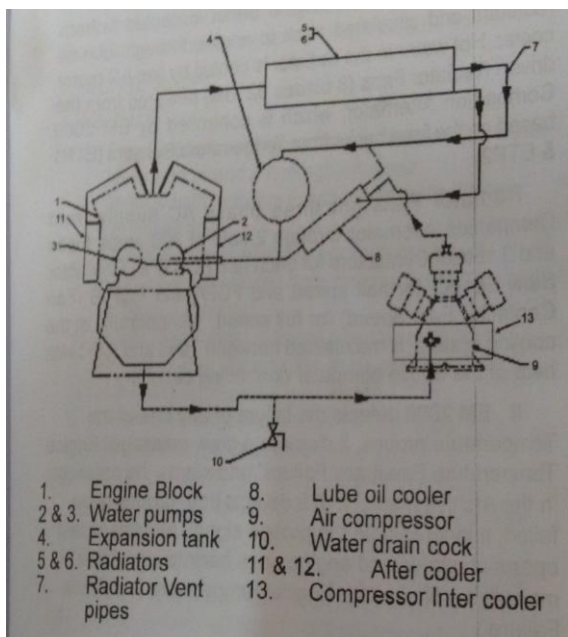
FUNCTIONS OF COOLING WATER:

Cooling water is used in locos for three functions.

1. To absorb the heat from the lube oil and the power pack.
2. To cool the turbo super charger which get heated on account of exhaust gases.
3. In WDM2 locos to cool the super charged air in the after cooler.

The heat absorbed by the cooling water will be dissipated through radiators to the atmosphere and the water is again circulated.

LAYOUT OF COOLING WATER SYSTEM:



REPEATED FAILURES OF COOLING SYSTEM

GENERAL:

Though there are many failures in diesel locomotive, the failure of cooling system is a critical failure when compared to others failures of diesel locomotive. The cooling system cools the V type 16 cylinder engines. The cooling water is distributed to each cylinder liner through two inlet manifold pipes which are driven by separate pumps. The pump is driven by pump gear which is meshed with crankshaft extension gear. Hence, the pump gear is driven by extension gear. The hot water is then recycled through the radiator assembly.

When the cooling system fails, the entire engine shuts down immediately. Therefore, the failures of cooling system have become a prominent issue. The following failures occur frequently during en-route and out of course action. The water leaks repeatedly from the pipe which distributes the water from the inlet manifold to the cylinder liner. On certain occasion, this pipe gets cracked.

INLET COOLING WATER PIPE FAILURE:

When the cooling system fails, the engine gets overheated due to high temperature. Hence, the engine ceases and shuts down. The system is designed such that if the cooling system fails, the entire system shuts down.

The temperature and pressure of working fluid is also limited within a certain range, above which the system shuts down. The cooling system fails due to the leakage of the pipe which delivers cooling water to the cylinder liner. There are 16 pipes which deliver the cooling water to the cylinder liner from the inlet manifold. The pipe is located in between the inlet manifold and the cylinder liner.

The properties of the working fluid inside the engine casing are tabulated below:

PROPERTIES OF WORKING FLUID	RANGE
Working temperature	60-90 ⁰ C
Working pressure	2-7 kg/cm ²

If the fluids range inside the casing exceeds or reduces beyond these ranges, the system automatically gets halted.

COMPONENTS OF COOLING WATER PIPE:

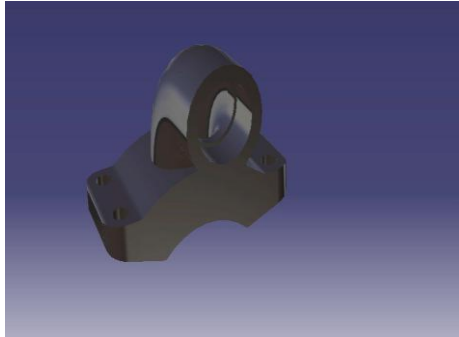
The pipe consists of three components:

1. Elbow saddle
2. Bent pipe
3. Flange

The elbow saddle is placed at the top of the inlet manifold. The elbow saddle is brazed with the bent pipe by using brazing ring. Brazing is done with the help of brazing ring. Brazing is used to join the mating parts. Bent pipe is also brazed with the flange. Flange should be fitted to the cylinder liner. So, the flange is brazed with the bent pipe.

