# CFD Analysis of Erythritol Melting Process in a Closed Cylindrical Container

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**Abstract -** *Latent heat storage (LHS) of thermal energy is very much attractive and shows great potential concept in past few years. A good design of LHS system with a proper phase change material (PCM) is required for the effective function of any heat transfer system. Thermal energy storage in the form of latent heat, by using PCM have many good features such as high energy to density and process of heat transfer is isothermal in nature. The aim of the present numerical study is to analyze and visualize the phenomenon of heat transfer and melting characteristics of PCM in a closed vertical cylindrical container using CFD tool ANSYS 18. The results are mainly focused in terms of temperature and time contours to melt the PCM. This study will be useful to the readers to understand the thermal behavior, melting time and amount of heat storage capacity of erythritol. Further this study can be useful to integrate with solar energy to provide the input heat which is required in melting process of PCM. As a result, ultimately it is possible to store solar energy in terms of latent heat.*

***Key Words***: ANSYS, Computational fluid dynamics (CFD) , Modeling, Sugar alcohol, Meshing

## 1. INTRODUCTION

An uninterrupted emergent demand for utilizing renewable energy sources, increased shortage of fossil fuels and importance of decreasing emission, gives the driving force to the researchers to explore new technology and apparatus that can fulfil the demand commitment economically. Phase Change Materials (PCMs) are the capable materials for the purpose of thermal heat storage for the different thermal components and thermal systems by making design of heat exchanger simple and compact. PCMs are available at diverse melting temperature ranges which can be selected depend on the required working temperature and safety criteria of particular application [1-7]. The technology of energy storage plays a principal role in energy preservation along with managing the mismatch between the demands and supply in case of solar energy.

Hence in such scenario, the analysis and visualization using proper computational tool for observing the physical and thermal behaviour of system is important. CFD is excellent tool in this regard. This study mainly aims to visualize and analyze the thermal behaviour of erythritol during melting process in a closed vertical cylindrical container using CFD tool ANSYS FLUENT 18.1.

The melting and solidification behaviour of erythritol was studied by Yifei Wang et al. [8]. They reported that, the melting process initiates through collecting the molten phase of erythritol from the top region to bottom region. Agyenim et al. [9] have experimentally investigated the thermal behaviour of an erythritol for the LiBr/H2O absorption cooling system for temperature range of 70°C-90°C. The study concludes erythritol melting time was more comparing to solidification time. Shatikian et al. [10] studied numerically the melting of RT25 PCM in a two dimensional and three dimension rectangular geometry. Rathod et al. [11] performed a parametric investigation for small system, the results shows that transient process depends on the geometric and thermal parameters. The result of analysis was presented in terms of comparison of Nusselt numbers and melt fraction with respect to Fourier and Stefan numbers. Shmueli et al. [12] investigated a numerical method for different combinations, using RT27 as a PCM. The vertical cylindrical cavity was selected as geometry for this study. Estrazulas [13] numerically studied the melting and solidification behaviour of five different PCM with the same vertical cylindrical geometry. RT4, RT35, RT35HC, RT55 and RT82 were used as a PCM. In addition to this the temperature difference of 10, 20and 30 K were considered. Oliveski and Del Col [14] have also reported for the study of numerical analysis of melting process in the rectangular geometry by using erythritol as a PCM, and temperature difference was considered as 10, 15 and 20 K. Bohrael et al. [15] investigated and obtained a two dimensional transient study of erythritol melting behaviour in a rectangular geometry, and analysis was focussed on effect of height on the melting process.

Many authors namely Longeon et al. [16], Assis et al. [17] , Al-Abidi et al. [18] have fascinated on numerical study of paraffin melting process for different melting temperatures by using RT35, RT27, RT82 respectively. Raymundo et al. [19] have numerically studied the heat transfer and hydrodynamic characteristics of erythritol in vertical rectangular cavity with inner fins.

