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Rapid Solidification Process Based on Life Cycle Assessment on Microstructure and Properties of Magnesium Alloy

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Abstract: Among many factors that affect the corrosion performance of magnesium alloy, its microstructure is an important factor. Rapid solidification aluminum alloy powder must be solidified and formed before it can be used as a finished product or a component. Therefore, its forming process is very important. It is required to maintain the microstructure characteristics of the rapidly solidified alloy in the hot forming process and avoid coarse microstructure, dilution of supersaturated solid solution and coarsening of precipitated phase caused by remelting and recrystallization. In this paper, the effects of extrusion temperature and extrusion speed on the microstructure and mechanical properties of several alloys are deeply studied, and the relationship between extrusion process and microstructure and mechanical properties of alloys is established. Based on life cycle assessment, mechanical alloying, hot extrusion, rapid solidification and other methods are used to refine the structure of the alloy, and Mg2Si phase is generated in-situ in the alloy to improve the properties of magnesium alloy AZ31B, which has achieved certain results.

Keywords: Life cycle assessment, rapid solidification, magnesium alloy, microscopic structure.

Introduction

Lightweight of mechanical equipment has always been the goal pursued by the mechanical industry. Lightweight brings many benefits to society. It can save materials and energy consumption, reduce environmental pollution, contribute to the construction of a resource-saving and environment-friendly society, and promote the sustainable development of society. Due to its low density, high specific strength, high specific stiffness, good damping, electrical and thermal conductivity, and good recyclability, magnesium alloy has broad application prospects in national defense fields such as aerospace and civil fields such as electronics and transportation [1]. Compared with common casting processes, rapid solidification technology can refine alloy structure, increase solid solubility, and reduce composition segregation, thus significantly improving alloy properties and preparing novel alloy with excellent properties [2]. Researchers have done a lot of research on how to improve the mechanical properties of magnesium alloy. Grain refinement is an important means to improve the comprehensive properties of magnesium and its alloys. Grain refinement can not only improve the strength of materials, but also improve their plasticity and toughness. Effectively obtain good tissue genetic effect [3]. Based on life cycle assessment, the forming process of magnesium alloy AZ31B and its effect on microstructure and properties were studied in this paper, and more reasonable hot forming process conditions were determined.

Methodology

The cooling rate of ingot solidification refers to the temperature change rate from the time when the alloy melt starts cooling to the time when the melt is completely solidified. Different solidification and cooling rates will result in different microstructure and phase composition of the material, thus greatly affecting the comprehensive properties of the material. As the rapidly solidified magnesium alloy products need to undergo crushing processing, consolidation molding and plastic processing (such as extrusion, rolling and forging) to be made into magnesium alloy body materials. The magnesium alloy AZ31B used in this experiment is remelted and refined by elemental metal, and then stripped of slag and impurities on the surface. The melt was then injected into a copper mold with high purity argon to produce an alloy round rod with a diameter of 50 mm. The chemical composition of the experimental alloy is shown in Table 1.

Table 1. Chemical composition (mass fraction) of magnesium alloy AZ31B

Element	Mg	Al	Zn	Mn	Si	Cu	Ni	Fe	Other
W/%	88.36	9.24	0.82	0.33	0.001	0.004	0.001	0.028	0.014

After the powder is cold compacted to a relative density of 70%, vacuum hot pressing and hot extrusion are respectively carried out to finally obtain the finished product. Due to high reverse extrusion efficiency, low energy consumption, reduction of coarse crystal ring defects and promotion of uniform alloy structure, the hot extruded alloy is subjected to reverse extrusion. Grind step by step with water sandpaper and metallographic sandpaper, then polish and corrode with mixed acid. When meeting the surface of the copper roller, the copper roller is rapidly cooled and rapidly solidified into fine flakes, and the rapidly solidified flakes are immediately thrown out along the tangent direction of the roller surface; With the increase of deformation passes and strain, the number of large grains decreases continuously, the degree of dynamic recrystallization increases continuously, and the grains are gradually refined. Magnesium alloy AZ31B without homogenization treatment has many coarse second phases Mg17Al12, which are distributed in a network and skeleton shape. After homogenization treatment, the second phase Mg17Al12 in magnesium alloy AZ31B has been basically dissolved into the matrix [4]. Suspend the sample in corrosive medium and soak it for 12 hours, then take it out and let it stand in boiling water solution containing 13% cro 3+2% agno 3 for 10 min. The hot extrusion process flow is as follows: coating lubricant on the drying die, cold pressing the powder in the female die, filling the die, fastening the furnace, heating and keeping warm, and pressurizing.

