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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 restof 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 sohot and thus seizure could occur. Therefore this heat must be maintained withfairly close limits to achieve maximum power. Too high the temperature wouldcause detonation and too cool and engine consumes fuel uneconomically. So, allengines are to be provided with some arrangement of radiating the heat to theatmosphere 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. Sinceour diesel engine is a heavy duty engine with enormous horse poweroutput, the cooling water system which is employed to maintain thetemperature and cool the components like cylinder liners, cylinder headsand turbo super charger is actually a “circulating water system” assistedby 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 andcirculates in its hollow passage to cool the intermediate casing wallsbetween the blower and turbine and bearings, which are in constantconnection with the exhaust gases.

Note:
1. From the intermediate casing water enters in the turbine casingthrough four circular interconnecting passages situated 90 degree apart onthe periphery of the casing.
2. The second connection from the three way elbow is taken through a steelpipe 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 thesteel pipe through the outlet. Then the cooling water enters the engineblock and circulates outside the cylinder liners and cools the cylinderparts.
3. The third connection from the water channels on both dies water isconducted to the individual cylinder heads through water jumper pipes.By flowing into the cavities of cylinder heads, water-cools the cylinderheads. 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 ‘Bubblecollector’ before reaching the radiators. This has done to break thebubbles formed by the water vapour. Various vent pipes are also providedto prevent steam formation in the system. Right side water return header is connected to the left side radiatorand 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 oilcooler. Here water passes through tubes to cool the lube oil, flowingaround the water tubes. From the

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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 abovefrom the junction of lube oil cooler outlet pipe and right radiator outletpipe 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 thewater temperature manifold, where the temperature switches TS1, TS2and ETS and water temperature gauge are provided for operating atappropriate temperature.Water entering the radiators is naturally cooled by atmospheric airand thereby air drawn by the rotation of radiator fan.

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

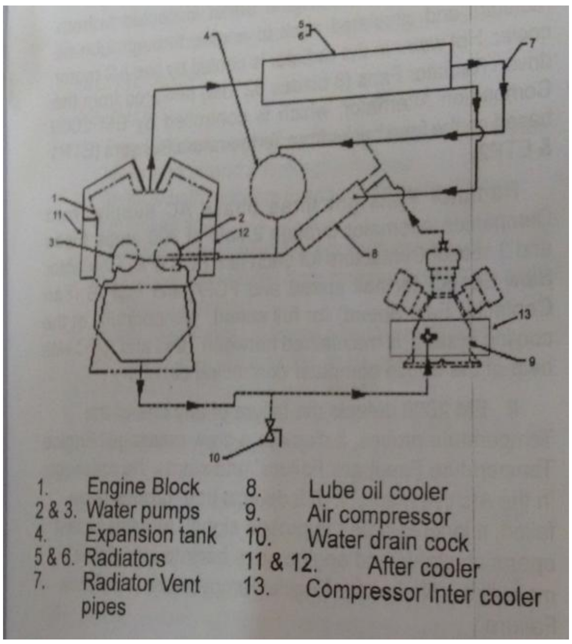
FUNCTIONS OF COOLING WATER:

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 exhaustgases.
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 coolingsystem is a critical failure when compared to others failures of diesellocomotive. The cooling system cools the V type 16 cylinder engines. Thecooling water is distributed to each cylinder liner through two inlet manifoldpipes which are driven by separate pumps. The pump is driven by pump gearwhich is meshed with crankshaft extension gear. Hence, the pump gear is drivenby 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. Thefollowing 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 hightemperature. Hence, the engine ceases and shuts downs. 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 deliverscooing water to the cylinder liner. There are 16 pipes which delivers the coolingwater to the cylinder liner from the inlet manifold. The pipe is located inbetween 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	60-90^0C
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 is 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 elbowsaddle is brazed with the bent pipe by using brazing ring. Brazing is done withthe help of brazing ring. Brazing is used to join the mating parts. Bent pipe isalso brazed with the flange. Flange should be fitted to the cylinder liner. So, theflange is brazed with the bent pipe.

