EFFECT OF HEAT TRANSFER USING NANOFLUIDS IN AUTOMOBILE RADIATOR WITH TWISTED TUBES

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ABSTRACT

With the advancement in the field of second-minute engineering, countless steps are being taken to reduce heat production or to increase heat dissipation that is part of almost all engineering processes. It could be a rooftop fan, or a cool fan near a computer CPU, or a radiator next to a car engine.

As mechanical engineers, our attention span has been reduced to that of a car radiator. The project consists of two programs, namely Mechanical Design and Applied Chemistry approved together to develop a new device that will increase the temperature of the radiator fluid which will eventually cool the engine more efficiently.

In our final year project, we aim to use Copper oxide, Aluminum oxide and Titanium oxide nanofluid as a coolant in a car radiator with twisted tubes and find its heat transfer effect and compare its effects with conventional cooling available, resulting in reduced radiator size and compacted hence increasing engine efficiency.

Keywords: Automobile engine, Radiator, Twisted Tube; Thermal conductivity; Effectiveness; Coolant; Copper oxide/water; Nanofluid.

CHAPTER-1

OVERVIEW

1. NANOFLUID

Nanofluids are stable suspensions of nanoparticles (1-100nm) in base fluids that show many interesting properties, and their distinctive features offer unprecedented potential for many applications. Our project highlights one of the uses of nanofluids through various routes and presents the current and future applications in the mechanical field.

The effective thermal conductivity enhancement achievable by nanoparticle suspensions is understood to be as a result of two different mechanisms.

1. The first is the contribution resulting from the higher thermal conductivity of the nanoparticle.
2. The second contribution is said to be due to the movement of the Nano-particles themselves, which produces enhanced thermal transport.

It was experimented that introducing nanofluids as an alternative to the conventional fluid enhanced the thermal conductivity more than 3 times.

The literature has revealed that the low thermal conductivity of these common base fluids is a primary limitation in enhancing the performance and the compactness of many devices. When nanoparticles are added to these base fluids, anomalous, but understandable behavior, results. Nanofluids have a substantially larger thermal conductivity compared to that of the common base fluids. The suspended nanoparticles in the fluid can change the transport and thermal properties of the common base fluid. A drastic increase in thermal conductivity is observed with the addition of the nanoparticles to the base fluid and this is observed to increase non-linearly with increased nanoparticle concentration. The thermal conductivity of a nanofluid is found to be highly temperature dependent.

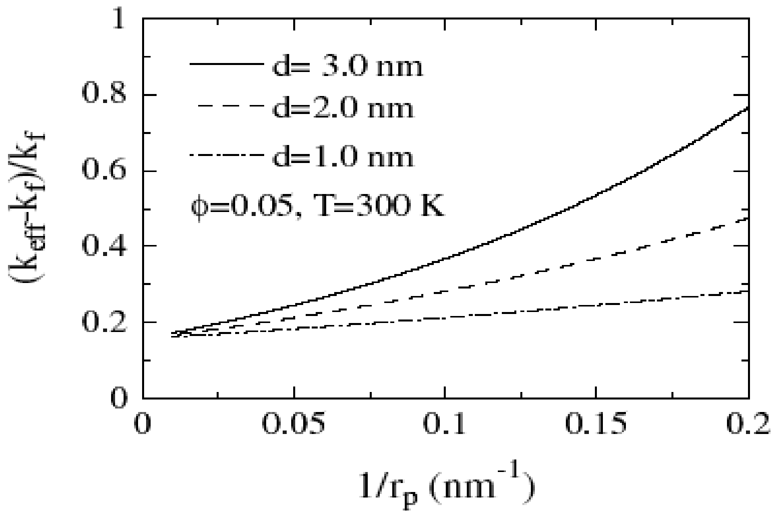

Fig.1.1 Dependence of thermal conductivity enhancement on Oxide/water Nanofluid on the reciprocal of the nanoparticle radius.

2. TWISTED TUBE HEAT EXCHANGER

Heat transfer rate enhancement is one of the fast growing areas of Heat transfer technology .In fact techniques are available for the improvement of various modes of heat transfer. Second and third generation enhancement technology is already in use in process industry. Coming to the Heat exchanger technology twist type heat exchangers, corrugated surface heat exchangers and extended surface heat exchangers have greater advantages when compared with conventional type of heaters.

