IOP Conf. Series: Materials Science and Engineering **735** (2020) 012010 doi:10.1088/1757-899X/735/1/012010

Effects of Magnesium-Calcium Alloys with Different Calcium Content on Their Mechanical Properties

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Abstract. Compared with traditional medical metal materials, magnesium alloys have the characteristics of small density, small elastic modulus and high specific stiffness. In order to study the effect of the addition of calcium on the mechanical properties of magnesium alloys, the tensile test and hardness test of magnesium-calcium alloy were carried out. The stress changes during the tensile test of magnesium alloy were discussed, and the microstructure of its section was further observed, so as to compare the effects of different calcium content on the mechanical properties of magnesium alloy. The results show that the addition of calcium content increases the hardness and tensile strength of the magnesium alloy, and it tends to rise first and then decrease.

1. Introduction

As we all know, magnesium is a very active metal, which has the advantages of high specific strength and low density, so it is widely used in transportation and aerospace fields[1-3]. At the same time, magnesium and magnesium alloys have excellent biodegradable properties, can be completely degraded in the human body, the elastic modulus and tissue for the human body is extremely close to, can effectively avoid stress shelter effect, promote bone tissue affected function reconstruction, so magnesium alloy as a new type of medical implant material has good application potential, and has been widely research [4-8] .However, magnesium, as a medical degradable metal material that can be implanted into the human body, is not only uncontrollable in corrosion rate, but also the key factor in the success or failure of surgery[9-10]. In this paper, vickers hardness test, quasi-static tensile test and mechanical analysis were carried out on Mg-Ca alloy with different calcium content, and then the tensile fracture was observed by SEM (Scanning Electron Microscope) to explore the influence of calcium content on the mechanical properties of Mg - Ca alloy.

2. Test Materials and Program

The selected materials are pure magnesium and magnesium calcium 15 as the intermediate alloy, and the as-cast alloy is formed after smelting in the electric resistance furnace according to the ratio. The extruded magnesium calcium alloy is formed after extrusion strengthening, and the alloy content obtained through smelting is MgCa0.8, MgCa1.2, MgCa1.6 and MgCa2.0. Its main components are shown in table 1.

Table 1. Smelting raw material ingredients(The mass fraction, %)

The raw materials	Mg	Ca	Fe	Cu	Mn	Ni	Si	Al	Zn
Pure magnesium	99.93	—	<0.01	<0.01	0.02	0.01	0.02	0.01	<0.01
Calcium magnesium 15	88.60	11.36	0.01	<0.01	0.01	<0.01	0.01	—	—

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Four kinds of magnesium alloys with different compositions were prepared by melting, heating, mixing and cooling. Due to its active chemical properties, magnesium is prone to oxidation and combustion in the smelting process. Therefore, protective gas must be introduced in the smelting process. CO_2+SF_6 is selected as the protective gas in the experiment.

2.1. Vickers Hardness Measurement

In order to study the effect of different calcium content on the mechanical properties of Mg-Ca alloy, four kinds of Mg-Ca alloy with different content were tested by quasi-static tensile test. Samples were taken from different alloys and tested on a digital microhardness tester after mosaic, grinding and polishing. The pressure applied during the test was 50N. Each sample was tested at 5 points under the same condition, and the average value was taken as the hardness of the sample.

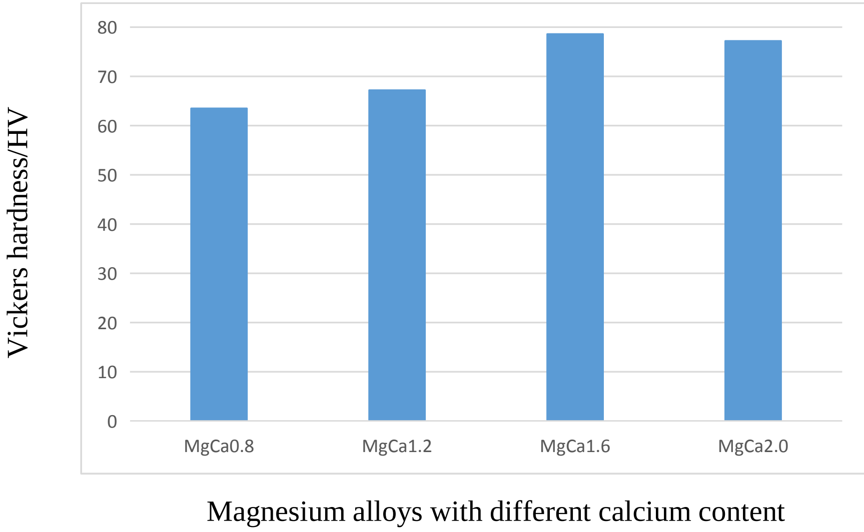

Figure 1. Effect of different calcium content on hardness of magnesium alloy

Figure 1. shows the effect of different calcium content on the hardness of magnesium alloys. The hardness of the alloy increases first and then decreases with the addition of calcium content. When the calcium content increases from 0.8% to 1.6%, the hardness of the alloy increases steadily. When the calcium content reaches 1.8%, the hardness of the alloy begins to decrease.

