FREE CONVECTION ON MELTING IN CYLINDER CONTAINERS

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Introduction:

Heat transfer during phase change is an important phenomena with applications in process industries and solar energy thermal storage systems. Accurate methods to predict the rate of melting and freezing would lead to improved design. Melting studies were carried by Pannu et al[1] who gave numerical solutions for melting in horizontal and vertical cylinders. Rayleigh number appears as the free convection parameter. Melting tends towards conduction control for large height to radius ratios. A thermodynamic design for thermal storage module was given by Conti et al[2] .El Dessouky et al[3] made experimental studies for melting outside a vertical cylinder . The temperature distribution is given by thermocouples and the interface position is traced from the temperature distribution. The author defined Stefan and Biot numbers for the phase change material (PCM) and gave correlation for Fourier number. Further investigation of the interface location based on temperature distribution and verification of dimensionless correlations is required. In this paper experimental for melting in cylinders are presented and discussed.

Experimental Work:

Experiments were conducted in copper containers with L/D of 1.1 to 3. The melting was effected by placing the container in the isothermal bath maintained to an accuracy of ±1K. The sample of PCM for melting experiments needs preparation done by freezing the liquid PCM in the container in a cold water bath(±1K). The sample was considered ready when freezing of PCM completed and the difference between temperature at the center of the PCM and water is 1ºC. The container was immediately placed in a hot water bath. It was removed after a known time and the melt was separated.

Temperature distributions of PCM were obtained in the copper cylinder holding 400 ml. In this set of experiments conducted with L/D of 1.1, temperature distribution in the melt was obtained by placing PT-100 sensors at 0.5 cm height from the bottom at four radial positions. Photographs have been obtained at various times during the melting process. The experiments conducted covered the following range of parameters.

Table 1:

PCM	n-Octadecane
L/D	1.1 to 3
Volume of material	130 – 400 ml
Initial PCM temperature	8.1 to 18.7ºC
Temperature drop across the melt	16 to 33ºC

Results and Discussions:

Only a limited data are presented for discussion. The effect of solid temperature on melting rate is shown in figure1. The melt mass is less at any time for the lower initial PCM temperature of 8.1ºC compared to the PCM at 18.7 ºC and the overall melting time is substantially longer(about 33.3%). The mechanism of heat transfer in the melt is expected to be free convection for most of the melting time.

Effect of increase in the temperature drop across the melt(at constant initial solid temperature) is seen from figure 2. An increase in the initial slope is observed as the super heat is increased. However, variations in slope exist during the melting process and the total melting time varied from 25 min to 90 min as temperature dropped from 33.3 ºC to 16.3 ºC. Heat transfer rates are expected to be influenced by free convection due to temperature difference and the spacing between the container wall and the solid-liquid interface.

The temperature distribution(figures 3,4,5) at the measured positions near the PCM bottom clearly indicate an increase in the slope near the wall with time there by increasing the heat flux. Photographic study of solid-liquid interface gives the melting shapes which undergo a substantial change during the melting process. For example, in figure 5 for temperature drop of 30.8 ºC across the melt, after 254.1 grams have melted the shape is shown. This is almost a truncated cone with base diameter equal to 4.9cm, top diameter equal to 1.9cm and height equal to 2.7cm. It was observed during experiments that the melt expands and effects heat transfer at the top surface of the PCM. This invariably causes a shallow structure when viewed from the top. Therefore, it is felt that the initial PCM preparation has a significant effect on the melting process. The volume calculated on the basis of the solid matches the experimental value within 5%.

Conclusions:

The following conclusions are drawn,
1.The initial PCM temperature has a significant influence on the total melting time.
2.The increase in the temperature difference across the melt is seen to effect the initial gradient on melting mass versus time graph as well as total melting time.

3.A limited photographic study shows a change of shape from cylinder to that of a truncated as melting progresses. The expanded liquid causes melting of the top surface of PCM there by influencing further melting.

Further studies on correlating temperature distribution at various times with the solid-liquid interface are required. A photographic study during the melting process will clearly explain the interface deformations and this should be related to heat transfer rate.

