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EFFECT OF ANNEALING TEMPERATURE ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 5052 ALUMINUM ALLOY PIPE FITTINGS ALPINE SKIING STICKS

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The continuous annealing treatment of 5052 aluminum alloy pipe fittings for alpine skiing sticks was carried out in the temperature range of 300-500 °C by means of metallographic observation and mechanical property test. The results show that with the increase of annealing temperature, the strength and hardness of the samples decrease continuously, and the impact value, section shrinkage and elongation change significantly. The experimental results provide a technical reference for preventing the fracture of alpine skiing sticks during use.

Keywords: 5052 aluminium alloy, ski, annealing temperature, microstructure, mechanical properties

INTRODUCTION

Alpine ski rod is mainly made of 5052 aluminum alloy, and 5052 aluminum alloy belongs to Al-Mg alloy, which is widely used. Especially in metallurgical industry, it is one of the most promising alloys. It has good corrosion resistance, excellent weldability, good cold workability and medium strength [1]. The main alloying element of 5052 aluminum alloy is magnesium, which has good formability, corrosion resistance, weldability, and medium strength. It is used to manufacture aircraft fuel tanks, tubing, and sheet metal parts for transportation vehicles and ships. Instruments, street lamp brackets and rivets, hardware products, electrical enclosures, alpine skiing stick, etc. [2]. At present, the research on 5052 aluminum alloy is mostly focused on the microstructure and properties of cold rolled sheet. In order to make it have better mechanical properties and prevent accidental damage in use, it is necessary to analyze the annealing temperature reasonably to explore more potential and lay the foundation for practical application. Therefore, this paper intends to take 5052 aluminum alloy as the experimental object, carry out a series of annealing temperature tests on it, use mechanical performance tests and other methods to determine the temperature points at which brittle transformation is easy to occur, and give its basic mechanical properties at each temperature point.

MATERIALS AND METHODS

The homogenized 5052 aluminum alloy ingot was used as the raw material. Its chemical composition (mass fraction): Si ≤0,25 %, Cu ≤0,10 %, Mg 2,20-2,28 %, Zn ≤0,10 %, Mn ≤0,10 %, Cr 0,15-0,35 %, Fe ≤0,40 %, Al remainder. The aluminum alloy sheet was kept at 580-640 °C for 20 h, oil quenched and ensured that the quenching hardness was above 75 HRC, and then annealed in an electric furnace for 5 h. The annealing temperatures were 300 °C, 400 °C, and 500 °C, respectively. The size of the ingot sample is 300 mm × 200 mm × 50 mm, and then it is rolled into an aluminum alloy plate of about 4 mm. Five samples were selected from each group and their arithmetic averages were taken. Using 10 % HF + 90 % water, 5 g fluoroboric acid + 200 mL water as the coating solution, the voltage was 30 V, the current density was 0,1-0,2 A / cm^2, and the coating time was 2 min. After cleaning, it was blown dry, and finally the grain morphology of the sample was observed under the Olympus positive metallographic microscope.

EXPERIMENTAL RESULTS AND DISCUSSION

The microstructure of 5052 aluminum alloy without annealing is shown in Figure 1.

