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FACULTY OF ENGINEERING

NUMERICAL SIMULATION OF SOLIDIFICATION IN SIMPLE SHAPED CASTINGS

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by

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NUMERICAL SIMULATION OF SOLIDIFICATION IN SIMPLE SHAPED CASTINGS

M.Sc. Thesis
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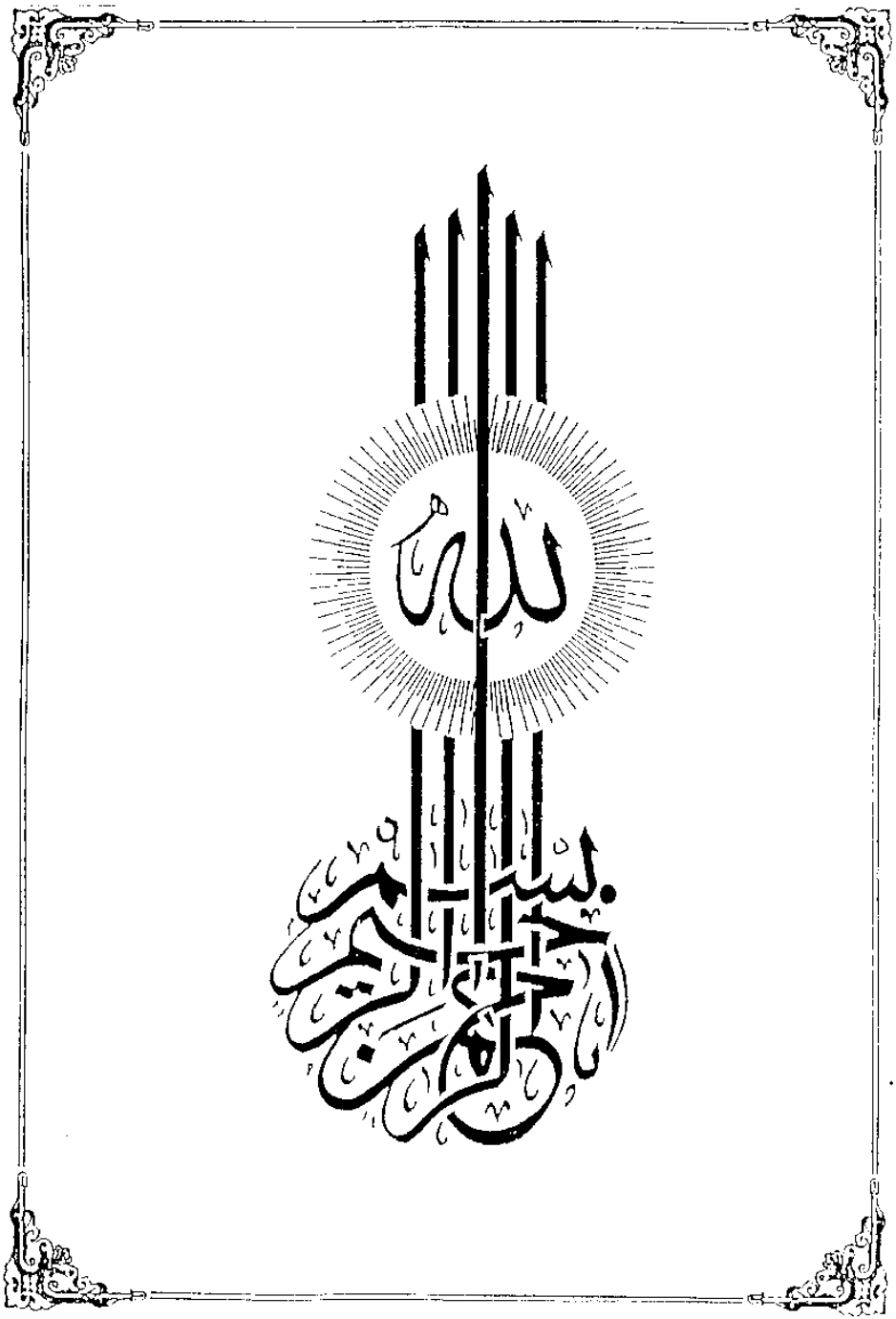

STATEMENT

This dissertaion is submitted to Ain Shams University for the degree of Master in Mechanical Engineering.