A twisted tube is a passive heat transfer enhancement device, generally classified in a swirl type flow device category. Swirl flow devices consist of a greater variety of geometrical flow arrangements in order to produce a stable form of forced vortex fluid motion in confined flows. This device facilitates fluid agitation and mixing of heat patterns induced by swirl flow. The main advantages are mainly they do not require extra attention during assembly, maintenance, inspection and cleaning when intermediate viscous fluids are used.

This device consists of helically twisted double radius oval tubes, welded their round ends to tube sheets. This device design is similar to structure of Human DNA which is double helical in patterns and extended all along the length and finally ends with DNA stands. The tubes contact one another at their wider sides, six times over the length of one twist pitch which makes the unit practically vibration free. The purely longitudinal shell side flow in twisted tube bundles thereby has an ability to provide high surface area (and density), low pressure drops, good heat transfer rates and coefficients.

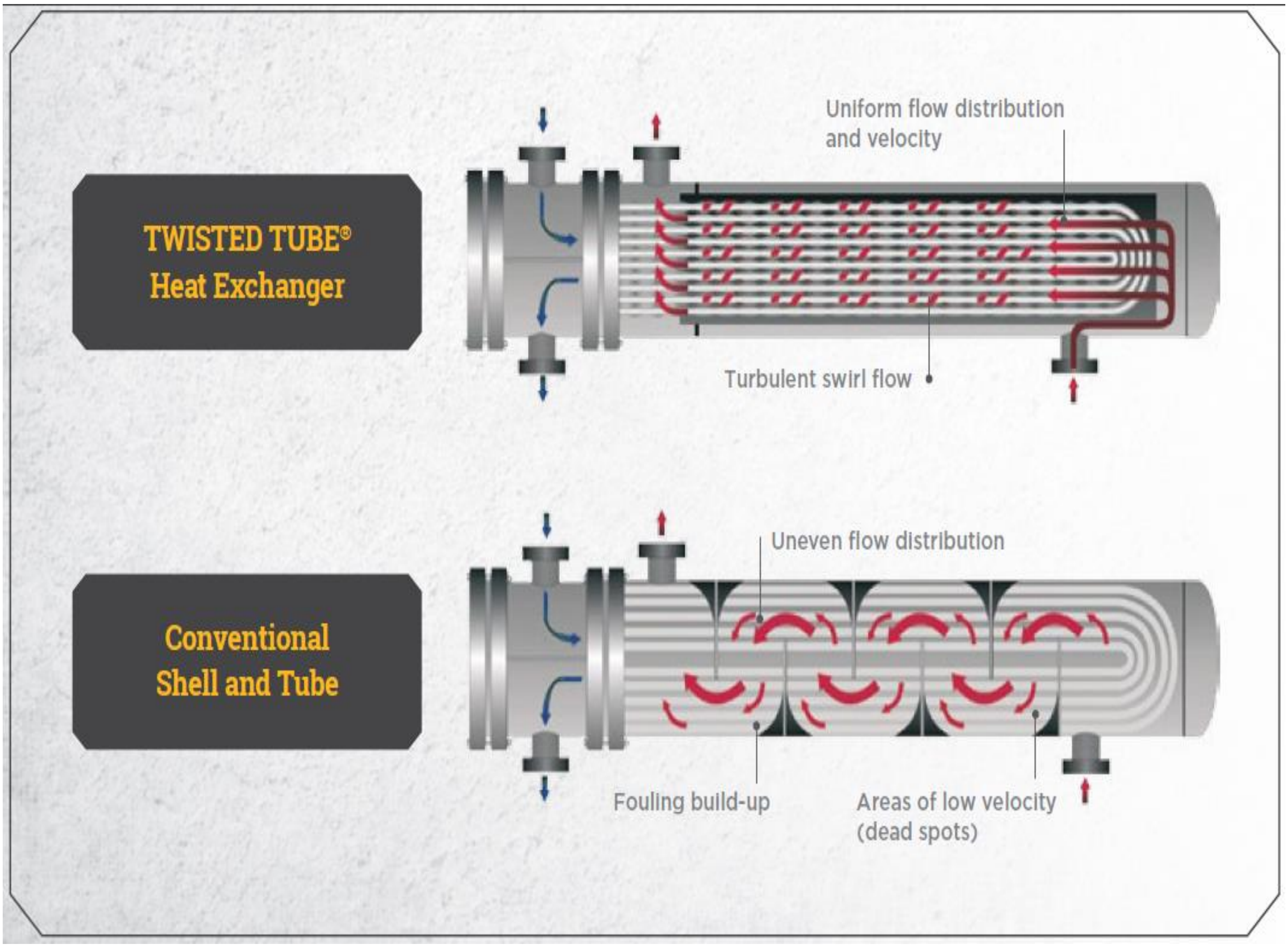