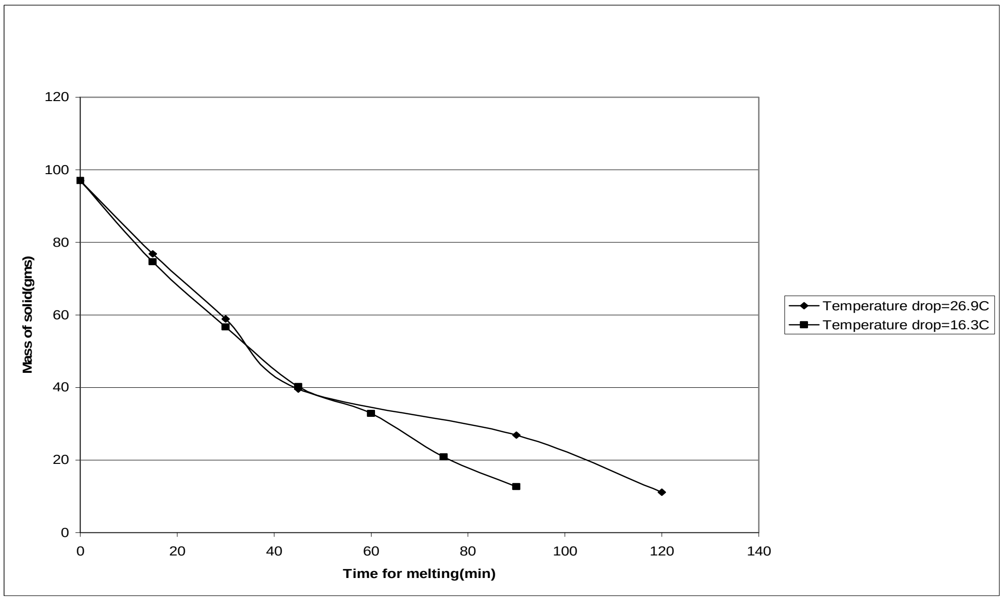

Figure 1. Mass of solid versus time for melting of n-Octadecane in a cylindrical container. Initial water temperature = 35ºC. Initial solid temperatures = 8.1ºC, 18.7ºC

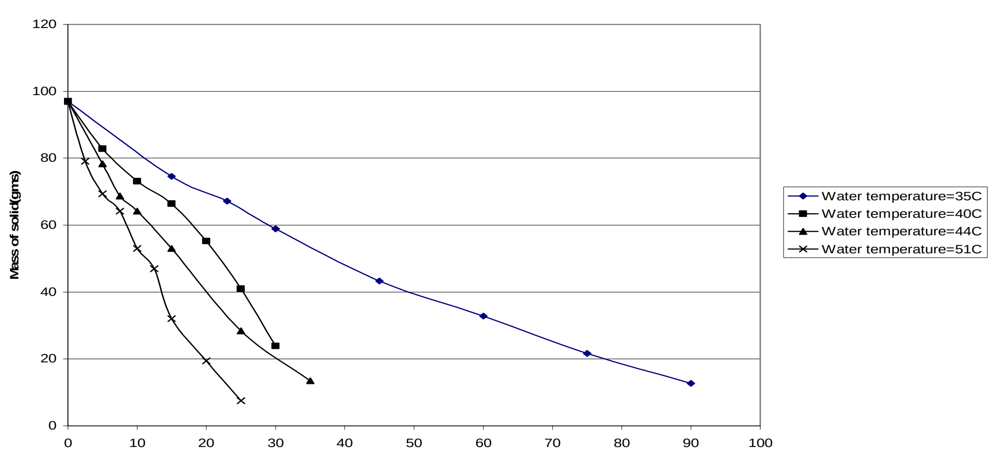

Figure 2. Mass of solid versus time for melting of n-Octadecane in cylindrical containers. Initial solid temperature = 18.7ºC

