ISSN: 2664-9640

Study on the Effect of Grain Refinement on the Properties of Aluminum Alloys

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Abstract

The refined grains have improved the mechanical properties of metal Strength of materials. Usually, a metal is a polycrystalline material composed of many grains, and the size of the grains can be expressed by the number of grains per unit volume. The more the number, the finer the grains. Fine grained metals have higher strength, hardness, plasticity, and toughness than coarse grained metals. This is because fine grains undergo plastic deformation under external forces and can be dispersed within more grains, resulting in more uniform plastic deformation and less stress concentration; In addition, the finer the grain size, the larger the grain boundary area, and the more tortuous the grain boundaries are, which is less conducive to crack propagation. This article mainly summarizes the research and development trends of grain refinement technology both domestically and internationally.

Keywords

Metal, Performance, Refinement method.

1. Introduction

Aluminum alloy is a high-strength deformed aluminum alloy with tensile properties up to 550MPa. Due to its excellent mechanical properties, it has enormous application value in important load-bearing components. Although it has excellent performance and good application value, it is difficult to weld, has poor corrosion resistance, and is prone to various surface defects during processing. After cutting, it was observed through microscopic inspection of the actual surface of the workpiece that a processing modification layer (Figure 1) was formed on the cutting surface, which was different from the substrate material. The grain refinement in this layer significantly refined its grain size [1]. This grain refinement layer can effectively improve fatigue resistance, corrosion resistance, and strength, and can also cause severe creep at high temperatures. The in-depth research on the cutting process of aluminum alloys will have great practical significance in improving the material's service life and performance.

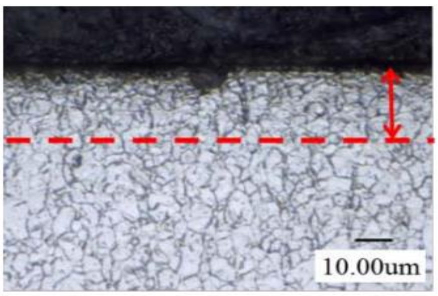

Figure 1: Refinement of Aluminum Alloy Cutting Surface

2. Cutting grain refinement

During the cutting process, due to the coupling effect of turning cutting heat and heat, the internal microstructure undergoes changes such as elongation and distortion, and the grains are finer than the matrix grains. Although the thickness of this metamorphic layer is only a few micrometers to tens of micrometers, it has a significant impact on the service life and performance of the workpiece.

Aluminum alloy, titanium alloy, copper, etc. are representative Polycrystal metals. As shown in Figure 2, their mechanical properties have been significantly improved. With the change of grain size d, their hardness Hv (or strength) generally follows the Hall Petch relationship [2]. That is to say, with the reduction of grain size, its mechanical properties have been significantly improved, while also giving it some special physical and chemical properties.

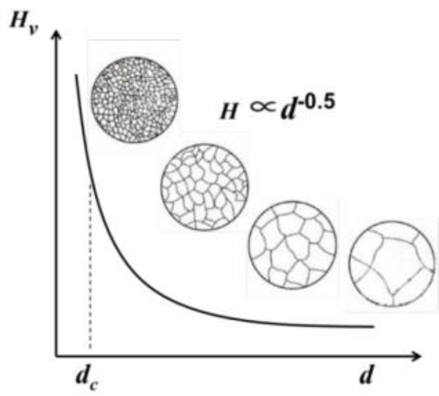

Figure 2: Schematic diagram of the relationship between microhardness and grain size

Shankar [3] [4] studied the deformation of pure titanium during high strain cutting. The microstructure of the chips is mainly composed of ultrafine grains, with a particle size of approximately 100 nanometers at the maximum strain point. Yang Guo [5] [6] studied and found that under low speed cutting conditions, the strain on the cutting surface gradually increases as the tool rake angle decreases and the cutting thickness increases during the cutting process. Che Heron [7] found that under different cutting speeds, feed rates, and back feed, the plastic deformation on the dry cutting surface became more severe, and a thickness of 10 was formed on the cutting surface μ The white layer around m is visually manifested as an increase in the hardness of the cutting surface. Pu [8] used two methods, liquid nitrogen spray cooling cutting and dry cutting, and found that reducing the cutting temperature and using larger cutting edge radius (0.07mm) tools can not only improve the cutting surface smoothness, extend tool life, but also facilitate grain refinement. Pusavec [9] found that under four different cooling conditions, namely dry cutting, micro lubrication cutting, low-temperature cutting, and cold cutting+micro lubrication cutting, low-temperature cutting can significantly improve these surface integrity characteristics, and grain refinement phenomenon was observed on the cutting surface.

