CASTING AND SOLIDIFICATION OF SEMI-SOLID ALLOYS

Ph.D. THESIS
IN
MECHANICAL ENGINEERING

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(Production Engineering)

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بسم الله الرحمن الرحيم

To my late father, who encouraged and assisted me strongly in life, to my mother and to my dear wife whose love and support enabled me to work hard.

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SUMMARY

is work has the aim of modelling the heat flow and analysing
ıeology of the semi-solid slurry inside the stirring cham-
: continuous rheocaster, then verifying both experimenta-
'or this purpose a continuous rheocaster suitable for Bi-
ın model alloy system and operating at practical values of
ıles, has been designed and constructed.

he processing variables considered are : the shear rate
ed in the rheocast (RC) slurry $\dot{\gamma}$, ranging from 270 s^{-1}
) s^{-1}, slurry flow rate $\dot{Q}_p$, ranging from 4.5×10^{-3} to
10^{-3} Kg/s and the input temperature T_i, ranging from 500
) K.

heat flow in the stirring chamber of the continuous
ıster is studied using a two - dimensional dynamic heat
'er model and solving it numerically.
rheological behaviour of the alloy slurry in the stirr-
ıamber is studied analytically and experimentally. Semi-
.cal relationships for the influence of structure and shear
nduced in the slurry $\dot{\gamma}$, on the apparent viscosity η_a
'ived . Structure parameters considered are : volume fra-
of primary solid particles G_s , average particle size
and solid-liquid interface area per unit volume of the
S_v .

e slurry flow rate $\dot{Q}_m$ in terms of stirrer radius R_1 he inner radius of the stirring chamber R_2 and the slur-parent viscosity η_a is obtained.

this work new awareness has been established about the ionships between the parameters influencing the rheocasting 3s which are valuable in the future work.

: main results obtained can be summerised as follow :

ry temperature at the exit port of the continuous rheo-er, T_{exit} : it increases with increasing , $\dot{Q}_p$ and T_i and easing the number of cooling coils per unit height of stirring chamber, N_g and its height, L.

ry apparent viscosity, η_a : it increases with increasing λ_m and S_v . It decreases with increasing the shear rate, .

ostructure : 1) G_s increases with decreasing $\dot{Q}_p$ and 2) λ_m decreases with increasing, $\dot{\gamma}$ and the primary cool-, $\dot{\varepsilon}$. 3) S_v decreases with increasing, $\dot{\gamma}$ and decreasing $\dot{\varepsilon}$.

ch results will be useful in designing the continuous ster as well as in determining the suitable processing ions.

CONTENTS

INTRODUCTION

INTRODUCTION

The rheocasting process uses a partially solidified alloy ry as a charge and thus differs from other commercial met- shaping processes which use either fully liquid(conventi- casting) or fully solid alloy(conventional forming). The ess consists of vigorously agitating the alloy in the d-liquid temperature range, to produce a highly fluid semi d slurry.

Rheocasting processes are either batch one or continuous Continuous rheocasting is more convenient to practical ications, and is more advantageous than batch rheocasting.

Most of the published work on rheocasting was directed tow- , studying experimentally the effect of process variables he viscosity of rheocast alloy slurries, the structure of completely solidified rheocast materials, and mechanical erties. Previous work(1-24) have shown that the process is ising so that it can lead to a novel structure, improved dness and homogeneous chemical composition and mechanical erties. On the other hand, the process seems to be econ- ally promising due to low energy consumption, better die , possibility of casting high temperature alloys into dies. advantages are gained since low temperature is used comp- to conventional casting.

Inspite of all these advantages, it is still too difficult pply the process technically. Indeed much better theoretical rstanding of the process is needed in order to be able to rol it and therefore apply it technically.

It is the aim of the present work, which is a part of a arch program in the metal casting laboratories - Ain-Shams ersity, to touch these area of research. This work includes lling of the heat flow and analysis of the rheology of semi l Bi-17%wt Sn alloy slurry inside the stirring chamber of :ontinuous rheocaster, then verifying both experimentally.

For the experimental work, a continuous rheocaster was des- l and constructed. A numerical model is presented which ;imulate the temperature fields in the alloy contained in ;tirring chamber. The results agree well with measurements. nodel is also used to predict some relationships between process parameters in continuous rheocaster

.nalytical models are also derived for describing the .ogy of partially solidified Bi-17%wt Sn alloy slurry .

'elationships obtained in this work between the parameters ıg in the rheocasting process throw more light on the 'standing of the process and may represent a step forward pproaching the practical application of it.

CHAPTER 1

LITERATURE SURVEY

CHAPTER I

LITERATURE SURVEY

ıe process of rheocasting was started in 1949 by Wheel-
ı England, who used it for producing permanent moulds
.es . However, the process started to be known on scie-
basis later on by Flemings(1-9) in the MIT in 1971 ,
work opened new areas for both science and technology.
histogram in figure(1.1) shows the distribution of the
of publications on the process appeared in the period
85). Flemings et al found that when metal alloys are
usly agitated during solidification they form slurries
viscosity, even at fraction solid as high as 0.6 .
ent names have been given which are : rheocasting, stir
ng, casting of semi-solid alloys and casting of part-
solidified alloys. The process includes the production

Types of rheocasting apparatus

The rheocast slurry can be produced as a unique batch in
ible. In this case the stirred slurry has to be poured
he mould as in conventional casting. Another technique
has been developed by Flemings et al[10] is the prod-
of continuous rheocast slurry. In the batch type, the
nental procedure was to heat the alloy above the liquid-
perature . The stirrer was then lowered in the melt, and
on begins as shown in figure(1.2). The temperature of