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Chemical Analysis of the Mechanical Properties of Aluminum Magnesium Alloy Badminton Racket under Heat Treatment

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At present, the pursuit of light weight and high strength of badminton racket has promoted the vigorous development of new badminton rackets materials and related research. Magnesium alloys, as the lightest metal structural materials, have been studied and applied to the new badminton rackets materials in recent years. This paper explores the effect of different heat treatment processes on mechanical properties after the new type Mg-4Al-2Si alloy badminton rackets materials is heat processed. It provides theoretical basis and technical support for the design, manufacture and selection of new type magnesium alloy badminton rackets.

1. Introduction

In recent years, badminton has been developed rapidly and widely in our country. The requirements of a light weight and high strength has promoted the development of new badminton racket materials and related research. The badminton rackets in different material not only have different responses to the force and speed of the ball, but also have great difference in the mechanical property of the rackets. Magnesium alloy, as the lightest metal material, has the advantages of high specific strength, stiffness, dimensional stability, good shock absorption and easy recovery, known as "the twenty-first Century green project metal structure materials (Fan, et al., 2014). It has a broad application prospect in the automotive, aerospace and other fields, and in recent years, it is also applied to new badminton rackets material.
The effects of different heat treatment processes on the mechanical properties of the alloy are discussed in this paper, which provides theoretical basis and technical support for the design, manufacture and selection of new type magnesium alloy badminton rackets.

2. An overview of magnesium alloy materials

2.1 Characteristics of magnesium alloys

The texture of pure magnesium is soft, not suitable for taking as a structural material to be directly used. By adding alloying elements, it can significantly improve and optimize the performance of magnesium (Feng, et al., 2014). In consequence, in the engineering application, it often appears as magnesium alloy. According to the actual needs, people have designed a series of magnesium alloy, and they usually have the following characteristics:
(1)Light weight, high specific strength and high stiffness: magnesium alloy is the lightest structural material up to now, and its specific strength is the highest among the commonly used structural materials (Gzyl, et al., 2015). Since that the magnesium alloy strength and stiffness ratio are significantly higher than those of aluminum, and compared with engineering plastics, it has high elastic modulus, stiffness and dimensional stability, making magnesium alloy become important materials in the development of lightweight (Mao, et al., 2015).
(2) High thermal conductivity, low thermal capacity, easy machining, and good casting performance (Min, et al., 2014): this characteristic of magnesium alloy makes the magnesium alloy processing cost low, and it can be cast into complicated thin-walled components close to the size of the cost.
(3) The magnesium alloy has strong ability to absorb the energy of the plastic deformation, and the fatigue resistant ability is better (Nasruddin, et al., 2016): magnesium alloy has strong absorption ability on the

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mechanical oscillation, and it can resist fatigue, so the magnesium alloy can be applied in the occasions under high load effect and those require high security.
(4) Magnesium alloy itself is not magnetic. It has good electromagnetic shielding, and the electrode potential is very negative.
(5) The toxicity of magnesium alloy is very low, and it can be recycled (Oliveira, et al., 2014). This characteristic is beneficial to the sustainable development of economy, and cannot produce the strong toxic material pollution environment in the process of recycling.