The work included in this thesis was carried out by the author in the Department of Design and Production Ain Shams University, from 2 - 10 - 1986 to 17 - 5 - 1990.

No Part of this thesis has been Submitted for a degree or a qualification at any other University or Institution.

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TO

MY DEAR PARENTS

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Summary

In the recent years, studying the natural convection current has been considered as one of the most important standard phenomenon in the solidification of casting and ingot processes. This phenomenon plays an important role in the formation of macro/microstructure which will affect the mechanical properties of cast structures and also will affect macrosegregation which deteriorates the quality of final products. It has been shown that natural convection current depends mainly on the constitution of the alloy system, the composition of alloy, the thermal parameters of alloy and the superheat.

The present work aims at studying the effect of natural convection during the solidification processes on the temperature distribution and the velocity profiles in Al-4.5% Cu and Al-12% Si alloys solidified directionally at different superheats and todescribe the effect of convection on the macro/microstructure and segregation.

For this purpose a mathematical model was set to describe the fluid flow and heat transfer phenomena during solidification process for two - dimensional rectangular mould cavity. The model used to determine the temperature distribution and the velocity profiles as a function of time.

An experimental set up was designed constructed, calibrated and then used for specimen preparation in which

temperature measurement in seven predetermined positions was achieved. Two alloys Al-4.5% Cu and Al-10% Si are used. These rectangular specimens 80x40x20 mm in the length, height and width respectively were directionally solidified against a steel end chill using the constructed apparatus.

The process variables taken into consideration are :

- Superheat of the melt : ranging from 20 to 75°C.
- Alloy constitution.

In Al-4.5% Cu the volume fraction of the second phase ($Cu\ Al_2$) and the grain size were measured. The results for different superheats indicate that the volume fraction increases in the lower part of the specimen and as the superheat decreases and also it decreases as the distance from chill increase until the steady state value is reached. The results indicate also that the grain size increases as the superheat decreases and also increases as the distance from chill increases.

In Al-12% Si the volume of fraction of (primary Si) was measured. The results for different superheats indicate that the volume fraction increases for the lower part of the ingot as the superheat decreases.

In the present work, comparison between experimental and computed results of cooling curves was made. It also includes the different solidification parameters at different phases, the shape of liquidus and solidus isotherm and the relation between the heat transfer coefficient and

time and chill temperature. Additionally, it includes the convection velocity profiles with time.

A general discussion is presented including the effect of temperature gradient on the velocity modes and also the effect of convection on solidification process, macrosegregation and grain size in view of the convection current velocity and formation of new crystals.

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INTRODUCTION

There is true basic that the natural convection currents phenomenon is inherently associated with the majority of solidification processes which are driven by density fluctuations in the fluid that are induced by inhomogeneous temperature distribution or different impurity concentration within the system. Natural convection currents can be classified into two categories : the first is thermal convection due to the temperature gradients and the second is solute convection due to the solute gradients which its effect in hyper-eutectic alloys is higher than in hypo-eutectic and eutectic alloys.

The convection currents affect mainly the structure of casting where the importance of generated convective flow is usually desirable to obtain fine grained equiaxed structure in casting as the convection currents help develop equiaxed zones. The solute convection also affects the solute redistribution (macrosegregation) in the fluid during solidification and cause some of macrosegregation types.

For treating this phenomenon to predict by the the free convection currents and to get more detailed information about the solidification processes such as controlling grain structure in cast metal, the explaining the mechanism of transition from columnar to equiaxed zone in ingots and the macrosegregation such as gravity segregation and normal segregation , a mathematical model is set and solved.