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EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER RATE FOR AN ENGINE RADIATOR BY USING CARBON NANOTUBES MIXER COOLANT

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Abstract

The quality of an engine coolant plays a crucial role in the performance of an engine. A good quality engine oil quickly and substantially removes extra heat generated from the engine. It keeps cool during the engine performance. Carbon nanotubes (CNT) based coolants are promising materials for such applications. The exceptionally high thermal and electrical conductivity of carbon nanotubes adds to the additional quality performance of engine coolant. However, carbon nanotubes are immiscible in water based coolants. To have a stable solution, a surfactant has to be used with it. The organic surfactant sodium lauryl sulphate used and found to be very effective in making CNT soluble in the water based coolant. This enhances both thermal and electrical conductivities of coolant.
Now a days, people need high performance automotive vehicles to do their work faster. Seeing this, the demand for vehicle is increasing continuously. One of the method for increasing the performance of the vehicle is the use of good coolant. In the present study, The investigation of this carbon nanotubes mixer coolant (water + sodium lauryl sulphate + carbon nanotubes) heat transfer rate by passing through the engine radiator.
The presence of Carbon nanotubes mixer coolant can enhance the best de rate of the automobile radiator. The degree of the heat transfer depends on the amount of nanoparticles added to the base fluid. Ultimately, the heat transfer enhancement of 33%to base fluid was observed.

Keywords: Engine Radiator, Carbon Nanotubes, Sodium Lauryl Sulphate**.**

I. Introduction

Introduction to heat exchanger

Heat exchanger is a device which transfers the energy from a hot fluid medium to a cold fluid medium with maximum rate, minimum investment and low running costs.

History of heat exchanger

In the 1950s, aluminium heat exchangers made moderate inroad in the automobile industry with the invention of the vacuum brazing technique, large scale production of aluminiumbased heat exchangers began to raise and grow resulting from advantages of the controlled atmosphere brazing process (Nicolo brazing process introduced by ALCAN). With increasing year's introduction of "long life" (highly corrosion resistant) alloys further improved performance characteristics of aluminium heat exchangers. Extra demands for aluminium heat exchangers increased mainly due to the growth of automobile air-conditioning systems.

About heat exchanger:

The heat transfer in a heat exchanger involves convection on each side of fluid and conduction taking place through the wall which is separating the two fluids. In a heat exchanger, the temperature of fluid keeps on changing as it passes through the tubes and also the temperature of the dividing wall located between the fluids varies along the length of heat exchanger.

Examples:

- Boilers, super heaters, reheaters, air preheaters.
- Radiators of an automobile.
- Oil coolers of heat engine.
- Refrigeration of gas turbine power plant.
- In waste heat recovery system.

Types:

1. Direct contact type of heat exchanger,
2. Non-contact type of heat exchanger.

Direction of motion of fluid:

1. Parallel flow,
2. Counter flow
3. Mixed flow.

2. Radiators

Radiators are heat exchangers used for cooling internal combustion engines, mainly in automobiles but also in piston-engine for cooling internal combustion engines, mainly in automobiles but also in pistonengine aircraft, railway locomotives, motorcycles, stationary generating plant or any similar use of such an engine.

IC engines are often cooled by circulating a liquid called engine coolant through the engine block, where it is heated, then through a radiator where it loses heat to the atmosphere, and then returned to the engine. Engine coolant is usually water-based, but may also be oil. It is common to employ a water pump to force the engine coolant to circulate, and also for an axial fan to force air through the radiator.

In automobiles and motorcycles with a liquid-cooled internal combustion engine, a radiator is connected to channels running through the engine and cylinder head, through which a liquid (coolant) is pumped. This liquid may be water (in climates where water is unlikely to freeze), but is more commonly a mixture of water and antifreeze in proportions appropriate to the climate. Antifreeze itself is usually ethylene glycol or propylene glycol (with a small amount of corrosion inhibitor).

The radiator transfers the heat from the fluid inside to the air outside, thereby cooling the fluid, which in turn cools the engine. Radiators are also often used to cool automatic transmission fluids, air conditioner refrigerant, intake air, and sometimes to cool motor oil or power steering fluid. Radiators are typically mounted in a position where they receive airflow from the forward movement of the vehicle, such as behind a front grill. Where engines are mid- or rear-mounted, it is common to mount the radiator behind a front grill to achieve sufficient airflow, even though this requires long coolant pipes. Alternatively, the radiator may draw air from the flow over the top of the vehicle or from a side-mounted grill.

For long vehicles, such as buses, side airflow is most common for engine and transmission cooling and top airflow most common for air conditioner cooling.

