Enhancing the Performance of an Engine Block by Varying Cooling Fluids

[1]Dr. Ashok Kumar Vootla, [2] Abhishek kumar mishra

Associate professor, Dept. Mechanical engineering mother Theressa College of engg & tech. Peddapalli, , india
Dept of Mechanical engineering mother Theressa College of engg & tech. Peddapalli, , india
E-Mail: ashoko.vootla9@gmail.com

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 are 1.Tap water, 2.Distilled water, 3. Distilled water with Ethylene glycol. Thermal analysis is done on the cylinder by varying the materials Cast Iron, Aluminum alloys 7475 and 6061.

KEYWORDS: CAD , ANSYS , Ethylene Glycol, Alloys, Effectiveness, etc

INTRODUCTION TO COOLING SYSTEMS IN VEHICLES

Although gasoline 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. [Leong, 2010]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 [Nice, 2012].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 [Ofria, 2006].

THE BASICS

Inside your car's engine, fuel is constantly burning. A lot of the heat from this combustion goes right out the exhaust system, but some of it soaks into the engine, heating it up. The engine runs best when its coolant is about 200 degrees Fahrenheit (93 degrees Celsius). At this temperature:

- The combustion chamber is hot enough to completely vaporize the fuel, providing better combustion and reducing emissions.
- The oil used to lubricate the engine has a lower viscosity (it is thinner), so the engine parts move more freely and the engine wastes less power moving its own components around.
- Metal parts wear less.

TWO TYPES OF COOLING SYSTEMS

There are two types of cooling systems found on cars: liquid-cooled and air-cooled.

Liquid Cooling

The cooling system on liquid-cooled cars circulates a fluid through pipes and passageways in the engine. As this liquid passes through the hot engine it absorbs heat, cooling the engine. After the fluid leaves the engine, it passes through a heat exchanger, or radiator, which transfers the heat from the fluid to the air blowing through the exchanger.
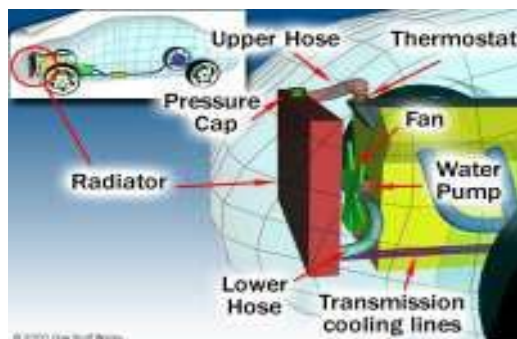
Figure 1.1: The Basic Parts of the Car Engine

Air Cooling

Some older cars, and very few modern cars, are air-cooled. Instead of circulating fluid through the engine, the engine block is covered in aluminum fins that conduct the heat away from the cylinder. A powerful fan forces air over these fins, which cools the engine by transferring the heat to the air.

Since most cars are liquid-cooled, we will focus on that system in this article.

AIR COOLED ENGINES

The premise of an air-cooled engine is actually pretty simple: Let air flow over the engine to keep it cool. But since this article needs to be a little bit longer than that, we'll touch on a few more details (for my editor's sake, anyway).

Most modern cars use water-cooled engines with radiators, water pumps and hoses that circulate a water and coolant mixture throughout the engine. The heat from the engine is transferred to the coolant, and then the coolant is cooled in the radiator and sent back around again.

Air-cooled engines want none of this. They rely on good old-fashioned air to cool them down. To be fair, all engines are technically air-cooled because even water-cooled engines use air to cool the fluid in the radiator. But let's not split hairs.Air-cooled engines have fins extending out from the engine to pull heat away. Cool air is then forced over the fins -- typically by a fan in cars. For aircraft and motorcycles, the vehicle's speed alone moves enough cool air over the fins to keep the engine cool.Some air-cooled engines may also have ducts around the engine to keep air flowing to the hottest areas. Some aircraft engines may even have baffling systems that channel high-pressure air into the cooling fins.Another design feature that keeps an air-cooled engine's temperature low is horizontally opposed cylinders they face away from each other and are spread farther apart than a typical water-cooled engine. This allows air to flow freely over the fins. Some air-cooled engines also make use of oil coolers to keep the oil temperature low.