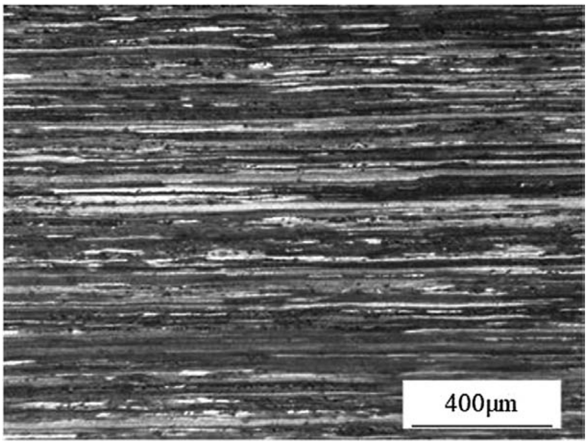

Figure 1 Microstructure of unannealed 5052 aluminum alloy

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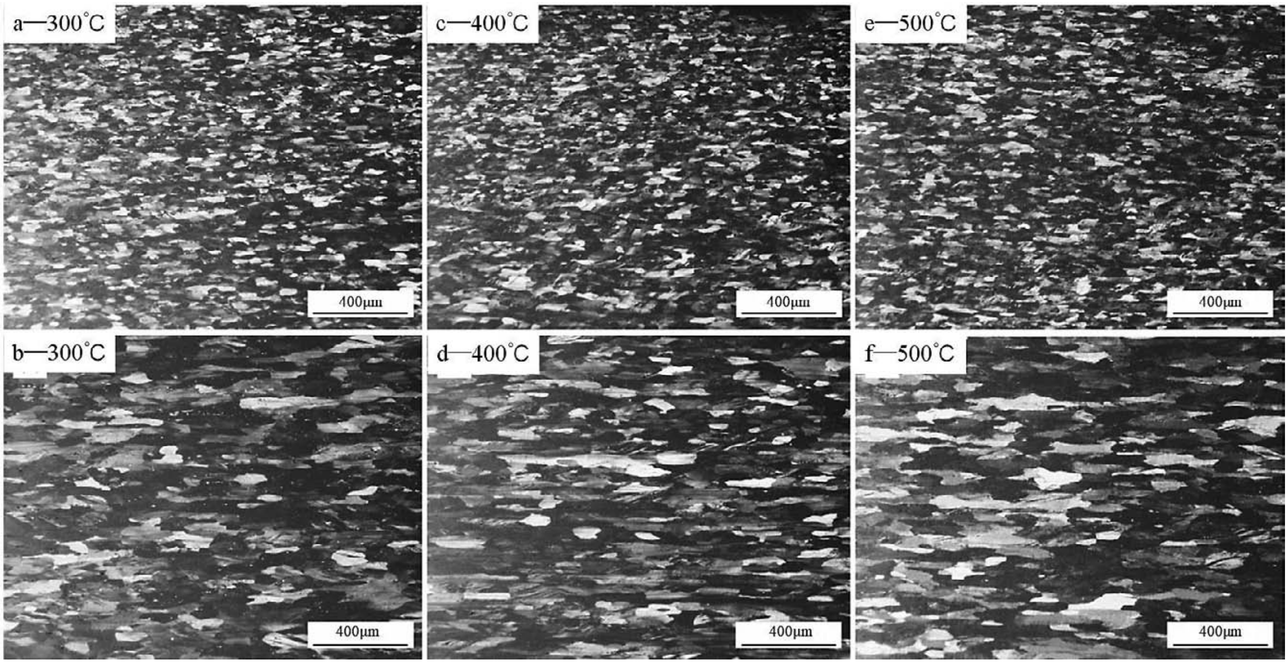

Figure 2 Microstructure of 5052 aluminum alloy at different annealing temperatures

