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Analysis of Metallographic Characteristics of Aluminum Alloy for Turbocharged Impellers

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Abstract

In this paper, the composition, two-dimensional and three-dimensional microstructure of heat-resistant wrought aluminum alloy with strong oxidation resistance, heat resistance and easy processing are analyzed by using direct reading spectrometer, metallographic microscope and scanning electron microscope. The main alloy elements of heat-resistant forging aluminum alloy include Cu, Mg, Si, Ni and Fe. The α solid solution of each element in aluminum consists of S phase (Al_2CuMg), Mg_2Si phase, bright gray Al_2CuNi phase and dark brown Al_9FeNi phase. The distribution of each phase in the aluminum alloy is determined by the three-dimensional energy spectrum analysis of the microstructure, and the distribution of each phase in the crystal position is analyzed. The mechanism of heat resistance, easy processing type and wear resistance is obtained, which provides the theoretical basis for the development and use of heat-resistant forged aluminum alloy.

Keywords

High Heat Resistant Aluminum Alloy, Metallography, Electron Microscope Analysis

1. Introduction

Heat-resistant forged aluminum alloy has a strong oxidation resistance at high temperature, and has creep resistance, heat resistance, small expansion coefficient and low-density characteristics under the action of temperature and load for a long time. The main ways to improve the heat resistance of aluminum alloy are solid solution strengthening, excess phase strengthening, grain boundary strengthening, etc. For this reason, the excess phases Al_2CuMg, Al_6Cu_3Ni, Al_2FeSi, Al_9FeNi, Al_2CuLi and Al_4Ce_4 with good thermal stability are formed by adding copper, magnesium, iron, nickel and titanium into aluminum alloy, $Al_2Cu_4Mg_5Si_4$, etc. According to different processing technologies, it can be divided into heat-resistant deformation aluminum alloy (including heat-resistant forged aluminum alloy and heat-resistant duralumin alloy) and heat-resistant cast aluminum alloy. Its working environment can work at 150˚C to 300˚C of various structural parts, such as turbine compressor blade disc, welding container, piston and so on [1]-[6]. The main application can be used for overhead transmission and distribution lines, the continuous use temperature can reach 90 degrees, with high current carrying capacity and good anti-corrosion performance.

After entering the 21st century, with the rapid development of social economy, the demand for electricity has increased sharply, so it has become more and more urgent and necessary to carry out relevant research to improve transmission efficiency and reduce transmission losses. Aluminum alloy materials, with better conductivity, formability and relatively low price, are widely used to replace copper in the application of power cables [7]. The use of aluminum alloy as an overhead transmission line has become an important trend and main carrier of electric energy transmission, and its application has been more than 100 years. Since the end of the 1950s, Japan has first successfully developed ordinary heat-resistant aluminum alloy wires and been widely used in power transmission lines, which has attracted wide attention from countries around the world [8]. At the end of the 20th century, Japan, the United States, Canada and other developed countries have widely used heat-resistant aluminum alloy wires [9] [10]. Until the early 1960s, China did not organize relevant forces to carry out relevant research on heat-resistant aluminum alloy wires; in 2007, 60% of IACS steel-core heat-resistant aluminum alloy wires were converted to mass production after the results were evaluated [11] [12]. Heat-resistant aluminum alloy wire has the characteristics of low sag, capacity increase, etc. When using it for line transformation, the operating temperature can be increased to more than 120˚C and the carrying capacity can be increased by more than 40% under the premise of less or no replacement of the pole tower. It is especially suitable for the new construction of large-capacity transmission lines and the expansion and reconstruction of old lines in densely populated areas [13]. However, the current main use of overhead transmission lines in China is still mainly the traditional steel core aluminum stranded wire, heat resistance is more limited and the transmission capacity of the line will also be limited. Undoubtedly, the research and application of heat-resistant aluminum alloy conductor materials and wires have significant economic value and social benefits [14].

In this paper, the microstructure of 2A70 aluminum alloy in diesel engine is analyzed to provide a theoretical basis for the development of heat-resistant forged aluminum alloy material and the development of lightweight engine.

2. Analysis of Metallographic Characteristics

In this paper, the material of turbocharged impeller in engine is studied, and the metallographic research is done on the working environment and the performance of the impeller material.

2.1. Component Detection

Direct reading spectrum was used to analyze its composition. First, the test sample was obtained by wire cutting, and polished by sandpaper to improve the surface cleanliness of the sample and improve the detection accuracy. The basic principle of detection is that each element composed of atoms has a unique distribution of electrons outside its nucleus. The direct reading spectrometer emits electrons to stimulate the electrons in the nucleus to transition to a higher energy level, and the process of unstable electrons returning to the ground state after the transition emits a specific wavelength of energy, as shown in Equation (1).

$$\Delta E = Eh - El = ch/\lambda \tag{1}$$

In the formula,

ΔE For the energy released.