Common Uses for Air-Cooled Engines

The air-cooled engine has had a long and well-loved history. At least, depending on whom you talk to. In the 1960s and 1970s some carmakers used air-cooled engines to power their vehicles. The 1964 Porsche 911 may be one of the fastest air-cooled engines, but the Volkswagen air-cooled engine may be one of the most beloved. It was used in the original Beetle.You'd be hard-pressed to find an air-cooled engine rolling of the auto assembly line these days, but that doesn't necessarily mean they're anywhere near dead.If you hop on a motorcycle, all-terrain vehicle, or even a common riding mower then you're probably experiencing an air-cooled engine (although some motorcycles are liquid-cooled). But its aircraft that have had the longest running air-cooled track record because many helicopters and small planes have remained air-cooled right from the beginning.

Benefits and Limitations of Air-Cooled Engines

So an air-cooled engine has no need for a radiator, a water pump, coolant, hoses or any other associated parts a liquid-cooled engine has. But is this actually a good thing?

The short answer: Sometimes.Obviously, and air-cooled engine doesn't have coolant leakage problems and won't ever require things like the water pump or radiator to be replaced, which can be a great thing. Typically, they're lighter than liquid-cooled engines, too, because they have fewer parts.Air-cooled engines also warm up a lot faster than liquid-cooled engines and don't have any risk of the coolant freezing, which is beneficial if you're operating the vehicle in extremely cold temperatures.

But there are some considerable drawbacks, too. For starters, air-cooled engines are more likely to overheat. Yeah, that's a bummer. They can also be more expensive to build and the large fans used to cool the engine can take away a lot of power.This doesn't mean that air-cooled engines are bad or ineffective. In fact, for motorcycles, recreational vehicles and certain aircraft the air-cooled engine works extremely well. But on cars, the common consensus is that the drawbacks outweigh the benefits.

Cooling Components Consist of

1. Source of heat
2. Radiator
3. Water pump
4. Thermostat
5. Fan
6. Expansion tank

International Journal of Research

Available at https://edupediapublications.org/journals
Special Issue on Conference Papers

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 06
March 2018

LITERATURE SURVEY

Different Fluids and Its' Impact Towards Car Cooling System

This study was conducted to study the effectiveness of various types cooling agent in the vehicle cooling system which will influence the operation time of the radiator fan in the light vehicle cooling systems. 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. A simple model that consist car's cooling system components was design for this study. Two main type of fluid were used in this study, which are fluid with coolant and fluid without coolant[Pang, 2011]. This study used the fan operating time and temperature as a determinant to review the effectiveness of cooling agent. Results showed that treated tap water is the most effective liquid without coolant. Meanwhile, for the liquid with coolant, we recommend the mixture of 60% long life coolant with 40% distilled water. It also proves that liquids containing coolant not necessary an effective cooling agent.

Summary

Cooling System is one of the most important systems in the engine because it is assigned to control and keep the engine operating temperature. It removes excess heat from the engine, to keep the engine operating at the most efficient temperature, and to allow the engine to reach its ideal operation temperature in the shortest time possible [Schappell, 2011]. Improper usage of cooling liquid can cause negative effects on the system and further damage the engine. Users are advised to be alert and recognize the name and function of any coolant before use it.

In conclusion, for the users that prefer liquid without coolant, this study suggests the use of treated tap water for the car cooling system; for the users that prefer liquid with coolant, this study suggests to use the mixture of 60% long life Coolant with 40% distilled water for the car cooling system. Both of the liquid can be used in cooling systems, as it has the same functions and

interests, which provide cooling to the system during engine operation [Salah, 2010].

In addition, the vehicle cooling system operating temperatures are also influenced by other factors such as the air flow, type of radiator, radiator cap, thermostat, fan motor efficiency, and the size of the fan blades (Hammer, 2008). Further studies may be performed to identify the main factors which influence the operating temperature of the present car cooling system.

CHAPTER III

Heat Transfer Calculations

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

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

Where

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

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^{2}K)

L= the wall thickness (m)

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

Alloy Cast Iron : 53.3 W/mK

Aluminum 6061: 205 - 250 W/mK

Aluminum7475 : 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^{2}K

Distilled Water: 10 000 W/m^{2}K

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

International Journal of Research

Available at https://edupediapublications.org/journals

Special Issue on Conference Papers

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 06
March 2018

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)

METHODOLOGY

Introduction to CAD& PRO/Engineer

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes;

drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.