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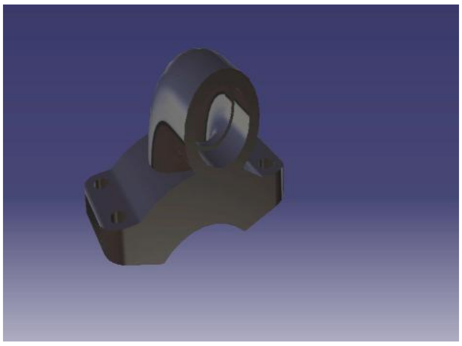
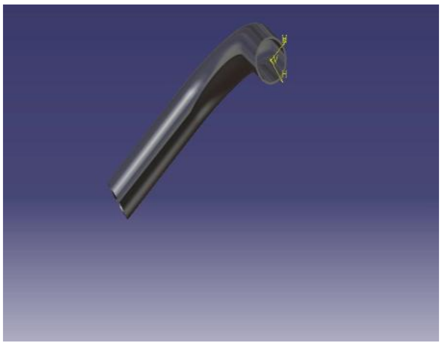
2. DESIGN OF EXISTING PIPE:

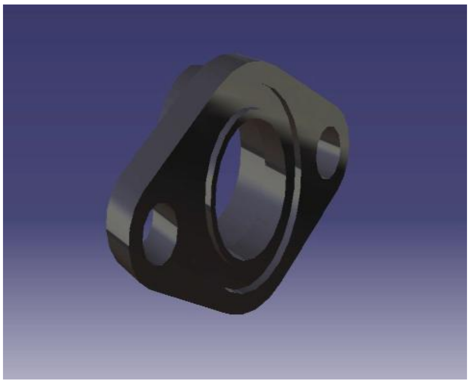
ELBOW SADDLE:



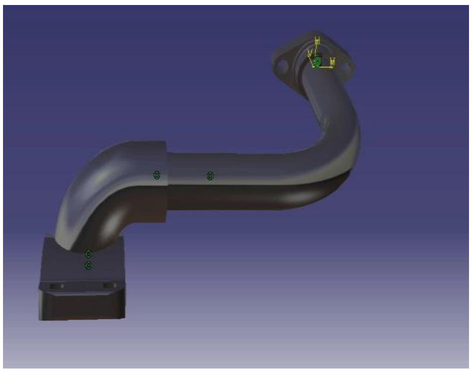
BEND PIPE:



FLANGE:



EXISTING ASSEMBLY:



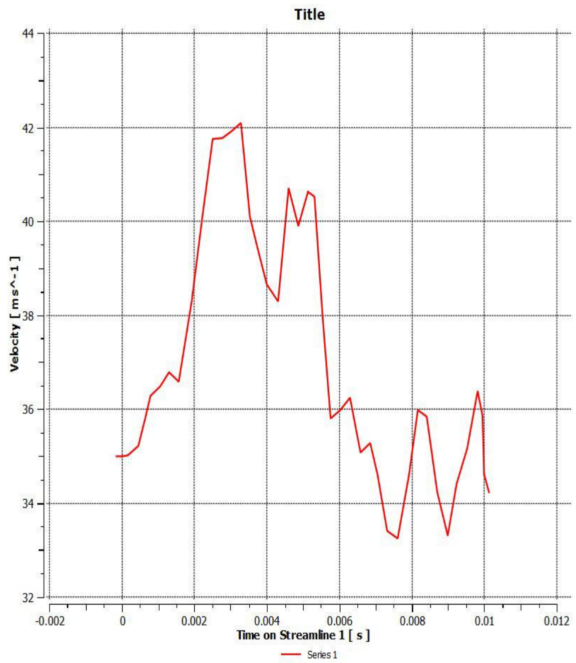
3. FLUID FLOW ANALYSIS OF EXISTING PIPE

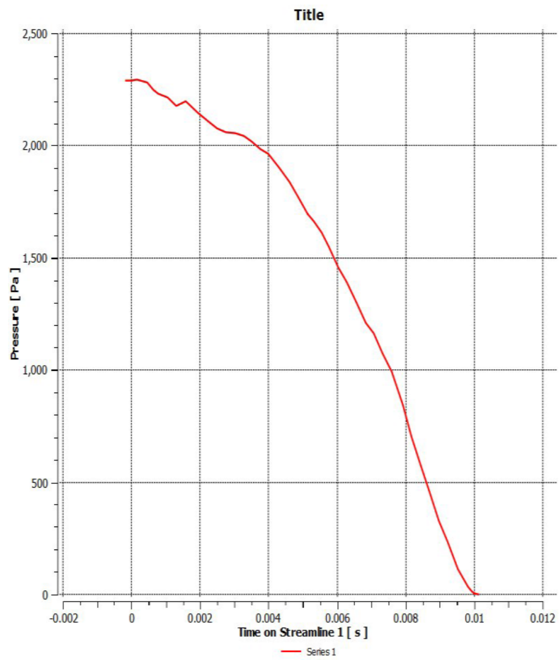
GENERAL:

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 beanalysed on the subjects related to thermal, fluid mechanics, structural and vibration. The analysis process needs more time to analyse them. So, wethought 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:





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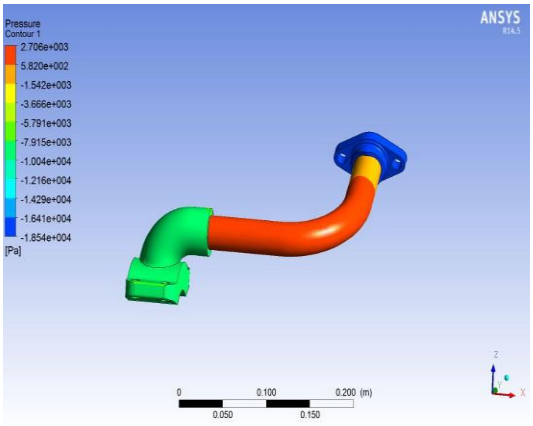
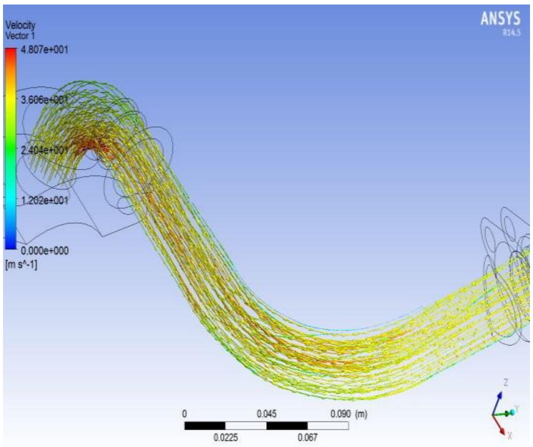
PRESSSURE CONTOUR:



VELOCITY PROFILE:



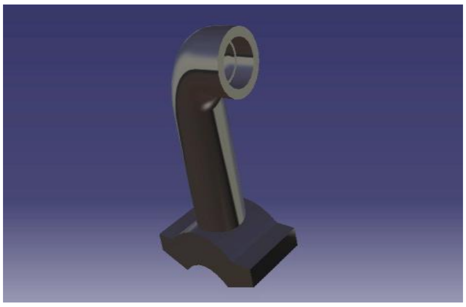
FLUID FLOW CALCULATION OF EXISTING PIPE:
VELOCITY CALCULATION:

The properties of the working fluid (water) are
Working pressure= 7 kg/cm^2
Working temperature = $900^0 c$
Pressure = ½(ρv^2)
Velocity at inlet manifold = 37 m/s
Therefore, the flow rate Q = AV
Area A = (π/4)D^2
Q = 0.223 m^3/s
Since, the water is distributed from the inlet manifold into the 8 pipessimultaneously. Hence, the flow rate at each pipe is given by Q/8.
Flow rate at each pipe = 0.0278 m^3/s
From the equation, Q = AV
Velocity of the water at each pipe = 35.2m/s
After one bend of the elbow saddle, velocity of the water is given by
$(V_1{}^2/2g) = (V_2{}^2/2g) + HL$

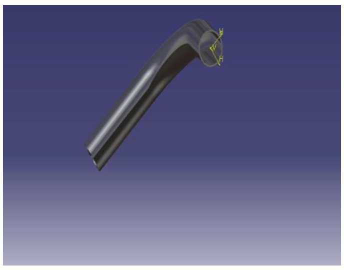
Where HL = bend loss
= $0.5(V_1{}^2/2g)$
V_2 = 24.89 m/s
After second bend of the pipe, velocity of the water is given by
$(V_2{}^2/2g) = (V_3{}^2/2g) + HL$

Where HL = bend loss
= $0.5(V_2{}^2/2g)$
Finally, the velocity of the water at exit isV_3 = 17 m/s.
REYNOLDS NUMBER CALCULATION:
The properties of the working fluid at $900^0 c$ are
Kinematic viscosity, μ = 0.315 x 10-3 Ns/m^2.
Density, ρ = 1000 kg/m^3.
Reynolds number Re = (ρVD)/μ
At inlet manifold, Re = 4.4 x 106
Since, it exceeds 4000. Therefore, the flow is turbulent.
At inlet of the pipe, Re = 3.5 x 106
Since, it exceeds 4000. Therefore, the flow is turbulent.
At exit of the pipe, Re = 1.72 x 106Since, it exceeds 4000. Therefore, the flow is turbulent.