Fig.1.2 Comparison between twisted tube and conventional heat exchanger

This project represents nanofluid as a new coolant technology in automobile engines compared with a conventional coolant (Ethylene glycol/water) experimentally. The increase in thermal conductivity of the base fluid (water) by adding nanoparticles in certain ratios leads to higher amount of heat absorption from engine block.

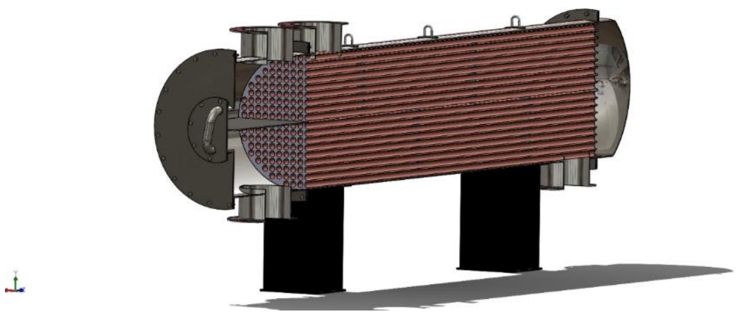

Fig.1.3 Cross section of conventional tube heat exchanger

CHAPTER 2

INTRODUCTION

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).

A typical automotive cooling system comprises:

- a series of channels cast into the engine block and cylinder head, surrounding the combustion chambers with circulating liquid to carry away heat;
- a radiator, consisting of many small tubes equipped with a honeycomb of fins to convict heat rapidly, that receives and cools hot liquid from the engine;
- a water pump, usually of the centrifugal type, to circulate the liquid through the system;
- a thermostat to control temperature by varying the amount of liquid going to the radiator;
- a fan to draw fresh air through the radiator.

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.

