Research on Situation and Application Prospect of Automotive Body Sheets Al-Mg-Si Based (6000series) Alloy

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Abstract. This paper mainly focuses on the situation of materials used for body panels at home and abroad. It is found that 6000 series aluminum alloys are widely used in automotive work due to their high strength, good plasticity and excellent corrosion resistance. At the same time, the main problems of automotive aluminum alloy sheets are also analyzed, and the research direction of developing high-performance Al-Mg-Si-based aluminum alloy sheets is prospected.

1. Introduction

In recent years, aluminum alloys have become more and more widely used in the automotive industry. This is due to that energy, environment and safety are the three major concerns of all countries in the world today. Reducing the weight of automobiles is one of the most basic way to save energy and improve fuel economy. According to statistics, for every 10% reduction in weight, fuel consumption can be reduced by 6% to 8%. The body quality accounts for 30% to 40% of the total mass of the car, so the weight of the car body plays an important role in the weight reduction of the car. There are two ways to reduce the weight of a car: one is to optimize the structural design, and the other is to use lightweight materials. The application of lightweight materials in automobiles is an important way to achieve lightweight vehicles. Aluminum alloys are widely used in the automotive industry due to their excellent properties and high material recyclability, and have become important materials to manufacture the automobiles. The aluminum alloy has the characteristics of light weight, high strength and good corrosion resistance [1].

Al-Mg-Si (6000 series) alloy not only has good thermoplasticity, excellent corrosion resistance and ideal comprehensive mechanical properties, but also is easily oxidized and colored. It is widely used in industrial profiles and construction industries, and is also the main automobile body. Aluminum alloy for sheet metal [2]. With the development of the automotive industry, especially the increasing requirements for lightweight vehicles, higher requirements have been placed on the strength of Al-Mg-Si-based aluminum alloys. The conventional Al-Mg-Si alloy materials have not been able to meet the needs. It is especially important to develop high-strength, high-performance aluminum alloy materials.

2. Application of Al-Mg-Si alloy plate for automobile at home and abroad

It have gained the attention of all countries that a large number of aluminum alloys used in the body to achieve lightweight. In the future, most of the models may use aluminum alloy sheets, and more aluminum models will appear. According to the forecast of Ducker Company of the United States, the probability of using aluminum alloys in automobiles is 60% in the United States of 2020. The proportion
of aluminum alloys used in automobile body panels will increase exponentially such as the EU and Japan in the next five years. By 2020, the annual demand for aluminum alloy sheets will reach 700,000 to 800,000 tons for auto bodies in these three regions[3].

It mainly include Al-Cu-Mg (2000) series aluminum alloys researched and used currently for automotive, such as 2036 in the United States, CP483 in France, and Cv5: Al-Mg (500) in Japan, such as 5182 in the United States and AlMg5 in Germany, Japan's GZ45, GC45 and GC150; Al-Mg-Si (6000 series, such as the United States 6009 and 6010, Japan's GV10, etc). [4]. Many of the current automotive aluminum alloy panels can provides excellent properties in certain key performance aspects, such as formability, strength and corrosion resistance.

6000 series aluminum alloy is suitable for manufacturing key parts such as knuckle, rocker arm and control arm in automobile chassis, structural parts such as body frame, power transmission frame and engine bracket. It has developed greatly in China's automobile industry of recent years. In order to strengthen the competitiveness of products in the international market, it is urgent to develop aluminum alloys for automobiles in China. It is in its infancy that the research on China's 6000 series aluminum alloy used in automotive aluminum alloy materials, so it is necessary to carry out research on 6000 series aluminum alloys for automobiles. Moreover, the proportion of aluminum alloys used in domestic automobiles is still far from that of foreign automobiles, so the application of aluminum alloys has great potential in domestically produced vehicles.

