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Heat Transfer Enhancement of Phase Change Materials (PCM) in Thermal Storage Device

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Abstract: The analysis was performed on the PCM materials by varying outer radii of thermal energy system for paraffin wax material. The analysis was continue for various PCM materials to estimate the melting time of the PCM materials for this problem Examine the melting time of PCM material n-Eicosane wax and increasing radius of pipe in PCM system. The melting time was decreased for Outer radius of Pipe varying from 0.022 m and 0.028m but the melting time was increased for Outer radius of Pipe 0.03m. It was clearly show that the melting time was decreased from 1187 seconds to 1152 seconds with respect to the radius of pipe. At the radius of 0.03m of pipe the melting temperature found that 1177seconds i.e. the time duration was again increased.

The melting temperature of the PCM materials and the duration of melting time. The highest melting time (6127 sec) of PCM material is NH4 Al (SO4)2_12H2O liquid and lowest melting time (915sec) of PCM material is CaCl2_6H2O for selected PCM materials from this study.

Keywords: PCM, heat transfer, FEM, specific heat, fixed mesh, ANSYS

I. INTRODUCTION TO PHASE CHANGE MATERIALS AND METHODOLOGY

Numerical techniques, such as finite element method, are commonly utilized to solve phase change heat transfer problems. For modelling phase change problems, there are two main approaches: moving-mesh and fixed-mesh methods. The mesh of the moving-mesh method is allowed to change to track the solid/liquid interface. This method is rarely used in practice because it will highly complicate the computations. The fixed-mesh method is commonly used for modelling phase change. Heat transfer analysis in thermal sorage system was performed by considering the different phase change materials (PCM) like CaCl2_6H2O, Mg (NO3) _6H2O, NH4 Al (SO4)2_12H2O liquid, MgCl2_6H2O and Polyethylene Glycol. In this work found the melted temperature time of these materials and temperature history at centre of the location of the phase change materials.

II. LITERATURE SURVEY

Kamal Abdel Kader Ismail, Carlos L. Wolf [1] The heat exchanger generally considered in the storage of thermal energy for phase change is the type of casing and tube, where the phase change material (PCM) fills the side of the casing of the exchanger while the heat transfer fluid (RTF) flows through the pipes and transfers energy to and from the storage unit. Ning Xie , Zhaowen Huang , Zigeng Luo [2] Using phase change materials (PCMs) for thermal energy storage has always been a hot topic within the research community due to their excellent performance on energy conservation such as energy efficiency in buildings, solar domestic hot water systems, textile industry, biomedical and food agroindustry. Esam M. Alawadhi [3] This book focuses on the use of ANSYS in solving practical engineering problems. ANSYS is extensively used in the design cycle by industry leaders in the United States and around the world. Additionally, ANSYS is available in computer laboratories in most renowned universities and institutes around the world. Courses such as computer aided design (CAD), modeling and simulation, and core design all utilize ANSYS as a vehicle for performing modern engineering analyses. Senior students frequently incorporate ANSYS in their design projects. Graduate-level finite element courses also use ANSYS as a complement to the theoretical treatment of the finite element method. Idris Al Siyabi, Sourav Khanna, Tapas Mallick [4] A small-scale phase change material (PCM)-based heat sink can regulate the temperature of electronics due to high latent-heat capacity. Three different heat sinks are examined to study the effects of PCM combination, arrangement of PCMs in multiple-PCM heat sink, PCM thickness, melting temperature and intensity of heat source on the thermal behavior of heat sink. Randeep Singh , Sadegh Sadeghi and Bahman Shabani [5] Low thermal conductivity is the main drawback of phase change materials (PCMs) that is yet to be fully addressed. This paper studies several efficient, cost-effective, and easy-to-use Experimental techniques to enhance thermal conductivity of an organic phase change material Used for low-temperature thermal energy storage applications. In such applications, the challenges associated with low thermal conductivity of such organic PCMs are even more pronounced. In this investigation, polyethylene glycol (PEG-1000) is used as PCM. M. Alipanah and A.

