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COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF WAX MELTING

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Abstract - *In the present numerical study and analysis a three dimensional sphere with hallow section is considered as test section. The grid independent test and time independent test are performed and chosen the appropriate grid size for numerical study. The diameter of hallow section of sphere is 84 mm. The aluminium wall thickness is 1 mm. The isothermal boundary condition is taken for numerical simulation. The three different PCMs (Paraffin wax, Sodium acetate tri-hydrate and Lauric acid) are tested for energy storage and for performance analysis. The energy stored by PCMs is compared. The melt fraction contour and temperature contour are also analysed at different time of simulation.*

***Key Words*: (Evacuate tube; Phase Change Material; Paraffin Wax; Melting Process.)**

1.INTRODUCTION

In the modern world with improved lifestyle the energy demands of human beings have increased. We all know that our conventional energy resources (fossil fuels) are limited in quantity and are being used up at higher rate. The use of fossil fuels such as coal, petroleum poses a large number of problems due to their high cost, emission of greenhouse gases (GHGs) and oil security. So it becomes important to conserve these fossil fuels and to protect our environment from the harmful effects of environmental pollution. We all know that most of our fossil fuels are used in power plant and transportation sector, which are not much efficient in terms of energy use. There are huge amount of energy losses in these systems. Most of these energy losses are in the form of heat loss. If we take the example of an automobile about 30-40% of the energy produced by burning fuel is lost as waste heat, which reduces the range of automobile. Also we have HVAC systems in our automobile. A heating system of about 5kW is used in i-MiEV of MITSUBISHI Motors. This excess need of energy reduces the driving range of such vehicles by about 10-65%. So it becomes important to do the proper thermal management of such systems to increase their efficiency which can help us in achieving our goal of conserving fossil fuels and protecting the environment. The use of thermal energy storage (TES) systems is an emerging technology used nowadays for thermal management. These systems are designed to store thermal energy. This can be done with various modes such as by storing it as sensible heat, latent heat and thermochemical process. The latent heat storage (LHS) system makes the use of Phase Change Materials (PCMs) for thermal energy storage.

1.2 Phase change material

PCMs are the materials which are used for storing latent heat energy. These are the materials which changes its one state to another when heat energy is supplied or extracted away from them. They can change from solid to liquid state by absorbing latent heat of fusion and vice versa or they can change their state from liquid to gaseous by absorbing latent heat to vaporization and vice versa or they can change their state from solid to gaseous by absorbing latent heat of sublimation and vice versa at constant temperature. The solid to liquid phase change mode is most widely used for LHS. The fig -1 shows the phenomenon of phase change for solid to liquid phase change mode. The shaded region shows the total heat energy stored during phase change of a material from solid to liquid. The total energy stored is the sum of sensible heat in solid state, latent heat during phase change at constant temperature and sensible heat in liquid state.

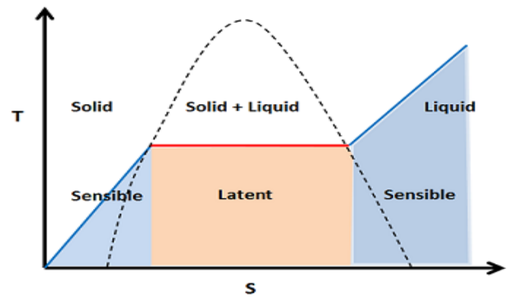

Fig -1: Heat stored during phase change of material

Fig- 1: Heat storage during phase change of material

2.THERMO-PHYSICAL PROPERTIES OF PARAFFIN WAX

Table 2.1: Thermo-physical properties of paraffin wax

Property	Value
Density (kg/m^3)	870 at T =300k 780 at T =340k
Specific heat (J/Kgk)	2900
Thermal conductivity (W/mk)	0.24 at T =300k 0.22 at T =340k
Viscosity (Ns/m)	0.0057933
Latent heat (J/Kg)	190000
Solidus temperature (k)	331
Liquidus temperature (k)	3318

3.MATERIAL SELECTION

Paraffin waxes come directly from the vacuum distillation of petroleum crude. Paraffin waxes can be refined, formulated, modified with additives and are offered in packaged slabs, powder, chips, etc. Petroleum crude is the raw material used to obtain paraffin waxes among other derivatives.

