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IMPROVING THE PEFORMANCE OF AN ENGINE BLOCK BY USING VARYING COOLING FLUIDS

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***Abstract* - Cooling system plays important roles to control the temperature of car's engine. One of the important elements in the car cooling system is cooling fluid. The usage of wrong cooling fluid can give negatives impact to the car's engine and shorten engine life. An efficient cooling system can prevent engine from overheating and assists the vehicle running at its optimal performance. This thesis was conducted to study the effectiveness of various types cooling agent in the vehicle cooling system which will influence the operation time of the engine block mainly cylinder in the light vehicle cooling systems. Theoretical calculations were done to determine the overall heat transfer coefficient and heat lost by the cylinder by varying the fluids and material of cylinder. Three main types of fluids were used in this study, which are1. Distilled water, 2. Distilled water with Ethylene glycol and 3. Organic acids. Thermal analysis is done on the cylinder by varying the materials Cast Iron, Aluminum alloys 7475 and 6061.**

I.INTRODUCTION

Although gasoline engines have improved a lot, they are still not very efficient at running 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. In fact, the cooling system on a car driving down the freeway dissipates enough heat to heat two average-sized houses! 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.

The engine in your car runs best at a fairly high temperature. When the engine is cold, components wear out faster, and the engine is less efficient and emits more pollution. So another important job of the cooling system is to allow the engine to heat up as quickly as possible, and then to keep the engine at a constant temperature.

Cars operate in a wide variety of temperatures, from well below freezing to well over 100 F (38 C). So whatever fluid is used to cool the engine has to have a very low freezing point, a high boiling point, and it has to have the capacity to hold a lot of heat. Water is one of the most effective fluids for holding heat, but water freezes at too high a temperature to be used in car engines. The fluid that most cars use is a mixture of water and ethylene glycol ($C_2H_6O_2$), also known as antifreeze. By adding ethylene glycol to water, the boiling and freezing points are improved significantly. [1]

Car cooling system is a system that responsible for cooling the engine by releasing heat through the cooling fins, so that the car's engine is not too hot or not too cold. This system will maintain the engine at a constant temperature for efficient function of the car engine. If the engine temperature is too low, fuel consumption will rise; and if the temperature is too hot for too long, the engine will self destruct.

There are two types of car cooling system, the air cooling system and liquid cooling system. Air cooling system is a system that uses air as a cooling agent. It is commonly used in single cylinder engines such as motorcycles; while liquid cooling system is known as the radiator system, a system that uses liquid as a cooling agent and is used in a multi-cylinder engine, such as cars and trucks. Radiator is the crucial components in the car cooling system. It ensures the engine not overheating [2]

A normal conventional car cooling system consists of eight important components which includes the engine's water jacket, thermostat, water pump, radiator, radiator cap, temperature switch, cooling fan (radiator fan), and hoses

Various cooling liquid are available to meet the objectives of the study. Experimental liquid was divided into two main groups, namely: - i. Liquid without coolant ii. Liquid with coolant

Liquid without coolant

There were 7 experiments for this study that namely E1-E7 that can be found in Table 1. The result of E1 shows that tap water has the highest temperature of 79.6 o C, with the time taken from initial temperature for the operation of the fan is 6 minutes and 44 seconds. This shows that tap water is not suitable to be used as cooling fluids in car cooling system. [3]

No	Type of liquid	Temperature for the radiator fan start its operation	Time needed for the radiator fan start its operation	Remarks
E1	100% Tap water	79.6°C	6 m 44 s	
E2	100% Distilled water	73.5°C	6 m 20 s	
E3	100% Treated Tap Water	72.6°C	5 m 36 s	
E4	100% RO water	76.9°C	6 m 03 s	
E5	50% tap water + 50% RO water	77.5°C	6 m 27 s	
E6	50% tap water + 50% Distilled water	77.3°C	6 m 26 s	
E7	50% tap water + 50% Treated Tap Water	77.7°C	6 m 15 s	

Table 1 : Results Of Experiments Of Liquid Without Coolant

Liquid with coolant

The findings indicate that the use of liquid with coolant has a temperature range between 76.5oC to 82.0oC; while the time taken for the fan operation is within 5 minutes 34 seconds to 6 minutes 46 seconds.