Most modern cars use aluminium radiators. These radiators are made by brazing thin aluminium fins to flattened aluminium tubes. The coolant flows from the inlet to the outlet through many tubes mounted in a parallel arrangement. The fins conduct the heat from the tubes and transfer it to the air flowing through the radiator.

The tubes sometimes have a type of fin inserted into them called a turbulator, which increases the turbulence of the fluid flowing through the tubes. If the fluid flowed very smoothly through the tubes, only the fluid actually touching the tubes would be cooled directly. The amount of heat transferred to the tubes from the fluid running through them depends on the difference in temperature between the tube and the fluid touching it. So, if the fluid that is in contact with the tube cools down quickly, less heat will be transferred. By creating turbulence inside the tube, all of the fluid mixes together, keeping the temperature of the fluid touching the tubes up so that more heat can be extracted, and all of the fluid inside the tube is used effectively. Radiators usually have a tank on each side, and inside the tank is a transmission cooler. The transmission cooler is like a radiator within a radiator, except instead of exchanging heat with the air, the oil exchanges heat with the coolant in the radiator. The radiator is the most important element of the cooling system and has the critical function of reducing temperature of the passing coolant. The "cooled" coolant continues recirculating throughout the engine, removing heat waste. The coolant carrying the heat waste from the engine moves into the radiator core via the inlet hose.

- The function of the radiator is to transfer heat from the hot water flowing through the radiator tubes to the air flowing through the closely spaced thin plates outside attached to the tubes.

A radiator consists of an upper tank, core & the lower (Collector) tank. Coolant from the engine enters the radiator at the top & is cooled by the cross flow of the air, while flowing down the radiator. The coolant collects in the collector tank from where it is pumped to the engine for cooling.
• Radiator is heat exchanger, in this case the fluids exchanging heat are on either side of dividing walls (in the form of pipes or tubes). These heat exchangers are used when two fluids cannot allow to mix i.e., the mixing is undesirable

Fig 1.1 Radiator

Coolant moves through the interior of tubes that are bounded to rows of fins at many points. Heat, since it will always more to a cooler place-moves from the coolant to the tubes, to the fins, and then to the outside air.

The fins are designed to create a pause in air flow around the tubes and to asset in greater heat dissipation. The heat movement from metal to air occurs primarily at the points where the tubing and fines meet the exact points of heat dissipation. The coolant enters into the "hot" or inlet tank of the radiator, moves through the tubing to the "cool" or outlet tank is re circulated. During normal operation between 7570 and 26500 litres of coolant will move through the radiator per driving hour.

Since overheating causes engine damage, the radiator must work quickly to transfer heat from the coolant into the air so that the cooled coolant can re circulate through the engine. There is an inlet and outlet tank bonded to header plates that hold the tubing and fines together on the inlet tank is a filler neck.

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The purpose of the radiator is to allow fresh air to reduce the temperature of the coolant. This is done by passing the coolant through tubes, as the coolant passes through the tubes; air is forced around the tubes. This causes a transfer of heat from the hot coolant to the cooler air.

This process is called heat exchange in this case, heat is exchanged from the coolant, to air, this is called a liquid to air heat exchanger, note that the coolant flows through the tubes and air flows through the air fins.

2.1 INTRODUCTION TO CARBON NANOTUBES

Heat transfer fluids such as water, minerals oil and ethylene glycol play an important role in many industrial sectors including power generation, chemical production, airconditioning, transportation and microelectronics. The performance of these conventional heat transfer fluids is often limited by their low thermal conductivities. According to industrial needs of process intensification and device miniaturization, development of high performance heat transfer fluids has been a subject of numerous investigations in the past few decades. It is well known that at room temperature, metallic solids possess an order-of- magnitude higher thermal conductivity than fluids. For example, the thermal conductivity of copper at room temperature is about 700 times greater than that of water and about 3000 times greater than that of engine oil. Therefore, the thermal conductivities of fluids containing suspended solid metallic or non-metallic (Metallic oxide) particles would be expected to be significantly higher than those of conventional heat transfer fluids. An inventive way of improving the heat transfer performance of common fluids is to suspend various types of small solid particles, such as metallic, non-metallic and polymeric particles, in conventional fluids to form colloidal. However, suspended particles of the order of µm (micrometre) or even mm (millimetre) may cause some problems in the flow channels, increasing pressure drop, causing the particles to quickly settle out of suspension. In recent years, modern nanotechnology has been discovered. Particles of nanometre dimensions dispersed in base liquids are called nanofluids. This term was first introduced by Choi in 1995 at the Argonne National Laboratory.Compared with millimetre or micrometre sized particle suspensions, nanotubes have shown a number of potential advantages such as better long-term stability and rheological properties, and can have significantly higher thermal conductivities.