The other hydrocarbons can also be found within its composition:

- Normal & Branched Paraffin's
- Naphthenic
- Aromatic

Paraffin waxes are made up of a blend of saturated hydrocarbons (alkenes) with a chain length from C20 to C60.

Depending on the structural shape of the chain, two different types of paraffin exist

- Linear Paraffin Wax.
- Branched Paraffin Wax.

Table 3.1: Properties of Paraffin Wax

Levels of Refinement	Oil Content (% of weight)
Fully Refined	<1
Semi Refined	1-3
Petrolatum	➢ 3

	Macrocrystalline	Microcrystalline
Melt Point	Medium(50-70 ℃)	High(70-90℃)
MolecularWeight	MediumC19-C42	High C25->C50
Crystals	Large and regular	Small & Irregular
Flexibility	Low	High
Aspect	Brilliat	Opaque

3.1 LIST OF COMPONENTS

3.3.1 PARAFFIN WAX

Paraffin wax is a soft colourless solid, derived from petroleum, coal or shale oil, that consists of a mixture of hydrocarbon molecules containing between twenty and forty carbon atoms. It is solid at room temperature and begins to melt above approximately 37 °C (99 °F) and its boiling point is >370 °C (698 °F).

THE GENERAL FORMULA

PARAFFIN WAX : C_nH_{2n+2}.

PROPERTIES

- It is mostly found as tasteless, odourless and waxy solid.
- It is melting point is 46 and 68^o C (115 and 154^{o}F).
- Paraffin wax is an excellent material for storing heat, with a specific heat capacity of 2.14–2.9 J g^{-1} K^{-1}.
- And its heat of fusion is 200–220 J g^{-1}.

3.1.2 ALUMINIUM

Aluminium or aluminium is a chemical element with symbol AI and atomic number 13. It is a silvery-white, soft, nonmagnetic and ductile metal in the boron group. aluminium makes up about 8% of the Earth's crust. The chief ore of aluminium is bauxite. it is found combined in over 270 different minerals.

PROPERTIES

- Density of aluminium is 2700 kg/m^3.

- Melting point of aluminium is 660°C.
- Thermal conductivity of aluminium is 204 W/mk.
- Specific heat capacity of aluminium is 940 J/kg °C.

3.3.3 EVACUATED TUBE

Evacuated Tubes are the heart of the Apricus AP solar collector, responsible for absorbing sunlight and converting it into usable heat. Tube Design. The tube is essentially two glass tubes that are fused at the top and bottom. The inner tube has a solar absorbing coating, and the space between the two tubes is evacuated to form a vacuum.

PROPERTIES

- They have normal reflective of 0.04.
- The maximum temperature upto 430°C.
- The outer and the inner emisivity of evacuated tube is 0.9 and 0.35.

Sample paragraph Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper.