3. Different processing methods and methods to refine grains

In terms of processing methods, Lewandowska [10] refined the grain size of metal materials through hydrostatic extrusion (HE), resulting in significant changes in their properties, a significant increase in mechanical strength, and improved wear and corrosion resistance. Alawadhi [11] used equal channel angular pressing (ECAP) to process oxygen free copper at room temperature, and then further deformed the ECAP specimen at 298 K using a strain rate of 10 s-1. The effect of initial microstructure induced by ECAP on grain refinement and

ISSN: 2664-9640

mechanical properties after dynamic testing was experimentally studied. The results indicate that as the number of ECAP passes increases, the strength of copper increases, and significant additional grain refinement is generated in the ECAP sample through dynamic testing. I. V. Khomskaya [12] obtained commercial copper with sub microcrystalline and nanocrystalline structures using dynamic channel angle pressing (DCAP) method with high strain rate deformation, and found that it ranges from 100 to 0.5 − 1.0 μ The dynamic Elastic Limit and dynamic yield stress of copper are increased by 6 times due to grain refinement of m. Ahmad [13] effectively refines grains to micrometers or nanometers through the technology of high ratio differential rolling HRDSR, and evenly disperses particles or reinforcing materials throughout the entire matrix, which helps to improve the environmental and superplastic mechanical properties of various metals and alloys. Kiran Babu B [14] was successfully produced through friction stir processing, with grain refinement ranging from 107 μ M ± 6.7 μ M to 3.5 μ M ± 1.5 μ M. Due to grain refinement, the hardness of fine-grained ZE41 magnesium alloy (≈ 30%) is higher than that of the base alloy.

From the Tensile testing, compared with the base alloy, the strain of fine grain ZE41 is lower, but the ductility is lower, but the yield strength and ultimate tensile strength are significantly improved. In terms of treatment method, Manjunath Yadav S [15] and Tong Ying [16] refined the microstructure and improved the hardness and wear resistance of the steel through thermal cycling heat treatment.

4. Adding Refiners to Refine Grain Size

E Abd [17] studied the effect of different percentages of Al-5Ti-1B grain refiners (GR alloy) on the mechanical properties and corrosion behavior of aluminum magnesium silicon alloy (Al Mg Si). The results indicate that the addition of GR alloy improves the mechanical properties of Al Mg Si alloy. In addition to Al Mg Si alloy, GR alloy produces fine grain structure and better hardness and compressive strength. Apparao K. Ch [18] studied the effect of Al-3.5FeNb-1.5C grain refiner and Ni alloy element addition on the alloy, and the results showed that the ultimate tensile strength (UTS) and hardness (Brinell and micrometer) of Al-Si9.8-Cu3.4 alloy were improved. An Yukang [19] studied the effect of Co addition on the solidification rate, hardness, and refined microstructure transformation of undercooled nickel copper cobalt alloy. The results showed that the addition of Co significantly increased the solidification rate and stress induced deformation effect. The low angle GBs in the refined structure of Ni Cu Co alloy increased, and the grain size significantly decreased, significantly improving the average hardness of the refined structure. Q B [20] prepared Al-Ti-C-Ce grain refiner by adding CeO. 2. Under the condition of holding for 3-5 minutes and adding 5.5wt% Al-Ti-C-Ce grain refiner, the average size of pure aluminum grains decreased to 48.4-48.8 μ M. Qiang Z C [21] Ce has the most positive adsorption energy and maximum charge transfer value, and has the most effective modification ability. The experimental results show that adding rare earth elements to Al-5Ti-1B alloy can greatly refine the particle size of TiB, improve particle distribution, and have better refining effect than Al-5Ti-1B alloy without rare earth elements. Ao W [22] found that the average grain size decreased to 68.1 μ m. 21.1%, 83.5%, and 5.1% lower than the optimized rotating magnetic field treated alloy, Al-60Ti-8B refining machine, and untreated alloy, respectively. The tensile strength and elongation of the alloy reached 232.5 MPa and 18.6%, respectively, significantly higher than those of the alloy treated with rotating magnetic field, Al-5Ti-1B refining machine, and the alloy without any treatment. Wenxue F [23] designed a new Al-1.2V-3.2B grain refiner containing VB5 and VB particles. Based on the basic crystal growth theory, the growth mechanism of VB2 and VB particles in the grain refiner follows the principles of atomic adsorption and layer by layer growth. The grain refinement and mechanical properties of AZ91 alloy induced by subsequent extrusion were investigated. In order to refine the eutectic grain size, a combination of Eu (up to 500 ppm) and P (up to 40 ppm) was used in IS [24]. As the concentration of P increases, the modification of eutectic Si becomes worse. The size of eutectic Si increases, and the shape factor of eutectic Si decreases.

5. Development Trend of Grain Refinement Technology

Advanced processing methods: With the development of advanced processing technology, the means of refining metal grains are also constantly improving. For example, high-energy ball milling, Thermal spraying, rapid solidification and other processing methods can achieve efficient refinement of metal materials and obtain smaller grains.

New additives and alloy design: Introducing new additives and microalloying technology can effectively control the grain growth of metals and achieve grain refinement. According to the specific application requirements, the dynamics and Thermodynamic process of grain growth are controlled by alloy design to achieve precise control of grain size.

Overall, the development trend of metal grain refinement technology is diversified and comprehensive. Through the comprehensive application of various means, combined with Computer-aided design and advanced processing methods, as well as new additives and interface engineering technology, more accurate control and refinement of metal grains can be achieved. This will bring higher performance and more reliable metal materials to the fields of materials science and engineering. If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

Acknowledgements

This paper was supported by Research Fund for the Graduate Science program of North China Institute of Aerospace Engineering (grant No YKY202203).

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