

Effect of 300Hz/70V pulse current processing on properties of AZ31 magnesium alloy

Zunyu Guan^{1, a}

¹School of Engineering, Hong Kong University of Science and Technology, Hong Kong 999077, China.

^apuppy94315@163.com

Abstract. In this paper, the pulse current treatment on AZ31 magnesium alloy material is compared to the ordinary heat treatment of AZ31 magnesium alloy in terms of influence of the macro mechanical properties, through mechanical tensile test and microhardness measurement. By adjusting the electric pulse processing time, the different metallographic structures can be obtained, then we analyzed the differences between the two ways of dealing with the AZ31 magnesium alloy in terms of microstructure and mechanical property. The result shows that the pulse current processing on the optimization of AZ31 magnesium alloy mechanical properties better than conventional annealing heat treatment. Magnesium alloy specimen can acquire greater tensile strength and elongation after pulse current processing. What's more, static recrystallization caused by pulse current is more likely to happen compared to normal annealing heat treatment and it is easier to get more uniform fine grain through pulse current processing.

1. Introduction

Magnesium alloy has low density, and at the same time, has high specific strength and specific stiffness [1-3]. It also has high dimensional stability and good damping shock absorption. Mg alloys is known as "green engineering metal structure materials in the new century" because of these advantages. At present, the 3C production demand is increasing, besides, aerospace and automotive industries are experiencing a trend of lightweight, combined with current society's requirements of environmental protection, energy saving and emission reduction, magnesium alloy material is attached great importance because of its great performance [4,5].

In this paper, we choose AZ31 magnesium alloy material as the object of study. AZ31 magnesium alloy, as a superior lightweight metal structure material, shows low density, high specific strength and specific rigidity, and therefore is often used for manufacturing sheet, forgings among others.

What's more, AZ31 magnesium alloy presents excellent endothermic performance, and has common characteristics of the magnesium alloy family - excellent seismic performance, making it the ideal material for the manufacture of aircraft hub. According to relevant studies, large quantities of energy consumption of a car is related to its self-weight, and reducing the weight of the car can improve fuel efficiency, which is beneficial to carbon dioxide emissions reduction, and essential for achieving energy-saving, emission reduction and environmental protection at large. Therefore, reducing the weight of a car has great impact on environment and energy, and becomes an inevitable requirement and trend.

AZ31 magnesium alloy is widely used in the automotive industry such as the clutch housing, valve deck, cylinder head of gearbox casing and so on. In order to achieve lightweight and cushion the impact of crash after the car collision, AZ31 magnesium alloy can be sometimes used in the steering wheel, seat, steering and brakes as well. In addition, as AZ31 magnesium alloy is very stable and not easy to



produce adverse reactions in gasoline, kerosene and lubricants, it is suitable for the manufacture of engine gear casing, oil pump and tubing; and thanks to generating small inertia force in the rotation and reciprocating motion, it is often used as arm, hammock and rudder surface and other moving parts. [6-8]

Magnesium alloy material not only has a wide range of applications in the general production areas, but also plays an important role in the military industry. Civil aircraft and military aircraft, especially bombers see the widespread use of magnesium alloy products [9]. Boeing aircraft and many helicopter transmissions also use magnesium alloy material. In addition, the magnesium alloy also has a good biocompatibility, which means magnesium-based materials implanted in the human body can automatically degrade in a period of time and will not cause harm to the human body; as there is no need for additional surgery, the treatment is greatly facilitated, so it has been applied in clinical medicine [10].

Due to the advantages of AZ31 magnesium alloy mentioned above and its wide application in the field of production, it is getting more important to explore the method of strengthening magnesium alloy in industry. At present, the traditional heat treatment is the main method of processing such materials, but because of its operational complexity and inefficiency and many other shortcomings, this paper will try to take AZ31 magnesium alloy as a sample to study whether the pulse current processing can achieve the same or even better enhancement effect.

2. Experiment

2.1 Processing AZ31 Magnesium Alloy Specimen

AZ31 magnesium alloy sheet is machined by HF320D industrial wire cutting machine. The machined blanks are subjected to a simple surface grinding by 400 mesh sandpaper, until the specimen surface becomes bright and clean.

2.2 Pulse Current Treatment of AZ31 Magnesium Alloy Specimen

In this experiment, the pulse current treatment of the AZ31 magnesium alloy specimen is performed on a pulse current generator connected to an oscilloscope and a computer. Pulse current frequency is 300Hz, pulse width 88.32us, root-mean-square voltage 336mV. The time of pulse current treatment for each group of specimens is 10s, 20s, 30s, 40s, 50s, and 60s. Each group consists of two specimens, and is labeled respectively.

