ANALYTICAL INVESTIGATION OF HEAT TRANSFER ENHANCEMENT IN A MICRO TUBE USING NANO FLUIDS

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Abstract— In the last few years, the fast growth of research in the heat transfer area was improved by using new kind of heat transfer fluids called nanofluids which have nanosized particles. Forced convective laminar flow of different types of nanofluids such as (TiCand MgO), with different volume fractions 0.4 and 0.5 using water as base fluids was investigating by using CFD analysis.

The Micro tube (MT) with 0.01 cm diameter and 20 cm length is using in this investigation. This investigation covers Reynolds number in the range of 90 to 800.

CFD analysis to determine the heat transfer coefficient, heat transfer rate, pressure drop and mass flow rate at different NANO fluids(MgO and TiC) at different volume fractions 0.4 &0.5.

Thermal analysis to determine the temperature distribution and heat flux with different materials. present used material for micro tube copper, replaced with composite materials.

INTRODUCTION TO CAD

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD [Type text]

output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

Its use in designing electronic systems is known as electronic design automation,

or EDA. In mechanical design it is known as mechanical design automation (MDA)

or computer-aided drafting (CAD), which includesthe process ofcreating a technical

drawing with the use of computer software.

CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output

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of CAD must convey information,suchas materials, processes, dimensi ons, 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) space.

INTRODUCTION TO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling

applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

The name was changed in 2010 from Pro/ENGINEER Wildfire to CREO. It was announced by the company who developed it, Parametric Technology Company (PTC), during the launch of its suite of design products that includes applications such as assemblymodeling, 2D orthographic views for technical drawing, finite element analysis and more.

PTC also offers comprehensive training on how to use the software. This can save businesses by eliminating the need to hire new employees. Their training program is available online and in-person, but materials are available to access anytime.

A unique feature is that the software is available in 10 languages. PTC knows they have people from all over the world using their software, so they offer it in multiple languages so nearly anyone who wants to use it is able to do so.

The time saved by using PTC CREO isn't the only advantage. It has many ways of saving costs. For instance, the cost of creating a new product can be lowered because the development process is shortened due to the automation of the generation of associative manufacturing and service deliverables.

ADVANTAGES OF CREO PARAMETRIC SOFTWARE

1. Optimized for model-based enterprises
2. Increased engineer productivity
3. Better enabled concept design

4. Increased engineering capabilities
5. Increased manufacturing capabilities

6. Better simulation
7. Design capabilities for additive manufacturing

CREO parametric modules:

[Type text]

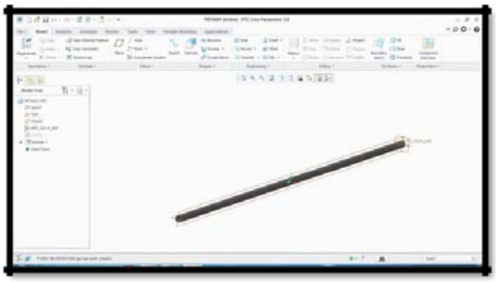
- Sketcher

- Part modeling

- Assembly

- Drafting

3D MODEL OF MICRO TUBE



2d model of micro tube

INTRODUCTION TO FEA

Finite Element Analysis (FEA) was first

developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational 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. Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day

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supercomputers are now able to produce accurate results for all kinds of parameters.

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.

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

[Type text]

- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection

- Point, pressure and gravity dynamic loads.

Types of Engineering Analysis

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in.

Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Fatigue analysis helps designers to predict the life of a material or structure by showing the

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effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

CALCULATIONS TO DETERMINE PROPERTIES OF NANO FLUID BY CHANGING VOLUME FRACTIONS

Volume fraction= 0.4 & 0.5(taken from journal paper)

MATERIAL PROPERTIES MAGNESIUM OXIDE Density = 3560 kg/m3

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Thermal conductivity =45 W/m-k

Specific heat = 955 J/kg-k

TITANIUM CARBIDE

Density = 4930 kg/m3

Thermal conductivity =330 W/m-k

Specific heat = 711 J/kg-k

WATER

Density = 998.2 kg/m3

Thermal conductivity = 0.6 W/m-k

Specific heat = 4182 J/kg-k

Viscosity = 0.001003kg/m-s

NOMENCLATURE

ρnf = Density of nano fluid (kg/m3)

ρs = Density of solid material (kg/m3)

ρw = Density of fluid material (water)

(kg/m3)

ϕ = Volume fraction

Cpw = Specific heat of fluid material (water)

(j/kg-k)

Cps = Specific heat of solid material (j/kg-k)

μw = Viscosity of fluid (water)

(kg/m-s)

μnf = Viscosity of Nano fluid (kg/m-s)

Kw = Thermal conductivity of fluid material (water) (W/m-k)

Ks = Thermal conductivity of solid material (W/m-k)

NANO FLUID CALCULATIONS

MAGENSIUM OXIDE

[Type text]

DENSITY OF NANO FLUID At ϕ =0.4

$$\rho nf = \phi\times\rho s + [(1-\phi) \times \rho w]$$

ρnf = 2022.92 kg/m3 At ϕ =0.5

ρnf = 2025.94 kg/m3

SPECIFIC HEAT OF NANO FLUID

$$Cp\ nf = \frac{\phi\times\rho s\times Cps + (1-\phi)(\rho w\times Cpw)}{\phi\times\rho s+(1-\phi)\times\rho w}$$