2.2 Heat treatment of magnesium alloy

The mechanical and technological properties of magnesium alloys can be improved by heat treatment. Heat treatment of magnesium alloy generally adopts two methods, solid solution aging or annealing. In order to reduce the casting stress or quenching stress of the alloy, the annealing method is generally adopted, which is helpful to improve the dimensional stability of the work-piece. Only the alloy elements in the solid solubility change with temperature can heat treatment strengthen the role of the alloy (Phomsoupha, et al., 2015). The recent research results show that the solid solubility of alloying elements of most magnesium in magnesium alloys will change with temperature change, so most of magnesium alloy can be strengthened by heat treatment.
According to the type of alloying elements in magnesium alloy, in the magnesium alloy, there are 6 series that can be strengthened by heat treatment, namely Mg-Al-Mn (such as AM100A), Mg-Al-Zn (such as AZ63A, AZ81A, AZ91C and AZ92A), Mg-Zn-Ar (such as ZK51A and ZK61A) and Mg-RE-Zn-Zr (such as EZ33A and ZE41A), Mg-Ag-RE-Zr (such as QE22A) and Mg-Zn-Cu (such as ZC63A); in the wrought magnesium alloy, there are 3 series that can be strengthened by heat treatment, namely Mg-Al-Zn (such as AZ80A), Mg-Zn-Zr (ZK60A) and Mg-Zn-Cu (such as ZC71A) (Sun and Wang, 2014). Heat treatment hardening does not have obvious effect on all heat treatments of magnesium alloy, then can use annealing as the final heat treatment method, and thus strengthen the strengthening effect of heat treatment on magnesium alloy.
During the process of heat treatment, the alloy phase decomposition and the diffusion of the alloying elements are extremely slow, so the heat treatment process of the magnesium alloy has the following two characteristics:
(1) Solid solution aging treatment time is relatively long, which is the most important characteristics of the heat treatment of magnesium alloy.
(2) After the quenching, the magnesium alloy work-piece is usually cool in the natural environment, it also can help it cool with artificial manufacturing flow air. Generally, do not need to quickly cool the work-piece.

3. Experimental method

3.1Sample preparation

The nominal compositions of Mg-4Al-2Si alloy are Al 4.0 and Si 2.0, and the rest is Mg. Industrial specialized protection agent is used in alloy SG2-5-10 type well crucible furnace, to make ϕ50 mm * 120 mm ingot. The ingots are homogenized; the craft is to keep warm at 420 Deg. C for 12h. In the 3150kN hydraulic press, make use of special mold for reciprocating extrusion of the casting samples. The alloy material is carried out with 2 times, 4 times and 6 times of reciprocating extrusion (The materials, through the times of the core, are defined as the number of reciprocating extrusion), to prepare the extruded samples.

3.2 Heat treatment

Solid solution treatment and aging treatment are carried out for 6 times reciprocating extrusion samples.
(1) solid solution treatment (4 schemes): to keep warm at 420 DEG C for 4h, water-cooled; to keep warm at 420 DEG C for 8h, water-cooled; to keep warm at 420 DEG C for 12h, water-cooled; to keep warm at 420 DEG C for 16h, water-cooled (Suttner, 2016).
(2) solid solution + aging treatment (4 scheme): to keep warm at 420 DEG C for 12h, water-cooled +100 DEG, 2h; to keep warm at 420 DEG C for 12h, water-cooled +150 DEG for 2h; to keep warm at 420 DEG C for 12h, water-cooled +200 DEG C for 2h; to keep warm at 420 DEG C for 12h, water-cooled +250 DEG C for 2h.

3.3 Organization observation and performance test

Etching agent is 60mL ethanol, 20mL acetic acid, 19mL H_2O and 1mL HNO_3; micro-structure observation is carried out in Olympus optical microscope; phase analysis is carried out in XRD-7000S type X ray diffractometer; hardness testing is carried out in HV-120 Vivtorinox hardness; tensile test is carried out in the electronic universal tensile machine; fracture morphology is observed by JSM-6700F scanning electron microscope; TEM observation is carried out in Nissan JEM-3010 transmission electron microscope (Tian, et al., 2015).

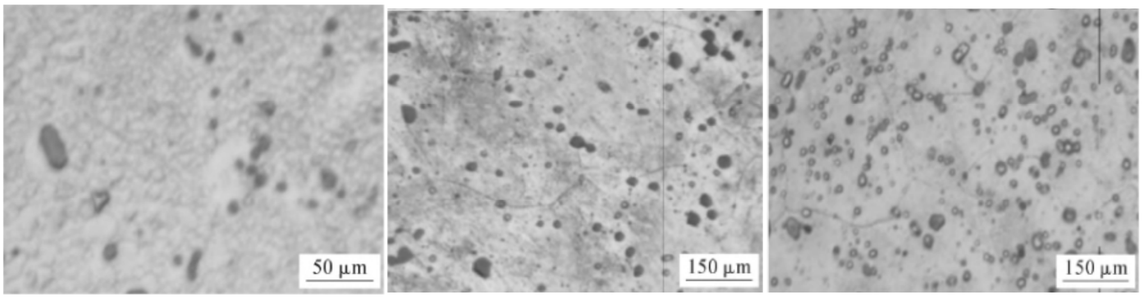
4. Experiment results and discussion

4.1 Micro-structure of heat treated alloy

Figure 1 shows the micro-structure of heat treated alloy after reciprocating extrusion. According to XRD analysis, it is known that the alloy structure of the solid solution treatment after reciprocating extrusion is composed of α(Mg) matrix, β(Mg17Al12) phase and Mg2Si phase. This suggests that in the 420 DEG heat insulation for 12h water-cooled solid solution treatment, the β(Mg17Al12) phase is only partially dissolved (Zhang, et al., 2015).