2.3 Annealing Heat Treatment of AZ31 Magnesium Alloy Specimen

In the experiment, the box-type resistance furnace is selected as annealing treatment equipment for the second group of AZ31 magnesium alloy specimen. According to the results obtained by the pulse current treatment, holding temperatures are 200 °C, 250 °C, 300 °C, 350 °C, 400 °C and 450 °C respectively, and the holding time is 30 minutes. Two specimens are subjected to heat treatment in each set of experiments. In the first set of experiments, the resistance furnace is set to make room temperature rise to 200 °C in 20 minutes, and then into the insulation phase. In each of the later experiments, the resistance furnace is set automatically into stage of heating the specimen, then automatically into thermal insulation. After heat treatments of all the specimens are completed, reserve them for follow-up experiments. Same as pulse current treatment group, two test pieces are kept at each temperature section, and marked respectively.

2.4 Microhardness Test of AZ31 Magnesium Alloy Inserts

The instrument used to measure the microhardness is the MHV-100Z digital micro-Vickers hardness tester. In the test, the microhardness of five points at each specimen is measured, and after the unreasonable data are excluded, the average value is taken as the microhardness value of the temperature specimen under the treatment method. After the corrosion of the polished samples is completed, specimens are subjected to metallographic experiments using an AxioCam ERc 5s metallographic microscope.

2.5 Mechanical Tensile Test of AZ31 Magnesium Alloy

Computer software can be used to adjust various parameters of the stretcher in the tensile test. The stretcher has an operation panel in which the upward and downward buttons can move up or down its upper and lower jigs; and the spin button and the stop button are used to remove the impact of the residual pretension.

3. Results and discussion

3.1 The Relationship between Pulse Current Parameters and the Power-on Time as well as the Temperature

Pulse current parameters employed in the experiment are shown in the following table:

Table 1. Table of Current Pulse Parameters

Current parameter	Voltage	Frequency	PW	Peak voltage	RMSV
300Hz/70V	70V	300Hz	88.32us	3.2-3.36V	336mV

The relationship between the pulse current treatment's time and temperature is shown in Figure 1. It can be seen that as the time increases, the sample rapidly warms up to 450°C or so within 15-20s and thereafter the temperature remains constant.

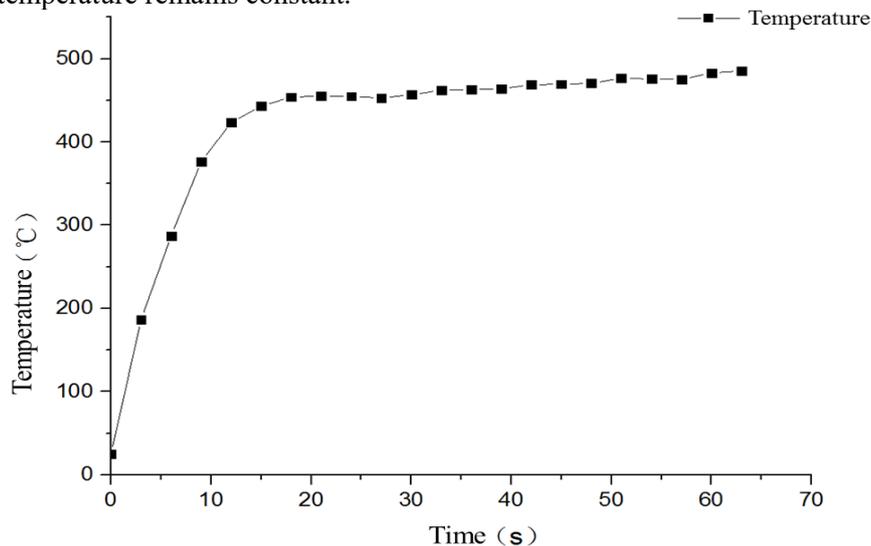


Figure 1. The Relationship between Pulse Current Treatment's Time and Temperature

After the pulse current treatment, the sample's temperature maintains at a maximum of 450 °C or so, same with the sample's highest temperature by conventional heat treatment, so the 450 °C sample by conventional heat treatment and the sample by pulse current treatment should be selected and compared in the metallographic observation.