CADD environments often involve more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.

CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) objects.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

The design of geometric models for object shapes, in particular, is often called computer-aided geometric design (CAGD).

Current computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surfacemodellers. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Some CAD software is capable of dynamic mathematic modeling, in which case it may be marketed as CADD — computer-aided design and drafting.

CAD is used in the design of tools and machinery and in the drafting and design of all

types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories).

Introduction to PRO/Engineer

Pro/ENGINEER is a feature based, parametric solid modeling program. As such, its use is significantly different from conventional drafting programs. In conventional drafting (either manual or computer assisted), various views of a part are created in an attempt to describe the geometry. Each view incorporates aspects of various features (surfaces, cuts, radii, holes, protrusions) but the features are not individually defined. In feature based modeling, each feature is individually described then integrated into the part.

The other significant aspect of conventional drafting is that the part geometry is defined by the drawing. If it is desired to change the size, shape, or location of a feature, the physical lines on the drawing must be changed (in each affected view) then associated dimensions are updated. When using parametric modeling, the features are driven by the dimensions (parameters). To modify the diameter of a hole, the hole diameter parameter value is changed. This automatically modifies the feature wherever it occurs - drawing views, assemblies, etc. Another unique attribute of Pro/ENGINEER is that it is a solid modeling program.

The design procedure is to create a model, view it, assemble parts as required, then generate any drawings which are required. It should be noted that for many uses of Pro/E, complete drawings are never created. A typical design cycle for a molded plastic part might consist of the creation of a solid model, export of an SLA file to a rapid prototyping system (stereo lithography, etc.), use of the SLA part in hands-on verification of fit, form, and function, and then export of an IGES file to the molder or toolmaker. A toolmaker will then use the IGES file to program the NC machines which will directly create the mold for the parts. In many such design cycles, the only print created will be an inspection drawing with critical and envelope dimensions shown.

Different Modules in PRO/Engineer

- PART DESIGN
- ASSEMBLY
- DRAWING

- SHEETMETAL
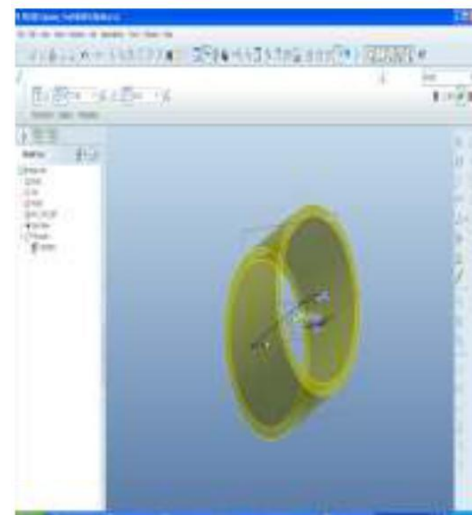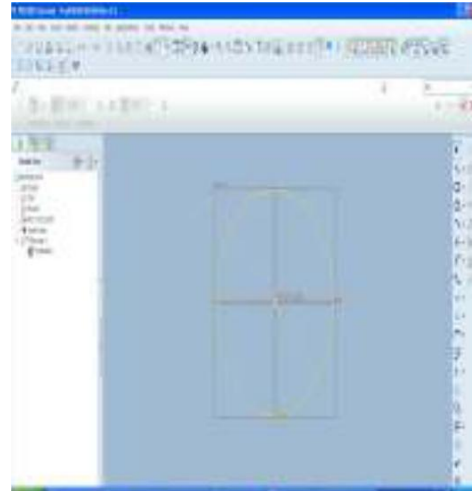
Introduction to FEA& ANSYS

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topps established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or

structure for a new service condition.In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system. Some examples are shown:

- Point, pressure, thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements
- Beam elements
- Plate/Shell/Composite elements
- Shear panel
- Solid elements
- Spring elements
- Mass elements
- Rigid elements
- Viscous damping elements