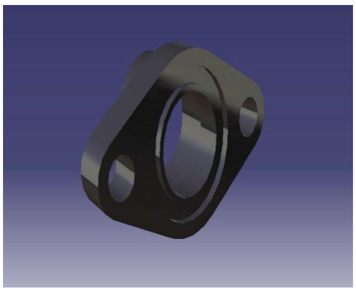
DESIGN AND DRAFTING OF MODIFIED COOLING WATER PIPE DESIGN OF MODIFIED PIPE:
ELBOW SADDLE:



BEND PIPE:



FLANGE:



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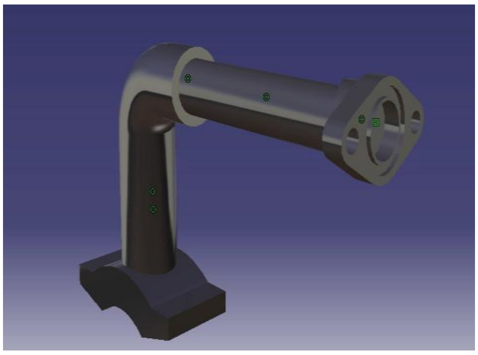
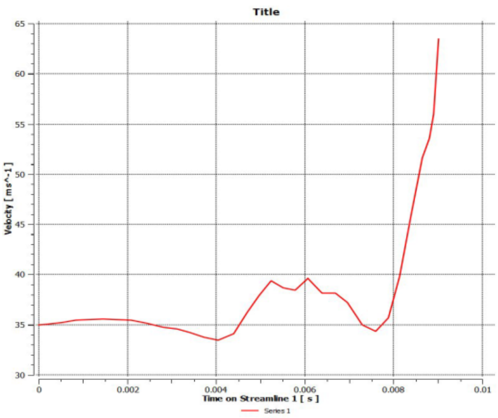
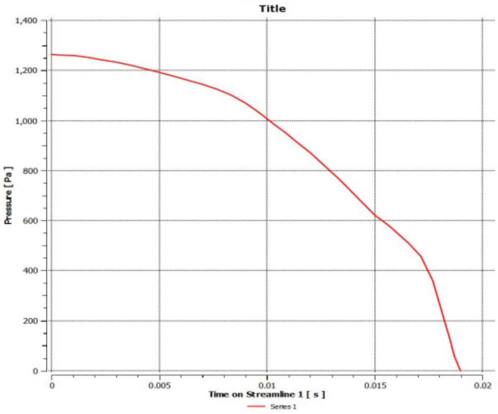
MODIFIED ASSEMBLY:

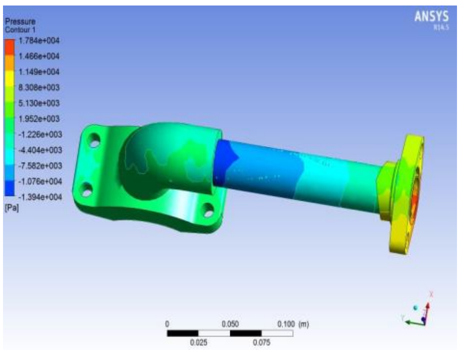


FLUID FLOW ANALYSIS OF MODIFIED PIPE GRAPHS:

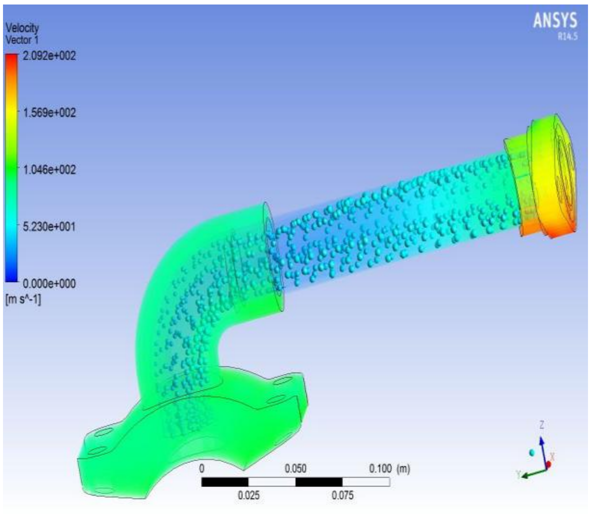




PRESSURE DISTRIBUTION:



VELOCITY PROFILE:



4. CONCLUSION

From the above collected data, analysis and calculations, it isbeing concluded that when there is more number of bends it tends toincrease the pressure and reduce the velocity of the working fluidabove the safe limit.

When the number of bends is reduced it tends tomaintain the pressure and velocity of the working fluid within the safelimit.

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

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