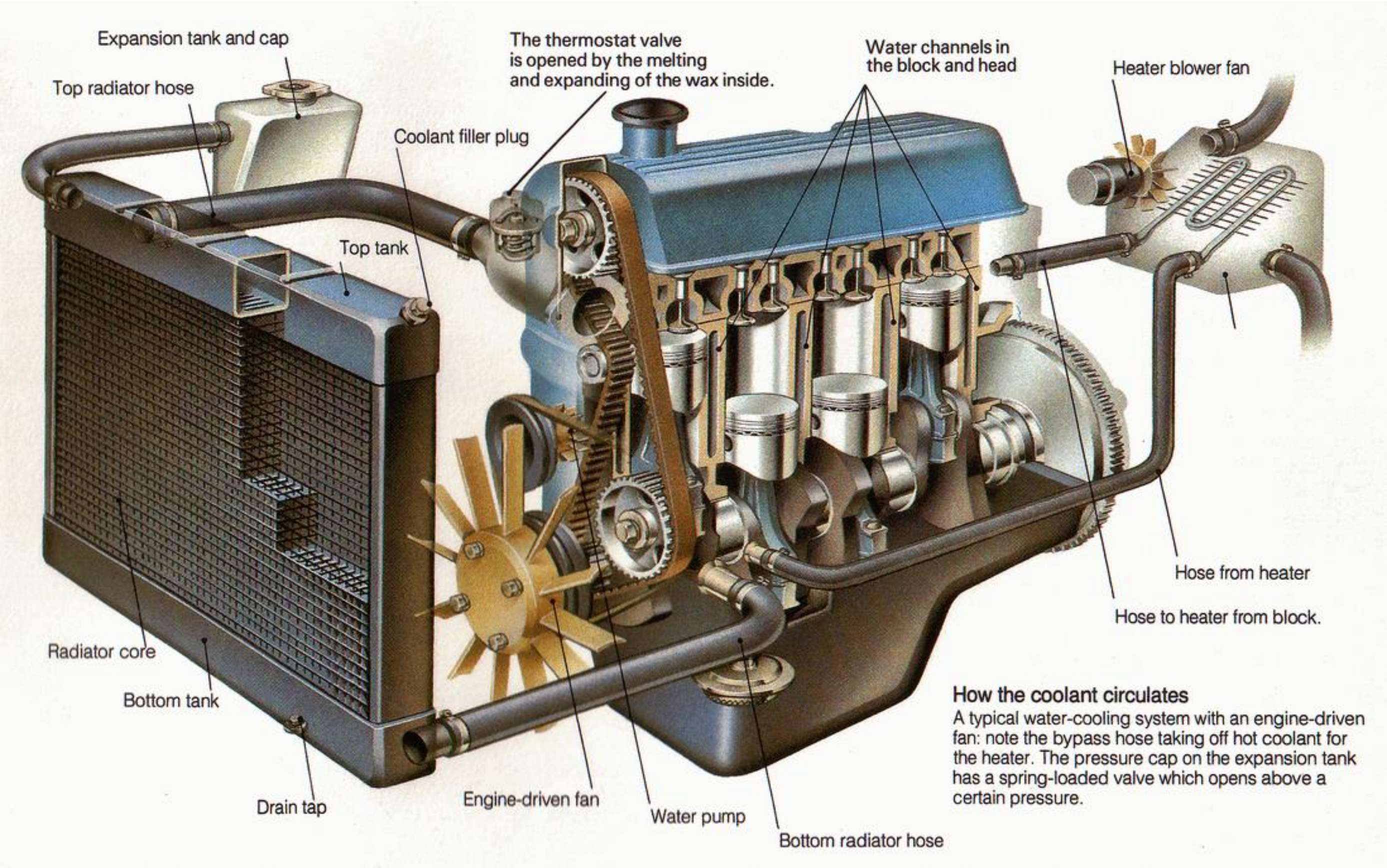

Fig. 2.1 Engine-Radiator Assembly

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

There are many noticeable studies for enhancement of the application of heat transfer fluid. Recently many researchers found that dispersing high thermal conductivities nanometer size (diameter of 1–100 nm) particles into the liquids gives highest thermal conductivity liquid compared with the (base) original liquid, these fluids are called nanofluids, **Taylori**.

Eastman showed that thermal conductivity of ethylene glycol with 0.3% concentration ratio of (Cu) nanoparticles can be improved up to 45% compared with ethylene glycol (EG).

Y. Dingetal showed that convection coefficient heat transfer of nanofluids was higher at the tube entrance length. But it decreases with axial length and consummate the fully developed region at a constant value. Carbon nanoparticles offer highest improvement at a taken nano particle concentration and flow.

CHAPTER 3

PROBLEM IDENTIFICATION

Internal combustion engines are often cooled by circulating a liquid called engine coolant around 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.
Increasing power from engines in smaller bonnet spaces makes a problem because of insufficient rates of heat dissipation in automotive radiators.

More than 35% of the energy produced by the engine through internal combustion is lost as heat. The overheating in engines is a result of insufficient heat dissipation from these engines that leads to breakdown of lubricating oil, engine parts weakening, and wear between these parts. To keep or eliminate the problems in the engine resulted from high heat generated from combustion, automotive radiators must be more effective to have high levels of heat transfer performance to reject heat or the coolant fluid must be more effective. Production power within the engine comes through combustion of fuel and air mixture. Just a portion of the total power generated is actually power supplied to the automobile; the rest is wasted in the form of heat and exhaust. If this excess heat is not rejected, the engine temperature will overheat and breakdown lubricating oil viscosity, which lead to damage the engine.