Zahmatkesh [6] Nowadays, given the increasing importance of energy sources, the possibility of energy storage in the heat exchangers through the Phase Change Materials (PCM) and releasing it when needed have been extremely essential. P. Sivasamy, A. Devaraju, S. Harikrishnan [7] For effective utilization of thermal energy storage (TES) system, selection of Phase change material (PCM) and heat transfer mechanism plays a significant role. PCMs employed in TES system undergo poor heat transfer rate due to low thermal conductivity. U. S. Ramakanth; Putti. Srinivasa Rao [8] Presents the research examined the influence of sic and fly ash on the wear behavior of Aluminum 7075/5 and weight percentage of hybrid complex. Aluminum alloy 7075 strengthened with sic-fly ash were examined. Uppada Rama Kanth, Putti Srinivasa Rao, Mallarapu Gopi Krishna [9] Reports that Al-Zn compound supplement / fly ash / Thus, using a device to measure the vortex of casting, while stirring. The carrots are many thermal power plants Industrial waste fly ash, the main service. E.E.U. Haque, P.R. Hampson [10] A 3D thermal transient analysis of a gap profiling technique which utilises phase change material (plasticine) is conducted in ANSYS. Phase change is modelled by assigning enthalpy of fusion over a wide temperature range based on Differential Scanning Calorimetry (DSC) results.

A. Analysis of Phase Chase Material (PCM) - Paraffin wax

The thermal storage devices system as shown in Fig1.1, the PCM material play very important role, in this analysis paraffin wax PCM material was used. The stored heat in the PCM can then be used during high-energy demand periods to conserve energy. The PCM storage system a s shown in Fig, the outer radius of pipe R0 is 0.022m and outer radius of paraffin wax R1 is 0.02m it was subjected to external thermal load 100^{o}C maintained at pipe outer line and initial temperature of PCM system is 25oC. The following table 1.1 show the thermal properties are used for estimating of melting time of paraffin wax material in this thermal storage device.

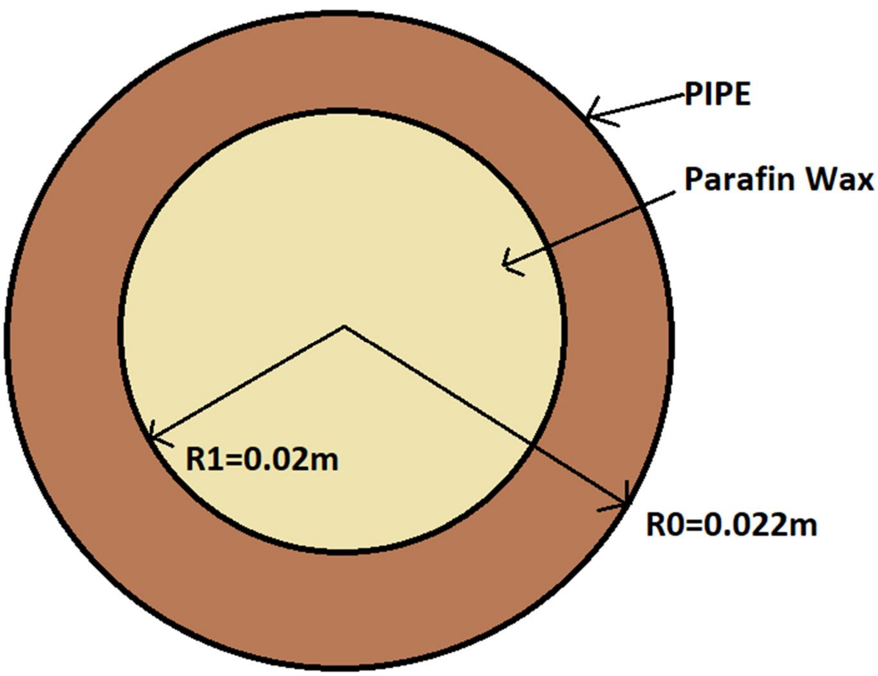

Fig 1.1 thermal storage devices and problem definition

Table 1.1 show the thermal properties of pipe and paraffin wax

PIPE	MATERIAL PROPERTIES	N-EICOSANE WAX
□= 1200 kg/m3	□=Density	1000 kg/m^3
k = 50 W/kg-°C	*k* =Thermal Conductivity	0.5 W/kg-°C
Cp = 900 J/kg-°C	*Cp* = Specific Heat	1050 J/kg-°C
	□=latent heat of fusion	210 kJ/kg
	*T*m =melting temperature	36°C

The melting time was decreased for Outer radius of Pipe varying from 0.022 m and 0.028m but the melting time was increased for Outer radius of Pipe 0.03m. The below Table 1.2 show that it was clearly show that the melting time was decreased from 1187 seconds to 1152 seconds with respect to the radius of pipe. At the radius of 0.03m of pipe the melting temperature found that 1177seconds i.e. the time duration was again increased. The wax is melted completely the temperature at its centre reaches to 37^0C the estimated meeting time of wax is found that 1187.5sec (radius -0.022).The Specific heat as a function of temperature, temperature distribution and temperature history of the selected location show in Fig 1.2. In this model (outer radii 0.03m) observed that the temperature 25^o C to 35^o C was increased at the time duration from 2.5 seconds to 1127seconds after that the temperature decreased in few seconds 1130 to 1157. The melting time of PCM martial found that 1177 seconds PCM system outer radius 0.03 shown in Fig 1.3.