2. DESIGN OF EXISTING PIPE:

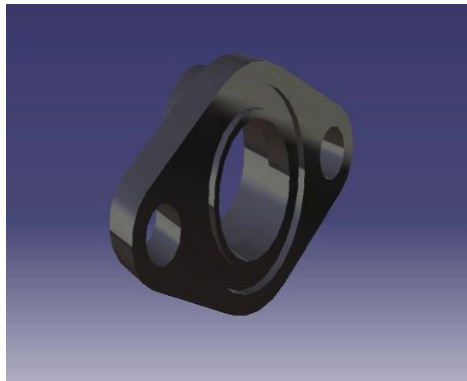
ELBOW SADDLE:



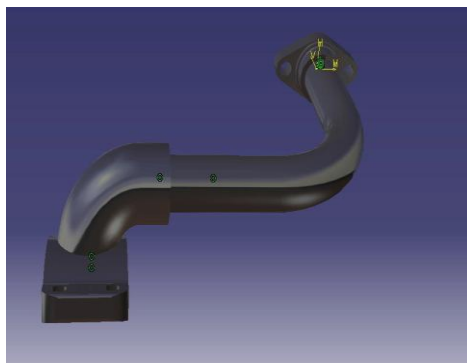
BEND PIPE:



FLANGE:



EXISTING ASSEMBLY:



3. FLUID FLOW ANALYSIS OF EXISTING PIPE

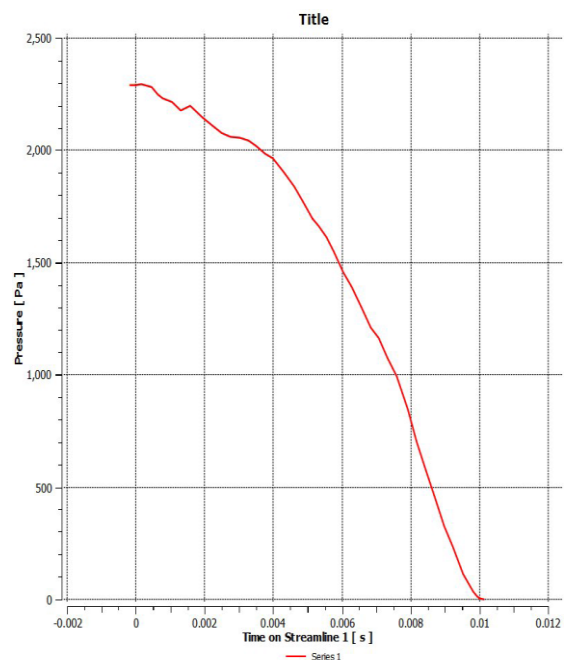
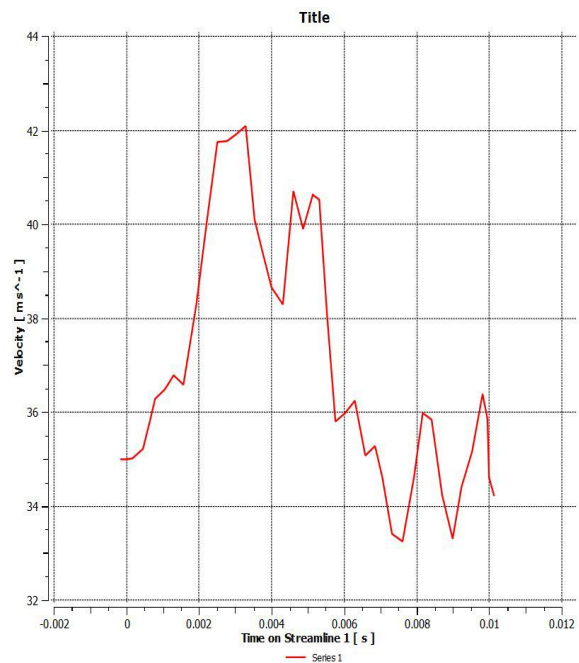
GENERAL:

The cooling water pipe has many reasons for both the leakage and cracks.