The automobile cooling system consists of a radiator, water pump, cooling fan, pressure cap of radiator and thermostat. The cooling fluid (coolant) plays important roles in the cooling mission (coolant moves through the engine’s cylinder block and accumulates heat to reject it through the radiator). Conventional automobile cooling fluids, such as water, ethylene glycol, etc. have poor heat transfer performance (such as thermal conductivities), that lead to more problems in automobile engines in summer season in hot climate regions. Therefore, high tightness and effectiveness of heat transfer systems are important to enhance the rate of heat transfer.

CHAPTER 4

REVIEW OF LITERATURE

Production Of Nanoparticles

Production of nanoparticles can be divided into two main categories, namely, physical synthesis and chemic synthesis. Listed are the common production techniques of nanofluids as follows.

Physical Synthesis: Mechanical grinding, inert-gas-condensation technique.

Chemical Synthesis: Chemical precipitation, chemical vapor deposition, micro-emulsions, spray pyrolysis, therm spraying.

Production of Nanofluids

There are mainly two methods of nanofluid production, namely, two-step technique and one-step technique.

In the **two-step technique**, the first step is the production of nanoparticles and the second step is the dispersion o the nanoparticles in a base fluid. Two-step technique is advantageous when mass production of nanofluids considered, because at present, nanoparticles can be produced in large quantities by utilizing the technique of ine gas condensation. The main disadvantage of the two-step technique is that the nanoparticles form clusters during th preparation of the nanofluid which prevents the proper dispersion of nanoparticles inside the base fluid.

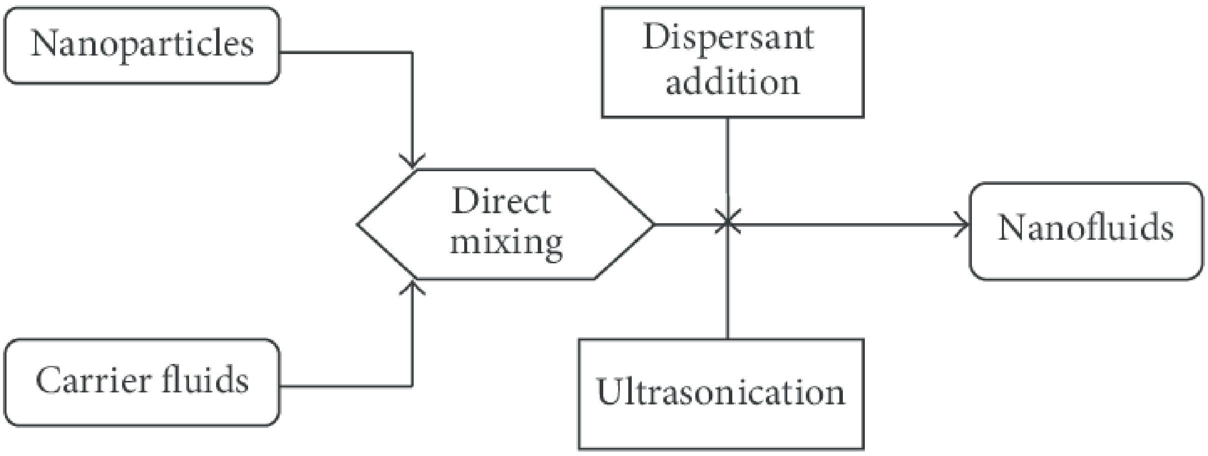

Fig.4.1: Two step method for preparing Nanofluid

One-step technique combines the production of nanoparticles and dispersion of nanoparticles in the base fluid int a single step. There are some variations of this technique. In one of the common methods, named direct evaporatio one-step method, the nanofluid is produced by the solidification of the nanoparticles, which are initially gas phas inside the base fluid. The dispersion characteristics of nanofluids produced with one-step techniques are better tha those produced with two-step technique. The main drawback of one-step techniques is that they are not proper fo mass production, which limits their commercialization.

