Microstructure and Properties of Welded Joint of 6063 Aluminum Alloy Medium and Thick Plate

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Abstract. In this paper, the welding parts of the 6063 aluminum alloy 15mm and 20mm plate on the solar wing expansion frame of a certain type of satellite are studied. The structure of the welding structure is analyzed and tested. The relationship between the distribution characteristics of the joint and the mechanical properties of the weld and the influence law of the weld are analyzed, and the welding process is rationally formulated in the actual production. Provide theoretical basis and technical support for improving welding quality. The two thickness aluminum plates are formed by MIG welding. The metallographic samples and tensile specimens are intercepted from the welded parts, and the metallographic samples are prepared. The microstructure and tensile strength and hardness of the welded joints are analyzed by metallographic microscope, scanning electron microscope, X ray diffractometer, tensile test machine and microhardness tester. Degree. The results show that there is a softening zone in the welded joint, which mainly exists in the heat affected zone; at the same time, there will be a high hardness point (15mm 84.6HV; 20mm 70HV) in the fusion zone, which is due to the presence of more strengthening phase Mg2Si and a small amount of Al12Mg17. The average tensile strength of the welded joint with two thickness is 166MPa and 218MPa respectively, and the thickness of 15mm is lower than the tensile strength of 6063 aluminum alloy, while the 20mm thickness is higher than the theoretical tensile strength of 6063 aluminum alloy, and the elongation is higher than that of the 6063 aluminum alloy theory, in which the joint of 15mm thick welded joint is pulled from the 15mm at the weld seam. Extension fracture, 20mm thick welded joint tensile fracture at the weld.

1. Introduction
With the rapid development of Aeronautics and Astronautics, many experts and scholars have studied the properties of the welded joint of 6063 aluminum alloy, the study of welding joint performance and
the improvement measures, as well as the deformation and damage behavior of the welded joint, and got some very meaningful results.

However, the connection and interaction between the welded joints of 6063 aluminum alloy and its mechanical properties have not been well summarized, such as the distribution, content and Si phase of the enhanced phase Mg2Si, and the influence of other relative welding joint properties.

In this paper, the microstructure and properties of the welded joint of 6063 aluminum alloy plate are mainly studied. The tensile, hardness, composition and phase analysis of the 15mm angle joint, the butt joint and the 20mm butt joint are carried out, and the microstructure, the hardness distribution, the tensile strength and the matrix microhardness are analyzed and compared. The relationship and interaction between the microstructure and mechanical properties of welded joints are obtained, so as to achieve the goal of optimizing alloy properties.

2. Experimental materials and methods

2.1. Welding characteristics of aluminum alloy

Aluminum alloy started industrial production in early Twentieth Century, but the manufacture of aluminum alloy by welding started in the middle of Twentieth Century. With the application and development of aluminum alloys, the welding technology of aluminum and aluminum alloys has been progressed, thus speeding up the pace of aluminum alloy replacing other materials.

Aluminum alloy has the advantages of light mass, non-magnetic, high specific strength, corrosion resistance, easy forming, and good thermal stability, recyclable and simple structure. It is very ideal for the application of various welding structures and products. However, due to the unique physical and chemical properties of aluminum alloys, it is difficult to weld aluminum alloys.

2.2. Chemical composition of 6063 aluminum alloy

In the aluminum alloy, the silicon element can reduce the thermal expansion coefficient of the aluminum alloy, improve the wear resistance, heat resistance and corrosion resistance of the aluminum alloy, and can also make the aluminum alloy have a better dimensional stability. Mg will strengthen the alloy through the precipitation of Mg2Si in the aluminum matrix. The excess silicon exists in the alloy in the form of silicon and further strengthens the aluminum alloy. The alloy also contains trace elements such as manganese and titanium to further improve the comprehensive properties of aluminum alloy. The ingredients are shown in Table 1.

| Chemical element | Si | Fe  | Mg  | Ti | Cu | Mn | Zn | Cr | Al |
|------------------|----|-----|-----|----|----|----|----|----|----|
| Content /%       | 0.20-0.60 | 0.35 | 0.45-0.50 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | Allowance |

2.3. Properties of 6063 aluminum alloy

Its main alloy elements are magnesium and silicon, with excellent machinability, excellent weldability, extrude and electroplating, good corrosion resistance, and stable anodization.