3.2 The Analysis of Mechanical Property, Microhardness and Microstructure

After the tensile test, data are stored in the computer as the loading force and micro-displacement. Force P and displacement s are converted into engineering stress and engineering strain on the basis of $\sigma = P/A$ (A is the gauge cross-sectional area), $A = 6 \times 0.8 = 4.8$ and $\epsilon = s/h$ (h is the gauge length), $h = 10$.

For magnesium alloy samples by the pulse current treatment, data from six sample groups are drawn in relationship curves as engineering stress-engineering strain, as shown in Figure 2. Similarly, for magnesium alloy samples by conventional heat treatment, all data are drawn in graphic curves, as shown in Figure 3.

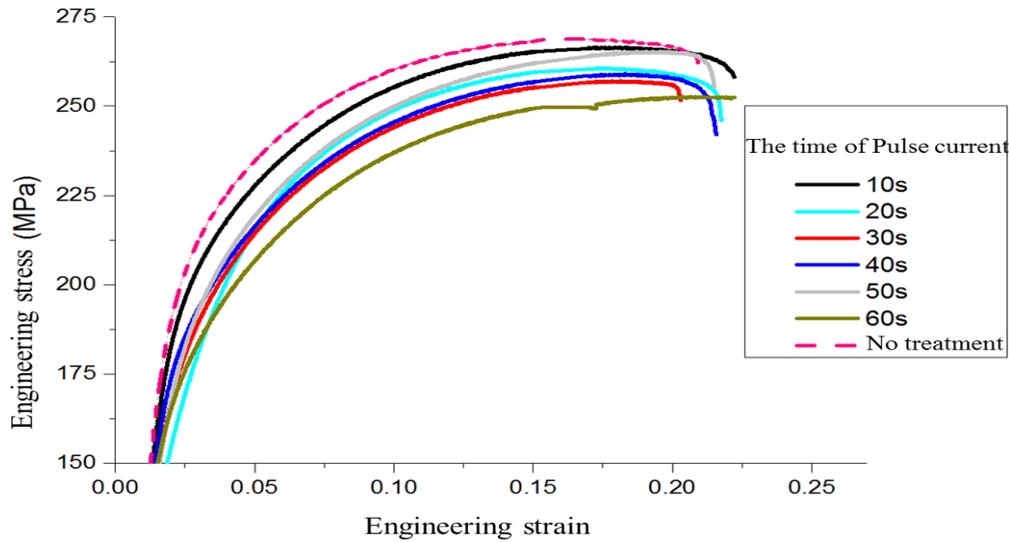


Figure 2 .Stress - strain Relationship of Samples by Pulse Current Treatment

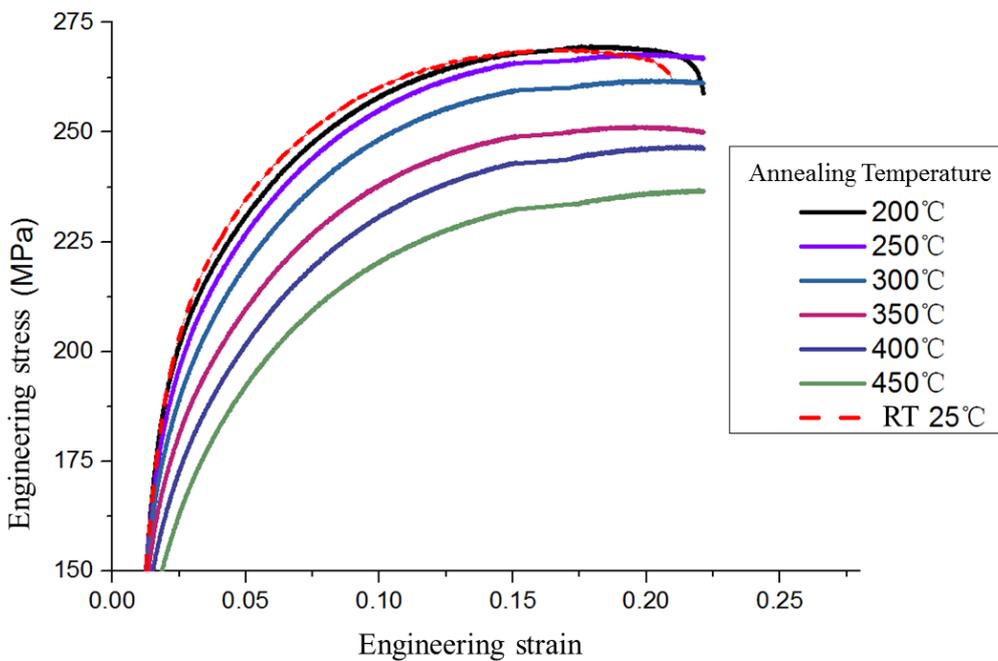


Figure 3. Stress - strain Relationship of Samples by Conventional Heat Treatment

Based on the separate observation of two figures, it can be seen that as the treatment time increases, the elongation of AZ31 magnesium alloy samples by pulsed current treatment has no obvious change, but the tensile strength decreases slightly. As the temperature goes up, the elongation of samples by conventional heat treatment has no significant change, but the tensile strength gradually reduces.

