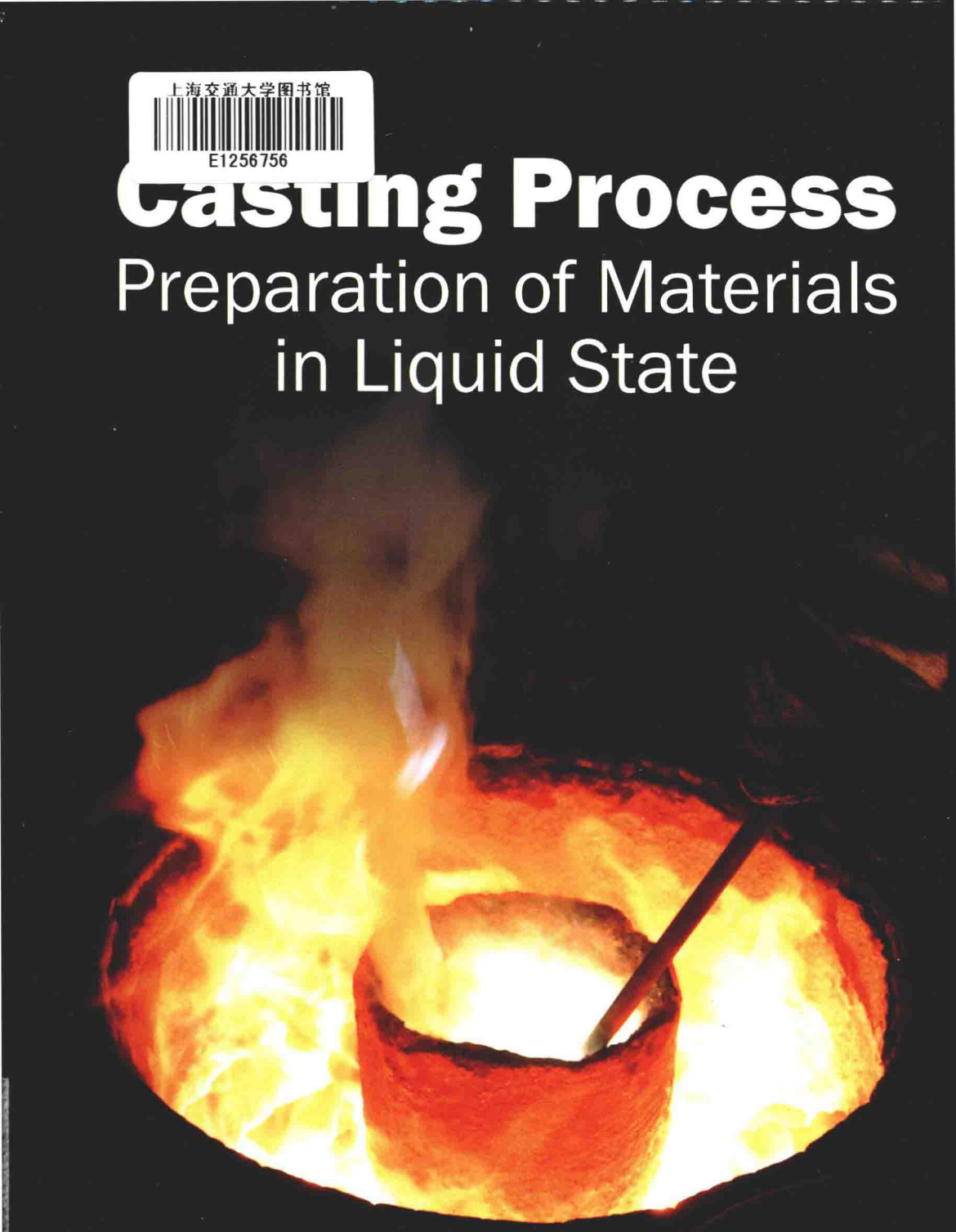
Casting Process

Preparation of Materials in Liquid State



Travis Xavier

Casting Process: Preparation of Materials in Liquid State

Edited by **Travis Xavier**

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Preface

Casting is basically described as a manufacturing process through which a liquid material is solidified with the help of a mould which consists of a hollow cavity of the desired shape. This book consists of different science and technology factors that require careful consideration for casting production. It includes contributions by various professionals with extensive experience in their respective areas. This book discusses topics such as simulation of continuous casting process, control of solidification of continuous castings, effect of mold flux in constant casting, segregation in strip casting of steel, and advancements in shell and solid investment mold methods. It also elucidates various issues related to permanent molding of cast iron, pressure control during filling sand molds, wear resistant castings, and progress in the accurate estimation of graphite nodularity in ductile iron castings.

This book is a comprehensive compilation of works of different researchers from varied parts of the world. It includes valuable experiences of the researchers with the sole objective of providing the readers (learners) with a proper knowledge of the concerned field. This book will be beneficial in evoking inspiration and enhancing the knowledge of the interested readers.

In the end, I would like to extend my heartiest thanks to the authors who worked with great determination on their chapters. I also appreciate the publisher's support in the course of the book. I would also like to deeply acknowledge my family who stood by me as a source of inspiration during the project.

Editor

Contents

	Preface	**VII**
Section 1	**Disposable Mold Castings**	**1**
Chapter 1	**New Casting Method of Bionic Non-Smooth Surface on the Complex Casts** Tian Limei, Bu Zhaoguo and Gao Zhihua	**3**
Chapter 2	**Sand Mold Press Casting with Metal Pressure Control System** Ryosuke Tasaki, Yoshiyuki Noda, Kunihiro Hashimoto and Kazuhiko Terashima	**17**
Chapter 3	**Evaluation and Modification of the Block Mould Casting Process Enabling the Flexible Production of Small Batches of Complex Castings** Sebastian F. Fischer and Andreas Bührig-Polaczek	**39**
Chapter 4	**Progress in Investment Castings** Ram Prasad	**67**
Section 2	**Reusable Mold Castings**	**115**
Chapter 5	**Mould Fluxes in the Steel Continuous Casting Process** Elena Brandaleze, Gustavo Di Gresia, Leandro Santini, Alejandro Martín and Edgardo Benavidez	**117**
Chapter 6	**Permanent Molding of Cast Irons - Present Status and Scope** M. S. Ramaprasad and Malur N. Srinivasan	**146**
Chapter 7	**Control Technology of Solidification and Cooling in the Process of Continuous Casting of Steel** Qing Liu, Xiaofeng Zhang, Bin Wang and Bao Wang	**198**

Section 3 Evaluation of Castings 233

Chapter 8 **Accuracy Improving Methods in Estimation of Graphite Nodularity of Ductile Cast Iron by Measurement of Ultrasonic Velocity** 235
Minoru Hatate, Tohru Nobuki and Shinichiro Komatsu

Chapter 9 **Fracture Toughness of Metal Castings** 254
M. Srinivasan and S. Seetharamu

Chapter 10 **Segregation of P in Sub-Rapid Solidified Steels** 282
Na Li, Shuang Zhang, Jun Qiao, Lulu Zhai, Qian Xu, Junwei Zhang, Shengli Li, Zhenyu Liu, Xianghua Liu and Guodong Wang

Chapter 11 **Research on Simulation and Casting of Mechanical Parts Made of Wear-and-Tear-Resistant Steels** 309
Ioan Ruja, Constantin Marta, Doina Frunzăverde and Monica Roşu

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List of Contributors

Section 1

Disposable Mold Castings

Chapter 1

New Casting Method of Bionic Non-Smooth Surface on the Complex Casts

Tian Limei, Bu Zhaoguo and Gao Zhihua

Additional information is available at the end of the chapter

1. Introduction

Many studies have shown that the surfaces of most creatures contain non-smooth structures, such as dimple concaves on the Cybister bengalensis and riblets on the shark skin, as shown in Figure 1. Non-smooth structures are formed in special non-smooth surfaces which have specific biological consequences, such as "shark skin effect" see in [1], "lotus leaf effect" see in [2] and "non-smooth surface effect" in references [3-4], all of which are closely related to certain functions. In accordance with the above-mentioned effects, the functions are drag reduction in [1], self cleaning in [2] and anti-adhesion, respectively in [3-4]. For shark skin, Singh, Yoon and Jackson in [5] found the riblets are directed almost parallel to the longitudinal body axis and this effectively reduces drag by 5%–10%.Ren et al [6] also demonstrated that both riblet and dimple concave non-smooth surfaces could be applied in pumps to increase efficiency. Other studies have shown that these non-smooth surfaces (called bionic non-smooth surface) have some certain functions in the fields such as aviation see in [7], pipeline in [8] and antifouling see in [9-10]. As for the riblet on shark skin and dimple concave on cybister bengalensis, when applied in the engineering, they are simplified as the shape of groove and dimple concave, as shown in Figure 2.

The traditional process method of such non-smooth surface includes Electro Discharge Erosion (EDE), Metal Engraving method (ME) and machining, all of which have disadvantages such as high processing cost and low processing efficiency. For example, ME processes rib-like non-smooth surfaces whose cross-section is a triangle on the complex surface casts directly, as shown in Figure 3. There are several disadvantages as follows: first, because of the limitations of tool radius, it is impossible to process sharp angles on the surface, the eventual angles of the cross-section are round on the surface, which is different from the original design ideas; second, the surface of rib-like non-smooth structures is rough and it needs oth-

er post-reprocessing like polishing, which increases the processing cost; third, residual stress on the surface are produced, which affects the quality of the casts. Most important of all, when the casts have complex surface such as impeller flow of centrifugal pump, it is difficult to form continuous rib-like non-smooth surfaces from flow channel entrance to the exit due to the complex flow of impeller. However, this is different from the design idea that the bionic non-smooth surfaces should be arranged in the entire flow channel.

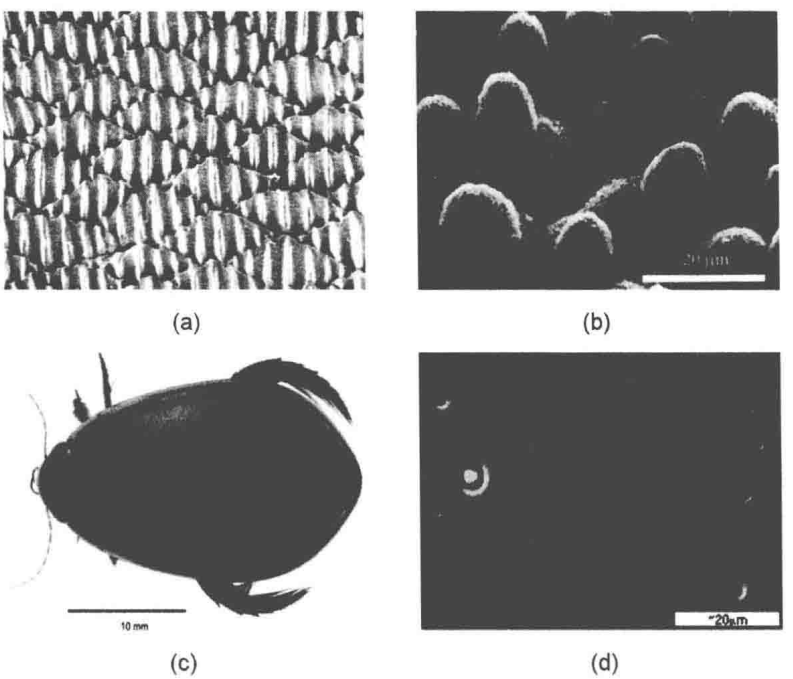


Figure 1. Non-smooth structures of some typical living creatures' skin. (a) riblets and grooves found on the shark skin [1]. (b) mastoid and micro-nano composite structure of lotus-leaf [2]. (c) Cybister bengalensis. (d) Dimple concave non-smooth structures on the back of Cybister bengalensis [3].

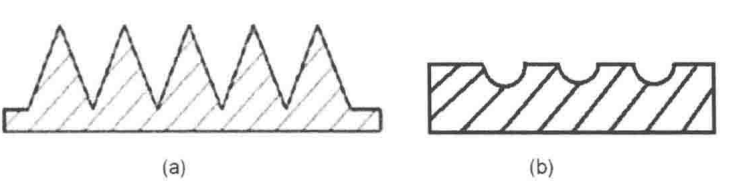


Figure 2. Simplified non-smooth structures. (a) Groove mimic from the shark skin. (b) Dimple concave mimic from the Cybister bengalensis skin.

Figure 3. Engraving rib-like non-smooth structures on the complex surface.

In addition to traditional processing method, biology constrain forming technology based on the mechanism of bionic manufacturing see in [11-13] is used to produce a kind of biomimetic skin, but it is suitable for the polymer materials rather than for metal surface process. In light of this, this chapter investigates a new casting method to process non-smooth structures on the complex cast surface.

2. Method and Mechanism

2.1. Disadvantages of traditional casting method of rib-like bionic non-smooth surface

Traditional casting method to form such rib-like non-smooth surface has following disadvantages.

1) It is difficult to form small narrow rib-like structures continuously, as shown in Figure 4(a). Because the cross-section of Structure 6 is equilateral triangle with very small and sharp angels on Casting Mold 5, as shown in Figure 4(c). As Convex Section 4 in Figure 5 is formed by sand sculpturing on Casting Mold 3, it is difficult to depart the molds smoothly in the process of demolding. As a result, the part or the whole of Convex Section 4 collapses and the narrow rib-like non-smooth structures will not be formed or formed incompletely.

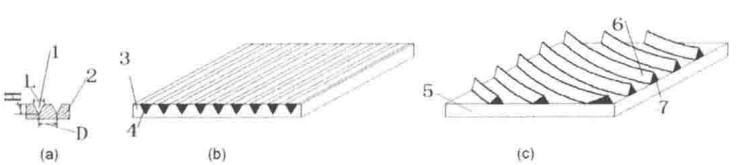


Figure 4. The casting mechanical diagram of rib-like non-smooth structures. (a) the cross-section of rib-like structures. (b) rib-like structures on the rubber plank. (c) paste non-smooth structures to form bionic non-smooth surface on the sand core.

In figure 4(a) L and H are the length and height of rib-like structures respectively, and D is the distance between them. 1 refers to the cross-section of rib-like non-smooth structure which is a triangle; 2 refers to the casting surface; 3 is the rubber plank; 4 is rubber rib-like structures cut from the plank; 5 is the sand core; 6 is the insulation coating materials painted on the rubber rib-like structure; 7 is rib-like non-smooth structures arranged on the sand core to form bionic non-smooth surface.

2) The sharp angle in design will not be formed. Many experiments have shown that, compared with other non-smooth rib-like structures whose cross-section is a triangle, those with a sharp angle have the best drag reduction. However, traditional casting method will not form a sharp angle directly in the demolding process.

2.2. The casting mechanism of one-time casting molding (OTCM) rib-like bionic non-smooth surface

In light of the disadvantages of the above-mentioned traditional casting method, a new casting method is investigated which is called one-time casting molding method (OTCM). During the casting process, two intermediate media are used, namely, hard rubber and high temperature insulation coating material (HTICM). The former is used to form the shape of rib-like non-smooth structures and the latter paints on the surface of rubber non-smooth structures in order to prevent the melted iron from contacting the rubber directly and keeps the rubber from melting within 1 or 2 seconds, so non-smooth structures would be formed as expected. It is especially helpful for the formation of a sharp angle of rib-like structures. After the metal liquids cool with a rapid decline of temperature, the rib-like non-smooth surface is formed. The mechanism of this method is shown in Figure 5. In order to form a triangular cross-section of rib-like non-smooth structure (indicated by 2) on the cast (indicated by 1), the same shape of the convex section (indicated by 4) should be formed on the sand core (indicated by 3), as shown in Figure 5(a) and 5(b).

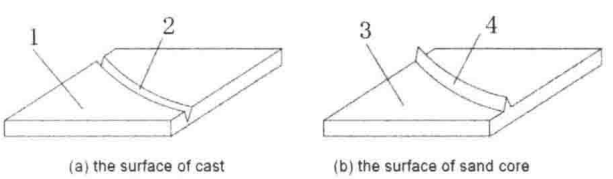


Figure 5. Schematic diagram of OTCM. 1 refers to cast; 2 is the triangle cross-section of the rib-like non-smooth structure; 3 is sand core; 4 is the rubber triangular convex section.

The steps of casting are as follows: ①cutting many rib-like structures on the rubber plank, whose shape is the same as the final target cast; ②brushing insulation materials evenly on the non-smooth structures, and only brushing two sides of the rib-like structures; ③pasting those rib-like structures on the sand core according to the designed direction, location and curvature to form rib-like bionic non-smooth surface; ④air-drying and trimming the non-smooth structures; ⑤installing the sand core with non-smooth surface to the cast mold; ⑥casting and demolding. In the casting period, both the hard rubber and HTICM are used as shape media. In the continual high temperature of metal liquids, HTICM become powder and triangular rubber convex melt and disappear, so the narrow triangular rib-like non-smooth surface is formed desirably. By using this method, rib-like non-smooth surface can be achieved even in complex casts. In order to describe the method of OTCM in detail, the impeller of centrifugal pump is selected to show the procedure of casting. The flow of impeller is an irregular complex surface; it is difficult to process such non-smooth surface desirably by using tradi-

tional casting or machining method. Non-smooth structure is designed as shown in Figure 4a. The cross-section form of it is triangle, the width of triangle is L, and L=0.5~3.0mm, the height H= (1~1.5) L, the distance between two rib-like structure is D, and D= (1~3) L. The method of OTCM process should be followed in the flow chart, as shown in Figure 6.

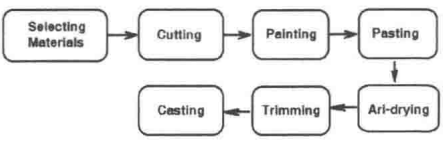


Figure 6. The flow chart of casting process.

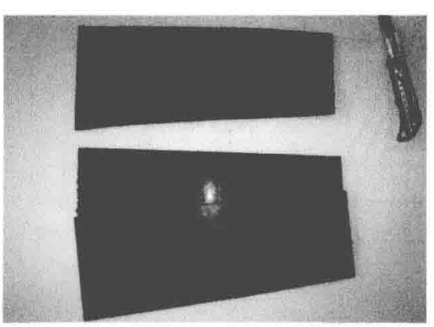
2.3. Process

1) Selecting Materials

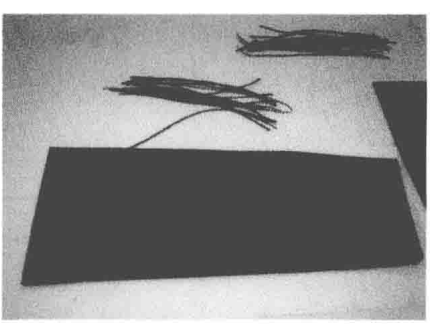
Two intermediate media, namely, hard rubber and HTICM, should be selected. They are the key factors to obtaining non-smooth surface.

a) Hard rubber

The thickness of hard rubber should more than the height of non-smooth structures. Since the height of this designed non-smooth structure is H=(1~1.5)L, and L=0.5~3.0mm; that means the maximum height is 4.5mm, so the thickness of hard rubber plank should be the 5mm. The hardness of rubber should be moderate; that means, on one hand, it should be convenient to machining, and on the other hand, the deformation should not be large at a high temperature in order to ensure the designed size of triangle. Considering this, the hard rubbers which had hardness values HD is 30 are selected, as shown in Figure 7(a). They are hard black materials at the room temperature; they have good chemical stability, excellent resistance to chemical corrosion and organic solvent resistance, low water absorption, high tensile strength and excellent electrical insulation; most important of all, they should have good machinability performance.



(a) Hard rubber



(b) convex section cutting from hard rubber

Figure 7. Hard rubbers.

b) High temperature insulation coating material (HTICM)

HTICM is a kind of coating, which can protect the surface at a special high temperature for a long time. It has excellent heat resistance compared with ordinary paint. The silicon element or inorganic high temperature insulation paint are used widely. In this chapter, the later insulation paint is selected, and in a certain condition, it still has protective function even at the temperature of 1700°.

2) Cutting

Triangular convex rib-like non-smooth structures which are in agreement with the designed ones should be cut on the selected hard rubber, as shown in Figure 7b. This process is very important, since it is related to the final quality of non-smooth surface on the casts. The non-smooth convex section structures can be machined by the special designed tools, and can also be cut by hand. Considering that some factors will affect the width of rib-like non-smooth structure, such as the thermal expansion and deformation of rib-like triangle in the process of casting and a layer of HTICM painted on the both sides of rib-like triangular convex section, as shown in Figure 8 the size of rib-like convex section should be smaller than that of the designed one, and the difference between them are called reserved size (refer to s, is shown in Figure 8) the size of it depend on the thickness of the coating layer and cross-section of non-smooth structure, and it can be expressed as following formula.$s = l / \cos\alpha$ The relationship between reserved size and thickness of coating layer is shown as Figure 8. Here l is the thickness of the HITCM layer, $\alpha$is the angle between l and s, which is related to the shape of rib-like non-smooth structure. For example, in this chapter, the cross-section of rib-like non-smooth structure is an equilateral triangle, and the reserved size$S = 2l / \sqrt{3}$. So, in order to produce the designed width of rib-like non-smooth structures, the width of rubber convex section L can be expressed asL=D-2S.

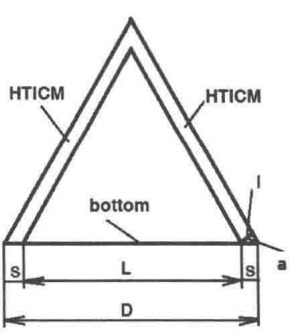


Figure 8. The schematic diagram of HTICM on the rubber convex section. Here, l is the thickness of the layer of HITCM, S refers to reserved size, L is the length of rubber convex section and D is the designed size of rib-like non-smooth structure.