

Core drying simulation and validation

In the manufacture of inorganic sand cores it is necessary to remove any moisture remaining in the core before it can be used. Several techniques are employed to remove the water including heating in an oven, microwave heating and forcing hot, dry air through the core. In all cases, heating of a core can be expensive so there is interest in investigating optimum arrangements for achieving the most efficient means of removing the residual water.

This paper describes a computer model that allows for a realistic simulation of the core drying process. The new model considers porous sand cores of arbitrary shapes with properties such as moisture content, temperature and vapor concentration that vary throughout. A fully non-equilibrium phase-change model is used to compute the evaporation and condensation of water vapor in sand. Compressible gas dynamics describes the flow of the mixture of vapor and air in and around a core.

A description of the model is followed by a validation test using a simple core geometry. Further validation is reported based on tests with a realistic, production grade core.

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1 Introduction

A new inorganic core making process has certain advantages over the traditional organic process. It is environmentally friendly and healthier for the workers on the shop floor because it uses water based binder systems and hence does away with the toxic amine based binders. Furthermore the inorganic process offers a potential for the improvement of the casting quality due to reduced core gas production and lower tool temperatures. In this process it is essential to remove water from the sand in order to harden the core after shooting the sand in the mold.

This paper describes a software development for a realistic simulation of the core drying process. A description is given of the new model, which has been validated with data from a simple core arrangement. Further validation is reported based on tests with realistic, production grade cores dried with hot air forced through the bulk of the core.

A similar physical model, restricted numerically to one-dimensional geometries, was used by Pehlke and Kubo [1] to model moisture transport in green sand molds. In our implementation the core can have an arbitrarily prescribed shape with properties such as moisture content, temperature and vapor concentration that vary throughout. Thus, the core may have dried on its surface but still be completely wet on the inside. Air and water vapor existing in or around a core constitute a two-component gas that is treated as compressible. Heat conduction is simulated in all gas and solid regions and a non-equilibrium phase-change model is used to couple the liquid and vapor states of water. Using this model it is possible to simulate transient conditions

throughout a core and thereby make detailed investigations of non-uniform initial conditions as well as a variety of drying techniques.

2 Basic assumptions of the drying model

The new model, which is described in the next section, is based on several assumptions and approximations that are summarized next. The model provides a fully three-dimensional and time-dependent description for the compressible flow of a mixture of air and water vapor through and around porous solids. Heat conduction is included in all solid and gaseous regions.

The mixture of air and water vapor is treated as a two-component, compressible gas described by a polytropic-gas equation-of-state that relates the gas pressure, density and temperature. Specific heat and gas constant of the mixture are computed as mass averages of the two components.

Although variable moisture content is allowed in a core, no account is taken for wicking of water in the material or for displacement by airflow. The neglect of such small displacements is not likely to be significant since the total mass of water in a core is only a small percentage of the core mass in any case.

A further simplification is that the temperatures of the water and core material are always in local equilibrium. This assumption is reasonable because the water and solid material are in intimate contact and distributed on a scale that is fine compared to the thickness of a core. Gas tem-