Eh High level energy.

El Is low grade energy.

c the speed of light.

h Planck's constant.

λ Wave length.

Through collecting and calculating the intensity of different wavelengths, the direct reading spectrum calculates the content of each element in the excitation sample, determines the purpose of the material, and detects the content of each element as shown in Table 1. According to the comparison table of material element content, this material is 2A70 heat-resistant forged aluminum alloy, and the microscopic metallography of this material is studied.

2.2. Metallographic Research

2.2.1. Sample Preparation

First of all, the impeller is prepared, and the sample is set with the insert machine to ensure the horizontal grinding of the sample. The surface of the sample was roughed by grinding wheel to obtain a smooth and bright surface. The sample surface was finely ground with sandpaper from 400 mesh to 2000 mesh using a grinder machine. Finally, the sample surface was polished with 0.5 μm polishing agent and polishing cloth to obtain a bright sample profile.

2.2.2. Erosion

As aluminum alloy and common iron base have different metallographic structures, the erosion formula and method of the sample obtained by inquiring relevant forged aluminum erosion agents are as follows: First, hydrofluoric acid is

Table 1. Composition of 2A70 heat resistant forged aluminum alloy.

Element	Cu	Mg	Fe	Ni	Ti	Al
Element content %	2.0	1.5	0.9	1.1	0.7	93.8

used to erode the surface of the part. Since hydrofluoric acid has the property of eroding glassware, rubber gloves, plastic dropper and plastic reagent bottle are used to configure and store the sample during configuration. 0.5% hydrofluoric acid configuration ratio: hydrofluoric acid 0.5 ml, 2 ml nitric acid and 98 ml alcohol suitable for most aluminum and aluminum alloys. After configuration, the states of each element are: the compounds containing Fe and Ni are brownish yellow, and Si is dark red. During the erosion process, hydrofluoric acid is dropped onto the surface of the sample to make the surface evenly covered, and the erosion occurs at room temperature for 10 - 40 seconds, and the surface becomes discolored. The sample surface is washed with alcohol solution and the surface is dried with a hair dryer. Then 5% nitrate alcohol solution was used to erode the surface of the part for 30 s and water was used to dry it to obtain the metallographic test sample.

2.2.3. Metallographic Analysis

The prepared sample was placed under Olympus inverted metallographic microscope for study, and the metallographic picture was obtained as shown in Figure 1. As shown in Figure 1(a), at 100 times the field of view, the metallographic structure of the sample presents a dark brown granular structure with white background, and the entire matrix is an α solid solution of aluminum. Since the iron and nickel in the aluminum alloy are dark brown, it is determined that the metallographic structure formed by the iron and nickel phase is evenly distributed in the entire field of view.

Further magnification of the metallographic structure shows that there are many kinds of structures in the 2A70 tissue in B, C and D below 500 times field of view. According to the metallographic map and the basic appearance of each

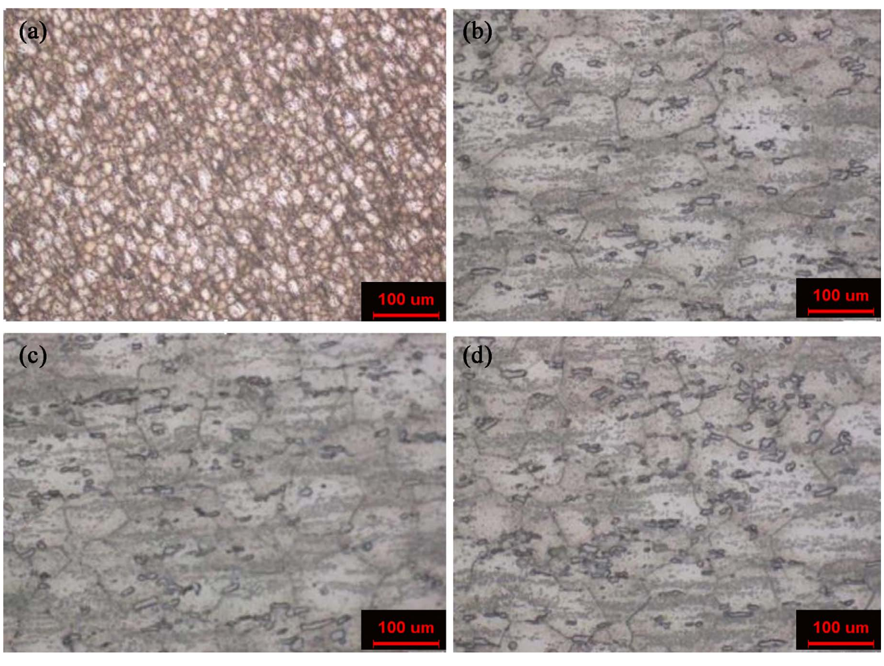

Figure 1. Metallographic structure of (a)-(d) in 100× and 500× field of view.