2.2. Quasi-Static Tensile Test

The bar material after extrusion is processed and the sample is obtained by wire cutting. Samples preparation and tensile test parameters were selected according to Chinese national standards (GB/ t228.1-2010). Compression test equipment is universal material testing machine (XYB305C), as shown in figure 1. In the compression test, the effect of the content of calcium on the mechanical properties of mg-ca alloy was mainly studied, and the tensile speed was 5 mm/min [11-12]. The sample size is shown in figure 2.

Figure 2. Universal material testing machine(XYB305C)

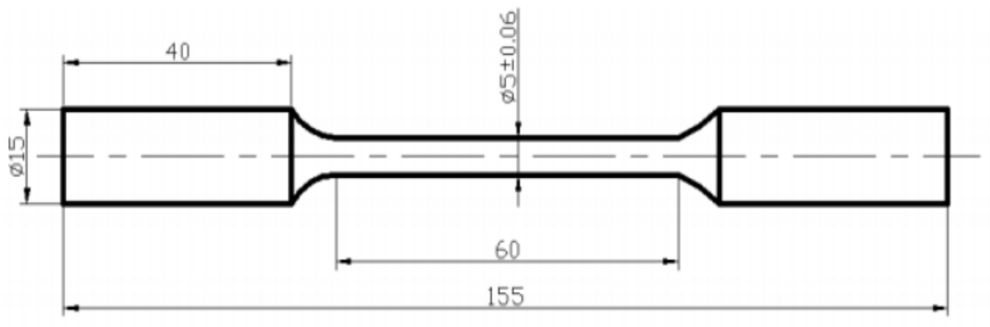

Figure 3. The sample size

The universal material testing machine was used to stretch the specimens to fracture successively, record the engineering stress and corresponding engineering strain, and draw the engineering stress-strain curve according to the original data, as shown in Figure 4.

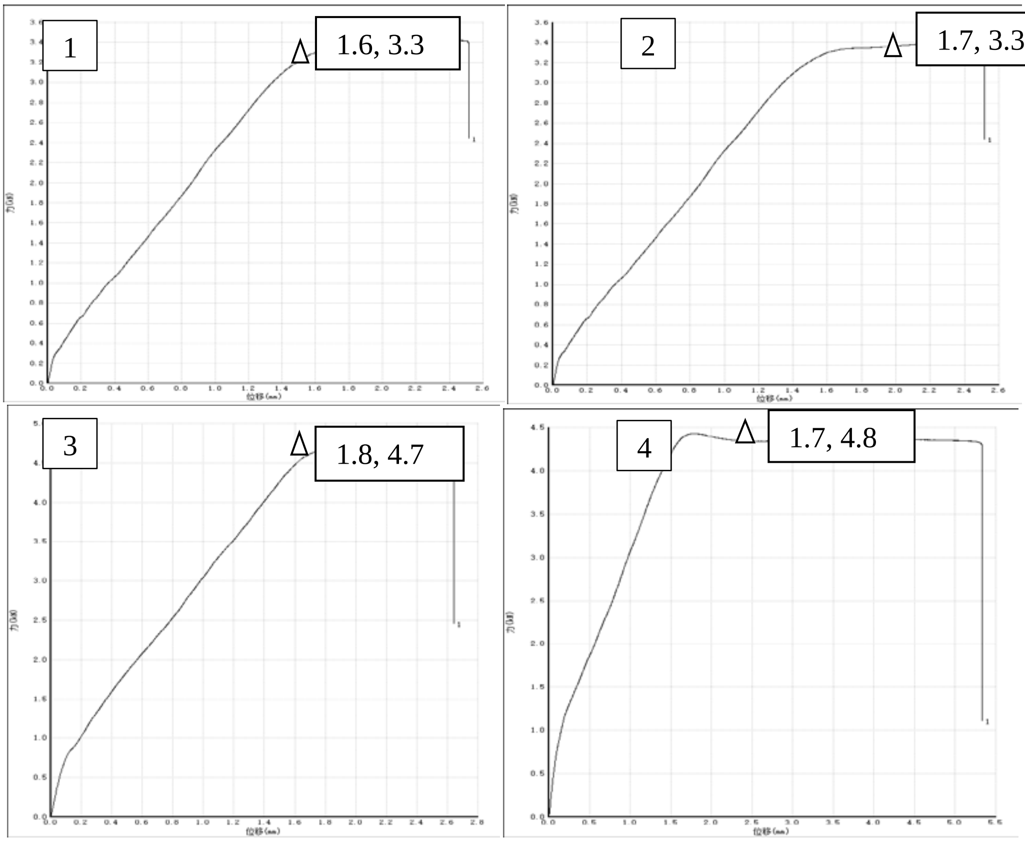

Figure 4. Stress - strain curve of magnesium - calcium alloy
(1. MgCa0.8 2. MgCa1.2. 3. MgCa1.6 4. MgCa2.0)

Quasi-static tensile test was carried out on magnesium-calcium alloy with different calcium content to obtain its stress-strain curve. During the tensile test, the tensile load on the sample gradually increased, and local plastic deformation occurred in the material, leading to the whole fracture of parallel parts [13]. It can be seen that as the calcium content increases, the force required to enter the yield state becomes greater and greater. This indicates that the addition of calcium content increases the tensile strength and mechanical properties of the alloy.