Table 1.2 varying pipe radius versus melting temp of PCM material

OUTER RADIUS OF PIPE	ESTIMATED TIME OF PCM TO MELT IN SECONDS
0.022	1187
0.024	1180
0.026	1175
0.028	1152
0.03	1177

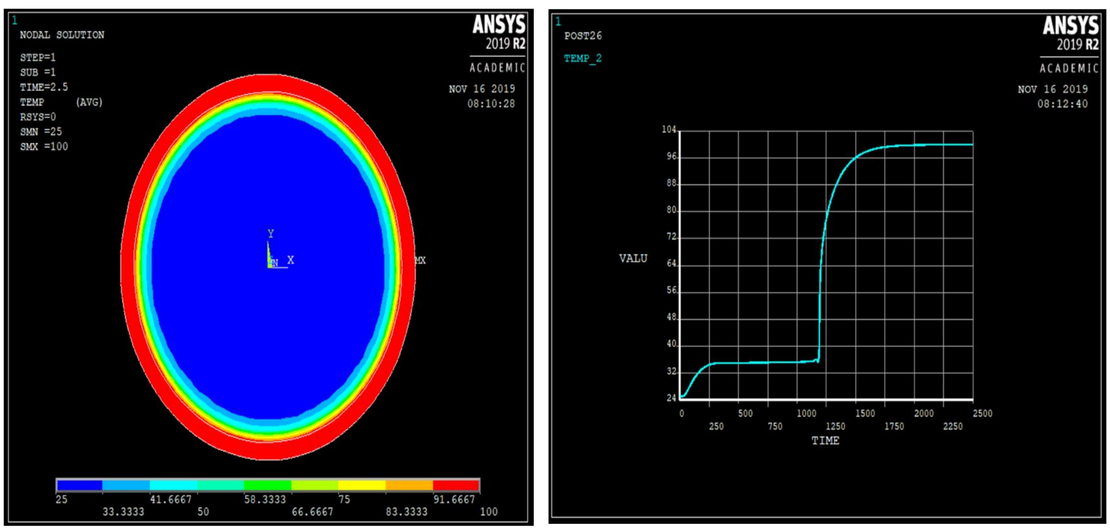

Fig 1.2 temperature distribution and Specific heat as a function of temperature in thermal storage devices of radii 0.022m

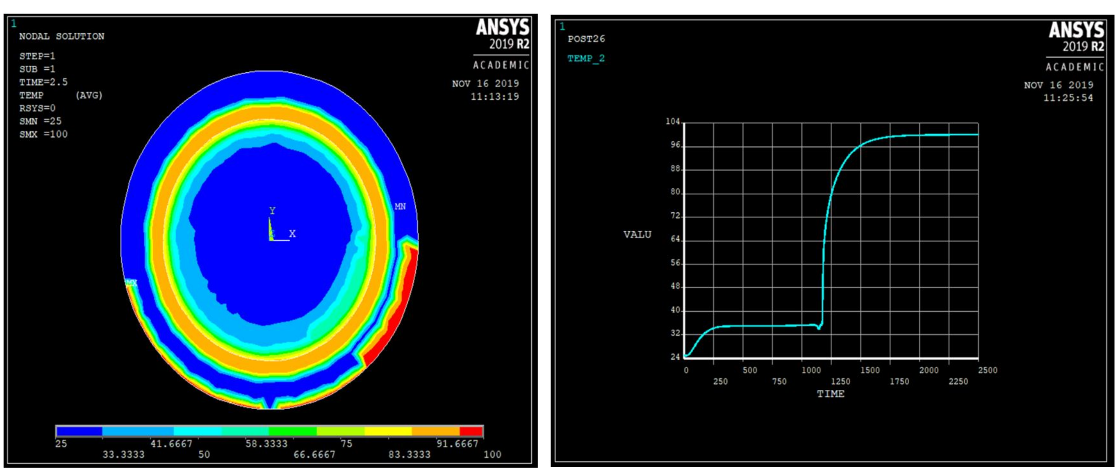

Fig 1.3 temperature distribution and Specific heat as a function of temperature in thermal storage devices of radii 0.03m

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B. Analysis of Different Phase Chase Materials (PCM)

