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Defocusing Effects of Laser Beam on the Weldability of Powder Metallurgy Ti-Based Shape Memory Alloys

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Abstract

The influence of defocusing distance of the fiber laser welding on Ti-51at%Ni, Ti-28%atNb and Ti-30at%Ta shape memory alloys (SMAs) was investigated. These alloys were produced by powder metallurgy (P/M) and sintered by furnace and microwave processes. The experimental results showed that the furnace-sintered Ti-Ni welds have the maximum porosity density and the lowest weld quality. While, the microwave sintered alloys of Ti-Nb and Ti-Ta SMAs presented better weldability, even though porosities were still observed. Ti-Ta SMA showed the best welding quality compared with the other welded joints. It can be concluded that porosities play important role in the welding of powder metallurgy alloys and in order to achieve high-quality welds, the porosities should be minimized.

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Keywords: Fiber laser welding, Shape memory alloys, powder metallurgy, microwave sintering, furnace sintering.

1. INTRODUCTION

Ti- based alloys are known as one of the most attractive materials, such as Nitinol alloy, which has been utilized in various biomedical applications, for example stent and dental implants due to the remarkable shape memory effect (SME), pseudoelasticity (PE), corrosion resistance and biocompatibility [1,2]. Nowadays, many researchers are making extensive efforts to replace Ni by Nb and Ta due to their better compatibility to the human body than Ni. In addition, Ti-Nb and Ti-Ta are considered as β titanium alloys and their low elastic modulus has made them excellent choices for biomedical applications [3-5].

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Powder metallurgy (P/M) provides the possibility for fabrication of semi-finished products and net-shape components, as well as allows avoiding the issues that associated with the traditional casting process, in addition in controlling the grain growth [6]. Moreover, the economic aspects and unique properties of powder metallurgy to produce multipart products along with innovations in the manufacturing process that makes it increasingly attractive for replacing wrought materials. Therefore, a wide range of application is expected for powder metallurgy parts and in turn it requires feasibility of welding and joining together and to other materials. However, the weldability of these alloys is varied based on the presence of porosity and their density. The pore volume or relative density has a great influence on thermal conductivity, thermal expansion and hardenability. In addition, other factors such as impurities and residuals as well as processing history shall be considered in order to achieve a better welded joint [7,8]. As a comparison with the welding of cast materials, there are less studies on welding and joining of powder metallurgy components which has been conducted by both fusion [9–11] and solid state welding [12,13]. However, the researches on welding of Ti powder metallurgy SMAs are limited [14,15]. Furthermore, with growing demand for high energy efficiency, the combination of fiber laser as an extremely efficient laser source with advantageous properties of components produced through powder metallurgy method can be of high significance for biomedical industry. In this research, the effects of defocusing of the fiber laser welding on the welding efficiency of powder metallurgy Ti-based SMAs were investigated.

2.0 Materials and method

In this research, commercially pure powders of Ti (<150μm), Ni (<45μm), Nb (<150μm) and Ta (<74μm)- supplied by Goodfellow Cambridge limited- were used in order to produce Ti-51at%Ni, Ti-28at%Nb and Ti-30at%Ta SMAs. Figure 1 illustrates the homogeneous distribution of the mixed powders after 3 hours in a cylindrical mixer. The blended powders were pressed into a die using a uniaxial pressure of 230 kg/cm^2 for 5 min to produce bar shape green compact with the diameter of 25mm and height of 20mm. Ti-51%atNi was sintered in the vacuum furnace at 900°C for 1 hour, followed by water quenched, whereas Ti-30%atTa and Ti-28%atNb were sintered by microwave sintering process at 900°C for 30 min with the heating rate of 30 °C/min and water quenched. The Sintered samples were cut into specimens of 2mm thickness by using electrical discharge machining (EDM). A Rofin Starfiber 300 Ytterbium fiber laser welding machine was used to join the produced powder metallurgy alloys. The welding parameters are shown in the Table 1. Laser power was kept constant at 300 watts, while, the welding speed and focusing distance were varied. The beam focal distance was set to 347mm. The distance from the surface of the specimen up to the focal plane is generally defined as the defocus value. Figure 2 shows the experimental setup, where the defocus distance is positive when the focal plane is above the specimen surface and negative when the focal plane is below the specimen surface [16]. Argon gas with a flow rate of 20 l/min was used to shield the fusion zone from oxidization. Welded joints were cut by EDM wire cut and then ground using abrasive papers of up to 2000 grit, followed by polishing using alumina suspension in order to obtain mirror polished surfaces. The polished samples were etched by H2O: HNO3: HF =18:1:1 solution [17]. X-ray diffractometer (XRD) (Siemens model D5000) was employed to examine the phase changes of weld seams within a locked couple mode, 2θ range between 30^o-80^o, and a scanning step of 0.05^o/sec. In