Figure 4 is a curve graph showing the change of the microhardness of samples by pulse current treatment with temperature increment.

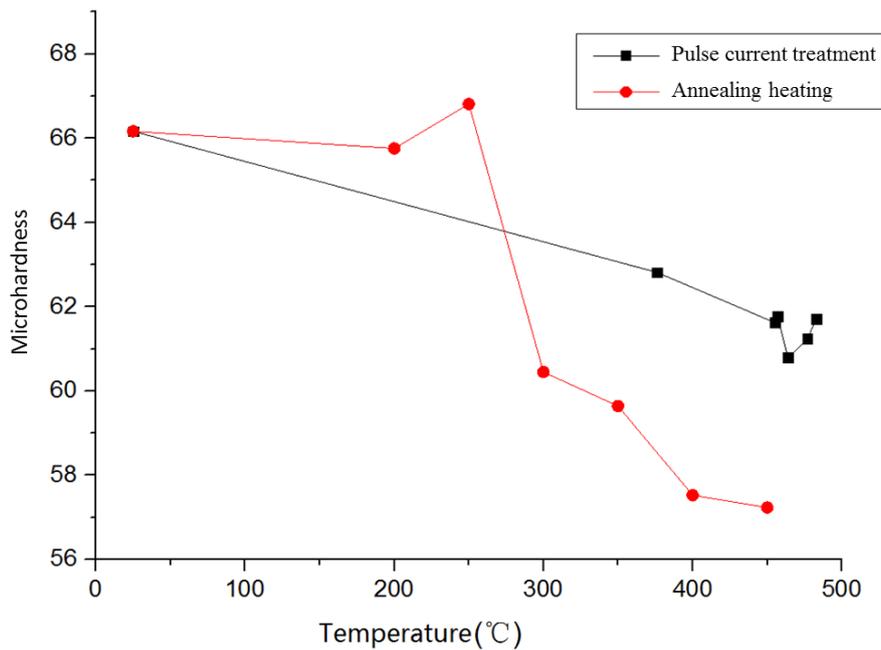


Figure 4. Microhardness-temperature of Samples

It can be clearly found from the figure 4 that for samples by the pulse current treatment, as the temperature rises, the microhardness of samples shows a slow decreasing trend, but the change is not obvious. However, for samples by conventional heat treatment, the microhardness is almost constant below around 240°C, and then decreases as the temperature exceeds 240°C. The minimum hardness measured of samples by the pulse current treatment appears at 50s, and the temperature of samples remains at 450 °C or so after the treatment, so we choose to observe the microstructures of samples representing first group data and samples representing the fifth group data, meanwhile, comparing microstructures of samples by 200°C and 450°C conventional heat treatment as well as control samples at normal temperature without any treatment.

The photographic images of crystal structure of samples photographed by a metallographic microscope in each group are shown in Figure 5 and Figure 6.