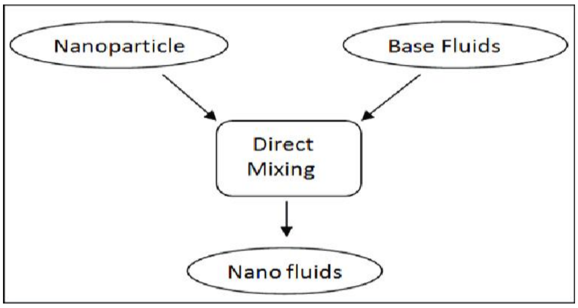

Fig.4.2 One step method to prepare Nanofluids.

Surfactant

Surfactants are compounds that lower the surface tension (or interfacial tension) between two liquids, between a gas and a liquid, or between a liquid and a solid. Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents, and dispersants.

Surfactants are usually organic compounds that are amphiphilic, meaning they contain both hydrophobic groups (their *tails*) and hydrophilic groups (their *heads*). Therefore, a surfactant contains both a water-insoluble (or oil-soluble) component and a water-soluble component. Surfactants will diffuse in water and adsorb at interfaces between air and water or at the interface between oil and water, in the case where water is mixed with oil. The water-insoluble hydrophobic group may extend out of the bulk water phase, into the air or into the oil phase, while the water-soluble head group remains in the water phase.

World production of surfactants is estimated at 15 Mton/y, of which about half are soaps. Other surfactants produced on a particularly large scale are linear alkylbenzene sulfonates (1700 kton/y), lignin sulfonates (600 kton/y), fatty alcohol ethoxylates (700 ktons/y), and alkylphenol ethoxylates (500 kton/y).

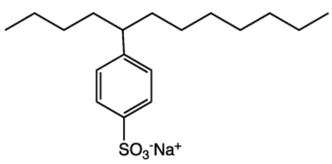

Fig.4.3: 4-(5-Dodecyl) benzenesulfonate, a linear dodecyl benzenesulfonate, one of the most common surfactants.

Nanofluid Preparation for the Experiment

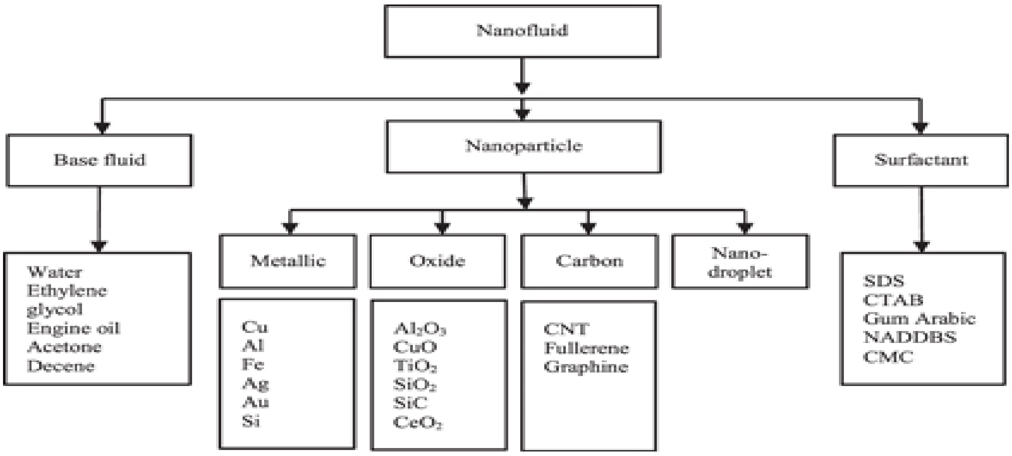

Fig.4.4: Preparation of Nanofluid (Tabulated View)

Twisted Tube Heat Exchanger

Twisted tube heat exchangers are compact having values of thermal conductivity. In process design and development these exchangers have wide range of applications than the niches currently being used in industry. In 1994, Koch Heat Transfer has been manufacturing and marketing twisted tube heat exchanger to world market. Their opinion was that main barrier to heat flow in conventional heat exchangers is the convective resistance to heat flow on inner and outer tube surface.

Considering losses and resistances thermal effectiveness is only 60-80% with the back-and-forth flows of shell side fluid giving higher pressure drop than expected value. Also, flow around baffles is not uniform creating fouling, dead spots, and low heat transfer. Instead, they suggested the use of these as a solution in which the tubes are subjected to a unique forming process in one step ensuring constant tube thickness and yield point is not exceeded which results in oval tubes twisted along the longitudinal axis.