tissue at 100 times, it is determined that the fine particles are S phase (Al_2CuMg) and Mg_2Si phase, and the bright gray is Al_2CuNi phase. The three-phase structure is to add metal elements Cu, Mg, Ni in aluminum alloy to increase the high-temperature resistance of aluminum alloy; Si elements increase material processing and wear resistance. Among them, the brown-yellow Al_9FeNi phase has thermal stability, which is difficult to dissolve in α solid solution at high temperature, dispersed in the structure after forging and heat treatment, which obstructs the deformation of the alloy, and the addition of titanium elements can refine the casting grain to improve the forging performance and the transverse performance of the product.

According to the low density of aluminum alloy, it is suitable to replace cast iron parts with high density, but its own lack of high-temperature resistance leads to the irreplaceable aluminum alloy problem. The metallographic analysis of 2A70 aluminum alloy provides a new idea to improve the high-temperature resistance of aluminum alloy to replace cast iron parts and reduce the weight of the engine.

2.3. Scanning Electronic Microscopy Analysis

Scanning electron microscope was used to detect the sample, and energy spectrum analysis of each phase was performed under the metallographic microscope. The metallographic structure under the electron microscope is shown in **Figure 2**.

As shown in **Figure 2**, gray and bright white matrix structures are distributed on the surface of the 2A70 aluminum alloy microstructure matrix, showing strip and block structures. The element composition of the gray block structure was analyzed by energy spectrum as shown in **Figure 2**. The Mg_2Si phase containing Al, Si and Mg elements was obtained by metallographic analysis, which was mainly distributed in the grain to improve the high-temperature resistance, processing and wear resistance of heat-resistant aluminum alloy.

As shown in **Figure 3**, the surface of 2A70 heat-resisting forged aluminum

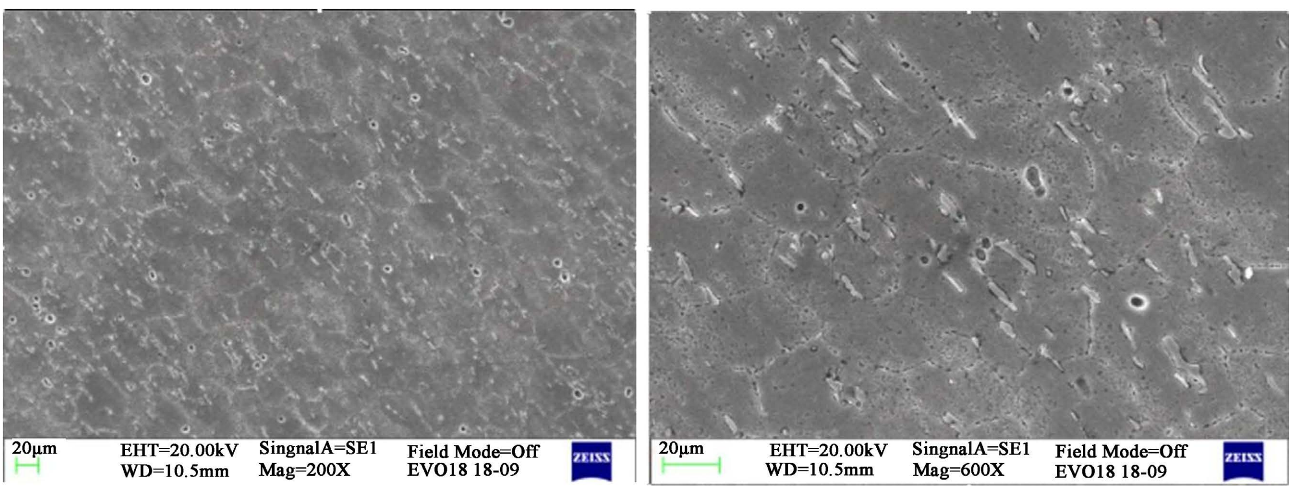

Figure 2. Microstructure of 2A70 aluminum alloy.

alloy has bright white strip structure, which contains Al, Fe and Ni elements combined with energy spectrum analysis and metallographic analysis to obtain Al_2CuMg phase, showing a dispersion distribution in the matrix structure to increase the heat resistance of aluminum alloy.

