Microstructure Change in Welded TiNi Alloys

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Abstract—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. Compared with the base metal, the microstructure of the alloy after laser welding was studied by experiment.

1. INTRODUCTION
Shape memory alloy is a new type of functional material, which not only has the characteristics of high specific strength, fatigue resistance, wear resistance, corrosion resistance and biocompatibility, but also has excellent shape memory effect (SME) and hyperelasticity (PE), known as the ideal material across the 21st century [1].

In terms of application, TiNi shape memory alloy is the alloy with the best memory performance, the most stable, the earliest development, the most comprehensive research and the widest application. So far, TiNi alloy has been widely used in space technology, energy development, medical devices, mechanical appliances, electronic equipment, automobile industry and daily life.[2-3].

As a product of modern high technology, laser welding has become an indispensable means of modern industrial development. With the rapid development of aerospace, microelectronics, light industry, medical and nuclear industry, the structure and shape of product parts are becoming more and more complex, the requirements for material performance are constantly improving[4-5], and the requirements for machining accuracy and surface integrity are increasingly strict, at the same time, the requirements for production efficiency and working environment of machining methods are also increasingly high. The traditional welding method is difficult to meet the requirements. The high energy beam welding method, represented by laser beam, has been paid more and more attention and widely used[6-7].

Nowadays, the composition design and preparation technology of TiNi alloy are becoming more and more mature, and it has entered the practical stage. With the further research on TiNi shape memory alloy and its more extensive application in various fields, the strength and shape memory performance of shape memory alloy welded joints are improved, and high-quality welded joints are obtained, which are the requirements for preparing structural complex components and broadening shape memory alloy. Therefore, it is more important and urgent to carry out the research work of TiNi alloy connection technology.

In this paper, Vickers hardness is used to test the mechanical properties and hardness of alloy of laser processing. Scanning electron microscope and electron microscope were used to observe the changes of microstructure, composition and structure of weld and heat affected zone.
2. PRELIMINARY TEST PREPARATION

Laser welding usually requires a good workpiece clamping mechanism and a high assembly accuracy of the welded parts, so that the actual speed of light and the welding position can be accurately aligned. The complete weld sample is prepared into metallographic sample, which is chemically polished. The diagonal length of the indentation is calculated in μm. The process of hardness measurement was carried out under the microscope of the hardness tester, with a load of 1.961 (0.2) N (KGF) for 15 seconds.

The cross section of the weld seam is cut off by WEDM, and metallographic samples are made respectively. After inlaying, sandpaper polishing (particle size is 500, 800, 1200, 1500 respectively), etching after polishing, acid ratio FH: HNO₃: H₂O = 1:2:10 (volume ratio), alcohol cotton ball is used to wipe off the chemical corrosion dirt on the surface. After alcohol washing, optical microscope (Olympus) and scanning electron microscope (Quanta200, FEI company, Netherlands) are used observation.

The cross section morphology of the weld was observed by optical microscope, and the size of each part of the joint was measured. The microstructure of different weld areas was observed by SEM.

3. RESULTS AND DISCUSSIONS

3.1. Micro-hardness tests

The hardness of the cross-section of the weld in the vertical direction of the plate thickness is shown in Figure 1. The lowest hardness value of the lower part of the cross-section of the weld is 220 (HV₀.₂), the lower hardness value of the upper part is 226 (HV₀.₂), and the highest hardness value of the middle part of the weld is 240 (HV₀.₂).

The hardness test of the weld cross section in the vertical direction of the plate thickness shows that, the hardness distribution of the inner hard and outer soft formed in the longitudinal direction of the weld center is related to the formation of the weld pool grain.

In the process of weld pool cooling in laser welding, due to the good heat dissipation conditions around the weld pool, the base metal around the weld pool is like mold wall to the weld pool metal, but the weld pool and its surrounding base metal are in direct contact with each other, unlike the casting, which has air gap.
Compared with the mass of the surrounding base metal, the mass of the weld pool is very small. The base metal has a great mass effect on the small volume weld pool, which promotes the heat absorption. Therefore, the heat conduction condition of the weld pool interface is very favorable. The temperature gradient of the molten pool boundary, which is the solid-liquid interface in solidification, is 100-102 times higher than that of the casting. Therefore, the cooling speed of the upper part and the lower part of the cross-section of the weld is faster than that of the middle part of the weld, the natural grain is coarse, and the hardness is reduced.

3.2. Microstructure test

![Fig 2. Microstructure of weld center](image)

The heat affected zone of laser welded TiNi alloy joint is narrow, and its boundary with matrix structure is not obvious. There is almost no heat affected zone in microstructure.

The base metal is fine equiaxed crystal and the weld is coarse columnar crystal. In Fig 2, from the fusion line to the weld center, the grains of TiNi alloy are fine columnar crystal, coarse columnar crystal and coarse equiaxed crystal.

The width of the fine columnar grains near the fusion line is about 100 μm. These fine columnar grains form a common grain with the base metal on the outside of the fusion line, and interpenetrate and crisscross with the unmelted particles of the base metal. The main microstructure of laser welded NiTi alloy is coarse columnar crystal.

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4. CONCLUSION

With laser brazing, the strength of the joint is high, the heat affected zone is small, and the property loss of TiNi shape memory alloy is small. Therefore, laser brazing is more suitable to weld TiNi shape memory alloy than micro plasma arc welding and energy storage welding.

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When TiNi alloy is used as functional material, laser welding is advisable, the melting area of laser spot welding joint is composed of dendrites, the heat affected area near the molten pool is coarse equiaxed crystal, and the area near the base metal is fine equiaxed crystal. In the future, Laser welding technology is suitable for shape memory alloy processing.

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