Heat transfer analysis in thermal sorage system was performed by considering the different phase change materials (PCM) like CaCl2_6H2O, Mg (NO3) _6H2O, NH4 Al (SO4)2_12H2O liquid, MgCl2_6H2O and Polyethylene Glycol. In this work found the melted temperature time of these materials and temperature history at centre of the location of the phase change materials. The thermal storage devices system as shown in Fig 1.4, the PCM material play very important role, in this analysis CaCl2_6H2O PCM material was used. The stored heat in the PCM can then be used during high-energy demand periods to conserve energy. The PCM storage system a s shown in Fig 1.4 , the outer radius of pipe R0 is 0.03m and outer radius of paraffin wax R1 is 0.02m it was subjected to external thermal load 100^{o}C maintained at pipe outer line and initial temperature of PCM system is 25^{o}C. The following table 4.1 show the thermal properties are used for estimating of melting time of CaCl2_6H2O material in this thermal storage device. Fig 1.5show the data of time – temperature history of PCM - CaCl2_6H2O and pipe system. The temperature was increased gradually with time but at the time of 880 seconds the temperature was start decreased until at the time of 892 second again the temperature was increased. Found that the melting temperature of PCM material CaCl2_6H2O is 28^{o}c and estimated time to melt the material is 915 seconds in this thermal energy system. The melting temperature of PCM - Mg (NO3) _6H2O material is 89.90c and the required time to melt the PCM is 2715 seconds it was shown in the Fig 1.6. The Fig 1.6 show the specific heat property, convergence curve, temperature distribution and time – temperature curves of PCM - Mg (NO3) _6H2O material of the energy storage system.

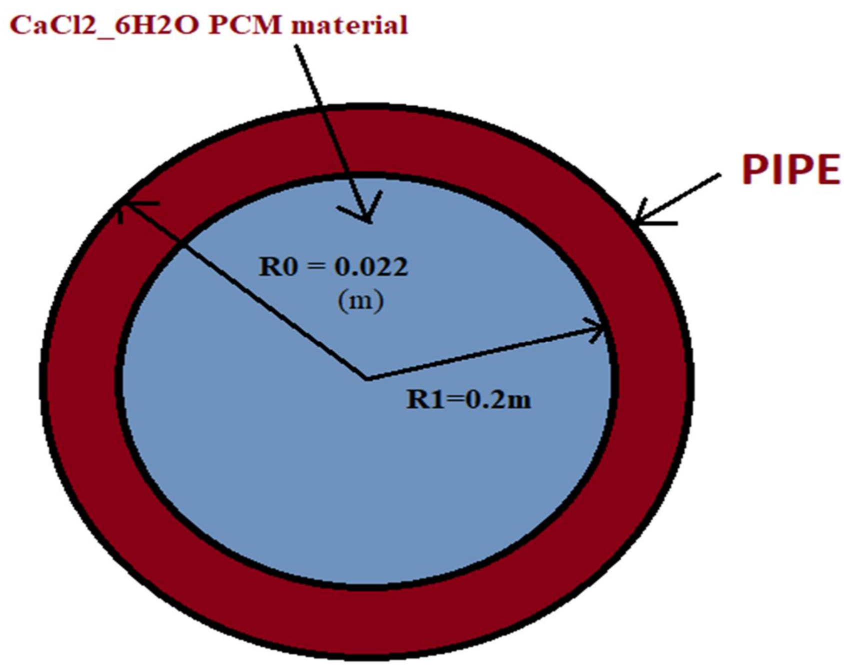

Fig 1.4 thermal storage devices and problem definition of various PCM materials

Table 1.2 PCM materials Properties

PIPE	N-EICOSANE WAX	CACL2_6H2O	MG(NO3)_6H2O	NH4AL(SO4)2_12H2O LIQUID	POLYETHYLENE GLYCOL
p= 1200 kg/m3	1000	1800	1636	1650	1120
k = 50 W/kg-°C	0.5	1.088	1.81	1.71	0.2
Cp = 900 J/kg-°C	1050	1420	669	728	226
□= latent heat of fusion kJ/kg	210	163	163	269	154.9
*T*m = melting temperature	36°C	28	89.9	95	37.1