The microstructures of the test alloy sheets at different temperatures were observed respectively. The polarized microstructures of the surface layer and the central layer in the thickness direction are shown in Figure 2. It can be seen that the surface structure of the sample at 300 °C has been recrystallized. The alloy structure is approximately equiaxed and the grain size is uniform. The measured average grain sizes are 58,13 μm, 62,34 μm and 63,67 μm, respectively. It can be seen that with the increase of annealing temperature, the surface grain structure grows slightly and the alloy recrystallizes fully. However, the central layer structure of the plate only undergoes a recovery process, and the internal structure is still a large number of deformed fibrous structures (subgrains). With the increase of temperature, the fiber structure becomes thicker and the segmentation is more obvious. The grain structure of the central layer of the thickness of the alloy sheet rolled at different temperatures is significantly different from that of the surface layer. The grains of the central layer of the plate have obvious fibrous structure characteristics, while the surface layer structure is basically completely recrystallized. From the central layer to the surface layer of the plate, the internal structure gradually changes from fibrous to recrystallized structure [3]. During the hot rolling process of thick alloy plate, due to the uneven deformation, the deformation near the surface of the plate is large, the deformation energy storage is high, and the driving force of recrystallization is large. At the same temperature, the driving force required for the recrystallization of the surface structure of the plate is small, the dynamic recrystallization is sufficient and the recrystallized grain size is small. However, due to the small energy storage of rolling deformation and the small driving force of recrystallization, most of the grains in the central layer still have the characteristics of fibrous structure [4]. As the rolling temperature of the plate increases from 300 °C to 400 °C, the driving force required for the recrystallization of the central layer of the plate increases, the recovery and recrystallization are sufficient, the degree of polygonization of the internal structure and the merging of subgrains increases, and the characteristics of the fibrous structure gradually weaken, which also reduces the strength of the plate and increases the plasticity [5]. Since the rolling temperature of the alloy sheet is lower than the recrystallization temperature, it is not conducive to the subsequent cold processing process to obtain a more uniform structure. Therefore, the annealing temperature of 5052 aluminum alloy should be as high as possible, and it is recommended not to be lower than 400 °C.

During the annealing process, both the annealing time and temperature affect the properties of the material. In general, the best ratio can be obtained by controlling the parameters. The change of mechanical properties of 5052 aluminum alloy at different annealing temperatures is shown in Table 1. In general, with the increase of annealing temperature, the tensile strength, yield strength and hardness of 5052 aluminum alloy decrease significantly, and the elongation increases gradually. When annealed at 300-400 °C, the yield strength and tensile strength of the sheet decreased slightly, the hardness decreased significantly, and the elongation increased gradually. When annealed at 400-500 °C, the yield strength, tensile strength and hardness of the sheet are slightly lower than before, and the elongation continues to rise.

As shown in Figure 2, after annealing at 300 °C and 400 °C, the fiber structure is still retained inside the plate, and no recrystallization is found. When the annealing temperature rises above 400 °C, the recrystallization trend of 5052 aluminum alloy appears, and recrystallization begins to occur in some areas of the matrix, forming fine recrystallized grains. After annealing at this temperature for 1h, the obvious recrystallization phenomenon can be observed in the plate, and the recrystallization is basically completed.

Table 1 **Mechanical properties of 5052 aluminum alloy at different annealing temperatures**

Number	annealing temperature	yield strength	tensile strength	hardness	elongation
1	300	139,1	206,9	76,0	20,1
2	400	127,9	197,1	72,9	21,0
3	500	119,8	190,1	71,0	22,6