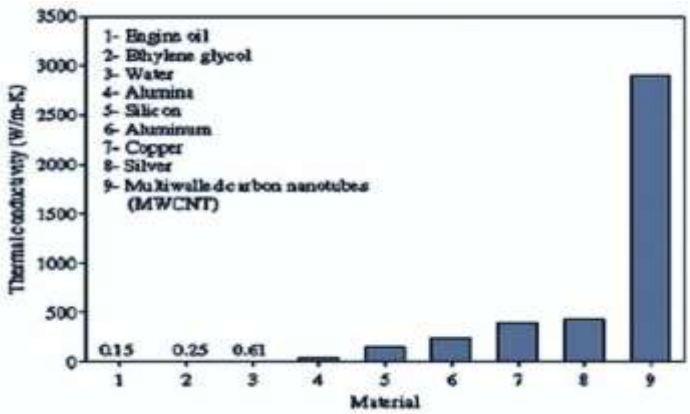

Figure 1.2: Thermal conductivity of typical materials (solids and liquids) at 30^{0C}

A number of researchers have researched and reported the correlations for predicting the thermal conductivity, density, viscosity and specific heat of the nanotubes. Understanding the physical and thermal properties of nanofluid is important before using nanofluids in practical applications. There are a few important correlations for predicting the thermo physical properties of nanofluids that are often cited by a number of researchers. Their works have both experimentally and theoretically investigated the heat transfer behaviour of the nanofluids.

The use of carbon nanotubes is one of the most effective mechanisms of increasing the amount of heat transfer in heat exchangers. The use of flat tubes, in which the fluid flow has a lower thermal resistance, is another way of improving the rate of heat transfer in tubes. The subject of the present paper is combining of the two mentioned methods for increase of heat transfer and parametric study of thermal and hydrodynamic performances of flow field. The word nanotubes refers to a mixture in which solid particles of nano size (generally less than 100 nm) are added to a base fluid and cause the increase of heat transfer in that mixture nanofluids are engineered by dispersion of fine metallic and non-metallic particles of nanometre dimension in traditional host liquids which include water, ethylene glycol, propylene glycol, oil etc. Use of such nanoparticles in the base fluids increase their thermal conductivity and heat transfer performance of nanotubes.

Nanotubes are new generation heat transfer fluids and can be used for heat transfer augmentations. Nanotubes have high heat transport capability and can replace traditional thermo fluids normally used for heat transfer applications in heat exchangers, chemical process plants, manufacturing processes, automotive and cooling of electronic components. Nanotubes are used in micro channel cooling without any clogging and sedimentation problems. The nanotubes can also be employed in high heat flux applications where single phase pure fluids are not capable of transferring the heat at desired rate.

Nanotubes conserve energy and hence preferred over conventional base fluids. Heat transfer augmentation using nanotubes are one of the emerging areas of research. Generally conventional single-phase fluids have low thermal conductivities when compared to metals and their oxides. The fluids with suspended particles of metals and metal oxides are supposed to exhibit better heat transfer properties than the conventional fluids without solid particles. Particles clogging, sedimentation and erosion are some of the common problems associated with the use of micro or millimetre sized solid particles when suspended in the host fluids.
Such problems can be minimized by replacing micrometre sized particles by nano sized particles.

Heat transfer enhancement in fluids can be affected primarily by two techniques viz. passive heat transfer technique and active heat transfer technique. Passive heat transfer techniques can be employed by provision of rough and extended surfaces tubes and creation of swirl in the flow using inserts of certain geometrical shape. Active heat transfer techniques include applying of electric/magnetic fields, inducing vibrations in the heated surface, injection and jet impingement of fluids etc. Compact heat exchangers with higher performance demand fluids having better heat transfer capabilities. Such devices result in material saving, energy conservation and hence low cost of heat exchangers. Nanofluids improve thermal conductivity of host fluids and now become important area of research attracting the attention of many researchers across the world. The nanotubes will quench the thirst of investigators who are in quest to engineer better heat transfer fluids. Heat transfer coefficient and friction factor are two important parameters associated with thermo fluids. Many experimental as well as theoretical investigations have been carried out to study heat transfer and pressure drop characteristics of pure fluids. Use of two phase nanofluids for heat transfer enhancement has boosted the research interest among many research groups across the globe.