2.3. Fracture Morphology Observation

The fracture morphology of the sample was subjected to SEM analysis, the magnification is 2000, as shown in Figure 5.

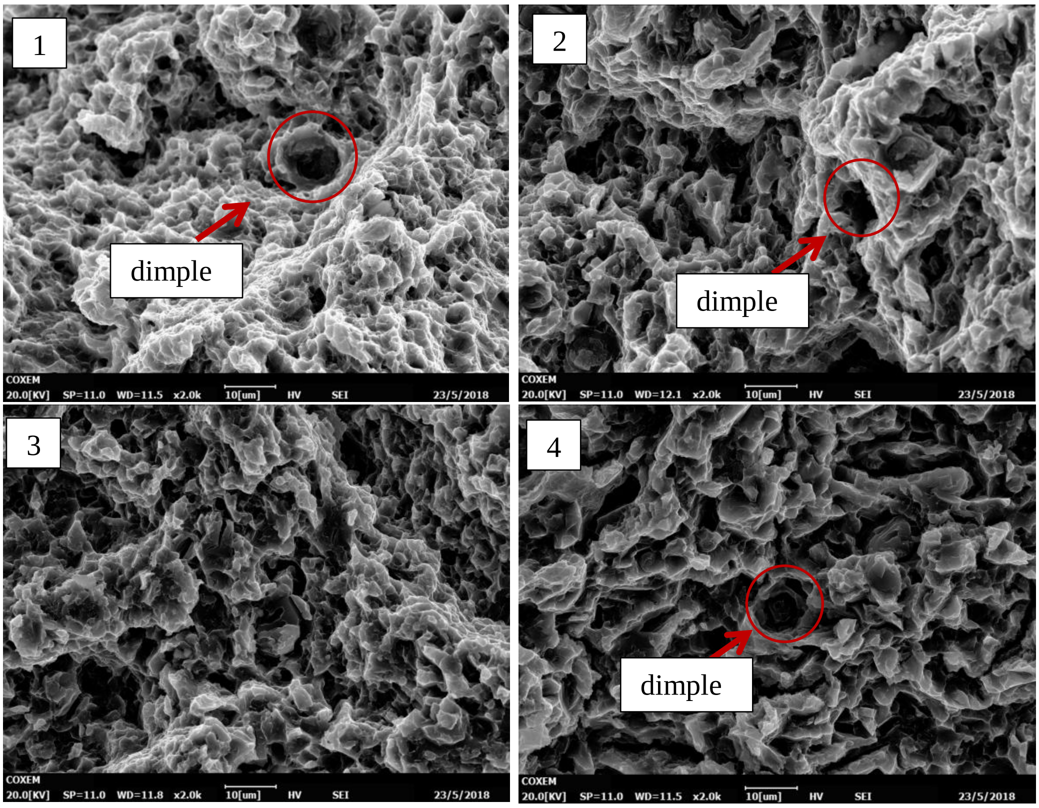

Figure 5. Magnesium-calcium alloy tensile fracture morphology
(1.MgCa0.8 2. MgCa1.2. 3. MgCa1.6 4. MgCa2.0)

As shown in figure 5 different calcium content of calcium magnesium alloys presented under SEM fracture morphology, it can be seen that the four different calcium magnesium alloys are different degrees of the toughening, belongs to ductile fracture. This is due to the dynamic recrystallization grain size and precipitation phase also experienced a greater degree of elaboration[14], so with the increase of calcium content, section presents the micro ball more and more dense, namely toughening nest is becoming more and more obvious. When calcium content reached 2%, the spread in the process of the precipitated phase within the grain of the snap is overall, there are a large number of globular carbide, alloy has the highest tensile strength.

3. Conclusions

(1)It can be seen from the stress-strain curve that the increase of calcium content in mg-ca alloy can enhance its tensile strength. And the SEM analysis was carried out on the cross section can be seen that the increase of calcium content makes crystal refining is apparent in the matrix, the existing studies have shown that grain refinement can effectively improve the corrosion resistance of the material and its tensile ability, thus to some extent, the calcium added to improve the mechanical performance of magnesium alloy has a positive effect.

(2)From the above experiments, calcium content in the range of 0.8% -- 2.0%, tensile test and hardness test results are consistent, are MgCa1.6 better results. However, whether MgCa1.6 is the magnesium calcium alloy with the best mechanical properties still needs to be further studied.

4. Acknowledgments

This study was supported by Shandong Provincial Natural Science Foundation (No. ZR2019QEE032) and Shandong key research and development program (No. 2017GGX30143)

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