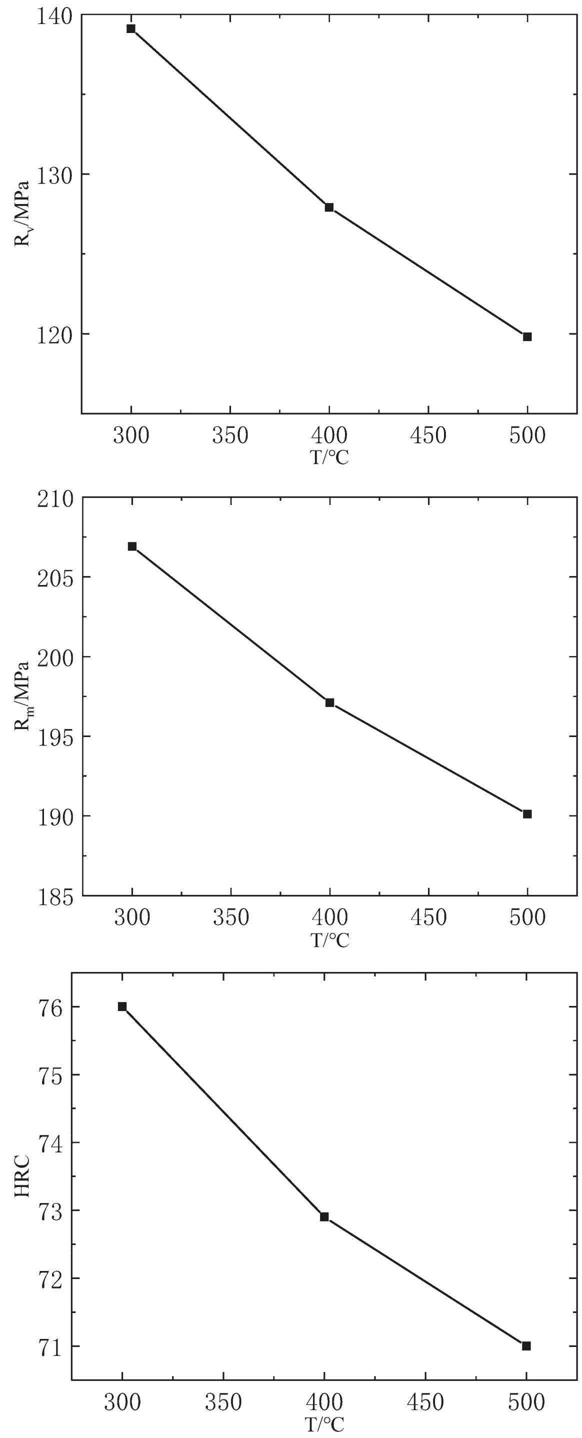

Figure 3 Effect of annealing temperature on properties of 5052 aluminum alloy

According to the curve of mechanical properties obtained from the data in Table 1, as shown in Figure 3, it is automatically generated by Origin data processing software. The basic law is that the yield strength, tensile strength and hardness curves of 5052 aluminum alloy show a uniform downward trend during annealing.

Figure 4 shows the relationship between annealing temperature and torsional strength. The basic law is that the torsional strength curve of 5052 aluminum alloy decreases uniformly during annealing. By comparing with the yield strength curve in Figure 3, it can be seen that their yield ratio is slightly larger, which is calculated to be 0,63-0,68. The strength decreases from 800 MPa at 300 °C to about 150 MPa at 500 °C, and the curve is concave.

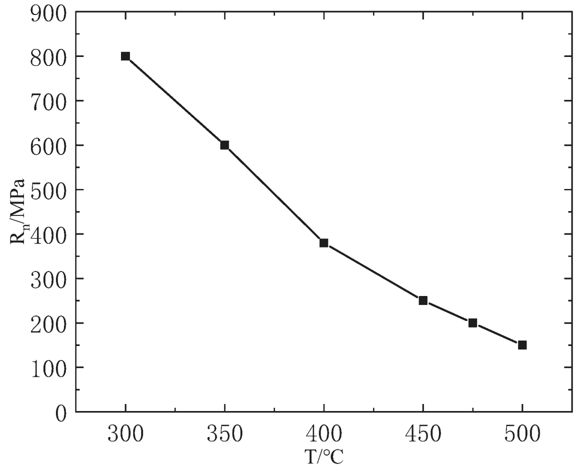

Figure 4 Effect of annealing temperature on torsional strength

Figure 5 shows the relationship between annealing temperature and impact toughness. The basic law is, during the annealing process of 5052 aluminum alloy, the impact toughness increases with the increase of annealing temperature, which conforms to the general law of annealing. However, at 475 °C, the impact brittleness value is only about 20 J, which is much lower than 36 J at 400 °C, indicating that annealing brittleness occurs at this temperature. Considering the jump of strength value, this is more obvious.