At ϕ =0.4

Cp nf = 1910.408 j/kg-k

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At ϕ =0.5

Cp nf = 1900.404 j/kg-k

VISCOSITY OF NANO FLUID μnf =μw (1+2.5ϕ)

At ϕ =0.4

μnf = 0.002006 kg/m-s

At ϕ =0.5

μnf = 0.002256 kg/m-s

THERMAL CONDUCTIVITY OF NANO FLUID
Knf = +2 −(−)(1+)³×× kw

At ϕ =0.4

β=0.1 taken from journal

Knf = 0.1.84577 (W/m-k)

At ϕ =0.5

β=0.1 taken from journal

Knf = 0.2015 (W/m-k)

TITANIUM CARBIDE

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DENSITY OF NANO FLUID ρnf = ϕ×ρs + [(1-ϕ) × ρw]
VOLUME FRACTION 0.4

ρnf = 2570.92 kg/m3

VOLUME FRACTION 0.5

ρnf = 2964.1 kg/m3

SPECIFIC HEAT OF NANO FLUID

Cp nf = ϕ×ρs×Cps +(1−ϕ)(ρw×Cpw)
ϕ×ρs+(1−ϕ)×ρw

At ϕ =0.4

Cp nf =5357.01 j/kg-k

At ϕ =0.5

Cp nf = 4069.1 j/kg-k

VISCOSITY OF NANO FLUID μnf =μw (1+2.5ϕ)

At ϕ =0.4

μnf = 0.002006kg/m-s

At ϕ =0.5

μnf = 0.00225675 kg/m-s

THERMAL CONDUCTIVITY OF NANO FLUID

Knf = Ks +2Kw +2(Ks −Kw)(1+β)³×ϕ × kw
+2 −(−)(1+)³×

β=0.1 taken from journal

At ϕ =0.4

Knf = 2.625 W/m-k

At ϕ =0.5

K = 4.12 W/m-k.
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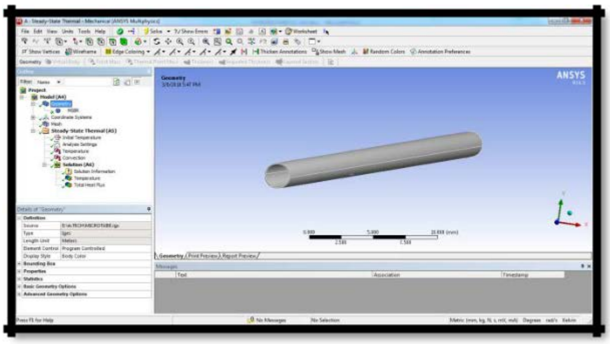
THERMAL ANALYSIS OF MICRO TUBE MATERIAL-COPPER IMPORTED MODEL



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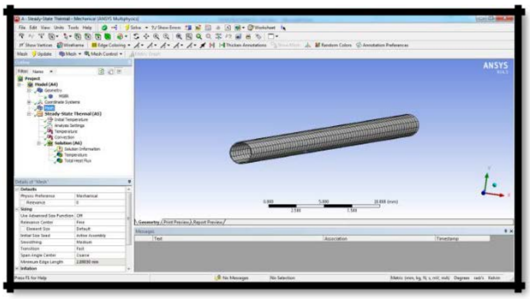
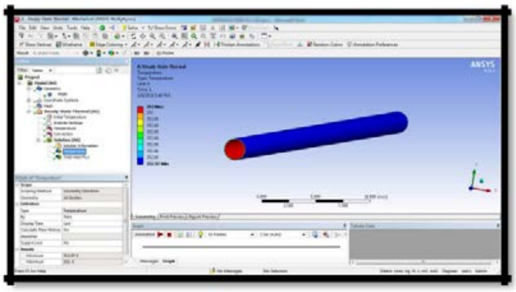
MESHED MODEL.



TEMPERATURE DISTURBUTION



DISCUSSION

Various authors have performed the experimental investigation related to heat transfer enhancement and it's affecting factors by using Al2O3, CuO, TiO2, ZrO2, Ag, SiC and Diamond nanoparticle. Amongst all CuO and Al2O3 are frequently used for higher thermal

conductivity, but many type of nanoparticle using to enhance the heat transfer rate at different application, and discussed many factor affecting the heat transfer rate of Nano fluid. Mixing is important for enhancement of heat transfer rate, so ultrasonic mixture is suitable for enhance thermal conductivity of nanoparticle.

CONCLUSIONS

Heat transfer rate increases with increasing concentration of nanoparticle. Heat transfer rate is directly proportional to the Reynolds number and peclet number of Nano fluid. The fine grade of Nano particles increases the heat transfer rate but it's having poor stability. Clustering and collision of nanoparticles is main factor to affect the heat transfer rate of Nano fluid. Concentration of nanoparticles increases the pressure drop of Nano fluid. Spherical shaped nanoparticles increases the heat transfer rate of Nano fluid compared with other shaped nanoparticles. Boiling was to reduce the enhancement of heat transfer rate. Spiral pipe having higher heat transfer rate compared with the circular plain tube. Inclined tube possess the low pressure drop compared with horizontal tube.

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