The microstructure of hot pressed alloy and backward extruded alloy was observed by Olympus BH2-UMA optical microscope, and the grain size was calculated by Optimas image analysis. Air is easily adsorbed at pits or scratch grooves. When the melt contacts the roll surface, the air is sealed between the melt and the roll surface, and then heated to expand to generate bubbles in the melt. After multi-directional forging, the hardness, strength and elongation of the material are increased. After homogenization treatment, the second phase and dendritic segregation are improved. After homogenization treatment, the composition of magnesium alloy AZ31B is more uniform and the internal stress in as-cast structure is eliminated [5]. The powder is teardrop-shaped, and its surface is smooth and crystalline groove-shaped. The microstructure of the powder is a mixed structure of dendritic crystal and cellular crystal, the cellular size is less than 10 μm, and the cooling rate is estimated to be more than 104 K/s from the dendrite spacing. the x-ray diffraction analysis of corrosion products is carried out on a d/max-2500 PC instrument. the surface of the sample is scanned by SEM, and the distribution of each element on the surface of the sample is analyzed.

Result analysis and discussion

Figure 1 shows the as-cast state of magnesium alloy AZ31B and the microstructure of the rapidly solidified sheet obtained by experiments. It can be seen from the figure that the as-cast microstructure of AZ91 is coarse and the grain size can reach 60 μm. Due to the large accumulated plastic deformation, the dynamic recrystallization temperature of the material decreases and the critical strain value for dynamic recrystallization decreases, which is the main reason for grain refinement by thermo-mechanical deformation. Among them, the homogenization treatment of magnesium alloy AZ31B blank is to keep the temperature at 480°C for 10 hours and then take out the furnace for air cooling. The more serious the corrosion to the protective film on the surface of the sample, the further damage to the existing weak areas and the appearance of new weak areas will result, thus the metal ions will be transferred to the solution faster and the corrosion process will be accelerated. The powder type and particle size distribution will not change under the experimental conditions, so the first three factors have the greatest influence. Vacuum hot pressing at temperature lower than 320°C results in looser pressed parts, and the recrystallized grain size increases with the increase of extrusion temperature. High extrusion temperature accelerates diffusion efficiency and dislocation annihilation rate, which is conducive to the growth of recrystallized grains.

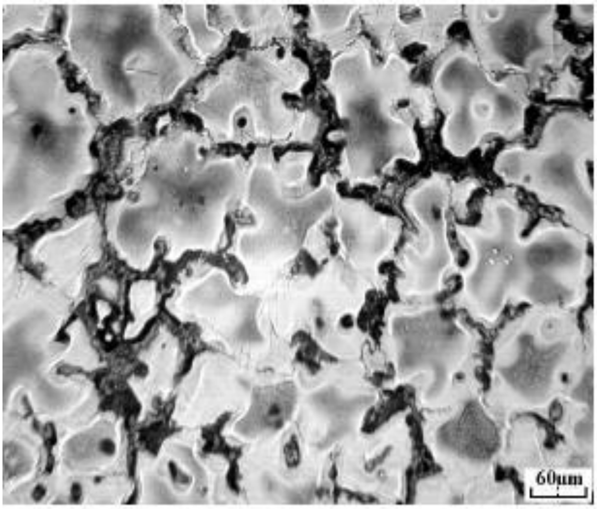

Figure 1. Metallographic structure of magnesium alloy AZ31B as-cast and rapidly solidified sheet

In the process of rapid solidification, grain refinement is mainly caused by the following reasons: due to the increase of cooling speed, the undercooling degree of alloy melt increases and the nucleation rate correspondingly increases, which increases the number of grains per unit volume, and also due to the rapid cooling effect, the grains solidify before they can grow up. Although this mechanism can only play a role in high-level misfit metals, previous studies have shown that continuous dynamic recrystallization is an important nucleation mechanism matrix in magnesium alloys [6]. Magnesium matrix and second phase have good wettability, which is related to the crystal structure of both. When the second phase compound exists between two matrix grains, its morphology is determined by the interfacial energy between the matrix and the second phase. Compared with that without Si, the grain size is much finer, and increases slightly with the increase of extrusion temperature. When vacuum hot pressing is carried out at 320°C, the relative density of pressed parts can reach 97.9%. The influence of pressing temperature is the largest, the influence of pressure is the second, and the change of holding time has little influence on the performance of pressed parts. The corrosion of magnesium alloy is relatively light. After soaking in corrosive medium for 25 h, only local spot corrosion occurs. After homogenization heat treatment, the second phase of magnesium alloy AZ31B is very fine and evenly distributed, with coarse second phase occasionally visible. In short, after homogenization heat treatment, magnesium alloy AZ31B is more conducive to the development of subsequent hot extrusion tests.