3. Chemical composition and properties of Al-Mg-Si based alloy sheets

6000 series aluminum alloy is heat-treatment reinforced aluminum alloy, which has good formability, strong corrosion resistance, high strength and good high temperature resistance. 6000 series aluminum alloy has higher fatigue strength than 7000 series alloy, and has higher corrosion resistance than 2000. the Sterling line and the orange peel effect of the 5000 series alloy are not satisfactory, and the above two properties of the 6000 series alloy are better [5]. 6000 series alloys can refine grains by adding a small amount of various alloying elements, and obtain good comprehensive properties by changing the recrystallization state and improving the processes of casting, rolling and heat treatment [6]. Table 1 shows the components of 6000 series aluminum alloy commonly used in automotive panels.

| Alloy | Mg | Si | Mn | Cu | Fe | Ti | Zn | AI |
|------|----|----|----|----|----|----|----|----|
| 6006A | 0.4-0.7 | 0.5-0.9 | 0.5 | 0.3 | 0.35 | 0.1 | 0.2 | margin |
| 6009 | 0.4-0.8 | 0.6-1.0 | 0.2-0.8 | 0.15-0.60 | <0.5 | <0.1 | <0.25 | margin |
| 6016 | 0.25-0.6 | 1.0-1.5 | <0.2 | 0.15-0.60 | <0.5 | <0.1 | <0.2 | margin |
| 6111 | 0.5-1.0 | 0.6-1.1 | 0.1-0.45 | 0.5-0.9 | 0.4 | 0.1 | <0.15 | margin |
| 6061 | 0.8-1.2 | 0.4-0.8 | 0.15 | 0.15-0.4 | 0.7 | 0.15 | 0.25 | margin |

The yield strength and tensile strength of the Al-Mg-Si T4 plate are similar. The value n exceeds the steel plate, and the yield strength and tensile strength of the plate are similar. At present, the 6009, 6010 and 6016 aluminum alloys are used for the outer and inner panels of automobile bodies due to their good plasticity and the ability to achieve artificial aging during the paint baking process after molding.

Typical room temperature mechanical properties of the main car body aluminum alloy sheets are shown in Table 2.

| Alloy and state | σ_b(MPa) | σ_a(MPa) | Bending fatigue strength(10^3)(MPa) | density(kg/cm^3) |
|----------------|----------|----------|-------------------------------------|-----------------|
| 2036-T4        | 340      | 195      | 125                                 | 2.75×10^3        |
| 5182-O         | 275      | 130      | 140                                 | 2.65×10^3        |
| 6009-T4        | 230      | 125      | 115                                 | 2.71×10^3        |
| 6010-T4        | 290      | 170      | 125                                 | 2.70×10^3        |
| Cold rolled and steel | 298      | 181      | -                                   | -               |
4. Alloying of Al-Mg-Si based alloy sheet

It can improve its overall performance if a small amount of alloying elements are added to the alloy. This microalloying method has been widely used to study aluminum alloys. The rare earth element can refine the crystal grains in the aluminum alloy, prevent segregation, eliminate pores, remove impurities, improve metallographic structure, and improve mechanical properties. Therefore, the use of rare earth elements as microalloying elements has great significance.

Studies have shown that microalloying is an important means to improve the microstructure and properties of Al-Mg-Si alloys. After the addition of rare earth elements, the intermetallic compounds formed by these alloying elements with the aluminum matrix during solidification can serve as the core of the subsequent nucleation of the alloy, thereby refining the grains has a favorable effect on the properties of the alloy [7].

The Si content in the alloy is usually excessive with respect to the equilibrium phase Mg2Si, and a large amount of excess Si is more likely to occur in the cast aluminum alloy. The Studies have shown that excessive Si does not change the order of precipitation and the structure of various metastable phases and their lattice constants, but it will change the chemical composition and density of the precipitated phase, and it can also form some additional effects on the alloy hard. It may even react to the metastable particle phase. Excessive Si will lead to more precipitation of a large number of clusters, and the molar ratio of Mg to Si is close to 1 in the cluster, thus, it is easier to precipitate β", and the β" phase is finer and more uniform, so that the density of the alloy is greatly increased and distributed. Uniformity, which in turn increases the strength and hardness of the alloy and achieves a better strengthening effect.