4. 3D MODELING

CREATING 3D MODEL BY USING CREO SOFTWARE

By draw the hollow sphere for using some commends in creo software

List below,

Circle, extrude and assemble

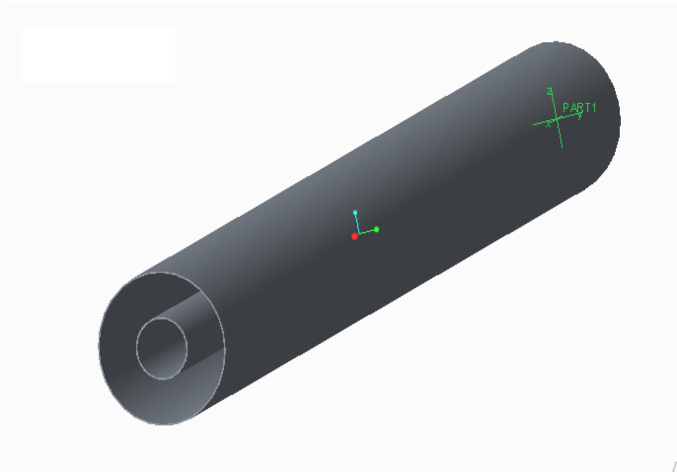

Fig 5.1 Isometric view

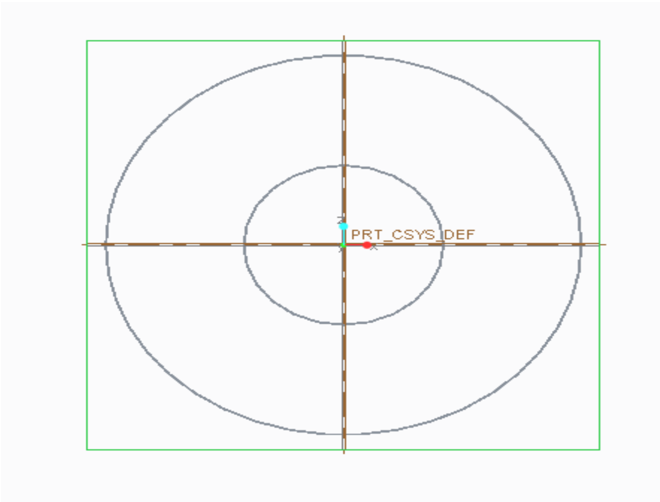

Fig 5.2 Front view

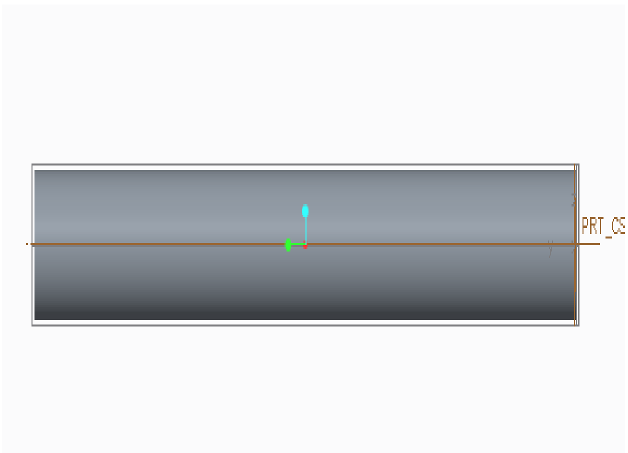

Fig 5.3 Side view

5.RESULT AND CALCULATION

5.1:Time interval 150 seconds

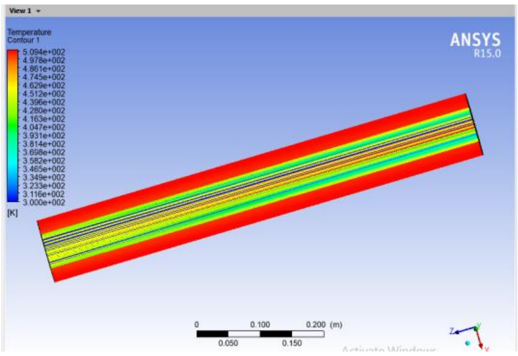

FIG:5.1 temperature distribution

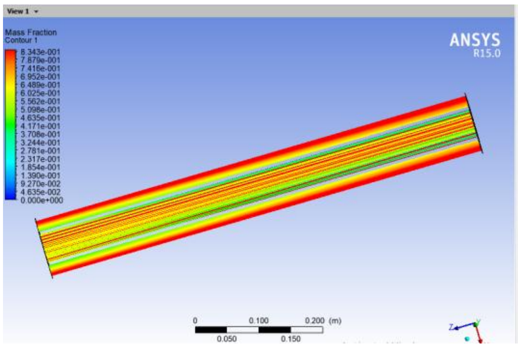

FIG:5.2 mass fraction

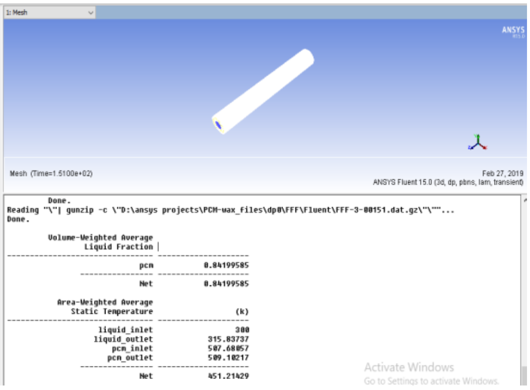

FIG:5.3 net result

The figure shows the temperature distribution over the entire length of the pipe that is obtained in a time interval of 150 seconds. The variations in temperature at various layers of the pipe were shown above. It is seen that the temperature at outer wall is maximum and the heat is gradually transfered to the center fluid.

