Comparative Analysis of Chinese and Foreign Die Casting Aluminum Alloy Standards

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Abstract: Material standards can better guide composition design, improve material properties, and promote the application of engineering materials. This paper provides an overview of the current status of die casting aluminum alloys at home and abroad. By comparing the domestic and international standards of die-casting aluminum alloys, it introduces the material characteristics of die-casting aluminum alloys, and looks forward to the key focus areas and analyzes the urgent problems to be solved in the future of die casting aluminum alloys.

Keywords: Die casting aluminum alloy; High pressure vacuum die cast; Standard interpretation

1 overall

The United Nations Sustainable Development Goals (SDGs) and its commits achieving carbon neutrality by 2050, driven by the target, the automotive industry is striving to implement energy conservation and emission reduction (ECER). Aluminum alloy, an effective ECER solution, has become the primary lightweight material for automobiles. Nearly 60% of automotive aluminum components are produced through die casting (DC), a technology that can achieve a weight reduction of 30%-50%, significantly improving fuel economy during the usage phase of the automotive life cycle, making it an essential method for green manufacturing. The main approaches to vehicle weight reduction involve optimizing the body structure and developing lightweight alloy materials. Aluminum alloy die castings have a particularly widespread application in automobiles, the aluminum alloy die casting industry has vast development potential. This paper comprehensively elaborates on the standards and applications of die casting aluminum alloys at home and abroad, aiming to provide a reference for the subsequent development of low-cost, high-performance die-casting aluminum alloys and advanced die casting technologies, and promoting the global development of the aluminum die-casting industry.

2 Overview of die-casting aluminum alloy

Take AlSi10Mg series alloy as example, like Y L101, A360, AD3.1 and EN AB-43400 alloy have similar design ideas. At present, the use of Silafont® -36 alloy or AlSi10Mg alloy materials, combined with high pressure vacuum die cast and subsequent T6 and T7 heat treatment processes, are the most used technical route. The following will review the development of the die casting aluminium alloy compared with Chinese national standard, ASTM, JIS and EU standard

2.1 Chinese standards

In the past 20 years, the market for electric vehicles is rapidly expanding, and we see more applications like large-scale structural components and body plate. The application of integrated giga casting technology also promotes the development and application of non-heat treatment materials. The non-heat treatment die casting aluminum alloy Al-Si-X (JDA 1x) and Al-Mg-X (JDA 2x) are developed by Shanghai Jiao Tong University, such as Al-Si-Cu-Mn-RE, Al-Si-Mn-Mg-RE, Al-Si-Cu-Mg-Mn, with high mechanical properties. Al-Si-Cu-Zn-Mg for casting [1] (Hereinafter referred to as HKA-1 aluminum alloy) Al-Mg-Mn-RE, Al-Mg-Si-Mn-RE alloy, has been successfully used in the rear cockpit of automobile. The as-cast alloy of JDA 2b has a yield strength of 200 MPa to 240 MPa, a tensile strength of 360 MPa to 400 MPa, and an elongation rate of 10% to 12%, exhibiting excellent strong toughness.

The newly edition Chinese national standard, GB/T 15115—2024, has introduced new alloy types, YL 118, YL 118, YL 119 and YL 120. YL 118 reduced the content of Cu and Zn on the basis of $AlSi_{12}(Cu)$ specified in ISO 3522:2007 standard, there are more phases in microstructure such as Q-$Al_5Cu_2Mg_8Si_6$ and θ-Al_2Cu with more Cu addition in the alloy. When the amount of Cu exceeds 0.3 wt. %, the θ phase begins to form and its content increases accordingly. However, Si is consumed in the formation of the Q phase, which decreases the total volume of the α-Al (Fe, Mn) Si phase slightly, and the volume of the Q phase was inverse to that of the α-Al (Fe, Mn) Si phase [2]. A small amount of Cu can play the role of precipitation enhancement, improve the elongation, mechanical properties and fatigue properties. Compared with the heat-treated Al-Si alloys, YL 118 requires no Mg. For example, YL 119, is similar to the 365.1 alloy, the upper limit of Fe and Ti is slightly widened. The actual production of Al-Si alloy contains iron at a relatively low level (0.1~0.2%), which is difficult to remove from the melt in a cost-effective way, so the upper limit of Fe is stipulated to be 0.2%. The Mn content is 0.40%~0.80%, which has a benefit effect on the elongation. The Ti content is limited to 0.20%. According to the research, after the addition of 0.0137% Ti, the α(Al) grains can be significantly refined [3], Reine the alloy grain to improve the castability.

2.2 The United States Standard

As early as 1996, the American Aluminum Association accepted the Silafont®-36 alloy, and registered it as 365.0. Currently, roughly 85% of aluminum alloy die castings in the American standard are produced by 380 alloy family, like 383 or 384, which is Al-Si-Cu alloy series. The remaining 15% of aluminum alloy die casts are mainly manufactured using alloys 360, 390, 413, along with smaller volumes of 443 and 518.

2.3 The Japanese Standard

Compare to JIS H 2118:1968, the alloy types in JIS H 2118:2006 were reduced from 13 classes to 7 classes. AD2, AD4, AD11 and AD13 alloys with only a different percentage of iron while other elements remained constant were removed. Additionally, considering practical usage demands, the less used ADC 8 and ADC 9 alloys were removed. During the revision process, reference was made to IS, German standards and American standards, allowing for minor adjustments and eliminations across certain alloy categories. The tolerance for the impurity element iron (Fe) was broadened to make better use of existing domestic resources and decrease reliance on scarce elements in Japan. For example, AD12.1 alloy was adjusted based on the A380.1, and the upper limit of Sn content is modified from 0.35 wt.% to 0.2 wt.%.

2.4 European Union standards

As early as 1994, German company Aluminum Rheinfelden GmbH developed high pressure vacuum die casting Silafont®-36 alloy, which corresponds to EN AB Al Si10MnMg alloy, also known as EN AB-43500. EN AB-43400 has a composition based on EN AB-43500 but with reduced iron (Fe) content, and low Fe content to improve the manufacturability of alloy during die casting. Furthermore, 0.4%~0.8% Mn were added to improve the harmful effects of Fe, and the Mn/Fe ratio was controlled to
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change the morphology of iron-rich intermetal compounds by extracting Chinese characters, stellate or polyhedral α-$Al_{15}(Fe, Mn)_3Si_2$ [2] phase, reducing the formation of needle or sheet β-Al_5FeSi phase, thus obtaining good strong toughness [3]. The additive of Mg, under the appropriate heat treatment conditions, forms precipitates with Si, to improve the alloy strength. With minimal amounts of Cu, Zn and impurities, this alloy exhibits superior casting properties compared to other die casting alloys.

3 Development trend of die casting aluminum alloy

(1) Develop new aluminum alloy series and alloy designation. Al-Ce and A1-Li alloys were studied to expand new fields of alloy materials. (2) Advanced R&D of non-Heat-Treated high-strength and toughness alloys. Understanding the material design method, mastering the material strong toughness design principle, developing high strength and high toughness, heat and corrosion resistance, easily processable die casting aluminum alloys remain a future development trajectory. (3) Unleash the full potential of secondary alloys. To achieve and primary alloy level with compromising properties, or keep higher impurity tolerance in alloy design, make full use of high recycling alloy can reduce carbon dioxide emissions, development of multi-purpose cross alloy, etc. (4) The development and optimization of manufacturing processes to produce die casting components with exceptional mechanical properties. With the introduction of the ‘unbox’ concept, ongoing development of innovative processes remains a crucial step in addressing the economics of vehicle manufacturing.

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