## 2. CFD GEOMETRY

The 3-D fluid zone modeled by using CFD -ANSYS 18. A three dimensional geometry of thermal energy storage system is a shown in **Fig -1.** It consists of a cylindrical tank which is fabricated with the SS304 material, and it is insulated with mineral wool for preventing heat losses from the system. A copper tube folded in coil shape was used through which a heat transfer fluid (HTF) was circulated. To increase the heat transfer rate one more coil shaped winding made up of SS304 tube was placed in the tank. 14 kg of erythritol was considered in the storage tank as a Phase change material according to the calculation of volume expansion during solid-liquid phase change. A hot air was used as a HTF which was circulated through the copper winding coils. The dimensional detail of storage tank is given in **Fig -2.** The thermo-physical properties of PCM were considered from the literature [5-6]. **Table-1.** Shows the properties of PCM used in the present analysis.

**Table -1:** Thermo-physical properties of pcm

| Physical Properties | Value |
|---|---|
| Melting point/Boiling point | 117.7 ○C/390○C |
| Heat of fusion | 339.8 kJ kg$^{-1}$ |
| Specific heat of PCM, liquid Cpl | 2.76 kJ kg$^{-1}$ K$^{-1}$ |
| Specific heat of PCM, solid, Cps | 1.38 kJ kg$^{-1}$ K$^{-1}$ |
| Thermal conductivity of PCM, liquid, kl | 0.326 W m$^{-1}$ K$^{-1}$ (140 ○C) |
| Thermal conductivity of PCM, solid, ks | 0.733 W m$^{-1}$ K$^{-1}$ (20 ○C) |
| Density of PCM, liquid, dl | 1300 kg m$^{-3}$ (140 ○C) |
| Density of PCM, solid, ds | 1480 m$^{-3}$ (20 ○C) |

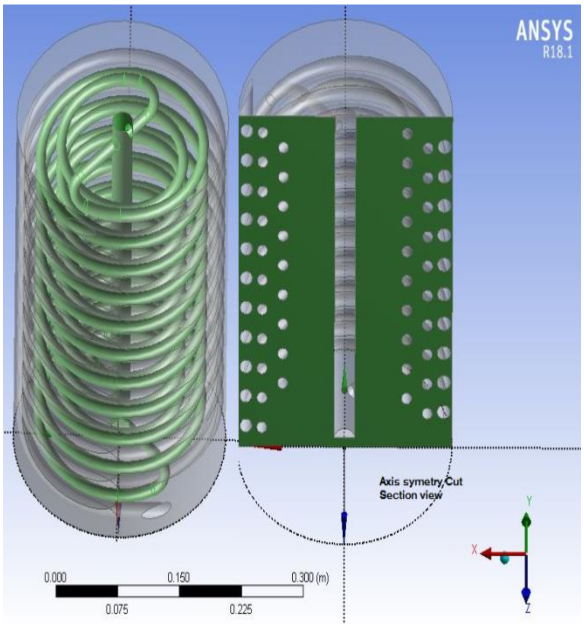


**Fig -1**: CFD modeling of heat storage system

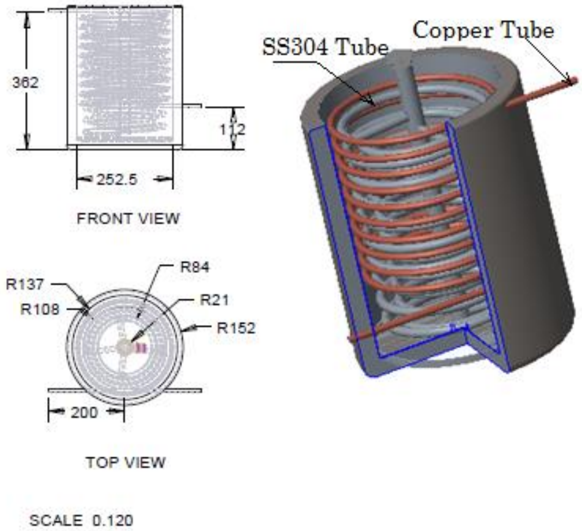


**Fig -2**: Dimensional detail of heat storage tank

### 3. CFD MESHING

The geometry of present work shows 2D axis symmetry. Hence meshing was considered on the basis of symmetric condition. Simulation of melting process was carried out by considering the Navier-Stokes equations. Fine meshing was done to discrete the fluid domain by considering triangular elements. About 10501 nodes and 19640 elements were considered during meshing. The minimum size and maximum face size were considered as 1.0mm and 5.0mm respectively. The growth rate was taken as 1.10 and normal curvature was 10°. The following **Fig -3** shows the meshing of the model.

