Effect of Si on Microstructure and Function of in-situ Mg2Si/AM60 Composite Material for Automobile

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Abstract: Magnesium-based composite materials can effectively improve the material properties of the matrix. At present, the main research focus is on the preparation of composite materials strengthened by additional particles. The process of this method is not simple, and the thermal stability is not good. The in-situ synthesis of composite materials has a simplified process and good interface bonding, which has become a core technology research goal for the development of composite materials. This thesis expounds the related theories of magnesium alloys, and discusses the effects of Si on the in-situ Mg2Si/AM60 composite materials in the car from the two secretions of material organization and function.

1. Introduction

Magnesium and magnesium alloys themselves highlight several advantages such as high specific strength and stiffness, shielding electromagnetic type, vibration reduction and outstanding radiation resistance, and are relatively easy to cut, process and recycle. Therefore, it is widely used in electronics, automobiles, electrical appliances, aviation, transportation, aerospace and national defense chemical industries, and has great application value and broad development prospects. It is considered to be the most important metal structural material developed after iron and steel and aluminium alloy, and is recognized as an important material for global green engineering in the 21st century. The application and development of magnesium alloys are obviously the important development trend of material exploration and application research and development at present. However, the overall performance of the magnesium alloy is not high, thus hampering its further application. Composite materials can effectively address this deficiency. In this paper, the related research on the effect of Si on the microstructure and function of in-situ Mg2Si/AM60 composite materials is studied.

2. Related theory of magnesium alloy

2.1 Characteristics of magnesium alloy

Magnesium alloys are mainly alloy types formed by adding magnesium as a foundation and adding several other elements. Magnesium alloys have a low density (about 1.8g/cm3), high specific strength and specific stiffness, and their relative specific strength (ie, the ratio of strength to mass) ranks first, and their specific stiffness (ie, stiffness and mass) The ratio) is close to aluminum alloy and steel, far beyond engineering plastics. Elastic modulus is large, strength, stiffness, shock absorption, chipability, shielding electromagnetic, attenuation, heat dissipation, wear resistance, shielding, workability, and electrical and thermal conductivity are better. It is non-magnetic, non-toxic and can be easily recycled again. In the elastic range, when magnesium alloy is subjected to external impact load, the energy absorbed by magnesium alloy is at least 50% higher than that of aluminum alloy parts. Therefore, the noise reduction function of magnesium alloy is remarkable. At the same time, it has outstanding resistance and alkali corrosion resistance, size has a sTable performance.

The main types of alloying elements of magnesium alloys include zinc, cerium, aluminium,

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manganese, thorium and part of cadmium or zirconium. At present, magnesium-aluminium alloy, magnesium-manganese alloy and magnesium-zinc-zirconium alloy are the most widely used alloys. Magnesium alloys are mainly used in automobiles, aerospace, aviation, electrical transportation, chemical industry, 3C, transportation, porTable equipment and national defense and military fields, which can achieve lightweight effect. Among all practical metals, magnesium alloy is the lightest. Among them, the magnesia ratio is about 2/3 of aluminium and 1/4 of iron. Although the magnesium alloy is heavier than plastic, the weight strength and modulus of elasticity in the unit are higher than that of plastic. Therefore, in the same strength component environment, magnesium alloy parts can be made thinner than plastic and lighter than plastic. Furthermore, since the specific strength index of the magnesium alloy is also higher than that of the aluminum alloy and the iron, the quality of the iron or the aluminum component can be reduced without weakening the strength of the component.

2.2 Application of Magnesium Alloy in Automobile

Although magnesium alloys are widely used, the biggest driving force for their development comes from the automotive industry, which has emerged since the energy crisis in the 1970s. The global automobile manufacturing industry is affected by two reasons: environmental protection and energy saving. Experts and scholars who design automobiles adopt various means to reduce the quality of automobiles, so as to reduce the consumption of gasoline and emission of exhaust gases. In fact, while reducing the quality of the car, it can reduce the cost of fuel, and thus reduce the degree of pollution to the environment. This is also one of the most attractive and important structural materials for magnesium alloys to become “lightweight“ in the automotive industry.

