The mechanical properties in Welded SMA Alloys

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Abstract—Laser welding technology is a more appropriate way in the processing of shape memory alloy. The mechanical properties and shape memory properties of the base metal and weld are tested, the comparison of the mechanical properties between the base metal and the laser weld is studied, and draw the conclusion. The mechanical properties are studied by temperature stress-strain test. The results show that stress-induced martensite changes little, the recovery mechanism of shape memory property is little affected by laser welding, and the laser welding method affects the properties of alloy weld to a small extent.

1. INTRODUCTION

Shape memory alloys (SMA) is a kind of functional material with shape memory effect and hyperelastic properties. The main feature of SMA is that after applying a large deformation to the material, when heated to a certain temperature, it can almost all return to the original shape. This is not the case with ordinary metals and alloys. Shape memory alloy has a very attractive application prospect because of its wonderful properties. Since its discovery, it has been widely concerned by material scientists and physicists, and has made many important discoveries. As a new type of functional material, it has been recognized by people, and has become an independent branch of science, which has experienced decades of development process [1].

Nowadays, the composition design and preparation technology of Shape memory alloy are becoming more and more mature, it can not be separated from the good mechanical properties, corrosion resistance, biological properties and biocompatibility of NiTi alloy, and it has entered the practical stage. With the further research on Shape memory alloy shape memory alloy and its more extensive application in various fields [2-3].

The strength and shape memory performance of shape memory alloy welded joints are improved, and high-quality welded joints are obtained, the pipe joint, fastening rivet and antenna made of NiTi alloy have been widely used in aviation, energy, transportation and chemical industry, which are the requirements for preparing structural complex components and broadening shape memory alloy [4-5].

In terms of application, NiTi is the alloy with the best memory performance, the most stable, the earliest development, the most comprehensive research, the most widely used and the most effective. NiTi alloy, with its superior shape memory function, especially its good compatibility with organism, is highly valued by engineering and biomedical circles. In medicine, NiTi alloy is commonly used to make dental arch wire, dental root implant, coagulation filter and other instruments, which are widely used in stomatology, orthopedics, thoracic surgery, urology and so on. Due to its super elasticity and strong damping properties, NiTi alloy is often used as memory driving element and shock absorber. NiTi alloy is expected to be a good material for friction parts due to its excellent wear resistance.

Laser welding is a kind of fusion welding. It is a processing process that uses laser as welding heat
source to heat the weld metal above the melting temperature and form a common melting pool to form a welding joint. The advantages of the laser welding are that the laser heat is concentrated, the welding speed is fast, and the efficiency is high; the laser beam has good directionality during the laser welding, and can be processed precisely.

The heat affected zone of the weld is narrow, and the welding deformation is small; the laser welding joint has great flexibility, and it can be used for long-distance welding, and it is difficult to access the parts. because the laser welding joint does not have serious stress concentration, it has good fatigue resistance performance. With high tensile strength, laser welding is one of the most important methods for welding of this kind of materials[6-8].

However, due to the obvious change of the weld structure and the original base metal structure after laser processing, under the action of instantaneous high energy density laser beam, the weld structure is coarse and the strength, plasticity and toughness are reduced. It is an urgent problem to improve the microstructure, properties and shape memory properties of laser welded shape memory alloy.

2. TESTING AND MATERIAL PREPARATION
The laser welding machine can weld alloy materials at the speed of 1.2 meters per second and the power is 800W. The stress-strain curve is tested by stress-strain test. Through the stress-strain test of temperature change, the martensitic transformation between the base metal and the weld is measured in the form of stress-strain curve.

Shape memory effect is a kind of peculiar property of alloy with martensitic transformation. The shape memory effect is shown as follows: when a certain shape of parent phase sample is cooled from above Af to below Mf to form martensite, the martensite is deformed below Mf, heated to above Af, and accompanied by reverse transformation, the material will automatically return to its shape in the parent phase.