No	Type of liquid	Temperature for the radiator fan start its operation	Time needed for the radiator fan start its operation	Remarks
F1	100% Normal Coolant	76.5°C	5 m 41 s	*thick precipitate
F2	60% Normal Coolant + 40% Tap water	78.8°C	6 m 21 s	*precipitate
F3	60% Normal Coolant + 40% RO water	77.9°C	6 m 36 s	*precipitate
F4	60% Normal Coolant + 40% Distilled water	79.3°C	6 m 12 s	*little precipitate
F5	100% Long life Coolant	82.0°C	5 m 34 s	
F6	60% Long life Coolant + 40% tap water	79.6°C	6 m 01 s	
F7	60% Long life Coolant + 40% RO water	78.2°C	6 m 46 s	
F8	60% Long life Coolant + 40% Distilled water	77.8°C	5 m 30 s	
F9	60% Normal Coolant + 40% Long life Coolant	77.8°C	5 m 30 s	*little precipitate
F10	30% Normal Coolant + 30% Long life Coolant + 40% tap water	79.8°C	5 m 47 s	*precipitate
F11	30% Normal Coolant + 30% Long life Coolant + 40% Treated tap water	80.0°C	6 m 06 s	*precipitate
F12	60% Engine Oil SAE 20w/50 + 40% Treated tap water	87.7°C	6 m 14 s	*precipitate

Table 2 :Results Of Experiments Of Liquid With Coolant

II.HEAT TRANSFER CALCULATIONS

The overall heat transfer coefficient for a wall or heat exchanger can be calculated as:

$$1 / U A = L / k A + 1 / hA \quad (1)$$

where

U = the overall heat transfer coefficient (W/m^2K)

A = the contact area for each fluid side (m^2)

k = the thermal conductivity of the material (W/mK)

h = the individual convection heat transfer coefficient for each fluid (W/m^2K)

L= the wall thickness (m)

The thermal conductivity - k - for some typical materials (varies with temperature)

Alloy Cast Iron: 53.3 W/mK

Aluminium 6061: 205 - 250 W/mK

Aluminium 7475: 138 W/mK

More about conductive Heat Transfer

Thermal Conductivity for Several Materials

The convection heat transfer coefficient - h - depends on

The type of fluid - gas or liquid

The flow properties such as velocity

Other flow and temperature dependent properties

Heat transfer coefficient for some common fluids:

Tap Water: 5000W/m^2K

Distilled Water: 10 000 W/m^2K

Distilled water with Ethylene Glycol: 350 W/m^2K

ENGINE SPECIFICATIONS

Length of the cylinder: 0.072 m

Bore diameter: 0.0685 m

Thickness of cylinder: 0.004 m

Heat Transfer Q = U A (Tg - Tc)

U = Over all heat transfer coefficient

A = Area of cylinder

Tg = Temperature inside cylinder

Tc = Temperature of coolant

Area of cylinder = $1.235e^{-5}$ m^2

Heat Transfer calculations with Aluminium 6061 with different coolants:

- U= 1666.7 W/m^2K Q = 5.128 W (with tap water without coolant)
- U = 2000 W/m^2K Q = 6.154 W (with distilled water without coolant)
- U = 2850 W/m^2K Q = 8.770 W (Distilled water with Ethylene glycol)

Heat Transfer calculations with Aluminium 7475 with different coolants:

- U= 1385.54 W/m^2K Q = 4.26 W (with tap water without coolant)
- U = 1608.39 W/m^2K Q = 4.949 W (with distilled water without coolant)
- U = 2266.67 W/m^2K Q = 6.970 W (Distilled water with Ethylene glycol)

Heat Transfer calculations with Alloy Cast Iron with different coolants:

- U= 644.81 W/m^2K Q = 1.98W (with tap water without coolant)
- U = 689.25 W/m^2K Q = 2.12 W (with distilled water without coolant)
- U = 1090.27W/m^2K Q = 3.35W (Distilled water with Ethylene glycol)

III.GENERIC STEPS TO SOLVING ANY PROBLEM IN ANSYS

Build Geometry
Construct a two or three dimensional representation of the object to be modeled and tested using the work plane coordinate system within ANSYS.

Define Material Properties
Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

Generate Mesh
At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces.

Apply Loads
Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions.

Obtain Solution
This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

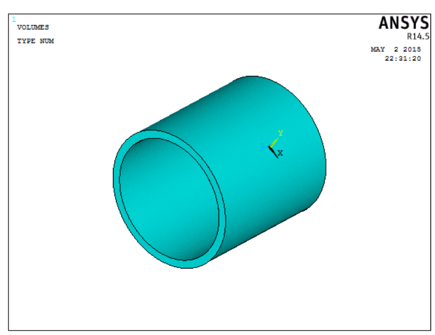
Present the Results
After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

THERMAL ANALYSIS

MATERIAL:ALUMINIUMALLOY6061

COOLENT: DISTILLED WATER WITH COOLANT-350

IMPORTED MODEL



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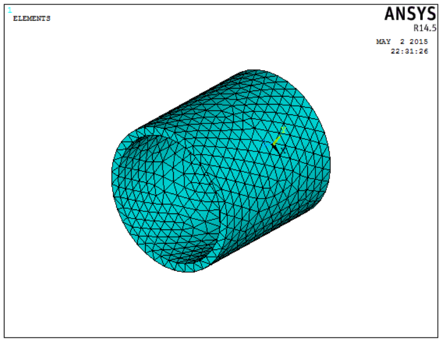
MESHED MODEL