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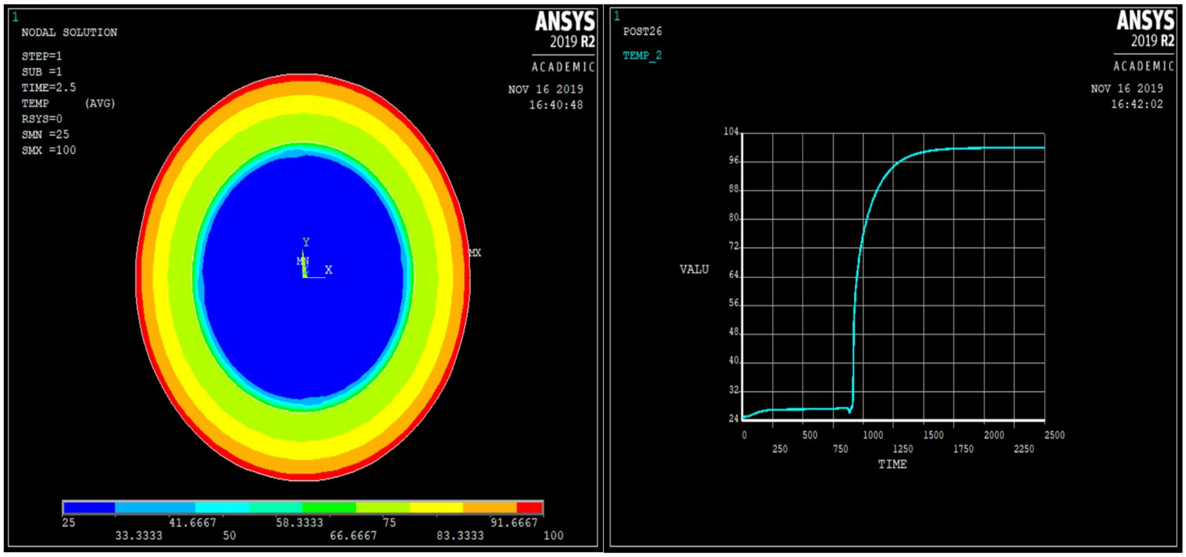

Fig 1.5 temperature distribution and Specific heat as a function of temperature of PCM materials - CaCl2_6H2O

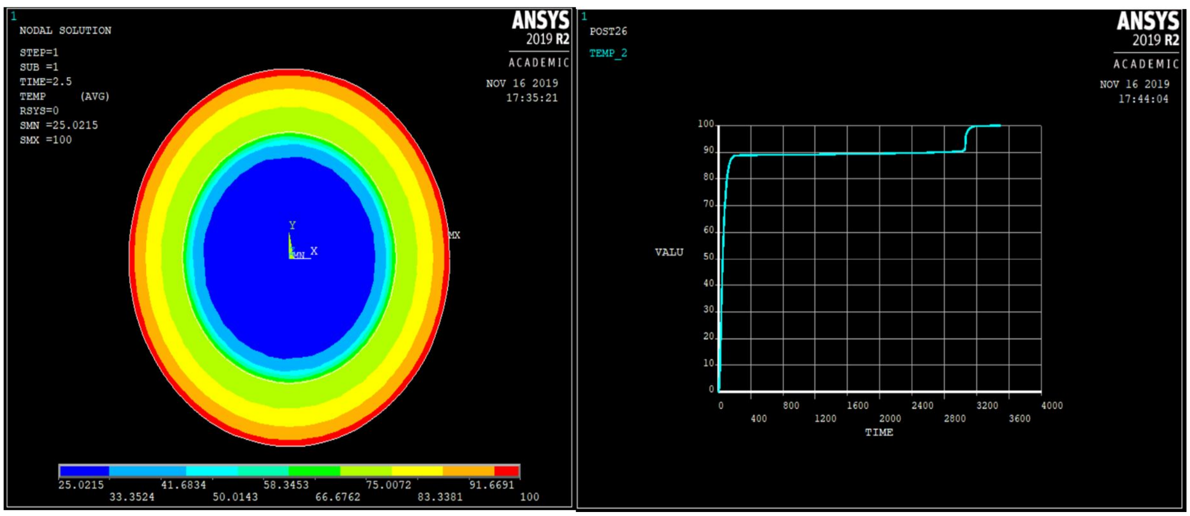

Fig 1.6 temperature distribution and Specific heat as a function of temperature of PCM - Mg (NO3) _6H2O