It can also be seen from Figure 2 that the corrosion rate of rapidly solidified magnesium alloy AZ31B is small, and the change is not large with the increase of medium concentration. It can be seen that the rapid solidification technology improves the corrosion resistance of magnesium alloy AZ31B.

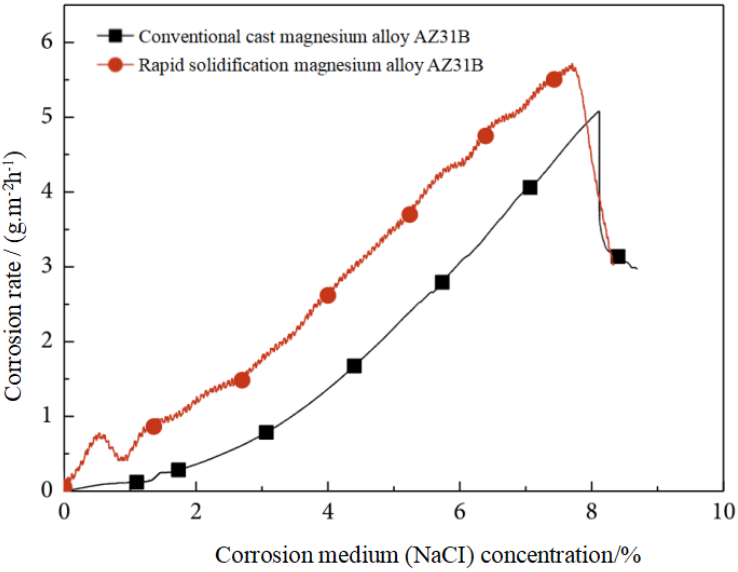

Figure 2. Influence of medium concentration on corrosion rate

From the above analysis, it can be seen that magnesium alloy AZ31B undergoes dynamic recrystallization after hot extrusion at different temperatures, and the crystal grains are significantly refined, forming a uniform equiaxed crystal structure. With the increase of extrusion temperature, the crystal grain size increases. However, the extent to which the fine crystal structure can be retained during hot pressing mainly depends on the hot pressing temperature. As for the surface oxide of the particles, if degassed properly, the surface oxide film is easily broken and evenly distributed, and will not have adverse effects on the performance. This is because dislocations can climb and annihilate each other when the temperature exceeds 0.4 Tm, so the higher the temperature, the lower the dislocation density, the lower the yield strength and tensile strength, and the greater the elongation. While the convex tumor grows, solute atoms are excluded from the top end and the side surface of the solid-liquid interface. Due to the increase of the dissolved mass in the side surface liquid, the lateral growth of the convex tumor is prevented, and the convex tumor maintains a stable shape. In addition, during the double-roll quenching process, molten metal is injected into the gap between the two rolls at a certain speed through the nozzle opening, the continuous rotation of the casting rolls and the downward movement of the solidified layer at the roll surface both cause the molten metal between the rolls to generate forced flow, forced convection and repeated changes in temperature [7]. This can effectively prevent corrosion and make the alloy have better corrosion resistance, which is the main reason for improving the corrosion resistance of rapidly solidified magnesium alloy AZ31B.

Conclusion

Compared with the uniaxial forming process, the material under multi-direction forging with large deformation is easy to produce staggered deformation zones, which is beneficial to the structure refinement. Its main grain refinement mechanism is deformation-induced grain refinement similar to continuous dynamic recrystallization. Compared with as-cast magnesium alloy AZ31B with coarse structure, the structure of rapidly solidified sheet is uniform and fine, mainly composed of supersaturated α-Mg solid solution and a small amount of β-Mg17Al12 precipitated phase. The magnesium alloy anode material prepared by rapid solidification has extremely fine crystal grains, a fine dendritic interface and no obvious second phase compound. With the increase of reverse extrusion temperature, the yield strength and tensile strength of magnesium alloy AZ31B decrease, while the elongation increases. Rapid solidification magnesium alloy AZ31B has better corrosion resistance. Through rapid solidification technology, the alloy grain is refined, and the element distribution of the alloy is more uniform, especially the uniform distribution of Zn element, which is beneficial to the improvement of corrosion resistance of magnesium alloy.

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