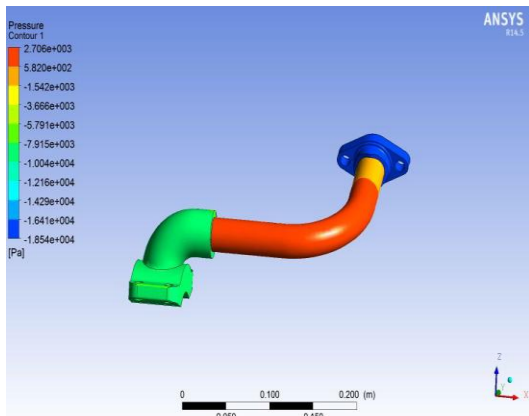
Since, the failure analysis is a vast area. The cooling water pipe has to be analysed on the subjects related to thermal, fluid mechanics, structural and

vibration. The analysis process needs more time to analyse them. So, we thought that fluid flow analysis is needed to analyse the flow through pipes. Therefore, the fluid flow analysis is done using ANSYS software i.e. fluent.

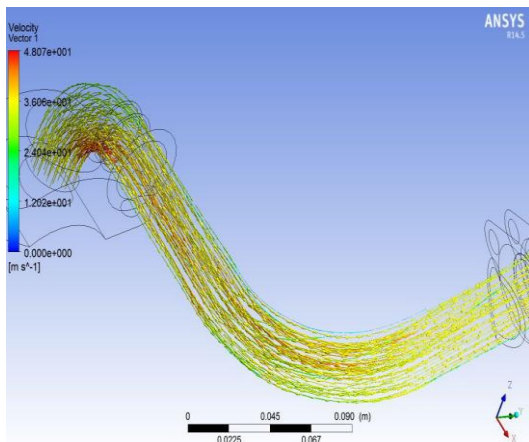
FLUID FLOW ANALYSIS:



PRESSURE CONTOUR:



VELOCITY PROFILE:



$$= 0.5(V_1^2/2g)$$

$$V_2 = 24.89 \text{ m/s}$$

After second bend of the pipe, velocity of the water is given by

$$(V_2^2/2g) = (V_3^2/2g) + HL$$

Where HL = bend loss

$$= 0.5(V_2^2/2g)$$

Finally, the velocity of the water at exit is $V_3 = 17 \text{ m/s}$.

REYNOLDS NUMBER CALCULATION:

The properties of the working fluid at 900^0 c are

Kinematic viscosity, $\mu = 0.315 \times 10^{-3} \text{ N s/m}^2$.

Density, $\rho = 1000 \text{ kg/m}^3$.

Reynolds number $Re = (\rho V D) / \mu$

At inlet manifold, $Re = 4.4 \times 10^6$

Since, it exceeds 4000. Therefore, the flow is turbulent.

At inlet of the pipe, $Re = 3.5 \times 10^6$

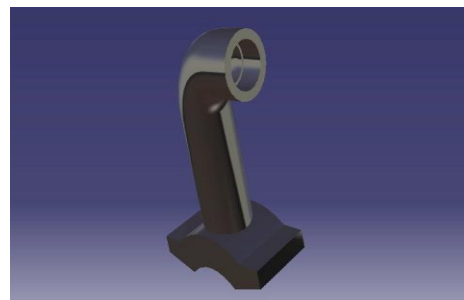
Since, it exceeds 4000. Therefore, the flow is turbulent.

At exit of the pipe, $Re = 1.72 \times 10^6$ Since, it exceeds 4000.

Therefore, the flow is turbulent.

DESIGN AND DRAFTING OF MODIFIED COOLING WATER PIPE DESIGN OF MODIFIED PIPE:

ELBOW SADDLE:



FLUID FLOW CALCULATION OF EXISTING PIPE:

VELOCITY CALCULATION:

The properties of the working fluid (water) are

Working pressure = 7 kg/cm^2

Working temperature = 900^0 c

Pressure = $\frac{1}{2}(\rho v^2)$

Velocity at inlet manifold = 37 m/s

Therefore, the flow rate $Q = AV$

$$\text{Area } A = (\pi/4)D^2$$

$$Q = 0.223 \text{ m}^3/\text{s}$$

Since, the water is distributed from the inlet manifold into the 8 pipes simultaneously. Hence, the flow rate at each pipe is given by $Q/8$.