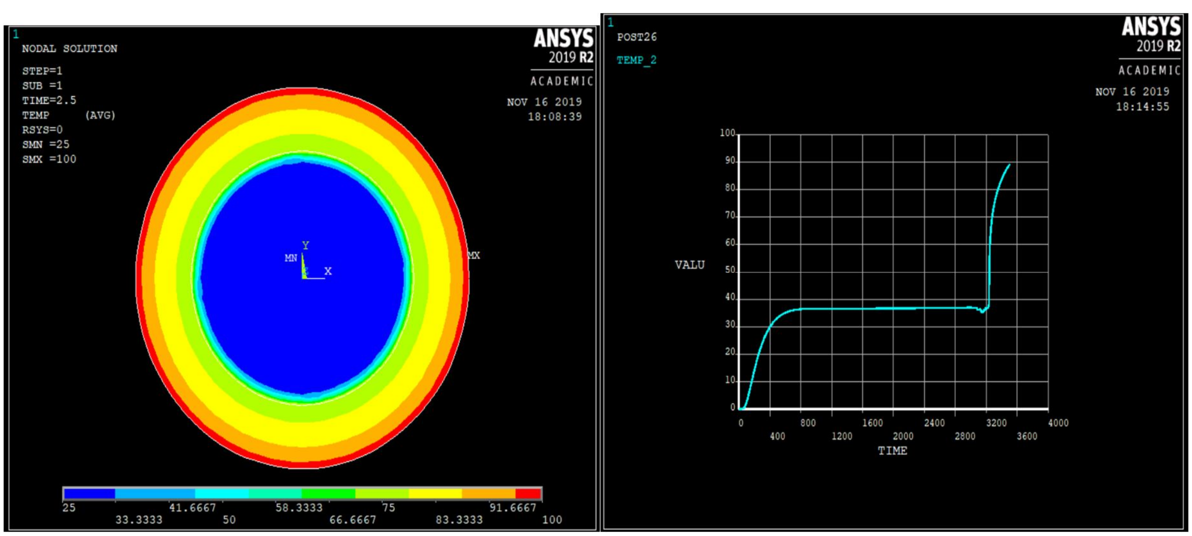

Fig 1.7 temperature distribution and Specific heat as a function of temperature of PCM - Polyethylene Glycol

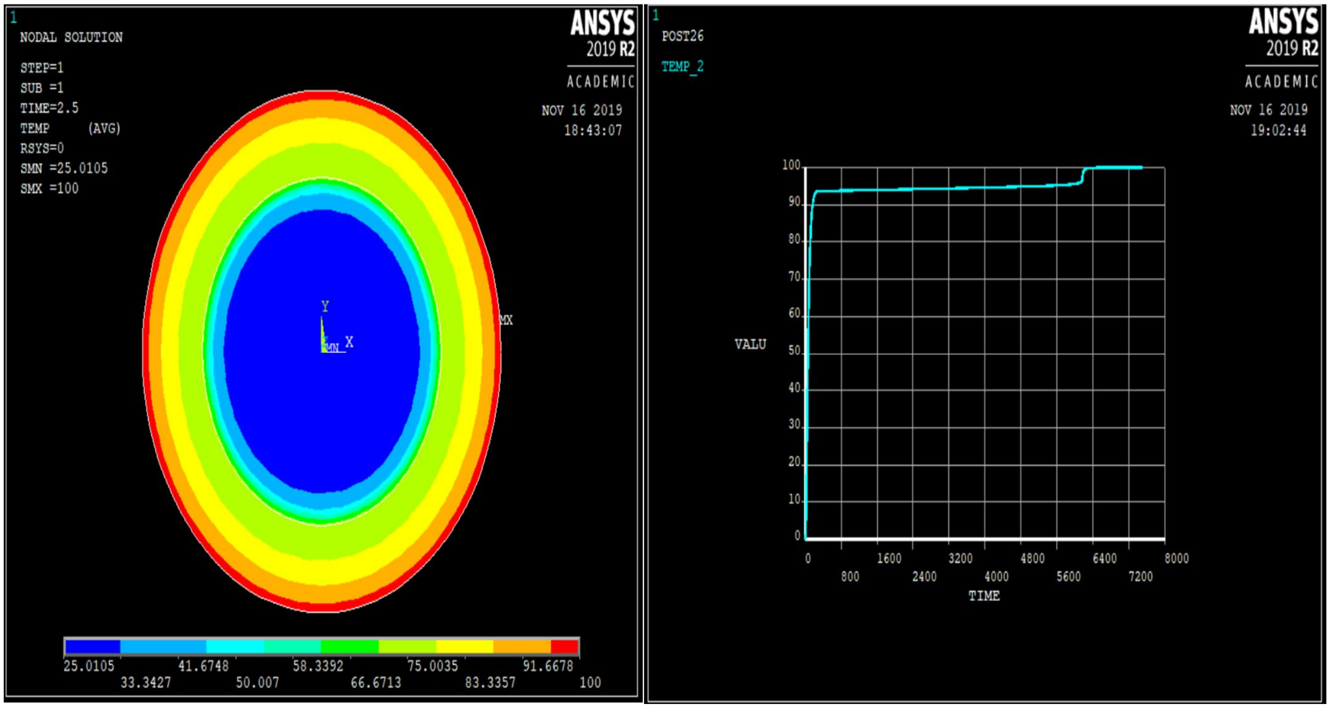

Fig 1.8 temperature distribution and Specific heat as a function of temperature of PCM - NH4 Al (SO4)2_12H2O liquid

The melting temperature of PCM - Polyethylene Glycol material is 37.1^{o}c and the required time to melt the PCM is 3235 seconds ,The Fig 1.7 show the specific heat property, convergence curve, temperature distribution and time – temperature curves of PCM - Polyethylene Glycol material of the energy storage system. The melting temperature of PCM - NH4 Al (SO4)2_12H2O liquid material is 95^{o}c and the required time to melt the PCM is 6127 seconds, the Fig 1.8 show the specific heat property, convergence curve, temperature distribution and time – temperature curves of PCM - NH4 Al (SO4)2_12H2O liquid material of the energy storage system.