Apply Loads

Loads – Define Loads – Apply – Thermal – Temperature Temperature –558K

Loads – define Loads – Apply – Thermal – Convection – on areas

Bulk Temperature – 313K

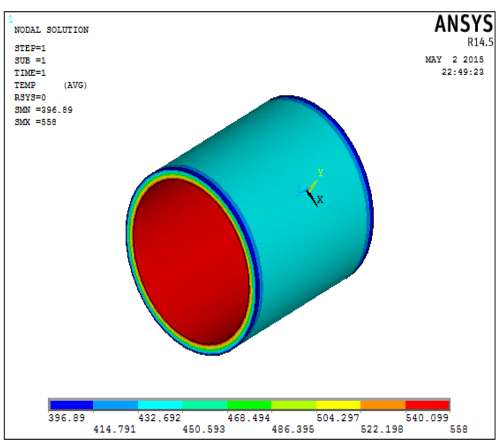
Film Coefficient – 0.005 W/mm^2 K

Solution

Solution – Solve – Current LS – ok

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Nodal Temperature Vector sum



Nodal temperature

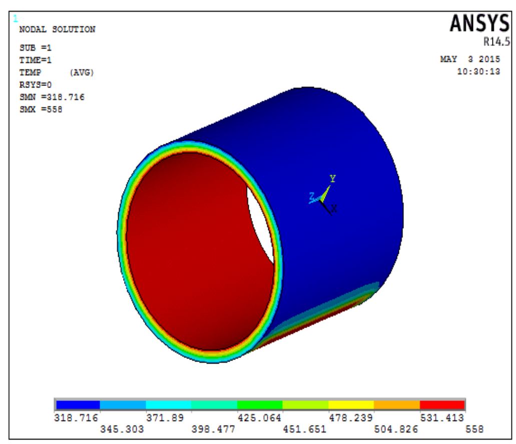
ORGANIC ACID (methanic)

ALUMINIUM ALLOY 6061

Element Type: Solid 20 node 90

Material Properties: Thermal Conductivity – 180W/mK
Specific Heat – 896 J/kg K
Density - 0.0000027 kg/mm^3
Apply Loads
Loads – Define Loads – Apply – Thermal – Temperature
Temperature –558K
Loads – define Loads – Apply – Thermal – Convection – on areas
Bulk Temperature – 313K
Film Coefficient – 0.4W/mm^2 K
Solution
Solution – Solve – Current LS – ok
Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Nodal Temperature Vector sum



Nodal temperature

IV. RESULTS AND DISCUSSIONS

DISTILLED WATER WITH COOLANT-350

	Nodal Temperature	Thermal Gradient	Thermal Flux
aluminum alloy 6061	558	69.2373	12.4627
aluminum alloy 7475	558	80.1391	11.0592
alloy cast iron	558	33.3209	17.7601

DISTLLED WATER WITHOUT COOLANT-10000

	Nodal temperature	Thermal Gradient	Thermal Flux
aluminum alloy 6061	558	29.2302	5.26144
aluminum alloy 7475	558	35.9186	4.95676
alloy cast iron	558	11.445	6.10019

ORGANIC ACID (METHANIC)

	Nodal Temperature	Thermal Gradient	Thermal Flux
aluminum alloy 6061	558	186.023	33.4842
aluminum alloy 7475	558	199.027	27.4657
alloy cast iron	558	130.521	69.5676

V.CONCLUSION

In this thesis a cylinder in the engine of a car is designed and modelled using Pro/Engineer. The present used material for engine block is cast iron. It is replaced with aluminium alloys 7475 and 6061 due to their high conductivity values and less densities. Three types of fluids were considered, Distilled Water , Distilled Water with Coolant Ethylene Glycol and organic acid

Theoretical calculations were done to determine the overall heat transfer coefficient and heat lost by engine cylinder. By observing the values, using material Aluminium alloy 6061 and fluid organic acid has high heat transfer rate.

Thermal analyses were done in Ansys to determine the heat transfer rate analytically on the engine cylinder. By observing the analysis results, using Cast Iron for cylinder and fluid organic acid has high heat transfer rate since thermal flux is more. But by using Cast Iron the weight of the engine block increases, so using Aluminium alloy 6061 is better since its density is less than that of Cast Iron and also the heat transfer rate is almost same as Cast Iron.

So we can conclude that by analytically and theoretically Aluminium Alloy 6061 is better for cylinder. But cooling fluid organic acid is better analytically and Distilled water with coolant is better theoretically.

REFERENCES

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