6063 aluminum alloy profiles are widely used in mobile phones, notebook computers, building profiles, vehicles, lifts and so on, with their good plasticity, moderate heat treatment strength, good welding performance and color diversity after anodic oxidation treatment. The mechanical properties at room temperature are shown in Table 2.

| Texture of material | σb/MPa | Tensile property | δ0.2/MPa | δ/% | Brinell hardness HBS10/500 | Fatigue strength /MPa |
|---------------------|--------|------------------|----------|-----|---------------------------|-----------------------|
| 6063-T5             | 185    | 145              | 12       | 60  | 70                         |                       |
2.4. Experimental analysis method

The relationship between the microstructure and mechanical properties of the welded joint of the 6063 aluminum alloy plate has been obtained by the experiment, which will guide the enterprises to adjust the welding process in theory and improve the performance of the products. The main components of the 6063 aluminum alloy are 0.47%~0.50% Mg, 0.20%~0.60% Si and 0.35% Fe. MIG welding is used, and 99.9% pure argon is used as the protection gas in the actual welding. The welding torch is preheated, preheated to the weld about 30mm, the preheating temperature is 80°C~120°C, and the thermometer is used to measure the temperature on the surface. The microstructure was observed by metallographic microscope, and the hardness was measured by microhardness tester. The two electrons images and back scattered electron images were obtained by XRD diffraction instrument and scanning electron microscope.

3. Analysis of experimental results

3.1. Microstructure of 6063 aluminum alloy

![Figure 1](image1)

*Figure 1.* (a) 6063 aluminum alloy structure 100x. (b) 6063 aluminum alloy structure 500x.

It can be seen from the diagram that the second phase enhanced particles are more evenly distributed in the matrix, but there are a large number of micro cracks. It is found that the micro crack is an organization that does not show the original parts during the sample making process.

3.2. Hardness distribution of welded joint

3.2.1. Hardness distribution of 15mm welded joint. According to the arrow direction shown in Figure 2, the hardness distribution curve is made from the weld center to the joint and the base material shown in Figure 3, respectively.

![Figure 2](image2)

*Figure 2.* 15mm hardness schematic diagram.
From the analysis of the hardness distribution of 3-2 directions in Figure 2, it is found that the lowest hardness point appears at the off weld -1.5mm, and is far from the hardness of the weld center, indicating the existence of a softening zone. In addition, the hardness of welded joints is not symmetrical with the weld center. From the hardness distribution of 1 and 4 in Fig.2, the softening zone is found at the distance between the center of the weld -3mm and -2.5mm. This indicates that the weld area is the weak area of the whole joint. There is a small hardness height near the fusion line, which indicates that there are more strengthening phases in the area.

3.2.2. Hardness distribution of 20mm thick welded joint. According to the arrow direction shown in Figure 4, the hardness distribution curve is made from the weld center to the joint and the base material shown in Figure 5, respectively.

Figure 3. 20mm hardness schematic diagram.

From the 2 and 3 directions in Figure 3, the hardness difference between the two sides of the weld center is large, the left hardness is generally low and the lowest point at -2.75mm can be found, but the front can be weakened by the rear weld. The two low hardness on the right side is due to the influence between the welding layers. From the 1 and 4 directions in Fig.3, it is found that the hardness value of the central area of the weld is higher than that of other regions, and is a strengthening part. The lowest point appears at the 3mm of the weld center, indicating that there is a softening zone, namely the thermal impact softening zone.

3.3. XRD phase analysis of 6063 welded joint

The results of phase analysis of welded joints of 6063 aluminum alloy are shown below.

Figure 4. XRD phase analysis Atlas of 15mm welding joint.
It can be concluded from Figure 6 that Al12Mg17 is precipitated in the fusion zone besides the matrix, mainly because of the high magnesium content of the welding wire and the occurrence of Al12Mg17 in the weld area.