After solid solution treatment and solution treatment + aging treatment, the morphology and size of Mg2Si phase have no obvious change, which shows that Mg2Si phase has higher thermal stability, as shown in Figure 1 (a), (b), (c).

Reciprocating extrusion and solid solution treatment state after reciprocating extrusion, the grain size of the α(Mg) matrix is small, the size is not obviously different, and the grain size is coarse after the solid solution and aging treatment, as shown in Figure 1 (b), (c).



(a) 420℃×12h (b) 420℃×12h+100℃×2h (c) 420℃×12h+250℃×2h

Figure 1: The micro-structure of heat treatment state after Mg-4Al-2Si alloy reciprocating extrusion

4.2 Mechanical properties of extruded alloy after heat treatment

Figure 2 to Figure 6 show the relationship curves between the extruded aluminum alloy heat treatment and mechanical properties; by Figure 2 and Figure 3, it shows that the hardness of the alloy decreases by solid solution treatment and aging treatment, and when the solid solution is 420 DEG C * 12h, the hardness is the lowest, 58 HV; the hardness of the alloy also decreases by solid solution and aging treatment, and when the solid solution is 420 DEG C * 12h and aging is 250 DEG C * 2h, the hardness is the lowest, 57HV.

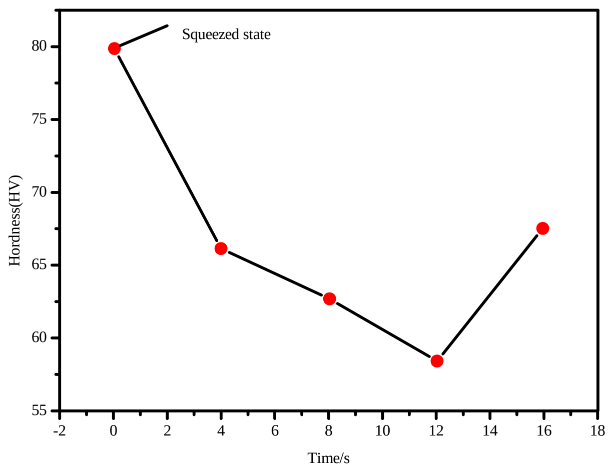


Figure 2: The effect of solid solution treatment time on alloy hardness

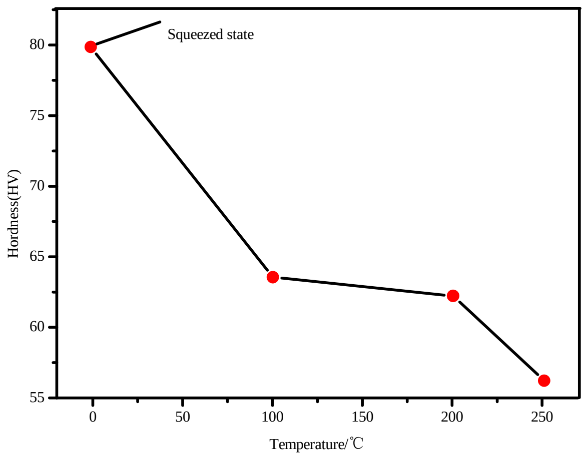


Figure 3: The impact of aging temperature on alloy hardness

From Figure 4, it is seen that, after 420 DEG C solution treatment, the tensile strength and yield strength of the alloy decrease, and the tensile strength and yield strength of the alloy decrease to 217MPa and 205MPa, respectively, when the keep warm for 16h. From Figure 5, it is seen that, the elongation of the alloy during the solid solution treatment of thermal insulation for 4h is the maximum, which is 28.6%; the elongation at 8h is the lowest, which is 13% (Wen and Ji, 2014). Figure 6 shows the relationship between aging temperature and alloy strength. Obviously, the tensile strength and yield strength of the alloy decrease at 420 DEG C * 12h and aging treatment. The tensile strength is lowest at 200 DEG C, which is 195MPa; the yield strength is the lowest at 100 DEG C, which is 205MPa.