The twist pitch's' is the tube length between each 360-degree twist. In twisted tubes the swirl flow produces secondary flow which enhances turbulence in low Reynolds number range. Materials used for tubes are carbon steels, stainless steels, titanium, copper and nickel alloys. Pressure drop in the shell side is low because of baffle free design and shell side no sharp diversion of fluid. The twisting of tubes produces swirl flow which enhances tube side mixing. The shell side flow path is complex and axial in nature. There is no solution that makes one technology absolutely superior, but there are technologies that for particular applications are more suited than others this concept are most required in process designing and development.

CHAPTER-5

EQUIPMENTS, DEVICES AND SETUP.

Fig.5.1 Thermometer

Fig.5.2: Rotameter

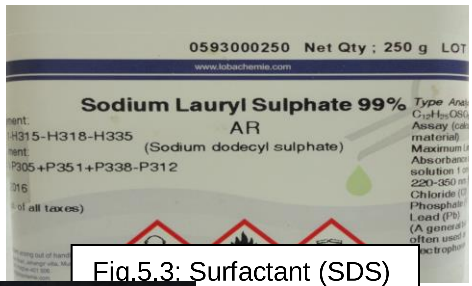

Fig.5.3: Surfactant (SDS)

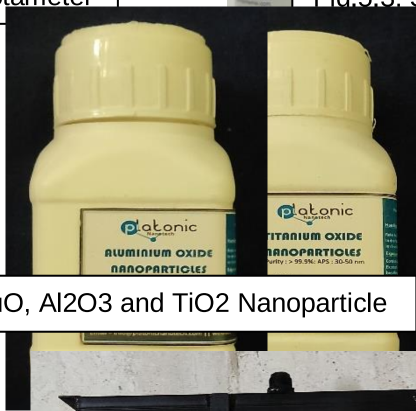

Fig.5.4 CuO, Al2O3 and TiO2 Nanoparticle

CHAPTER 6

PREPARATION OF NANOFLUID

Sonication

CuO nanofluids of different concentrations (0.05%, 0.1%, 0.15%, 0.2%) are prepared at various sonication times (2, 3 and 4 hours) and their effects on the heat transfer characteristics are investigated. Accordingly, an unsteady state heat transfer analysis of a heated vertical cylinder cooled in the aforesaid a CuO nanofluid is carried out. Investigation shows that the sonication time greatly influences the heat transfer performance of the nanofluids and this influence is affected by the nanoparticle concentration. However, a solid conclusive remark as an increasing or decreasing trend could not be observed during these studies. More research needed in future to determine the exactness Sonication time effect.

Fig.5.4: CuO, Al2O3 and TiO2 Nanoparticle

Fig.6.1: Sonication as a method of Dispersion

Fig.6.2 Sonicator Apparatus

SONICATION

- 2-step method to prepare Nanofluid.
- Particle loading- 0.05% by volume of base fluid.
- 0.05% comes out to be 8.39 grams of base fluid i.e., 2.5 liters of distilled water.
- Surfactant used: Sodium Dodecyl Benzene Sulphonate (SDBS) 10% wt. of CuO nanoparticle.

The nanoparticle was dispersed in the distilled water in a conical flask along with SDBS surfactant.

Table 6.1: Preparation steps of CuO Nanofluid.

Nanoparticles type	Base fluid	Synthesis process	Particle loading (vol. %)	Particle size (nm)	Dispersion method	Stability
CuO	Distilled water	Two-step	0.05 vol.%	NR	Sodium dodecyl benzene sulphonate (SDBS) of 10 wt.% of nanoparticles (reason: to prevent immediate settlement as CuO NPs have high density (6310 kg·m^{-3}) compared to water (995 kg·m^{-3})) + sonication for 60 min	Best with SDBS
CuO	Oleic acid	Two-step	1, 1.5, & 2	NR	Ultrasonicated at a frequency of 40 kHz	NR
CuO	EG + water	Two-step	NR	<40	Polyvinylpyrrolidone (PVP) with weight ratio of 0.25 : 1 (PVP : CuO) + mixture stirred and agitated thoroughly for 30 min	NR
CuO	Water	Two-step	NR	NR	Ultrasonic bath (100 W) for 4 hours	25 days

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PERFORMANCE

The performance was carried out to calculate the difference in the inlet and outlet temperatures of both the radiators (i.e., conventional radiator and the twisted tube radiator) with both the coolants (i.e., Ethylene Glycol and CuO, Al2O3 and TiO2 Nanofluid). The following table relates to the combinations that have been experimented so as to draw out the contrast amongst them.