Introduction to ANSYS

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 behaviour 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. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in

the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

Generic Steps to Solving any Problem in ANSYS

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and

(4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

THERMAL ANALYSIS OF ENGINE BLOCK

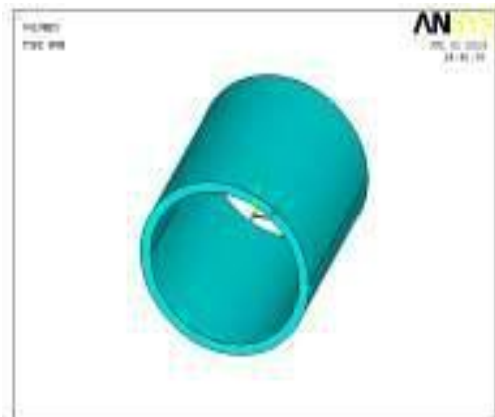Aluminium Alloy 6061

Tap Water Without Coolant

Imported model

Figure 6.1:Tap Water without Coolant

Element Type: solid 20 nodes 90

Material Properties: Thermal Conductivity – 0.18W/mm K

Specific Heat – 896 J/kg K

Density - 0.0000027 kg/mm^3

Meshed Model

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 in Fig

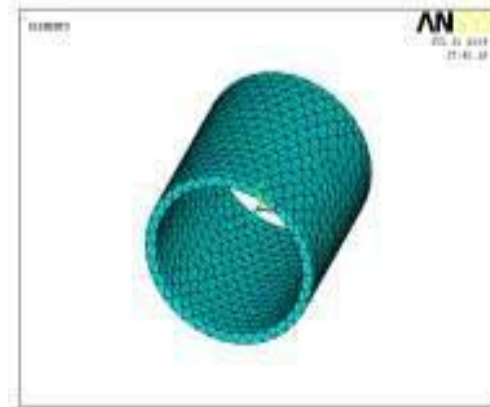[Mesh] < [Pick All] < [Close] Warning.

Figure 6.2: After Apply Mesh

Apply Loads

Loads – Define Loads – Apply – Thermal – Temperature

Temperature –558K

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

Bulk Temperature – 313K

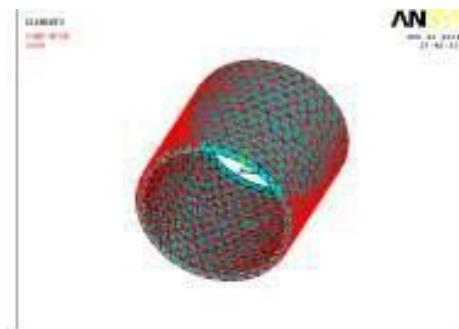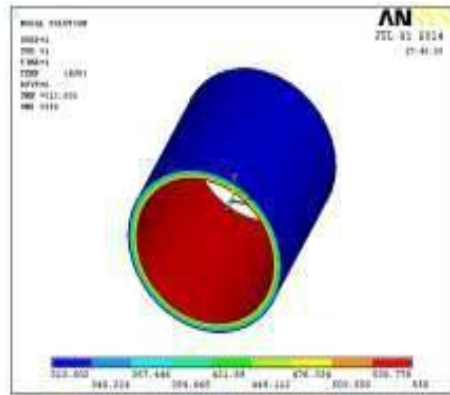Film Coefficient – 0.005W/mm^{2}K

Figure 6.3: after Apply Loads

Solution

Solution – Solve – Current LS – ok

Post Processor

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

International Journal of Research

Available at https://edupediapublications.org/journals
Special Issue on Conference Papers

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 06
March 2018

According to the contour plot, at inner surface the maximum temperature distribution is 558and at outer surface the minimum is 313.002

General Post Processor–Plot Results – Contour Plot - Nodal Solution – Thermal Gradient Vector sum

General Post Processor –Plot Results – Contour Plot - Nodal Solution – Thermal flux vector sum
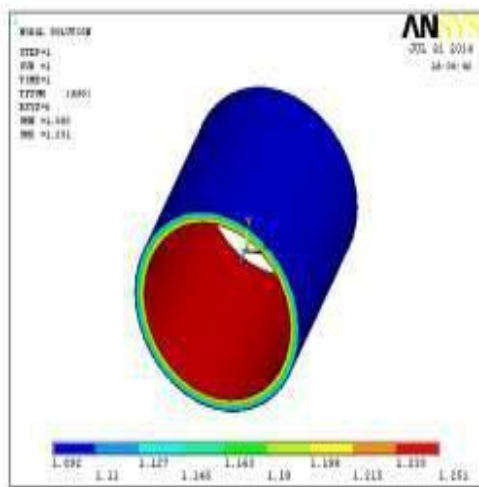
According to the contour plot, at inner surface the maximum rate of heat transfer (heat flux) area is 1.251and at outer surface the minimum is 1.092

Like this for different composition different analysis was carried out.