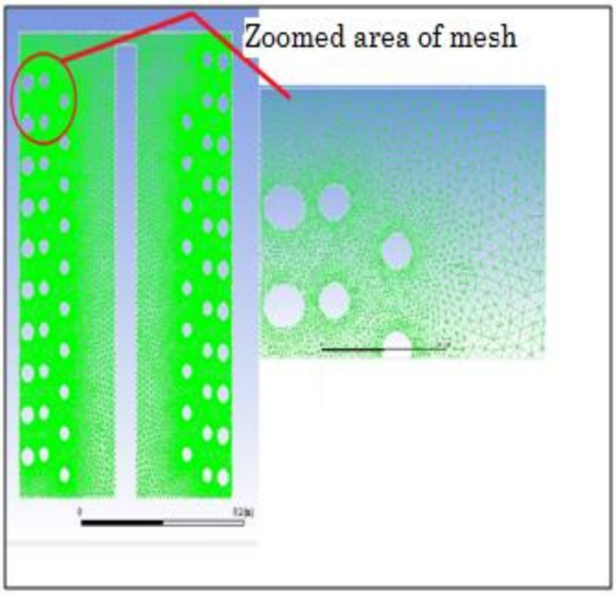


**Fig -3**: Meshing of the geometry

## 4. BOUNDRY CONDITIONS

In order to simulate the temperature flow during PCM melting process, a constant air input temperature of 140°C was defined at the wall boundaries of the heat storage tank. The initial temperature of PCM was considered as room temperature. The method of simple scheme with least cell was used. The mushy zone constant effect was taken in to consideration considered.

## 5. RESULT AND DISCUSSIONS

A high resolution plane for visualizing the results with respect to time, and capturing the temperature contours were used. The ANSYS FLUENT post processor was used to analysis the melting process. Maximum of forty six thousand iterations were considered for the study. Conduction heat transfer was taking place at the beginning and later on natural convection heat transfer leads the melting process. The Results found were having good agreement with the literature present on erythritol melting process [8]. Further in future work, the results of present simulation study will be compared with the experimental results. The results of transient temperature during PCM melting process is as shown in **Fig -4**.

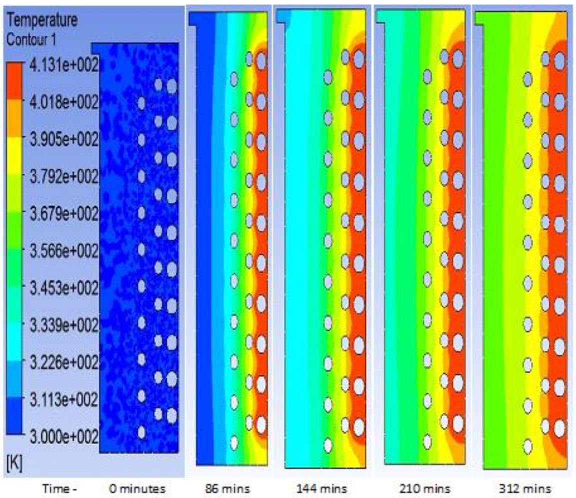


**Fig -4**: Contours of temperature during melting process of erythritol

## 6. CONCLUSIONS

The major intention of present study was to analyze and envision the 2D transient axis-symmetric CFD model at the melting phase of erythritol in the closed vertical cylindrical container. The study was focused on, the time required to melt 14 kg of erythritol in the closed vertical cylindrical tank, when a constant input temperature of air (HTF) of 140°C was circulated to the tank through the coil shaped copper tubes. The major conclusions are as follows:

1. The PCM was completely melted in 312 minutes.
2. The total latent heat energy stored is $6.494\times10^5$J/kg which can be utilized for 2 hrs.
3. Hence simulation study was possible effectively. by using Computational Fluid Dynamics (CFD) with FLUENT code

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