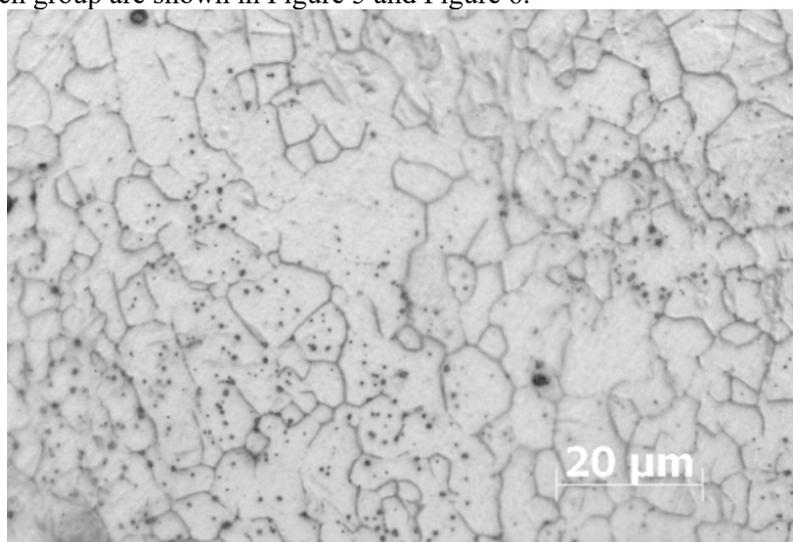


Figure 5. Control Samples at Normal Temperature without any Treatment

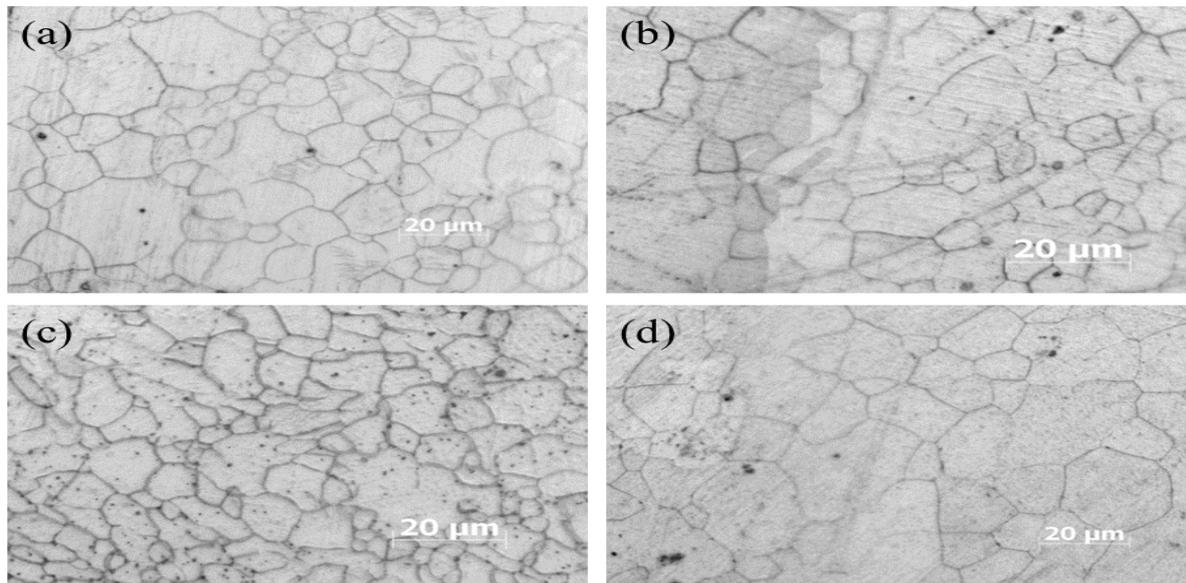


Figure 6 .Microstructures of Samples by Pulse Current Treatment (a) 10s, (b) 50s, microstructures of Samples by Conventional Annealing Heat Treatment (c) 200°C, (d) 450°C

According to the observation of microstructures of samples in each group and comparison of grain sizes, arrangement structures, etc., it can be found that compared with samples without any treatment, magnesium alloy grains are loose and uneven with different sizes, overall poor microstructures presenting in samples without any treatment. However, grains of samples by pulse current treatment or conventional heat treatment have significant microstructure homogenization, and it can be seen that both treatments can make AZ31 magnesium alloy recrystallize. Microstructures of samples by the pulse current treatment have no significant change as time increases, but the recrystallization of magnesium alloy happens within 60s. The results show that the pulse current treatment can accelerate the recrystallization of magnesium alloy. In the samples by conventional heat treatment, as the temperature rise, grain structures are more uniform, and grains significantly grow at high temperature.

4. Conclusion

Based on microhardness measurement, room temperature tensile test and metallographic observation, the paper compares different effect of the pulse current treatment and conventional annealing heat treatment on strengthening AZ31 magnesium alloy, studies the evolution of microstructures and the changing rule of mechanical properties of materials during the treatment, and gets the conclusion consistent with the experimental expectation. Specific conclusions can be summarized as the following:

(1) As time increases, microhardness of samples by pulse current treatment slightly decreases with no big change, while microhardness of samples by the conventional heat treatment changes slightly below 240 °C, and then presents a downward trend over 240 °C.

(2) As temperature rises, the elongation of samples by the pulse current treatment has no obvious change, but the tensile strength decreases slightly; while the elongation of samples by conventional heat.

(3) Both the pulse current treatment and the conventional heat treatment can make the magnesium alloy material recrystallize, but compared to the latter, the former can faster promote the occurrence of recrystallization.

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