The addition of Cu accelerates the precipitation of the β" phase during the artificial aging, and refines the precipitate phase in the alloy, thereby it can increase the hardness. The addition of Cu does not change the precipitation sequence of the β" phase, but there is a small amount of hardened phase near the peak time to form a I phase, such as strip QP phase. After the aging phase, the Q phase appears, which is strip-like and belongs to the hexagonal crystal system, a=1.04nm, c=0.405am. It is called the precursor phase of Q because its crystal structure is similar to Q (A15Cu2Mg8Si6).

Adding a trace amount of Mn to the Al-Mg-Si alloy, it can greatly improve the strength of the alloy. The strengthening effect is mainly derived from the substructure strengthening and dispersion precipitation strengthening of the Mn-dispersed phase particles and the age strengthening of the β" phase.

In addition to the traditional alloying elements, such as Mn, Zr, Cu, etc., which have been widely used in Al-Mg-Si alloys, it has paid to the application of rare earth elements, especially Sc is used, in Al-Mg-Si alloys. Attention is paid to the fact that the formation of Al3Sc in the aluminum alloy by the rare earth Sc has the functions of deterioration, refining and purification, and can improve the thermal stability and hardness of the aluminum alloy material. But Sc is a strategic element and is expensive, which limits its application. Therefore, the search for alternative relatively inexpensive rare earth elements is one of the research directions of rare earth microalloying.

It has shown that rare earth Er has a similar strengthening effect as Sc in Al-Mg alloy, but compared with Sc, the price of Er is only 1/40 of Sc, which has attracted much attention. Extensive research has been conducted on the role of Er in the Al-Mg alloy. During the solidification of Al-Mg-Si alloy, most of the Er is segregated at the grain boundary of the alloy to form a coarse intermetallic compound. The secondary intermetallic compounds formed by Er and Al are dispersed in the matrix to produce dispersion strengthening. It was found that Er interacted with elements such as Mg and Si.

5. Conclusion

Aluminum alloys are not used on a large scale in automobiles because their prices are higher than steel (about twice that of steel) and the formability of aluminum sheets is worse than that of steel sheets, and dimensional accuracy is difficult to grasp. These problems will be solved with the development of science and technology and the progress of society.

At present, steel is still the most important material for automotive panels. Aluminum alloys are not used for automotive body panels for a long time, and aluminum alloy sheets are not as good as steel
such as strength, stamp formability, weldability and cost. The main trends in the research and development of aluminum alloy sheets for automobiles in the future are:

5.1 Establish aluminum alloy standards for automobile bodies, and develop more adaptable aluminum alloys for automobile bodies, especially to pay the main attention on the 6000 series alloys;

5.2 Optimize the composition of 6000 series alloys, improve industrial structure, develop connection technology for industrial production, and reduce production costs;

5.3 Develop advanced production process of aluminum alloy to improve alloy formability and weldability;

5.4 Study the relationship between composition and microstructure, mechanical properties and stamping properties of aluminum alloy sheets Systematically.

References

[1] Li Bingfeng. Discussion on the production of aluminum strip for automobile body[J]. Nonferrous Metals Processing 2012( 8) : 22- 24.

[2] Li Yongbing, Chen Changnian, Lang Lihui, et al. Research on Key Manufacturing Technology of Automobile Aluminum Body[J]. Journal of Materials Application, 2013( 3) : 50- 58.

[3] Zhang Shengjun. Application and development trend of aluminum alloy sheet for automobile body Automotive Engineer 2015(3),16-18

[4] Nargess Shahmanesh. Lightening the Material[J].Automotive Engineering, 2003, (9 ); 70

[5] Willian Kimberley. Enlightened Process J.Automotive Engineer. 2003, 11:50-51

[6] LI YJ, Brusethaug S, Olsen A. Influence ofCu on the mechanical properties and precipitation behavior of AISi7Mg0.5alloy during aging treatment[J].Scripts Materialia, 2006, 54; 99-103

[7] LI Y J, Brusethaug S, Olsen A. Influence ofCu the mechanical properties and precipitation behavior of AISi7Mg0.5alloy during aging[J]. Scripts Materialia, 2006, 54; 99