学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（工学）　氏名　KIM, Yangkyun

学 位 論 文 題 名

A multiphase-based numerical study on time-dependent melting, deforming and dripping process of Phase Change Material (PCM) induced by external heat source
(外部加熱を受ける可溶解性固体 (PCM) の諸非定常過程 (溶融・変形・落下) に関する数値解析)

Deep understanding of fire damage triggered by combustion of electric wires is one of important issue in terms of the fire safety of automated facilities, such as factories, power plant etc. Combustion process of electric wire is, nevertheless, quite complicated since it consists of multi-phase, multi-dimensional time-dependent heat and mass transfer with chemical reactions in each phase and several fundamental processes are equally important so that it is relatively hard to simplify the system. For such reasons, very few attempts have been made at numerical study on the combustion involving multi-phase phenomenon, and no complete model which could cover combustion of electric wire with multi-phase phenomenon has been established yet. This research is particularly motivated by an interest in the establishment of numerical model for combustion of electric wire under multiphase framework.

In chapter 1, research of combustion of electric wire is briefly described first, and then possible numerical approach to simulate combustion of electric wire is introduced next, and then objective and strategy of thesis are shown last.

In chapter 2, mathematical formulation and numerical detail is described. To achieve our ultimate goal; such as propose of acceptable model of wire combustion, the most fundamental case that there is no species transport and reaction is considered first, then main part to be modeled is (1) how to consider the size change of the molten polymer, and (2) how to handle the complex melting process. In this regard, the governing equations in this chapter can only consist of the fundamental conservation equations (for mass, momentum and energy) under a multi-phase framework. We use the Enthalpy-Porosity and Volume of Fluid method (VOF) methods in order to approach the melting and dynamic motion of molten matter suspended by a metal plate. 2-D calculation domain, which consists of copper, PCM (Phase Change Material as a model of polymer) and air, is tested under the normal gravity with exposing localized external thermal input. This simplified geometry provides a physically similar analogy of the wire combustion under normal gravity condition.

In chapter 3, validation of numerical models is described. This chapter mainly shows

two types of validation; validation of modeling for liquid-gas interface and for melting front. Based on validation, it is concluded that models for liquid-gas interface and for melting front are qualitatively validated.

As results, chapter 4 shows melting and dynamic behavior of PCM (Phage Change Material) attached on metal plate by exploring various surface tension coefficients, external thermal inputs and melting temperatures. Pure effect of dynamic behavior of PCM is precisely investigated by comparing cases with/without deformation of gas-liquid interface on similar physical domain with experiment. It is found that behavior of molten polymer affects melting speed during its growth and dropping, and this dynamic effect on melting speed varies with different Stefan number and surface tension coefficient.

In chapter 5, by use of same computational configuration with same material properties used in chapter 4, thermocapillary convection effect on heat transfer, melting and dynamic behavior of PCM is examined. In order to consider thermocapillary convection, the source-based tangential force driven by surface tension, which linearly depends on the temperature, is modeled in the previous-proposed model. Numerical parameters are selected in order to investigate the thermocapillary motion in effective way, concluding that effect of thermocapillary convection on melting of Phase Change Material (PCM) is not so significant. However, it should be taken into account if the precise prediction of dripping-off timing is desired.

In chapter 6, the dynamic effect on melting speed is investigated with a moving external thermal source in order to explain the unsteady phenomena involved in experimental wire combustion. In this chapter, melting and deformation of polymeric material induced by a constant moving heat flux is investigated. The time-dependent melting and the behavior of the PCM are visualized together with the temperature distribution. The effect of the dynamic motion on the melting process with/without a deformable interface is discussed.

In appendix, gasification model based on previous-suggested model is discussed as ongoing research.