$$\text{Flow rate at each pipe} = 0.0278 \text{ m}^3/\text{s}$$

From the equation, $Q = AV$

Velocity of the water at each pipe = 35.2 m/s

After one bend of the elbow saddle, velocity of the water is given by

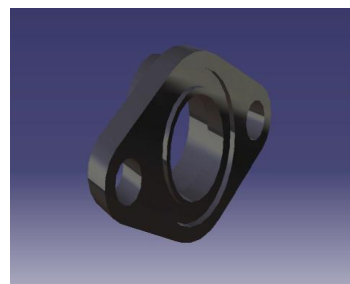
$$(V_1^2/2g) = (V_2^2/2g) + HL$$

Where HL = bend loss

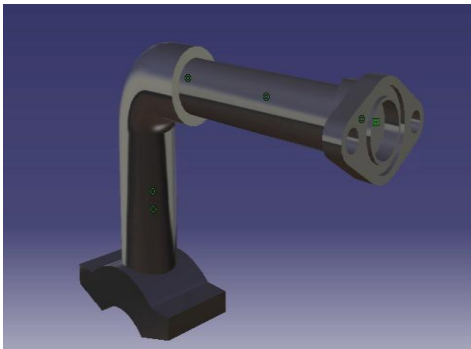
BEND PIPE:



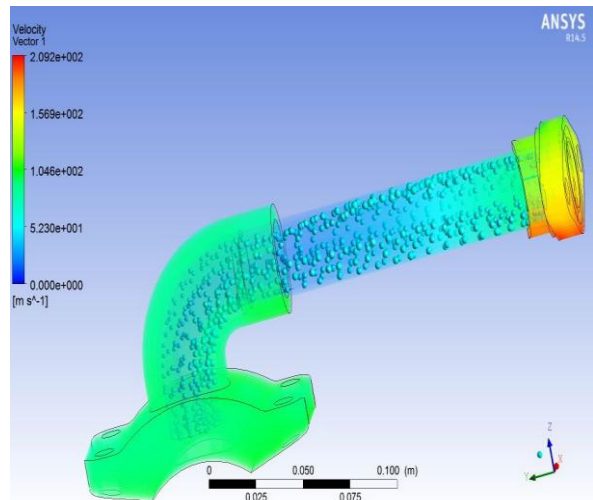
FLANGE:



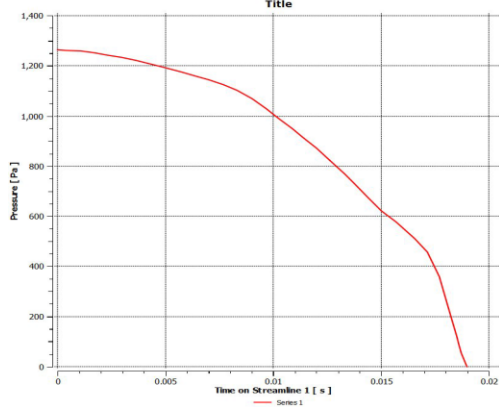
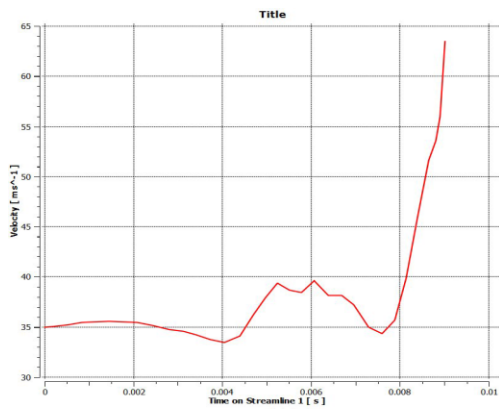
MODIFIED ASSEMBLY:



VELOCITY PROFILE:



FLUID FLOW ANALYSIS OF MODIFIED PIPE GRAPHS:



4. CONCLUSION

From the above collected data, analysis and calculations, it is being concluded that when there is more number of bends it tends to increase the pressure and reduce the velocity of the working fluid above the safe limit.

When the number of bends is reduced it tends to maintain the pressure and velocity of the working fluid within the safe limit.

The fluid velocity increases in the modified design as head loss is reduced and hence the Reynolds number increases which makes the fluid flow turbulent. Since the fluid flow is made turbulent it also increases the efficiency of the system.

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PRESSURE DISTRIBUTION:

