Advances in Applied Sciences
2022; 7(3): 73-78
http://www.sciencepublishinggroup.com/j/aas
doi: 10.11648/j.aas.20220703.16
ISSN: 2575-2065 (Print); ISSN: 2575-1514 (Online)

Research on Application of High Strength Die Cast Aluminum Alloy in Industrial Hinge

Ding Fan, Wang Jun Wei, Wang Wei, Yao Chun Liang

Ningbo Shengjiu Technology co., Ltd, Ning bo, China

Email address:
ding3fan@163.com (Ding Fan)

To cite this article:
Ding Fan, Wang Jun Wei, Wang Wei, Yao Chun Liang. Research on Application of High Strength Die Cast Aluminum Alloy in Industrial Hinge. *Advances in Applied Sciences*. Vol. 7, No. 3, 2022, pp. 73-78. doi: 10.11648/j.aas.20220703.16

Received: July 26, 2022; **Accepted**: August 9, 2022; **Published**: August 17, 2022

Abstract: In order to meet the comprehensive performance requirements of high load, impact resistance, corrosion resistance and high cost performance of industrial hinges, it is urgent to develop a lightweight and high strength material, while traditional materials such as zinc alloy and stainless steel cannot meet the requirements of use due to high processing costs and mechanical properties. In view of the high strength die cast aluminum alloy has high bearing capacity, high strength and toughness, lightweight and cost advantages, through the application analysis and data collection of high strength aluminum alloy products, combined with the application specific requirements of hinge products, respectively selected No. 5 zinc alloy and HS380-N high strength aluminum alloy, this article conducts material composition analysis and molding sample comparison. By means of casting and mold temperature control, and the product to test the bearing capacity of metallographic analysis and product data base material, and according to the data analysis, hinge tensile and yield strength than zinc alloy material increase by around 30%, the product of axial and radial load and torsional performance achieve the expected effect, meet the using demand of the high load. The experimental data provided an important theoretical basis for material selection of industrial locking products and expanded the application range of high-strength aluminum alloy.

Keywords: High Strength Die Cast Aluminum Alloy, High Load, High Toughness, Light Weight, Metallographic Analysis

1. Introduction

In the industrial lock control industry, most of the lock control products such as power and communication cabinet locks, hinges, and toggles are made of zinc alloy, carbon steel, and stainless steel. However, with the intelligentization of lock control products, the requirements for light weight are getting higher and higher, and the application scope of products is expanded, especially in the application of construction machinery. Because the working environment of industrial lock control products is harsh, factors such as product bearing capacity, corrosion resistance and cost performance determine the quality and vitality of the product. This article is mainly based on the strength, toughness, specific gravity and cost advantages of high-strength die-casting aluminum alloys, and conducts performance analysis and sample preparation tests.

In this article, micro-crystal die-casting aluminum alloy is selected, and the casting process and performance data comparison are optimized for material selection. AlSi10Mg series die-casting aluminum alloys are high-strength and tough aluminum alloys. The ratio of material components, casting and heat treatment processes are optimized to achieve high-strength weldability and are widely used in the manufacture of automobile frames [1]. By treating the surface of the high-strength die-casting aluminum alloy, the adhesion of the paint film can be enhanced, and the acid, alkali, salt and other properties of the substrate can be improved. In the casting process of aluminum alloys, the specific pressure (the pressure on the aluminum alloy melt per unit area) is the most influential factor affecting the components organization and mechanical performance of the parts [2]. The pressure above 91Kpa is high vacuum die casting. Vacuum die casting is divided into: chilled exhaust tank method and vacuum valve method. High-vacuum die-casting technology means that under vacuum, the molten metal fills the cavity in a very short time, which greatly reduces the gas involved and greatly improves the mechanical properties of the casting [3]. The Shock Tower of the automobile body structure adopts the advanced technology of vacuum die casting, and the composition and heat treatment of the material are optimized, and the composition and metallographic structure of the base material are obviously improved [4]. As shown in Figure 1 below: In order to reduce die sticking, the content of iron in die castings is generally high. Iron is easy to form needle-like brittle phases in aluminum alloys, but after modification treatment and T7 heat treatment (as shown in Figure 2), The eutectic silicon is granulated and rounded, reducing the stress concentration of the sharp structure, and significantly improving the shape and strength of the casting.

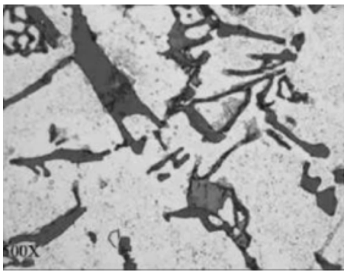


Figure 1. *Unmodified eutectic silicon phase.*

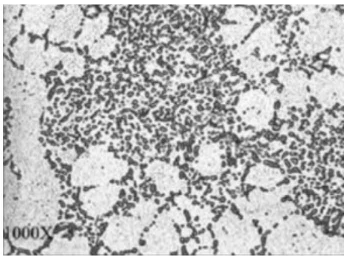


Figure 2. *Metallographic phase after modification and T7 heat treatment.*

Remarks: T7: After solution heat treatment, artificial aging (precipitation heat treatment) reaches the degree of overaging. Stabilization heat treatment reduces strength, but improves plasticity, dimensional stability, and resistance to stress corrosion [7].

Due to the characteristics of multiple varieties and small batches, the molding process and material cost of industrial lock control products have become the priority factors, but the mechanical performance requirements are higher. High-strength die-casting aluminum alloys are widely used in electrical appliances, automobiles, aerospace and other fields, and can realize integral molding of parts with complex structures. In view of this, industrial lock control products can use high-strength die-casting aluminum alloys instead of traditional zinc alloys and other materials, and achieve expected mechanical properties through material formulation and process control.

2. Material Selection Strategy

In lock control products, the material selection of common parts of load-bearing locks such as lock latch transmission gear and industrial hinge (fork gear shown in Figure 3), respectively: microcrystal alloy (ZA89, ZA66, HS380-N), Die-casting zinc alloy, stainless steel, ordinary aluminum alloy ADC12 to compare the performance of materials, the relevant data are shown in Table 1 below:

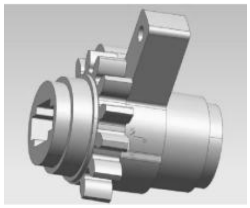


Figure 3. *Fork gear.*

Data comparison: stainless steel powder metallurgy: torsion resistance - 50N.mZA89 material die-casting precision molding: torsion resistance - 65N.m.

Table 1. *Comparison of properties of various metal materials.*

Metal brand	density g / cm^3	Tensile strength Mpa	YieldstrengthMpa	Extend rate%	Internal stress	Sticky mold
ZA89 (self aging)		310	260-290	2.0-3.5	small	good
ZA66 (self aging)	2.7-3	280	210-260	5-7	small	excellent
HS380-N (self aging)		360-390	260-300	>2	small	excellent
ADC12	2.7	230-250	140-150	0.8-2	big	excellent
Die cast Zinc alloy 3#, 5#	6.6-6.75	250-320	215-230	10	/	excellent
Stainless steel	7.93	>520	>205	40	small	/

It can be seen from the data in Table 1 that the microcystal alloy has better yield strength and tensile strength than the ordinary aluminum alloy ADC12 under the same quality, the deformation of the die-casting product is smaller, and the dimensional accuracy is easy to guarantee. Compared with the traditional zinc alloy material, it has the advantages of light weight and high strength. microcystal metal refers to a metal with micron-sized grains. The refined grains obtained by rapid solidification are generally between 0.1-10 μm, and some even reach 3 nm. This material has high strength and has the characteristics of high strength and high elongation [5]. The selected microcystal alloy: ZA89, ZA66, HS380-N is also a micron-order high-strength aluminum alloy material. Features of high-strength die-casting aluminum alloy material:

(1) It has the characteristics of high strength, high bearing capacity and high corrosion resistance, and can replace some stainless steel precision castings, powder metallurgy structural parts and some steel components.
(2) It has the characteristics of efficient production, light weight and high cost performance.
(3) The characteristics of high yield and high elongation can be achieved by natural aging in the die-cast state; Through the performance data analysis in Table 1, HS380-N self-aging tensile strength, yield strength and mold forming characteristics are better than other materials, HS380-N can be selected for product

samples, and compared with the traditional material zinc alloy for verification. 2 Product sample preparation and verification.

Product selection: engineering hinge CL213-8, as shown in Figure 4 below. Material selection: die-casting 5# zinc alloy, microcystal high-strength die-casting aluminum alloy HS380-N.

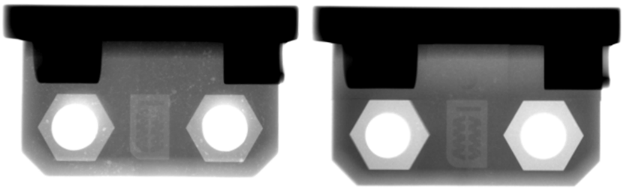
Die-casting 5# zinc alloy casting process conditions: hot pressure chamber casting, melt temperature 420 degrees; high-strength die-casting aluminum alloy HS380-N casting process conditions: cold pressure chamber casting, melt temperature: 680 degrees, using vacuum die casting [8-9, 11, 13, 15].

Figure 4. *Industrial hinge CL213-8.*

Table 2. *Main components of HS380-N.*

Spectral Analysis of Main Components of High Strength Die Casting Aluminum Alloy HS380-N							
element	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**
component ratio (%)	97.87	0.644	0.21	0.253	0.03	0.86	0.086

The composition analysis of the HS380-N sample by spectrometer shows that the content of Si and Mg in the aluminum alloy is relatively high, which can strengthen the matrix structure and improve the corrosion resistance and tensile strength of the product.



5# Zinc Alloy HS380-N (high-strength aluminum alloy)

Figure 5. *X-ray imaging of industrial hinge CL213-8.*

As shown in Figure 5, the X-ray imaging of the hinge sample shows that the 5# zinc alloy sample has pores on the surface, and the surface quality is not as good as HS380-N.

2.1. Microstructure and Metallographic Analysis of the Samples Before the Test

The samples of 5# die-casting zinc alloy and microcystal alloy HS380-N were polished and polished with silk cloth respectively. After cleaning with absolute ethanol, they were respectively immersed in 3.5% NaCl etching solution and soaked for 3 h at room temperature. Then take it out, rinse it clean, dry it, and observe the corrosion condition of the alloy surface by scanning electron microscope, and do metallographic analysis.

As shown in Figure 6 below, the metallographic diagram of the zinc alloy material: alloy corrosion often extends along the grain boundaries and subgrain boundaries of the structure, thereby showing the surface structure. (white) Grain uniformity is poor, and grain spacing varies. Corrosion pits appear in some areas (arrows indicate the positions), and the black color between the grains is eutectic silicon phase, and the mechanical properties are general.

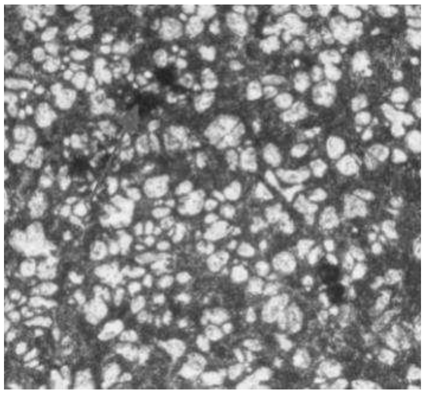


Figure 6. *Microstructure and metallographic diagram of die-casting 5# zinc alloy (magnified 200 times).*

High-pressure aluminum castings (hereinafter referred to as "die castings") are filled with aluminum soup driven by a large-tonnage press, and then rapidly solidified in a metal mold to obtain fine grains and high hardness. It is characterized by good forming, fast solidification, high work efficiency and high hardness [6, 10, 14].

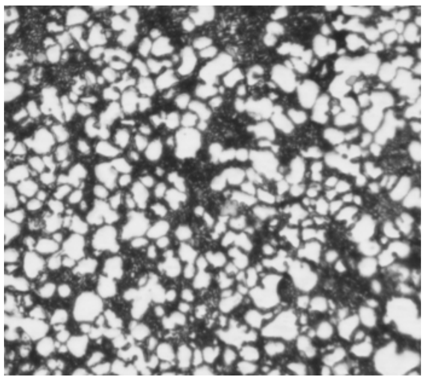


Figure 7. *Microstructure of HS380-N (200 times magnification).*

Figure 7 shows the microstructure and metallographic diagram of the HS380-N material: compared with the zinc alloy, the high-strength die-casting aluminum alloy has finer grains, smaller and more dispersed precipitated particles. The small spacing between grains greatly enhances the mechanical properties of the casting.

High-strength die-cast aluminum alloys combine liquid forming techniques (casting and forging) to reduce shrinkage porosity and refine grains [12]. Through the analysis of the microstructure and metallographic diagram of the HS380-N molded product, it can be seen that it basically conforms to the microscopic properties of the high-strength aluminum alloy.

2.2. Bearing Capacity and Torsion Resistance Test of Hinges

During the use of the hinge, it mainly bears loads in two directions, axial (longitudinal) and radial (transverse), and the fixation of the hinge mainly depends on the pre-tightening of the thread, so the bearing capacity and thread torsion test of the hinge is carried out.

2.2.1. Bearing Capacity Test

The transverse and longitudinal bearing capacities of the hinges of the above two materials are respectively tested for tensile force, the 5# zinc alloy hinge sample is 5pcs, and the HS380-N hinge sample is 5pcs. As shown in Figure 8 below, test equipment: electronic tensile and compression testing machine CMT0105, until the tensile failure of the sample (tear, fracture or material shedding). Record the tensile force data of the test, see Table 3.

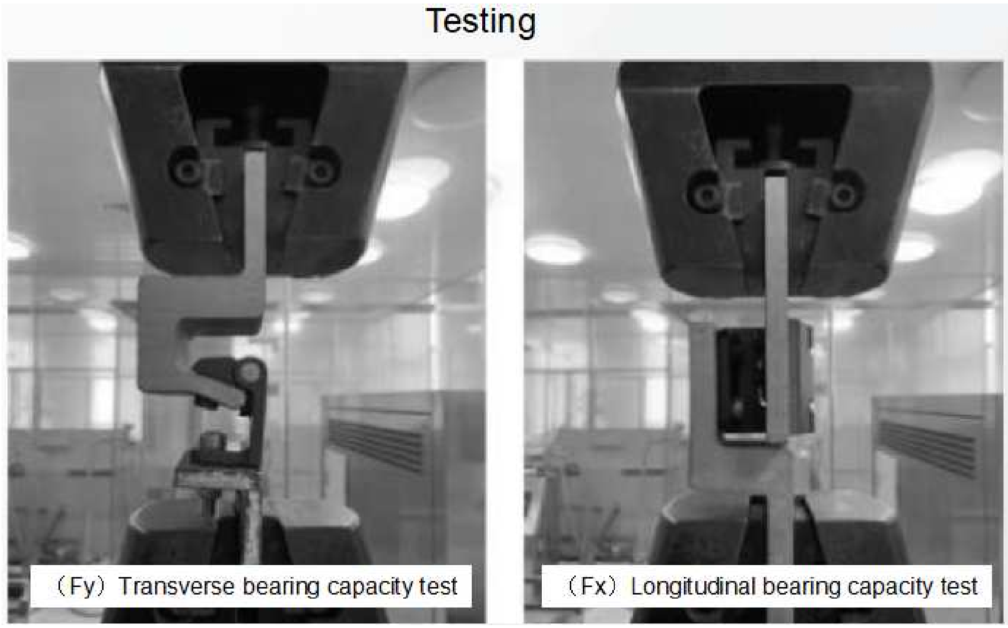


Figure 8. *Bearing capacity test of hinge.*

Figure 9. *Torsion test of hinge.*

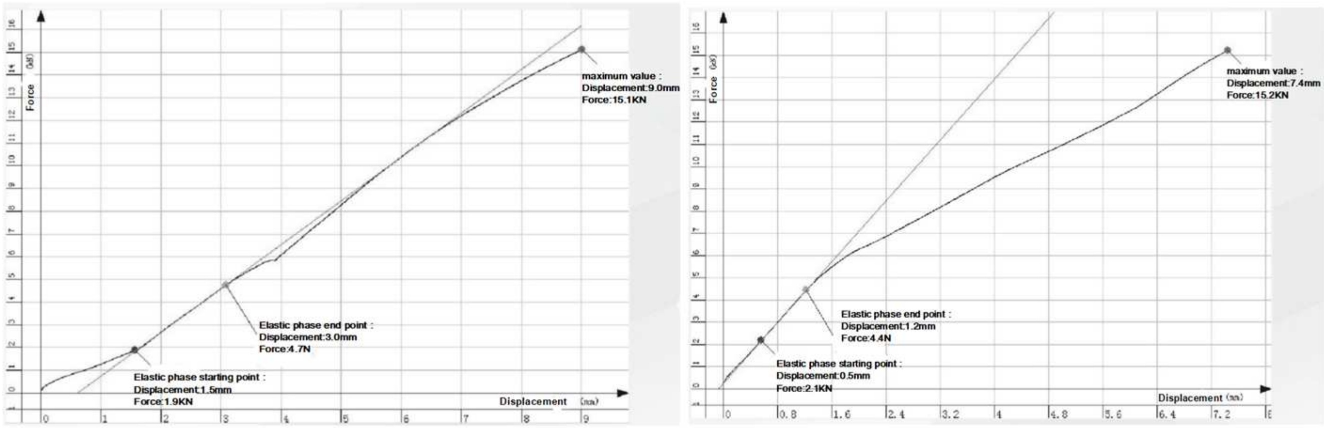
2.2.2. Torsion Resistance Test of Hinges

The threaded holes of the hinges of the above two materials are respectively tested for torsion, the 5# zinc alloy hinge sample is 5pcs, and the HS380-N hinge sample is 5pcs. As shown in Figure 9 below, test equipment: torque wrench 0-200N.m, until the torsional failure of the sample (tear, break or material fall off). Record the torque data of the test, see Table 3.

From the analysis of the tensile force and torsion force data of the test, it can be known that the maximum value, the minimum value and the average value in the test group are respectively taken. The transverse and longitudinal tensile force of HS380-N material is about 30% higher than that of zinc alloy, and the torsion force is increased by about 35%. It greatly improves the mechanical performance and safety life of the hinge, and expands the application scope of the hinge in the industrial environment. Figure 10 is bearing capacity test curve of HS380-N material hinge. With the increase of the applied force, the deformation curve of the product changes evenly, indicating that this material has good plasticity and ductility.

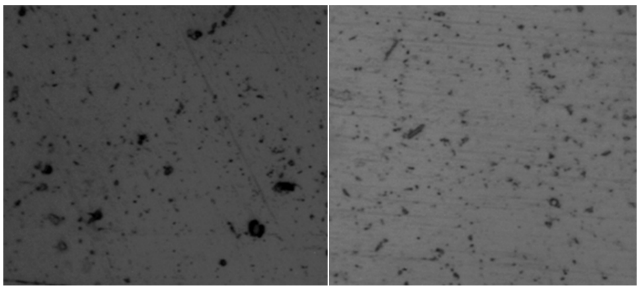
Table 3. *Strength comparison of different materials of CL213-8 hinge.*

CL213-8 hinge (5# and HS380-N) bearing capacity and torque test data				
material	**category**	**Longitudinal fracture value N**	**Transverse fracture value N**	**Thread torque value N.m**
	max	11134	11572	15
5# Zinc Alloy	min	10344	6754	13.5
	average	10739	9163	14
	max	15345	15145	26
HS380-N	min	15088	13712	18.5
	average	15216.5	14428.5	22.2



A. Lateral bearing capacity and deformation B. Longitudinal bearing capacity and deformation

Figure 10. *Hinge bearing capacity test curve.*



Transverse fracture surface Longitudinal fracture surface

Figure 11. *Metallographic diagram of specimen bearing test section (100 times magnification).*

The metallographic analysis of the cross-section of the hinge specimen after the bearing capacity test is shown in Figure 11: the transverse fracture surface is the microstructure of the specimen after being subjected to transverse shearing, and the longitudinal fracture surface is the microstructure of the specimen subjected to longitudinal shearing. In view of the fact that the lateral thickness of the hinge is much smaller than the longitudinal thickness, the dislocation structure of the lateral fracture surface is obvious, the grains are large, and the distribution is uneven; the grains of the longitudinal fracture surface are distributed in a band, and the grains are fine and uniform. Therefore, the shear resistance in the longitudinal direction is better than that in the transverse direction, which is consistent with the test data in Table 3.

3. Analysis and Discussion

From the mechanical properties comparison and product testing of high-strength die-casting aluminum alloys in Chapter 1 and Chapter 2, it can be known that: (1) Compared with the traditional zinc alloy material, the high-strength die-casting aluminum alloy has low material density, good plasticity and easy processing. Good electrical and thermal conductivity and high strength. (2) High-strength die-casting aluminum alloy adopts vacuum die-casting technology: degassing and slag removal of metal solution, exhausting of mold structure and sealing treatment. Reduce the shrinkage porosity of the material, refine the grain, improve the tensile strength of the product, and optimize the mechanical properties of the product. It has been verified by product sample testing that the expected performance requirements have been met.

4. Conclusion

With the development of industrial lock control products towards the direction of high quality, high reliability, light weight and low cost, the materials are characterized by light weight, high load bearing, high corrosion resistance, etc. The material characteristics and forming of high strength die-casting aluminum alloys The process has achieved its goal and can be used to replace some traditional zinc alloy and steel parts. In this paper, aiming at the application characteristics of industrial hinges, through (1) material selection and performance data analysis and comparison of various microcystal die-casting aluminum alloys; (2) 5# zinc alloy and HS380-N sample preparation and alloy composition analysis; (3) Analysis and comparison of metallographic structure and microstructure of 5# zinc alloy and HS380-N; (4) Test and verification of product sample material characteristics and performance, demonstrating the feasibility of high-strength die-casting aluminum alloy in the application of lock control products, which is an industrial cabinet The material selection of the lock product provides data support, which further improves the stability and reliability of the product.

5. Recommendations

Based on the application of high -intensity die -casted aluminum alloy in industrial hinges, it is necessary to expand the product breadth in the future, especially the promotion of the door lock on the door lock. At the same time, it is necessary to focus on the neutral salt mist requirements of outdoor products, and to fully test and verify the surface treatment process of high -intensity aluminum alloy.

References

[1] Liu Yongchang, Ge Sujing, Zuo Liqing, Zong Fuchun, Meng Hongyan, Yuan Gaoli, Weldable die-casting aluminum alloys for AlSi10Mg series high-strength, toughness and lightweight structural parts [R], 2020.

[2] Huang Caijiang, Cao Zhicheng, Liu Yang, Research on high-strength die-casting aluminum alloy and its heat treatment [J]. Science and Technology Information, 2015 (8): 90-91.

[3] Wan Li, Pan Huan, Luo Jirong, Development and Application of High Vacuum Die Casting Technology and High Strength Die Casting Aluminum Alloy [J]. China Die Casting, Squeeze Casting, Semi-Solid Machining Academic. 2007 (4): 195-197.

[4] Li Yingchao, Ye You, Liu Shuwen, Material research and development of new vacuum high pressure cast aluminum body structural parts [J]. Hebei University of Science and Technology, 2016 (5): 58-61.

[5] Zhao Liang, Development and application of microcystal alloys [J]. China Academic Journal. 2013 (6): 17-21.

[6] Huang Xiaofeng, Tian Zaiyou, Zhu Kai, et al. Research progress of die-casting aluminum alloy and die-casting technology [J]. Hot Working Technology, 2013, 37 (17): 137-141.

[7] Chen Rongshi, Mu Guanghua. Research on high-strength die-casting aluminum alloy and its heat treatment [J]. Research on Casting Equipment, 2012, 12 (6): 20-24.

[8] Wan Li, Zhao Yunyun, Pan Huan, et al. Development and application of aluminum alloy high vacuum die casting technology [J]. Special Casting and Nonferrous Alloys, 2008, 28 (11): 858 -861.

[9] Lin Hai, Wan Li. Liu Houyao et al. Injection process test and optimization of high vacuum die-casting aluminum alloy car chassis components [J]. Foundry, 2011, 60 (1): 42-46.

[10] Wu Chunmiao, Die Casting Practical Technology, Guangzhou: Guangdong Science and Technology Press, 2003.

[11] Edited by Yuan Chengqi. Standard Manual of Casting Aluminum Alloy and Magnesium Alloy, Beijing, China Environmental Science Publishing, 1994.

[12] Lu Shusun, Xu Minggang, Zhang Shaozong, Research on Hard Points in Aluminum Alloy Die Castings, Foundry, 2000, (1): 7.

[13] Han Yanfeng, Liu Xiangfa, Yang Zhiqiang, etc. Effects of pressure casting on the microstructure of Si-Cu alloys. Foundry, 2001, (4): 183-186.

[14] Translated by Yu Haipeng, etc., North American Die Casting Association (NADCA) Die Casting Production Technical Standards, Die Casting World, 2002, (4): 24-36.

[15] Xiao Jianmei, Shen Paulo, Chen Jian, Tu Mingjing, Influence of silicon on wear resistance of Al-Si alloy and its composites, Guangdong Journal of Nonferrous Metals, 2000, (12): 129-131.

Biography

Ding Fan, College of mechanical and electrical engineering; Changchun University of science and technology; Ningbo; China.