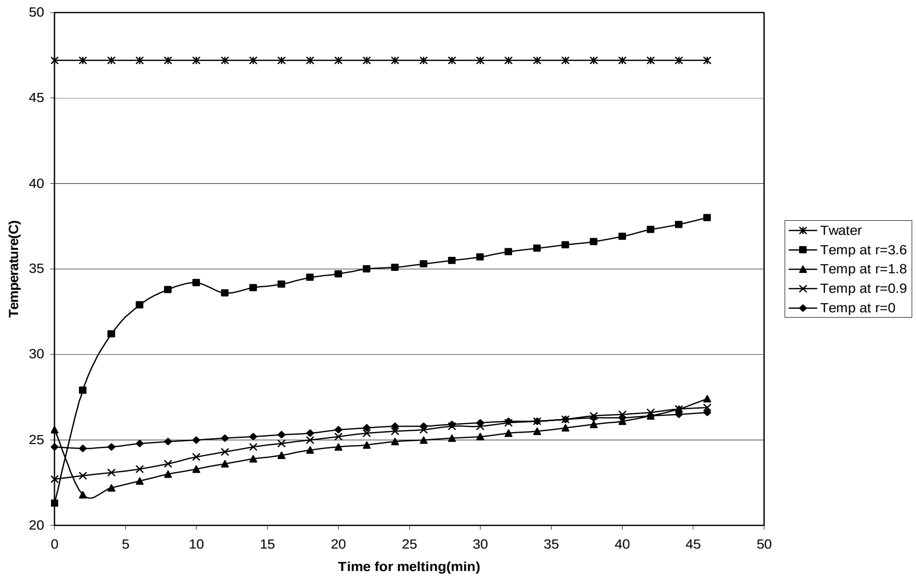

Figure 3. Temperature distribution for melting n-Octadecane in cylindrical containers.

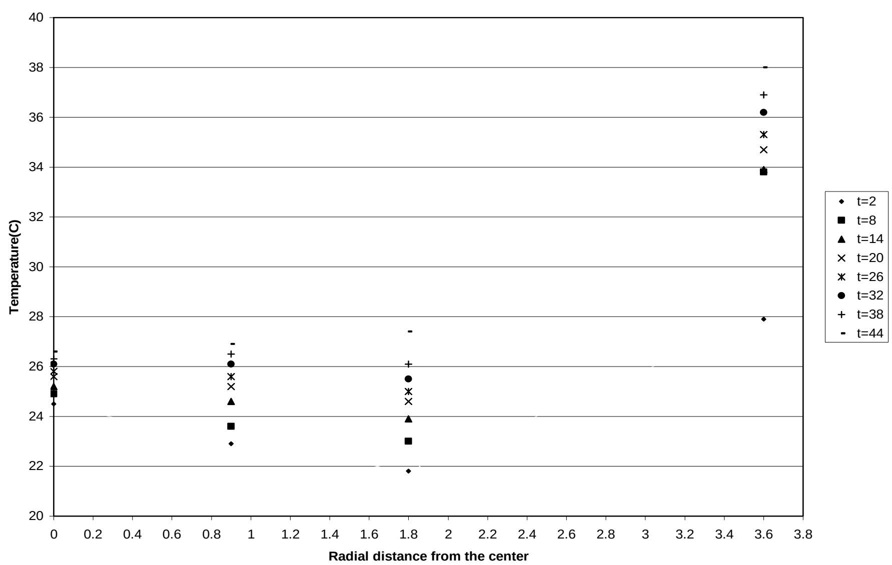

Figure 4. Temperature versus Radial distance for melting of n-Octadecane in cylindrical containers.

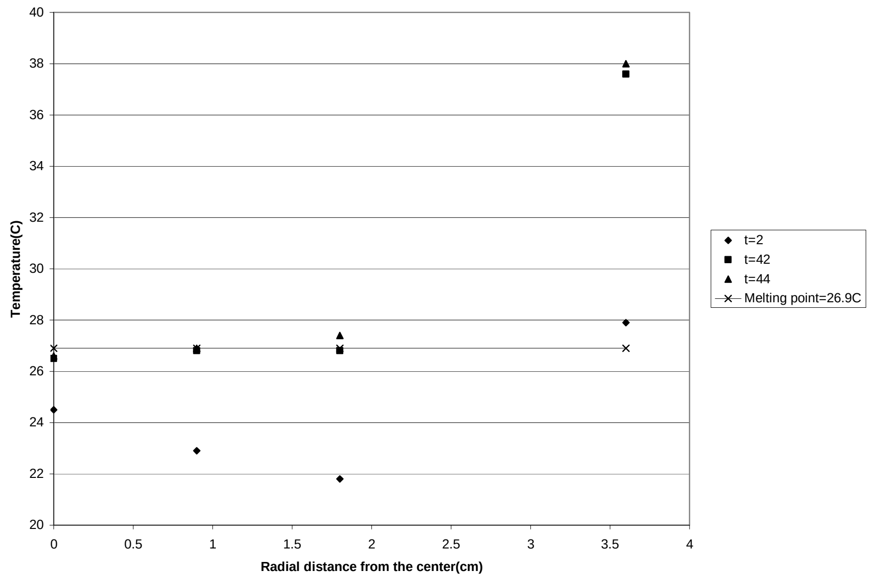

Figure 5. Temperature versus Radial distance for melting of n-Octadecane in cylindrical containers. Melting point of n-Octadecane = 26.9ºC.

Figure 6. Photograph of a molten solid for a temperature of 30.8ºC and after 254.1gms have melted. Base diameter = 4.9cm, Top diameter = 1.9cm and Height = 2.7cm.

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