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Heating Process with Modeling Water Vaporization in Solid Particle Materials

Yunhan Zheng, Ph.D.
Continental Research and Engineering
6825 East Tennessee, #101 Denver, CO 80224

Introduction

The amount of energy absorbed during water vaporization may have a critical effect on heating process for solid particle materials with high water level by weight due to high latent heat of water vaporization. Water need to be evaporated before solid particle materials can be heated beyond the boiling temperature of water. The amount of water in the solid particle materials will have significant impact on the heating process time. The more water that is present, the longer it will take to vaporize. This study will focus on how to use Fluent with User-defined functions (UDF) to model water vaporization in the heating process.

Problem Description

The problem to be considered is included in the solid particle materials, tray, and part furnace. Solid particle materials with different water percentage that are processed in the furnace need to be loaded onto trays. The burner inlet is a hot stream with constant temperature of 1600^{0}F (1143.89 ^{0}K). The process of heating the solid particle materials was modeled using Fluent k-ε turbulence model and Discrete Ordinates (DO) radiation model with UDF for water vaporization. The premise behind the water vaporization model is that when the temperature of a solid cell reaches 212 ^{0}F (373.15 ^{0}K) the water will begin vaporizing. During this process the heat flux in the solid is calculated and the water mass fraction decreases. The energy sources term in the energy equation and momentum source terms in the k-ε equation will be adjusted by water vaporization code in the modeling process. The temperature in each cell will remain at 212 ^{0}F until the water mass fraction in that cell reaches zero.

Results and Analysis

Figure 1 indicates the coldest temperature in the 2.0 inches thickness of solid particle materials with dry, 30% water mass fraction, and 45% water mass fraction. The heating process time to reach the minimum temperature of 1000 ^{0}F (810.9 ^{0}K) is listed in Table 1. It is very clearly shown that more heat processing time needed with the increasing of water mass fraction for the same thickness of solid particle materials. The heating time to reach 1000 ^{0}F in the solid materials with 45% water mass fraction requires 140 minutes, but only 75 minutes for dry solid particle materials. Figure 2 shows the water mass fraction variation in the heating process. The coldest point for 45% water mass fraction begins to vaporize at 75 minutes and finishes to vaporize at 101 minutes. In order to display the detailed temperature contours, a center cross section is defined as the plane in the middle of the solid particle materials which is parallel to the tray bottom. The detailed contours of temperature after 140 minutes are depicted in Figure 3.

Table 1 – Heating Process Time for Different Configuration

	Coldest temperature reaches 1000 ^{0}F (810.9 ^{0}K) in solid particle materials (Minutes)
Baseline 2 (Dry)	75
Case 2 (30% water mass fraction)	127
Case 4 (45% water mass fraction)	140

Conclusion

The presence of water in the solid particle materials has a significant impact on the heat processing time. As the amount of water increases, the time required for that water to vaporize also will increases. Fluent with UDF can be successfully used to simulate the effect of water mass fraction in solid particle materials.

Acknowledgement

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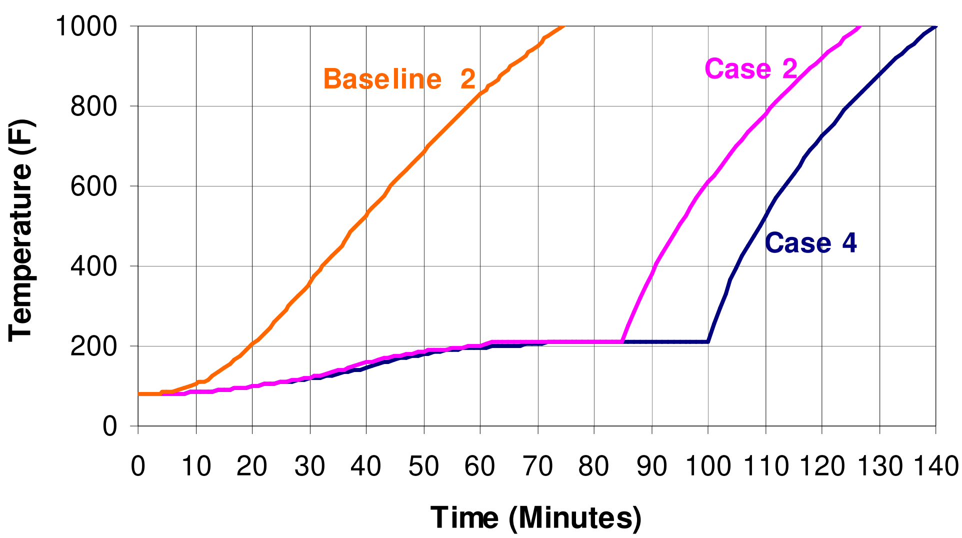