C. Results and Discussions

In this thesis heat transfer analysis was performed on phase change material (PCM) paraffin was used in thermal storage device. The outer diameter of pipe in PCM system was varying and estimated time of melting of paraffin was found. The outer radius initially consider as 0.022m in PCM system then the radius was increased up to 0.03m.

The specific heat of PCM material increases at that time the temperature was constant and the PCM material large amount of energy was absorbed.

The melting time of PCM material n-Eicosane wax and increasing radius of pipe in PCM system. The melting time was decreased for Outer radius of Pipe varying from 0.022 m and 0.028m but the melting time was increased for Outer radius of Pipe 0.03m. The below Fig 5.1 show the melting time in y- axis and pipe varying radius in x-axis. It was clearly show that the melting time was decreased from 1187 seconds to 1152 seconds with respect to the radius of pipe. At the radius of 0.03m of pipe the melting temperature found that 1177seconds i.e. the time duration was again increased.

Heat transfer analysis in thermal sorage system was performed by considering the different phase change materials (PCM) like CaCl2_6H2O, Mg (NO3) _6H2O, NH4 Al (SO4)2_12H2O liquid, MgCl2_6H2O and Polyethylene Glycol. In this work found the melted temperature time of these materials and temperature history at centre of the location of the phase change materials.

The melting temperature of PCM - NH4 Al (SO4)2_12H2O liquid material is 95^{o}c and the required time to melt the PCM is 6127 seconds it was observed in the analysis. The Fig 5.2 represents the melting temperature of the PCM materials and the duration of melting time. The highest melting time (6127 sec) of PCM material is NH4 Al (SO4)2_12H2O liquid and lowest melting time (915sec) of PCM material is CaCl2_6H2O for selected PCM materials from this study.

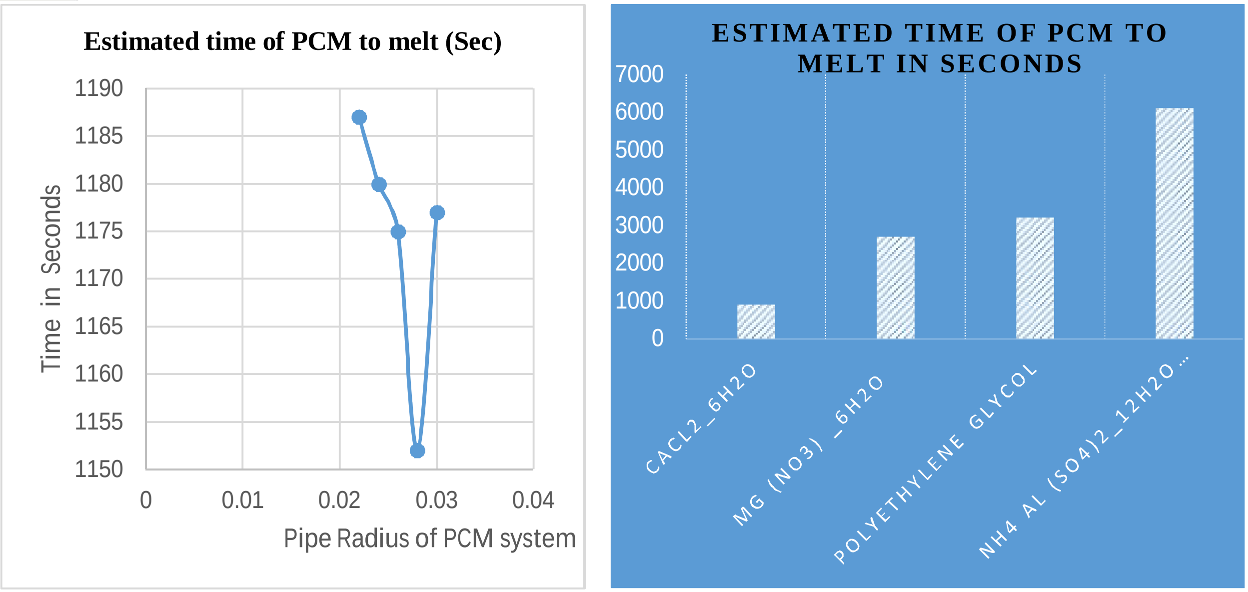

Fig 1.9 the melting time in y- axis and pipe varying radius in x-axis & Different PCM materials versus their melting temp

III. CONCLUSIONS

A. The PCM different materials properties are taken from the literature and by outer radii of thermal energy system the temperature distribution and estimated time of melting of the paraffin wax material was found successfully using ANSYS software.