RESULTS

ALUMINUM ALLOY 6061

	Nodal Temperature	Thermal Gradient	Thermal Flux
Tap Water Without Coolant-5000	558	6.948	1.251
Distilled Water Without Coolant -10000	558	12.567	2.262
Distilled water with coolant-350	558	0.53933	0.097079

ALUMINUM ALLOY 7475

	Nodal Temperature	Thermal Gradient	Thermal Flux
Tap water without coolant-5000	558	8.78	1.212
Distilled water without coolant-10000	558	15.49	2.138
Distilled water with coolant-350	558	0.701722	0.096838

CONCLUSIONS

In this thesis we have designed acylinderin the engine ofa car. The present used material for engine block is cast iron. We are replacing with aluminum alloys 7475 and 6061 due to their high conductivity values. Three types of fluids were considered Tap water, Distilled Water and Distilled Water with Coolant Ethylene Glycol.Theoretical calculations were done to determine the overall heat transfer coefficient and heat lost by engine cylinder. By observing the values, using material Aluminum alloy 6061 and fluid Distilled Water with Ethylene Glycol has high heat transfer rate.Thermal analyses were done in Ansysto determine the heat transfer rate analytically on the engine cylinder. By observing the analysis results, using Aluminum alloy 6061 for cylinder and fluid Distilled Water without coolant has high heat

transfer rate since thermal flux is more.So we can conclude that by analytically and theoretically Aluminum Alloy 6061 is better for cylinder. But cooling fluid Distilled water without coolant is better analytically and Distilled water with coolant is better theoretically.

REFERENCES

Leong, K.Y., Saidur, R., Kazi, S. N., &Mamun, A. H. (2010). Performance Investigation Of An Automotive Car Radiator Operated With Nanofluid-Based Coolants (Nanofluid As A Coolant In A Radiator). Applied Thermal Engineering, Vol 30, Issue 17/18, P2685-2692.

Heat and Mass transfer by R.K. Rajput

MohdRajuli, M. B. (2006). TeknologiAutomotif :PengenalanSistem. PetalingJaya : IBS BukuSdn Bhd.

Nice, K. (n.d.). How Car Cooling Systems Work. Retrieved 11 July 2012 from http://auto.howstuffworks.com/cooling-system3.htm

Ofria, C. (2006). A Short Course on Cooling Systems. Retrieved 11 July 2012 from http://www.familycar.com/classroom/CoolingSystem.htm

Pang, S. C., Masjuki, H. H., Hazrat, M. A., &Kalam, M. A. (2011). Integration of 1D and 3D Simulations of Engine Cooling System: After Keyed- Off. IEEE, P46 - 50. DOI 10.1109/DCABES.2011.53

Peyghambarzadeh, S. M., Hashemabadi, S. H., Hoseini, S. M., &SeifiJamnani, M. (2011). Experimental Study Of Heat Transfer Enhancement Using Water/Ethylene Glycol Based Nanofluids As A New Coolant For Car Radiators. International Communications In Heat & Mass Transfer, Vol. 38, Issue 9, P1283-1290.

Ross, S. (2006). An Antifreeze Antidote? Aftermarket Business, Vol 116, No.7, Advanstar Publication.

Salah, M. H., Mitchell, T. H., Wagner, J. R., & Dawson, D. M. (2010). A Smart Multiple-Loop Automotive Cooling System—Model, Control, and Experimental Study. IEEE/Asme Transactions On Mechatronics, Vol. 15, No. 1, 117 – 123.

Schappell, K. (2011). The Car Cooling System. Retrieved 11 July 2012 from http://www.whatprice.co.uk/car/maintainance/car-cooling.html