In some cases, a kind of hyperelasticity is produced in shape memory alloy due to the transformation between parent phase and martensite and between martensite and martensite. If the alloy is stretched between Ms and As, due to the stress-induced martensitic transformation, the plastic deformation occurs after the elastic deformation of the parent phase.

Heating can make this deformation disappear and show the shape memory effect. If the alloy is stretched above Af, the deformation due to stress-induced martensitic transformation disappears after stress removal. The martensite above the temperature of Af is stable only under the action of stress.

After unloading, it immediately reverses to a stable parent phase. This kind of transformation, which can return to the original shape without heating, looks like elastic deformation, but its stress-strain curve is nonlinear.

3. RESULTS AND DISCUSSIONS
3.1. Weld surface morphology
The front and back of the laser weld shows the weld morphology in Fig 1. The back of the laser weld shows the weld morphology in Fig 2. The weld can be seen that the weld surface is beautiful without obvious depression, also it is even and smooth. there is no reinforcement and undercut on the front and back of the weld.

The fusion line of the welded joint is very clear, and the weld formation is well. From the surface on the back of the weld, there are metal particles covering at weld edge.

This shows the process of laser welding, at the same time the welding speed is 3m/min. When the speed is fast, Rapid evaporation of metal are caused by the metal splashes, the large recoil pressure cause the metal evaporates. The metal splashes are obviously reduced when the welding speed is low.
3.2. Mechanical property test

The mechanical properties of laser welded shape memory alloy joints were measured by tensile test at room temperature.

The tensile specimen is made of shape memory alloy by laser welding. Aging treatment temperature is 300°C, holding time is one hour. Test at room temperature 20 °C.

Figure 3 shows the tensile curve of base metal and welded joint. The weld fracture is in the center of the weld. The strength of laser welded shape memory alloy joint is obviously reduced. The tensile strength of the weld. The welded joint is 70% of the strength of the base metal, and the strength of the welded joint is lower than that of the base metal. It is worth noting that the welding joint specimen can bear large deformation before fracture.
3.3. The thermal stress tensile cycles

As shown in Figure 4(a), the upper platform stress is 650 MPa, the lower platform stress is 400 MPa, the deformation corresponding to the upper platform stress is 0.5%, the deformation corresponding to the lower platform stress is about 4%, and the irrecoverable residual deformation is 0.3%.

As shown in Figure 4(b), the upper platform stress is 700 MPa, the lower platform stress is 450 MPa, the deformation corresponding to the upper platform stress is 4.3%, the deformation corresponding to the lower platform stress is about 4%, and the irrecoverable residual deformation is 0.7%.

When the temperature of base metal, laser weld is higher than Af, the typical hyperelastic curve is displayed, and the hyperelastic return line with upper and lower yield platforms is generated. When the stress is removed, the stress-induced martensite disappears completely, and the strain recovers accordingly, showing hyperelastic behavior.

The upper platform stress is 650 MPa, the lower platform stress is 400 Mpa, the deformation of the upper platform and the lower platform is 0.5% and 1% respectively, and the irrecoverable residual deformation is 0.4%.

The upper platform stress is 700 Mpa, the lower platform stress is 450Mpa, the deformation of the upper platform and the lower platform is 1.2% and 4% respectively, and the irrecoverable residual deformation is 0.8%.
4. CONCLUSION
Shape memory alloy welding joint should not only have certain strength and plasticity, but also keep its memory function as much as possible. Therefore, it is more difficult to connect than general materials, and the connection process is more limited, which brings certain difficulties to the welding technology.

The mechanical properties, memory hyperelasticity and recovery behavior of the base metal and the welded specimens were tested.

At the same time, the stress-strain curves and hardness of the base metal and weldment, the heat affected zone of the weld and the stress-strain curves were measured. The results show that the influence of laser welding is very small. Laser technology is suitable for welding shape memory alloy.

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