The volume of the phase change material is 0.84199585 m³ and it is the net volume of the material. And the inlet and outlet temperature of the liquid is 300 k and 315.83737 k respectively. And the inlet and outlet temperature of the phase change material is 507.68057 k and 509.10217 k respectively. . And net temperature during 250 second is 451.21429 k.

5.2:Time interval 200 seconds

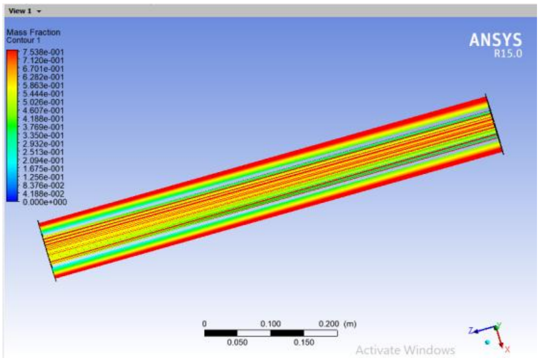

FIG:5.4 mass fraction

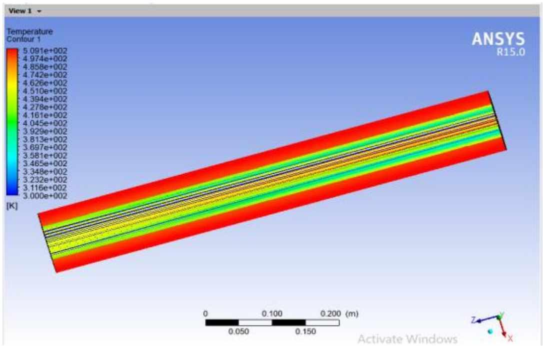

FIG:5.5 temperature distribution

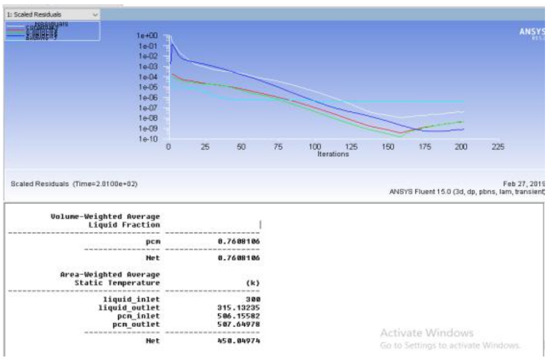

FIG:5.6 net result

The figure shows the temperature distribution over the entire length of the pipe that is obtained in a time interval of 200 seconds. The variations in temperature at various layers of the pipe were shown above. It is seen that the temperature at outer wall is maximum and the heat is gradually transfered to the center fluid.

The volume of the phase change material is 0.7608106 m^3 and it is the net volume of the material. And the inlet and outlet temperature of the liquid is 300 k and 315.13235 k respectively. And the inlet and outlet temperature of the phase change material is 506.15582 k and 507.64978 k respectively. . And net temperature during 200 second is 450.04974k.