As shown in Figure 4 and Figure 5, the surface of 2A70 heat-resisting forged aluminum alloy has a bright white strip structure, which contains Al, Mg, Cu, Fe and Ni elements combined with energy spectrum analysis and metallographic analysis to obtain two phases of Al_2CuMg phase and Al_2CuNi phase, in which the metallographic phase of Al_2CuNi presents bright gray.

3. Conclusions

The microstructure of 2A70 heat-resisting forged aluminum alloy consists of Al_2CuMg phase and Mg_2Si phase, with the bright gray Al_2CuNi phase and the dark brown Al_9FeNi phase. The metallographic composition introduces a novel approach to enhance the heat resistance of aluminum alloy, contributing to weight

元素	重 量/%	原 子/%
Al K	74.48	86.08
Fe K	13.13	7.33
Ni K	12.39	6.58
总量	100.00	

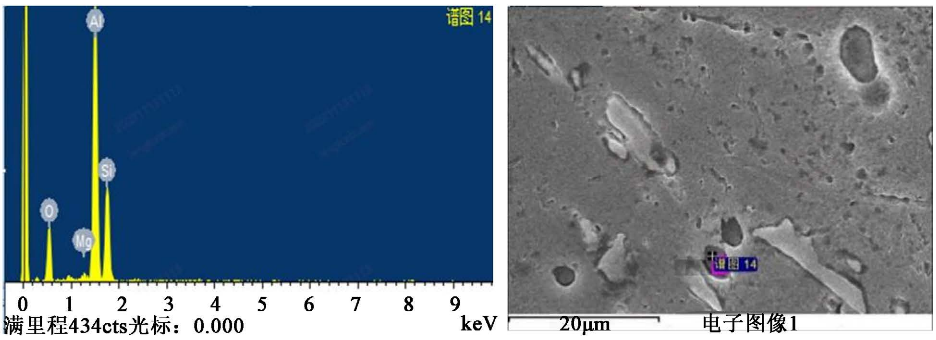

Figure 3. Mg_2Si phase of 2A70 aluminum alloy.

元素	重量/%	原子/%
O K	36.05	49.05
Mg K	0.89	0.79
Al K	40.19	32.43
Si K	22.87	17.72
总量	100.00	

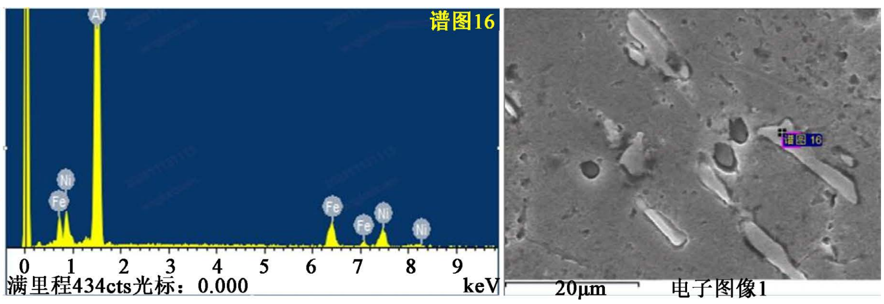

Figure 4. Al_2CuMg phase of 2A70 aluminum alloy.

元素	重量/%	原子/%
Mg K	1.39	1.59
Al K	76.70	79.04
Fe K	1.61	0.80
Ni K	1.36	0.65
Cu K	11.52	5.04
总量	100.00	

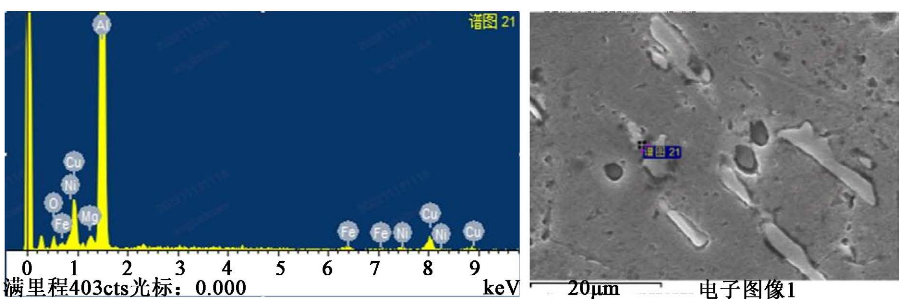

Figure 5. Al_2CuMg phase and Al_2CuNi phase of 2A70 aluminum alloy.

reduction in mechanical applications.

According to the electron microscope analysis of 2A70 heat-resistant forged aluminum alloy, the dispersed Al_2CuMg phase in the matrix, Mg_2Si phase within the grain, and Al_2CuNi phase distributed in the edge of the S phase emerge as pivotal factors in enhancing the characteristics of heat-resistant aluminum alloy.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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