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Numerical simulation of thermal convection in a fluid with the infinite Prandtl number and its application to a glass manufacturing problem

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ABSTRACT. Thermal convection phenomena of fluids with the infinite Prandtl number are studied via numerical simulations. These phenomena are governed by various physical mechanisms in a glass melting furnace that affect the quality of glass. As an extension of the numerical model for thermal convection phenomena with the infinite Prandtl number, we present an effective finite element scheme that is called a stabilized method and enables us to carry out stable computation even for the cases of high Rayleigh numbers. By means of this scheme, transient growth of thermal convection in a topcooled rectangular domain is studied. This problem is regarded as a model of cooling process in a glass melting furnace. The computational results reveal the mechanism of generating debasement of glass quality in the cooling process. Applying the results of the simulations, we present a new cooling method that enables us to shorten a residence time that is necessary for cooling without debasement of glass quality.

1. Introduction

In this paper we study transient thermal convection of fluid flows with the infinite Prandtl number by applying numerical simulations. This work is motivated by the study of quality debasement in the glass production in the glass melting furnace. Figure 1(a) shows a schematic illustration of a typical glass melting furnace producing the sheet glass. Figure 1(b) shows cross sectional illustrations of the melting and cooling sections of the furnace. In the glass melting furnace, glass materials are heated up to about 1500° C in the melting section and then molten glass is cooled down to about 1100° C in the cooling section. As shown in Figure 1(b), the molten glass is placed in two different types of thermal conditions in the furnace. In the melting section the temperature of the molten glass is high on the top surface and low at the bottom because it is heated on the top surface and cooled at the bottom

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