B. The different PCM materials used in thermal energy system to found temperature distribution and estimated time of melting of the paraffin wax material was found using ANSYS software.

IV. FUTURE SCOPE

For improving heat transfer enhancement use different fins material and different crosections fins used in PCM materials.

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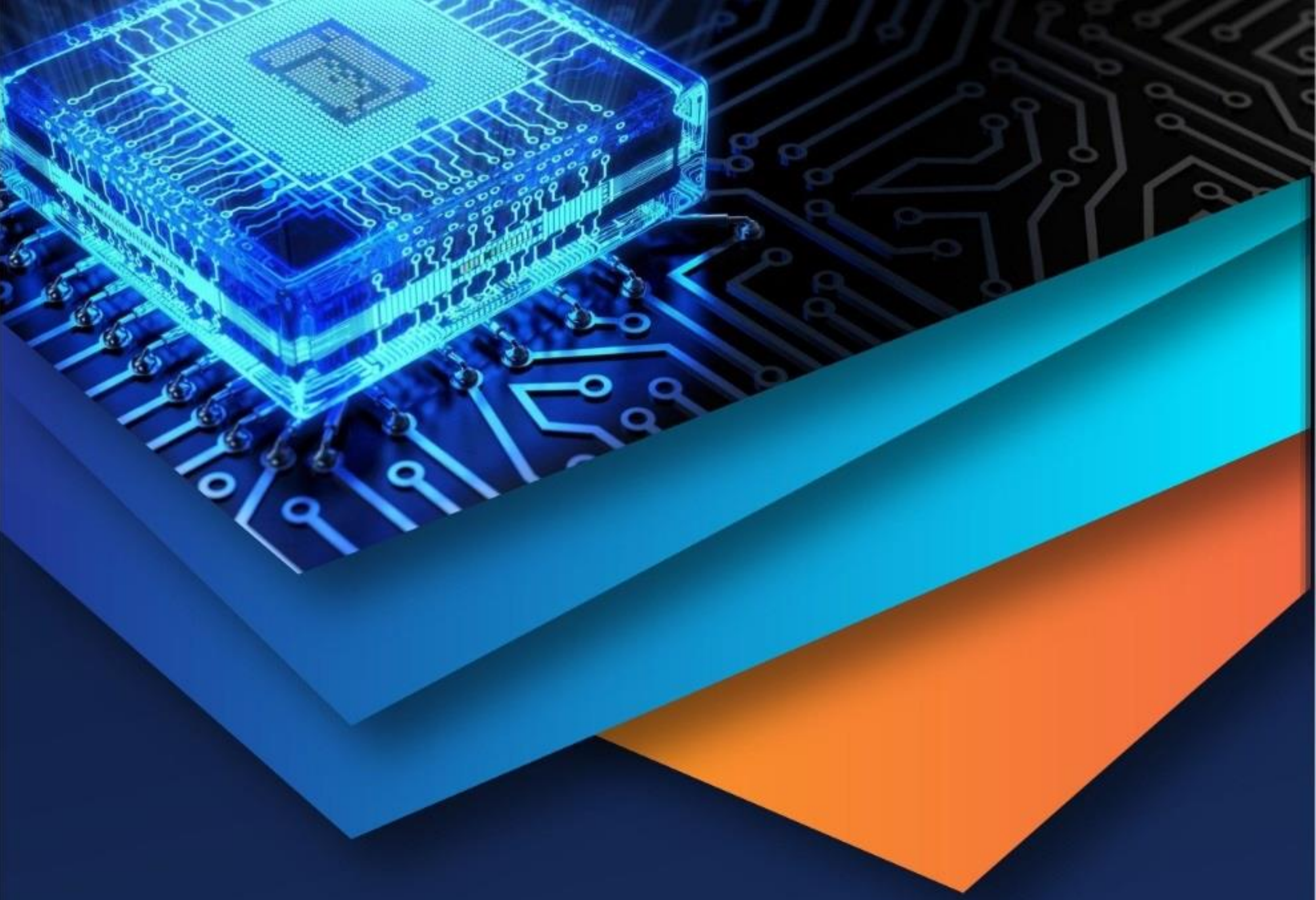

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