5.3 Time interval 250 seconds

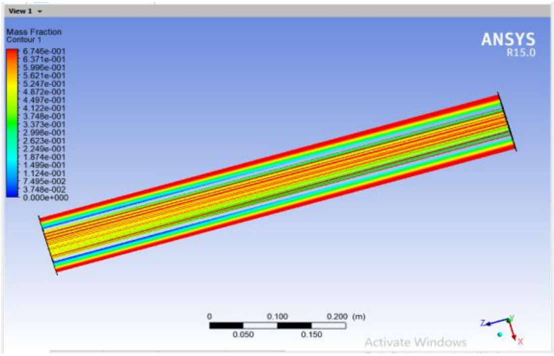

FIG:5.7 mass fraction

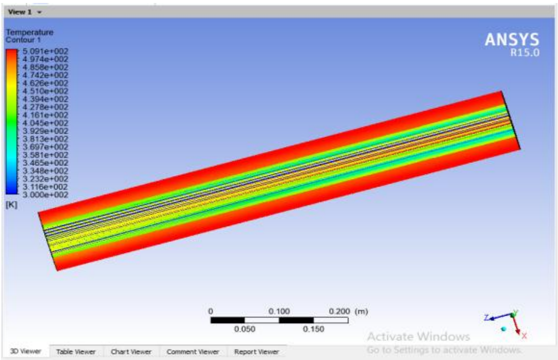

FIG:5.1 temperature distribution

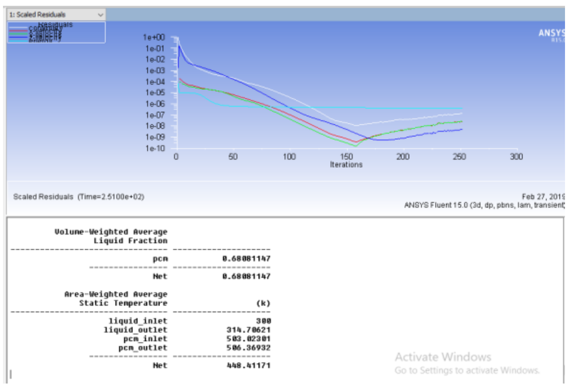

FIG:5.9 net result

The figure shows the temperature distribution over the entire length of the pipe that is obtained in a time interval of 250 seconds. The variations in temperature at various layers of the pipe were shown above. It is seen that the temperature at outer wall is maximum and the heat is gradually transfered to the center fluid.

The volume of the phase change material is 0.68081147 m^3 and it is the net volume of the material. And the inlet and outlet temperature of the liquid is 300 k and 314.70621 k respectively. And the inlet and outlet temperature of the phase change material is 503.02301 k and 506.36932 k respectively. And net temperature during 250 second is 448.41171 k.

5.4 CALCULATIONS

5.4.1 Heat transfer

diameter of inner aluminium plate d_1=35mm , r_1=17.5mm =0.0175m

diameter of outer aluminium plate d_2=36mm, r_2=18mm =0.018m

diameter of inner evacuated tube d_3=84mm, r_3=42mm =0.042m

diameter of outer evacuated tube d_4=85mm, r_4=42.5mm=0.0425m

aluminium thermal conductivity k_1=204w/mk

paraffin wax thermal conductivity k_2=0.24w/mk

evacuated tube thermal conductivity k_3=1w/mk

outer temperature T_b=393.1k

inner temperature T_a=509.4k

heat transfer

$Q = \Delta T_{overall}/R$

$\Delta T = t_a - t_b$

$=509.4-393.1$

$\Delta T = 116.3K$

[refer **hmt** data book pg.no.43&45]

$R=1/2\pi l[\ln(r2/r1)/k_1+\ln(r_3/r_2)/k_2+\ln(r_4/r_3)/k_3]$

=1/2π(0.5)[ln(0.018/0.017)/204+ln(0.042/0.018)/0.24+ ln(0.043

/0.042)/1]

R= 1/2πl[0.00028+3.5+1.012]

For l=500mm, l=0.5m.

=1/2π(0.5)[4.51228]

=1.4363mk/W

$Q=T_a-T_b/R$

=(509.4-393.1)/1.4363

Q =80.97W/m

5.4.2 AREA

A=2πrl

Area of inner sphere (aluminium)

A=2πrl

=2π(17.5)(500)

=54.977x10^3mm

Area of outer sphere(aluminium)

A_1=2πrl

=2π(18)(500)

=56.548x10^3mm

Area of inner sphere(evacuated tube)

A_2=2πrl

=2π(42)(500)

=131.946x10^3mm

For the area of evacuated tube is

$A_3=A_2-A_1$

=131.946x10^3-56.548x10^3

A_3 =75.398x10^3mm

5.4.3VOLUME

$$V = 4\pi r^3/3$$

Volume of water

$$V = 4\pi(17.5)^3/3$$

V = 22.449x10^3mm^3

For reducing aluminium thickness

$V_1= 4\pi(18)^3/3$

= 24.429x10^3mm^3

Volume of paraffin wax

$V_2= 4\pi(42)^3/3$

= 310.339x10^3mm^3

For get volume of paraffin wax

$V=V_2-V_3$

= (310.339X10^3)-(24.429X10^3)

V = 285.91X10^3mm^3

6.CONCLUSION

In this numerical work, melting of paraffin wax to achieve the vaporization of water in by low cost when comparing another glycolic acid like Sodium acetate tri-hydrate and Lauric acid.

Paraffin wax is phase change material to transfer the heat. And the heat transfer rate is Q =80.97W/m.

It have thermal conductivity of 0.24 W/mk at the temperature of 300K.

Temperature distribution curve is change in after addition of 50s.

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