HIGHER TECHNICAL INSTITUTE

MECHANICAL ENGINEERING COURSE

DIPLOMA PROJECT

METALLURGICAL EXPERIMENTATION ON THE CASTING OF PURE ALUMINIUM

M/937

ANASTASIADES PANICOS

JUNE 2002

Higher Technical Institute

Mechanical Engineering Course

Diploma Project

Metallurgical experimentation on the casting of pure aluminium

Project Number : M/937

Anastasiades Panicos
June 2002

Metallurgical experimentation on the casting of pure aluminium

by

Anastasiades Panicos

Project Report

submitted to

the Department of Mechanical Engineering

of the Higher Technical Institute

Nicosia Cyprus

in partial fulfilment of the requirements

for the diploma of

Technician Engineer

in

Mechanical Engineering

June 2002

To all the cans of beer
this diploma project's
award money will buy

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to my project supervisor Mr. G. Katodrytis for his inspiring and sincere support.

I also wish to thank Laboratory Assistances Dr. I. I. Angeli and Mr. C. Christodoulou for their aid in the casting process.

I would like to express my gratitude to all the workshop instructors for their assistance in constructing the metal mould.

Finally I thank all those unnamed who help me in any way in the completion of this project.

INTRODUCTION

The grain structure of a specimen, produced by casting, is affected by the cooling rate, under which it solidifies and reaches ambient temperature.

The principle objective of this diploma project is to show that indeed the cooling rate during solidification of a material dictates the grain structure of the cast specimen. This can only be accomplished by casting specimens, under different conditions, in order to compare and comment on the differences between the specimens' crystal structures. The material that is to be used is commercially pure aluminium, due to its low melting temperature. In addition pure metals have a more simple grain structure than alloys. Also pure metals can be examined at lower magnification than alloys.

To achieve that a simple metal mould must be designed and constructed, which must contain a cylindrical cavity. This mould should be able to produce cylindrical specimens, which later on are to be machined, to obtain parts of the specimens chosen to be examined.

By applying several techniques during casting process different cooling rates are to be attained which will produce specimens with different grain structures. Such techniques include heating up the metal or heating the metal to be cast just above its melting point, to reduce temperature difference between the liquid metal and the mould and effectively reduce the cooling rate of solidification.

The specimens cast, should then be prepared for microscopic examination. The preparation includes polishing and etching sections of the specimens. This will reveal the specimens structure in order to examine the arrangement and size of the grains. Then, after examining the specimens' grain structures and photographing them, they should be compared between them to denote that the cooling rate of solidification during casting process affects the grain structure of the cast specimen.

Contents

ACKNOWLEDGEMENTS iv

INTRODUCTION v

SOLIDIFICATION OF METALS 1

1.1 CRYSTALLISATION OF METALS 1
1.1.1 Introduction 1
1.1.2 Liquid-Solid Transformation (Crystallisation) 3
1.1.3 Homogeneous and Heterogeneous Nucleation 4
1.1.4 Crystal Growth 9
1.1.5 Variation of Nucleation and Growth due to Dynamic Conditions 17
1.1.6 Directional and Orientated Cast Structure 18

1.2. NON-EQUILIBRIUM EFFECTS AND VOLUME CHANGES 19
1.2.1 Introduction 19
1.2.2 Non-Equilibrium Cooling Rate: Crystallisation Of Primary Phases 20
1.2.4 Equilibrium Cooling Rate 29
1.2.5 Solidification in a Mould: Volume changes and Feeding 29
1.2.6 Solidification in a Mould: Volume changes and Solid Contraction 32

MOULDS 36

2.1 FUNDAMETALS OF CASTING 36
2.1.1 Introduction to Casting 36
2.1.2 Casting Terminology 38
2.1.3 The Solidification Process 40
2.1.4 Design Considerations in Castings 55

2.2 MOULD DESIGN 59
2.2.1 Mould Concepts Definitions and Materials 59
2.2.3 Metallurgy of Metal Moulds 60
2.2.4 Metallurgical Significance of Moulds 63

2.3 THE DESIGN OF THE METAL MOULD 70
2.3.1 AutoCAD drawings 70
2.3.2 Constructing the Mould: Manufacturing Processes 71

THE CASTING PROCESS 72

3.1 MELTING OF METALS 72
3.1.1 Compositional Problems 72

3.2 METALLURGICAL PRINCIPLES OF MELTING 75
3.2.1 Chemical reactivity 75
3.2.2 Physical properties 77

3.3 THE MELTING PROCESS 79
3.3.1 Stages of melting 79

3.4 THE CASTING PROCESS 81
3.4.1 Casting Conditions 81
3.4.2 The casting procedure 82
3.4.3 The Cast Specimens 83

GRAIN STRUCTURE EXAMINATION 85

4.1 THE PREPARATION OF SPECIMENS 85

4.2 MICROSCOPIC OBSERVATIONS 86

4.3 THE EFFECT OF COOLING RATE ON GRAIN STRUCTURE 92

SUMMARY 96