Figure1. Coldest Temperature in 2.0 inch Solid Particle Material with Different Water Mass Fraction (Baseline 2: Dry, Case 2: 30%, Case 4: 45%)

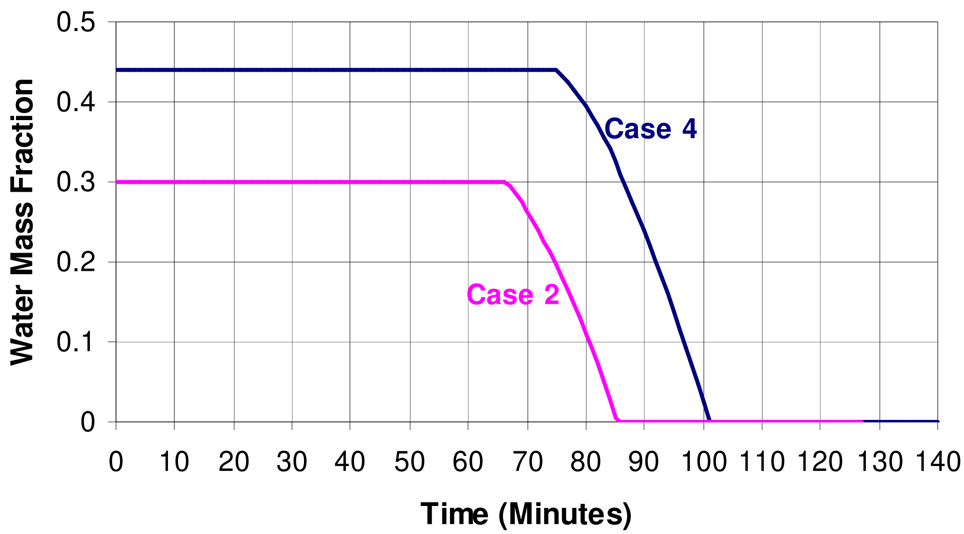
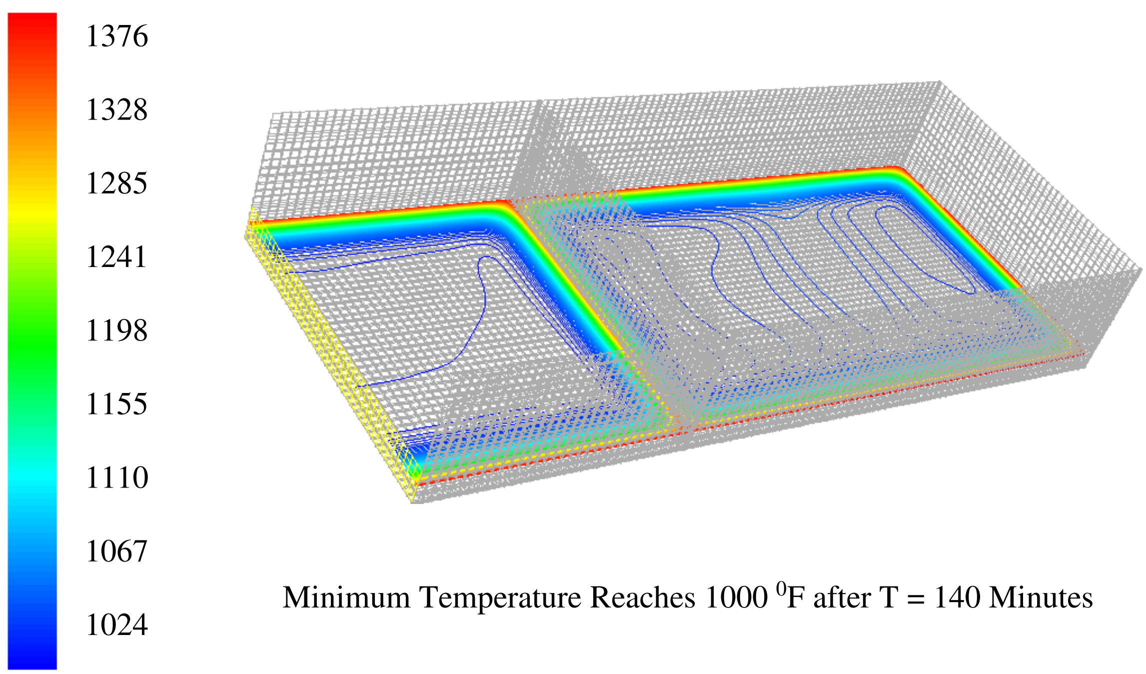


Figure 2. Maximum Water Mass Fraction in 2.0 inch Solid Particle Materials

(Case 2: 30%, Case 4: 45%)



Minimum Temperature Reaches 1000 ^{0}F after T = 140 Minutes

Figure 3. Contours of Temperature in Center Cross Section of Solid Particle Materials