Since the 20th century, automobile manufacturers in countries such as Europe, America, South Korea, and Japan have gradually applied magnesium alloys to automobile parts. In the past 10 years, some of the original steel and aluminum alloy parts in automobiles have been gradually replaced by magnesium alloy parts. At present, there are more than 60 types of magnesium alloy parts in automobiles, including the dashboard, intake pipe, transmission, steering system parts of the car, the car's seat and the engine's cover wheel. Among the products of many general-purpose vehicles, the application of magnesium alloy parts exceeds 17kg. Ford F-150 truck used 15kg and 6kg magnesium alloy parts in Chrysler truck in turn. Therefore, magnesium alloy parts will be more and more widely used in automotive products. The goal set by automobile manufacturers is to use 40 kg of aluminium alloy per car.

(1) Shell class. Such as clutch housing, valve cover, dashboard, gearbox, crankcase, engine front cover, cylinder head, air conditioner housing, etc.

(2) Brackets. Such as steering wheel, steering bracket, brake bracket, seat frame, mirror bracket, distribution bracket, etc.

According to relevant research, 60% of the fuel used in automobiles is consumed by the weight of the car. For every 10% reduction in the weight of the car, the fuel efficiency can be increased by more than 5%. For every 100 kg reduction in automobile weight, fuel consumption per 100 km can be reduced by about 0.7 L. For every 1 L fuel saving, CO_2 emissions can be reduced by 2.5 g, and annual emissions can be reduced by more than 30%. Therefore, reducing the weight of automobiles has a great impact on the environment and energy, and the lightweight of automobiles has become an ineviTable trend.

3. Effect of Si on Microstructure of in-situ Mg_2Si/AM60 Composite Materials for Automobile

3.1 Matrix Microstructure of AM60

The temperature of the Mg-Al alloy eutectic is 437 ℃. Among Mg, the solid solubility of Al is 12.2%, and in the magnesium alloy of AM60, the specific gravity of the Al component is about 6%. This means that the solidification occurs on the left side of the eutectic point. When the melt temperature of the alloy exceeds 650℃, it exhibits a full liquid state. When the temperature decreases, α-Mg gradually precipitates, and as the content of its precipitation increases, the proportion of AL in the melt increases, and then enters the stage of L+α-Mg, and the temperature decreases again until it reaches Supersaturated α-Mg state. In the process of decreasing temperature, the secondary phase Mg17Al12 precipitates slowly along the grain boundary first, and the content of Al in the melt also decreases. When the temperature decreases continuously, the secondary phase precipitates not only at the grain boundary, but also outside the grain boundary.

Microstructure and X-ray diffraction (XRD) of AM60 alloy in as-cast environment were studied. It was found that the structure of AM60 alloy in as-cast environment showed representative branch structure. The results of the XRD study and the alloy phase diagram data of Mg-Al can be concluded that the white branch morphology in the microstructure is the α-Mg of the primary phase. As for the mesh, gray, continuous distribution phase, and along the grain boundary, it is the secondary phase of the Mg17Al12 phase.

3.2 Effect of Si Content on Microstructure of In-situ Mg2Si/AM60 Composite Materials

Adding different Si content to the AM60B-Si specification magnesium-based composite material The experimental data of Mg2Si shows that the amount of Si added is 0.7%, which is a type of hypoeutectic. When the temperature is decremented below the liquidus, the remaining liquid phase will produce a eutectic composition of Mg+Mg2Si from the eutectic. When the eutectic is changing, its Mg2Si is continuously increasing and growing into a large and large Chinese character form. Since it belongs to the type of hypoeutectic, the original Mg2Si phase does not appear in the composite material. Since Si reacts with Mg to produce a Mg2Si phase, when the content of Si increases, the amount of Mg2Si increases by about twice the amount of Si. When the Si content reaches 2.0%, the alloy belongs to the type of hypereutectic, thus producing the original Mg2Si phase, while exhibiting a coarse branch morphology. When the proportion of addition of Si reaches 4.0%, the content of the Mg2Si phase is further increased and becomes coarser at the same time. When the proportion of Mg2Si added reaches 6.0%, the content of Mg2Si phase keeps increasing and the thickness is getting larger and larger. When the proportion of Mg2Si is 8.0%, the content of Mg2Si phase keeps increasing, and the coarseness of Mg2Si phase keeps increasing. It can be seen that the corresponding content of Mg2Si will increase with the increase of Si content. Meanwhile, the morphology of Mg2Si will become larger and thicker with the increase of Si content. Accordingly, the morphology of Mg2Si branches will become more and more developed. According to the theory of diffusion phase transition, there is an intrinsic relationship between the coarsening speed of precipitated particles and the atomic content of solute, that is, the higher the solute content, the faster the coarsening speed of particles. Therefore, when too much Si is added, Mg2Si will aggregate, increase and coarsen. Because Mg2Si belongs to brittle phase, at the same time, when Mg2Si is too large, the matrix will be cracked and the stress concentration effect will appear. Therefore, it is more appropriate to choose the content of Si at 2.0%.