Literature confirmed that nanofluids give higher heat transfer coefficient compared to the base fluid. The investigation results on nanofluids indicated that heat transfer coefficient increases with the increase of nanoparticle concentration in the base fluid.

Most of the research works done so far on nanofluids are experimental studies and confined either to laminar or turbulent flow conditions. The host or base fluid is water in majority of the cases. In severe cold climatic conditions glycols are added to water in different proportions to reduce the freezing point of heat transfer liquids. Glycol based fluids are used in base board heaters, automobile radiators and process plants particularly in cold countries where the ambient temperatures are below zero degree Celsius.

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2.2 The characteristic features of the nanotubes include:

1) Significant increase in the thermal conductivity with low volume concentrations.
2) Stronger dependence of thermal conductivity on temperature than the base- fluid alone.
3) Increased critical heat flux for pool boiling scenarios.
4) Substantial increase in heat transfer coefficient.

2.3 TYPES OF NANOFLUIDS
Single-walled Carbon Nanotubes

It is represented as SWCNT. The Single-walled Carbon nanotubes exist in a I-d structure.
Some examples of Single-walled CNT are armchair and zigzag Single-walled Carbon nanotubes Properties of Single-walled Carbon Nanotubes are:
•The diameter of Single-walled Carbon nanotubes is 2nm.
•The length of Single-walled Carbon nanotubes is around 2 micrometers.
•They exist in a one-dimensional structure. Therefore, it is also known as a nanowire.
•Electronics can be miniaturized by using a Single-walled Carbon nanotube.
•Their band gap varies from 0-2 electron volts (eV).
•They show conductivity like a semiconductor. Therefore, they exhibit both metallic and semiconductivitybehavior.

2.4 MULTI WALLED CARBON NANOTUBES
Multi Walled Carbon Nanotube Description The Multi Walled Carbon Nanotubes (MWCNTs) made from carbon tubular concentric tunnels with around 10-9mm diameter. It is a composite structure of concentrically layered carbon nanotubes nested in each other. It is an allotrope of carbon (i.e., graphene), one of the most robust materials for many purposes and applications. The MWCNTs are highly resistant to chemicals and do not produce heat. Therefore, they are mainly used in many devices that tend to heat up for longer hours. Being highly conductive, they are remarkable in exhibiting electricity. MWCNTs Structure An MWCNTs consists of a minimum of 3 and a maximum of 20 nanotubes. Similarly, the inner nanotube's minimum diameter is 2 nm, whereas it is 50 nm for the external tube. Multi walled carbon nanotubes suppliers prefer it over the other nanotubes because the quantity produced by this mixture is bulk, and the cost of production is significantly cheaper. We produced this material by using a Catalytic Chemical Vapour Deposition (CCVD) method. The SEM and TEM analysis shows that our MWCNTs materials diameter and length are 5-20 nm and 10 microns, respectively. The purity of the material is more than 99.99%, whereas it contains a negligible amount of impurities.

- Number of Layers – 4 to 8
- Material Form – Powder
- Colour – Black • Purity – > 99.99%
- Outer diameter – 10-15nm
- Length – 10 μm
- Specific Surface Area – 400 m2/gm
- Bulk Density – 0.20-0.35 G/cm3
- Thermal Conductivity – >3000 W/m.k
- Tensile Strength – 10-60 GPa

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2.5 Physical properties of base fluids and nanoparticles at 30 ^{0}C.

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S. No	Base Fluids/Nanotubes	Diameter (nm)	Viscosity (N - m²/sec)	Density (kg/m3)	Thermal conductivity (W/mK)	Specific Heat (J/KgK)
1	Water	-	0.00081	997.5	0.6130	4178
2	Ethylene Glycol	-	0.00226	1055.39	0.4210	3502

3	Carbon Nanotubes Mixer	1-10 nm	-	0.20-0.35	3000	5177

2.6 RESULT AND DISSCUSSION

In this section the calculations for pure water (base fluids) and different percentages of nanofluids are discussed. The obtained results are tabulated and the graphs are between inlet tube temperature difference, heat transfer rate, and fin temperature difference at different temperatures on constant pm. The automotive radiator was run at constant flow rates 5 litres/min at inlet temperatures(Room Temperature). A temperature difference (AT) was recorder for each flow rate, respectively. These obtained results are drawn graphically.