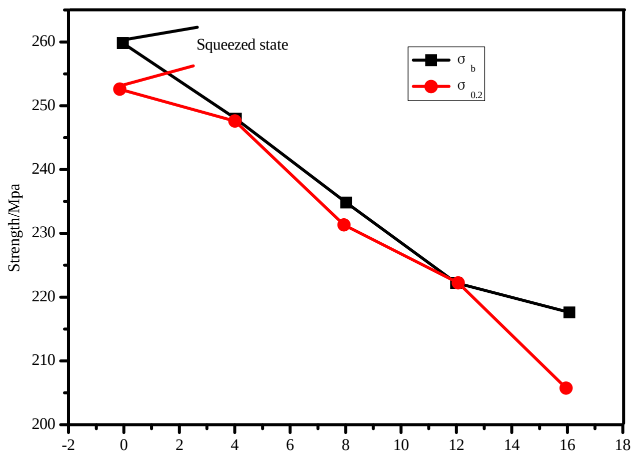


Figure 4: The influence of solution treatment time on alloy strength

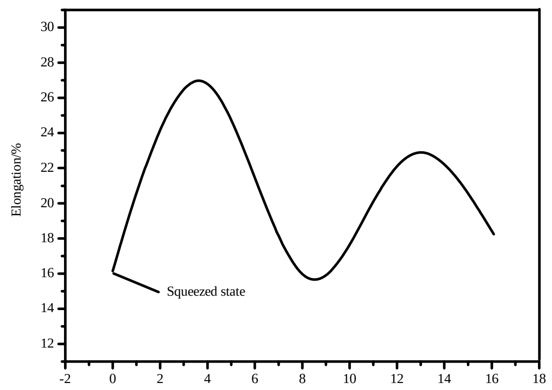


Figure 5: The effect of solid solution treatment time on the tensile strength

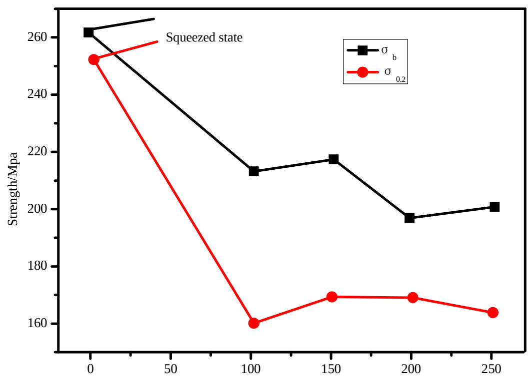


Figure 6: The impact of aging temperature on the alloy strength

In the Mg-Nd-Zr hot extrusion state alloy, there are a lot of dislocation sub-grains, and after the solid solution + aging treatment, the sub-grains disappear, replaced by a small amount of straight dislocation lines. It shows that the crystal grain has grown up after high temperature treatment. In the research in this paper, there is no obvious growth found in the grain after solution treatment, but the yield strength decreases from 260MPa to 205MPa after the solution treatment, which indicates that the grains also grow (Zhao, et al., 2015). This study shows that the grain size grows after aging treatment. Coarse grains have a serious impact on the mechanical properties of the materials. Because the effect of aging hardening is relatively weak, and the negative effect of coarse grain is more significant, the strength and plasticity of the alloy decrease.

5. Conclusion

(1) Solid solution treatment and solution treatment and aging treatment reduce the hardness of Mg-4Al-2Si alloy. Alloy after solution treatment, the tensile strength and yield strength decrease, and the elongation is the maximum; after solid solution and aging treatment, the crystal grain obviously grows; the tensile strength decreases, the yield strength decreases, and the elongation of the material decreases rapidly.
(2) The fracture form of the solid solution treated extruded alloy is ductile fracture, and the fracture form of the extruded alloy after solid solution and aging treatment is brittle fracture.

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