4. Effect of Si on Properties of in-situ Mg2Si/AM60 Composite Materials for Automobile

According to the conclusion of the experiment, the tensile strength and hardness of composite materials show an increasing trend with the increase of Si content, while the elongation shows a decreasing trend. The tensile strength of the composite material is 176.4 MPa without adding si. But when the content of Si is 1.0%, its tensile strength reaches 198.2 MPa, which increases by about 12%. However, further increasing the specific gravity of the si content, its strength shows a decreasing trend. As the content of Si increases, the hardness increases remarkably, and the hardness HB of the AM60 substrate is 460 MPa. When the content ratio of Si is 5%, HB is as high as 683 MPa, and the increase is about 48.7%.

Because the constant of the lattice is different from the structure of the crystal, the internal interface of the Mg2Si of the magnesium matrix and the reinforcing phase cannot be completely matched. Therefore, the strength improvement of the Mg2Si/AM60 composite material can be explained based on the following mechanism: (1) The difference in coefficient between the granule molecule Mg2Si and the thermal expansion inside the matrix. A high-density dislocation area occurs around the Mg2Si phase, thereby increasing the frictional resistance during dislocation motion and increasing the strength. (2) The second phase particles dispersed in the material can rapidly hinder the dislocation motion, thereby causing pinning effect on adjacent grains, thereby increasing the strength of the alloy itself. (3) Compliance with the delivery function. Because Mg2Si phase and matrix can bind well, the stress transfers from softer matrix to harder matrix during tension, because the strength of secondary hard phase Mg2Si is much higher than that of matrix. Therefore, it can protect the matrix to a certain extent and strengthen its strength. (4) The refinement function of alloy grain. Due to the addition of Si, the size of the crystal is refined. Based on Hall-Petch's formula, the correlation between yield strength and grain size can be expressed by the following formula:

$$\Delta\sigma = K\mathrm{d}^{-1/2} \tag{1}$$

In the above formula (1), $\Delta\sigma$ represents the increment of yield strength of composite materials, K represents a constant (in terms of Mg, K = 0.28MPa. m1/2), and D represents the average size of crystal particles. Therefore, when the size of crystal particles decreases, the yield strength of composite materials increases inversely. In addition, the size of crystal particles decreases, indicating that the grain boundary is increasing. At the same time, the grain boundary is the main obstacle to the movement of dislocation of crystal particles, so it can improve the strength of the alloy. When the specific gravity of Si exceeds 1.0% in crystallization, the overall performance of the composite material is gradually weakened. The reason is that the concentration of the particles is swollen when the content of Si is too large, and the stress produced by the larger-sized reinforcing particles is also concentrated. At the same time, the substrate is split, and the intergranular crack is more likely to occur during the loading process, thereby weakening the performance of the composite material. The material elongation rate tends to decrease gradually due to the gradual increase in the specific gravity of Si. The reason is that the brittle reinforcing phase formed by Mg2Si strengthens the hardness of the composite material, and when it is stretched, it hinders the dislocation motion, thereby strengthening the matrix, resulting in weak plasticity of the composite material.

5. Conclusion

In this paper, Si powder was added to the matrix of AM60 magnesium alloy, and the application of Mg2Si/AM60 composite material in in-situ synthesis of automobile was analyzed by mechanical stirring method. The characteristics of magnesium alloy and its use in the automotive industry were analyzed. When analyzing the influence of Si on the microstructure of automotive in-situ Mg2Si/AM60 composite materials, the microstructure of AM60 was also considered. Finally, the effect of Si on the properties of in-situ Mg2Si/AM60 composite material is analyzed.

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