SIMPLE CALCULATIONS:
FORMULAE:

Heat transfer Q=m*Cp*ΔT Q
= m*Cp*(Tin - Tout)

m = mass(kg)
Cp= Specific heat (J/kgK)
T_{in}= inlet temperature (°C)
T_{out} =outlet temperature (°C)
Q = heat transfer rate (kJ/s)

1.Water

Heat transfer Q = m*cp*(Tin - Tout)
=3*4.178*(45-32.6) (for 3 min)
=155.4 kJ/sec

Heat transfer Q = m*cp*(Tin - Tout)
=3*4.178*(48-30.9) (for 5 min)
=214.6 kJ/sec

2.Ethylene Glycol

Heat transfer Q = m*cp*(Tin - Tout)
= 3*3.502*(48-30.7) (for 3 min)
= 181.7 kJ/sec

Heat transfer Q = m*cp*(Tin - Tout)
= 3*3.502*(52-28.9) (for 5 min)
= 242.4 kJ/sec

3.cnt mixer coolant

Heat transfer Q = m*cp*(Tin - Tout)
= 3*5.177*(46-29.3) (for 3 min)
= 259.36 kJ/sec

Heat transfer Q = m*cp*(Tin - Tout)
= 3*5.177*(48-27.1) (for 5 min)
= 324.59 kJ/sec

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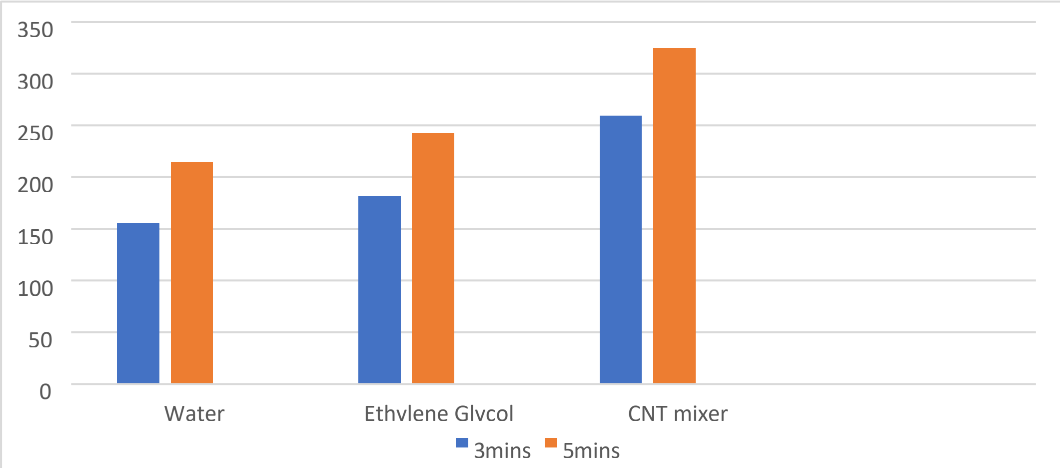
GRAPHICAL REPRESENTATION OF HEAT TRANSFER



COMPARISION OF HEAT TRANSFER BETWEEN BASE FLUID AND NANOTUBE MIXER COOLANT

S.NO	MASS (KG)	TYPE OF COOLANT	RADIATOR INLET TEMPERATURE (^{0}C)		RADIATOR OUTLET TEMPERATURE (^{0}C)	HEAT TRANSFER (KW)
1	3	Water	3 min	45	32.6	155.4

			5 min	48	30.9	**214.6**
2	3	Ehtylene Glycol (50% EG+ 50% W)	3min	48	30.7	181.7
			5 min	52	28.9	**242.4**
3	3	CNT mixer (1.8% CNT + 4% SLS + 94.2% W)	3 min	46	29.3	259.3
			5 min	48	27.1	**324.5**

Advantages

1. Improved fuel efficiency: By keeping the engine cooler, fuel consumption can be reduced, resulting in better fuel efficiency.
2. Lower emissions: Cooler engine temperatures can lead to lower emissions, which can help reduce the impact on the environment.
3. Longer engine life: By reducing the amount of heat generated by the engine, the lifespan of the engine can be extended, reducing the need for repairs or replacements.
4. Improved performance: Cooler engine temperatures can result in better engine performance, including better acceleration and smoother operation.

I. Conclusion

In the project the experimental heat transfer coefficient in the may have been measured with three working liquids the water, Ethylene Glycol, Carbon nanotube mixer coolant an centration's and temperatures. The presence of Carbon Nanotubes mixer coolant can enhance the best de rate of the automobile radiator. The degree of the heat transfer is depends on the amount of nanoparticles added to the base fluid. Ultimately, the heat transfer enhancement of 33%to base fluid was observed. Increasing the flow rate of working fluid (or equally Re) enhances the heat transfer coefficient for both pure water and nanofluid considerably while the variation of fluid inlet temperature to the radiator (in the ring tested) slightly changes the heat transfer performance.

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