The readings are based on 4 combinations:

Sr. No.	Type of Radiator	Type of Coolant
1.	Conventional Radiator	Ethylene Glycol (EG)
2.	Conventional Radiator	CuO, Al2O3 and TiO2 Nanofluid
3.	Twisted Tube Radiator	Ethylene Glycol (EG)
4.	Twisted Tube Radiator	CuO, Al2O3 and TiO2 Nanofluid

Conventional Radiator-Nanofluid			
Time(min)	Inlet temperature of radiator (˚C)	Outlet temperature of radiator (˚C)	Difference in Temperature (˚C)
1	60	45	15
2	70	52	18
3	75	55	20
4	82	58	24
5	90	59	31

Average=16.75 ˚C

Average=21.6 ˚C

2. Twisted Tube Radiator

Twisted Tube- Ethylene Glycol			
Time(min)	Inlet Temperature of radiator (˚C)	Outlet Temperature of radiator (˚C)	Difference (˚C)
1	55	35	20
3	70	47	23
5	77	53	24
7	82	56	26
			Average=23.25 ˚C

Twisted Tube- Nanoparticle			
Time(min)	Inlet temperature of radiator (˚C)	Outlet Temperature of radiator (˚C)	Difference (˚C)
1	58	32	30
3	80	52	28
5	85	57	28
7	90	55	35
9	90	45	35
10	95	40	55
			Average=36.8 ˚C

CHAPTER-8

CONCLUSION

Thus, from the above observation tables and calculations, Nanofluids along with the twisted tube radiator is observed to increase the heat transfer rate by 54% as compared to the conventional conditions.

Nanofluid along with twisted tube radiator increases the heat transfer rate by 41.3% as compared to the conventional radiator with Nanofluids comparatively.

It is therefore observed by the experiment that introducing nanofluids as a coolant as well as replacing Radiator with a twisted tube Radiator results in better heat transfer conduction compared to the conventional coolant, thereby cooling the automobile engine in smarter manner as compared to the conventional coolant.

CHAPTER-9

FUTURE SCOPE

Vehicle cooling has a very important technological importance as it directly or indirectly related to engine performance, fuel economy, vehicle aerodynamics, passenger comfort, maintenance, component life etc. Researchers have already acknowledged the high heat transfer capability of nanofluids relative to their host fluids. Therefore, such fluids can be a better option for coolants in automobiles. All automobiles in the market today have a type of heat exchanger popular as radiator.

A radiator is an important part of the complex cooling system of an automotive engine. Recent trend towards high heat dissipation results in larger radiators and increase frontal areas leading to additional viscous drag and rise in engine fuel consumption. Therefore, cooling is one of the important engineering challenges being faced by automobile industries specially the heavy vehicle (HV) industries. Nanofluids can overcome these problems. Due to their high heat transfer capacity, replacement of traditional coolants (Ethylene Glycol - Water mixture) with nanofluids has already been proved to increase heat transfer rate from the radiator.

According to some researchers such improvement can be used to remove more engine heat from higher horsepower engines with a relatively smaller radiator. Also down scaling of engine radiator can be beneficial to overcome aerodynamic drag along with rise in fuel economy due to lighter weight. Nanofluids can be used in the cooling jacket in IC engines. Ollivier numerically examined the probable application of nanofluids as coolant in cooling jacket of gas spark ignition engine. Their numerical simulations of unsteady heat transfer through the engine cylinder and the coolant flow showed that due to higher thermal diffusivity of nanofluids, the thermal signal variations for knock detection increased by 15% over that predicted by water alone.

CHAPTER-10

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