3.4. Scanning electron microscope image of 6063 aluminum alloy welding joint
The following picture is the 15mm aluminum alloy welding joint image:

![Image](a) ![Image](b) ![Image](c) ![Image](d)

**Figure 5.** 15mm welding joint scanning electron microscope photograph.

It can be seen that the resolution effect is much better than that of optical metallography. Due to the influence of thermal cycling, the strengthening phase is melted into the matrix, and the weld area has a small reinforcement phase distribution, and the reinforcing phase in the matrix is larger. In addition, the welding joint part also distributes the silver white phase, namely Al12Mg17.

The following figure 6 is the 20mm aluminum alloy welding joint image:

![Image](a) ![Image](b) ![Image](c) ![Image](d) ![Image](e)

(a) Two electron images of two electron images (b) 20mm welded joints in fusion zone of 20mm welded joints (c) 20mm electron backscattering electron image (d) 20mm two electron image of base metal welded joint (e) 20mm backscattered electron image of the mother wood.

**Figure 6.** 15mm welding joint scanning electron microscope photograph.
It can be seen from figure 8 that its resolution is much better than that of optical metallography. Due to the influence of thermal cycling, the strengthening phase is melted into the matrix, and the weld area has a small reinforcement phase distribution, and the reinforcing phase in the matrix is larger. In addition, the small silver white phase of the welded joint is Al12Mg17, and the parent material is distributed with rod like Al12Mg17.

3.5. *Static tensile test results of 6063 aluminum alloy welded joint*

3.5.1. *Tensile results of 15mm welding.*

As can be seen from Figure 7 and figure 8, the tensile strength of 15mm butt welded tensile specimens are above 160MPa, the elongation rate is above 15%, and the tensile strength is general, but it has good plasticity. It can be seen from the experimental results that the fracture did not occur in the weld area, but occurred at the 10mm and 7mm of the weld. Secondly, the fracture is basically about 45 degree angle cutting fracture. Its fracture shape is like Figure 8.
3.5.2. Tensile results of 20mm welding.

As can be seen from Figure 9 and figure 10, the tensile strength of 20mm butt welded tensile specimens are above 210MPa, with an extension of more than 15%, showing good tensile strength and good plasticity. From the experimental results, the fracture occurred in the weld area, but there was a serious welding defect at the fracture surface of the joint, that is, air hole. Under normal circumstances, the test data do not reflect the true tensile strength and elongation of 20mm welded joints. However, it can be concluded that welding defects have a great negative effect on the tensile strength and ductility of aluminum alloy welded joints. Secondly, the fracture of the fracture is about 45 degrees. Its fracture shape is like Figure 14.

4. Conclusion

In this paper, the microstructure and mechanical properties of welded joints of medium and heavy plate of 6063 aluminum alloy profiles were comprehensively tested. Through the analysis of the whole test data, a lot of specific distribution and mechanical properties of the welded joints of 6063 aluminum alloy have been obtained. During the test, the macro microstructure observation and microstructure observation of 15mm butt joint, 20mm butt joint and 15mm angle joint were carried out,
and the hardness and phase of the welded joint were measured and analyzed. At the same time, a static tensile test and an electron scanning microscope were carried out.

There is a softening zone in:

1) Welded joints, which mainly exist in the heat affected zone; at the same time, the melting zone will have a high hardness point, due to the presence of more strengthening phase Mg2Si and a small amount of Al12Mg17.

2) The tensile strength of the welded joint of the two thickness specimens is lower than the tensile strength 185MPa of the 6063 aluminum alloy theory, and the elongation is higher than that of the 6063 aluminum alloy theory. The welding defects, such as the porosity, will also have a greater impact on it.

3) Scanning electron microscopy (SEM), due to the effect of the thermal cycle on the reinforced phase into the matrix, the weld zone has a small intensification phase, and the strengthening phase in the matrix is larger. In addition, the small silver white phase of the welded joint is Al12Mg17, while the Al12Mg17 near the base of the weld is distributed.

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