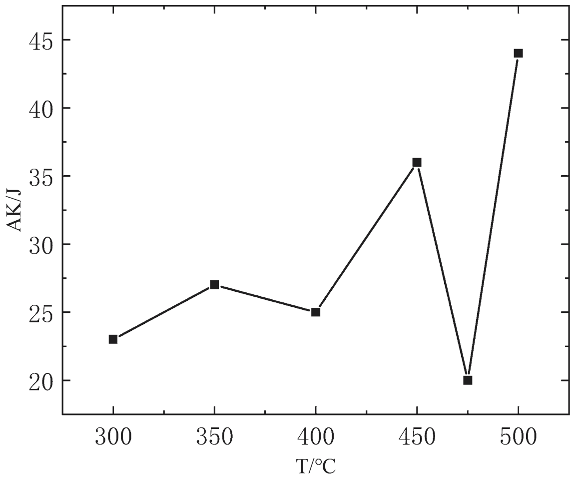

Figure 5 Effect of annealing temperature on impact toughness

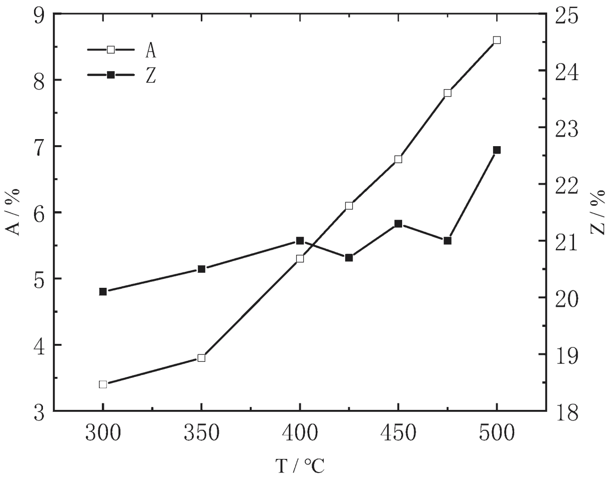

Figure 6 Effect of annealing temperature on reduction of area(A) and elongation(Z)

Figure 6 is the effect of annealing temperature on the reduction of area and elongation. It can be seen that with the increase of annealing temperature, the two parameter values gradually increase, although there is some fluctuation, but the range is not large. However, at 400 °C, the reduction of area is about 5,5 % and the elongation is 21 %. Compared with the adjacent data, the value decreases, but the change of the reduction of area is more obvious. Considering the data reflected in Figure 4, it corresponds to the index of impact toughness, that is, the toughness decreases, the reduction of area and the elongation decrease.

From the results of this experiment, it can be seen that the impact toughness of annealing does not increase monotonously with the increase of annealing temperature, and annealing brittleness occurs at 475 °C. The reason may be that at high temperature, the grain growth rate will be accelerated, and the number of grain boundaries will be reduced, so that the resistance of grain boundaries to plastic deformation will be reduced, and the processing performance of metals will become better. However, when the temperature is too high or the high temperature treatment process is too long, the grains will grow too fast, which will penetrate different grains, resulting in a decrease in the strength of the grains, and the connectivity between the grains is enhanced, which easily leads to the occurrence of high temperature annealing brittleness. Therefore, it may be that 5052 aluminum alloy conforms to the above reasons at 475 °C, which makes the hardness increase slightly and the toughness decrease.

The annealing brittleness mechanism of 5052 aluminum alloy needs further experimental research to clarify the internal mechanism of its formation. It should be noted that in the actual use process, because the plate is generally very thin, and the plate is required to have high stiffness and impact, therefore, low temperature annealing should be carried out as far as possible under the premise of satisfying the use. Considering the results of this experiment, annealing at about 500 °C should be avoided.

CONCLUSION

With the increase of annealing temperature, the surface layer of 5052 aluminum alloy sheet has undergone obvious recrystallization, while the central layer structure only undergoes a recovery process. With the increase of annealing temperature, the strength and hardness of the plate decrease, and the elongation increases. At the same time, the plasticity and toughness of the sheet are improved, and the annealing brittleness occurs at 475 °C, which is between the commonly considered high temperature annealing brittleness. Therefore, the analysis of the microstructure and properties of 5052 aluminum alloy has a preventive effect on the fracture of alpine skiing sticks during use.

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Note: The responsible translator for English language is B.W. Ning - Harbin Sport University, China.