ANNALS of the ORADEA UNIVERSITY.

Fascicle of Management and Technological Engineering, Volume VII (XVII), 2008

MACRO AND MICROSCOPIC ASPECTS OBSERVED ON ULTRASONIC WELDING OF SHAPE MEMORY ALLOYS

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Keywords: shape memory, ultrasonic welding, micro and microstructure, defects

Abstract: Bulk and ribbons made out of shape memory alloys have been assembled using ultrasonic welding with similar or dissimilar materials. The experiments have been made on Cu-Zn-Al and Ti-Ni-Cu ribbons as well as on bulk Cu-Zn-Al alloys. The macrostructurall analysis performed on the welded structures showed the possibilities to use this technique. Microstructural observations showed a good interface for bulk joints, but damages of the ribbons related to the welding process and the need for further research in order to adapt the welding parameters.

1. Introduction

Shape memory alloys (SMAs) can offer several functions such as: one way or two-way shape memory effect, superelasticity, damping, magnetostriction, biocompatibility, etc.

Several alloy families have been found until now, but most of the applications are developed on Ni-Ti and copper based alloys. Ni-Ti alloys are very important because they are biocompatible, while copper based ones are much cheaper to manufacture.

The thermal cycle needed in order to observe the shape change usually varies in a temperature range around room temperature (from -100^{o}C up to 200^{o}C) and heating much above these temperatures can significantly affect the properties.

For these reasons, shape memory alloy welding is a sensitive problem that needs continuous research. It becomes even more sensitive when the alloys are manufactured as thin films manufactured by sputtering or ablation and ribbons manufactured by melt-spinning.

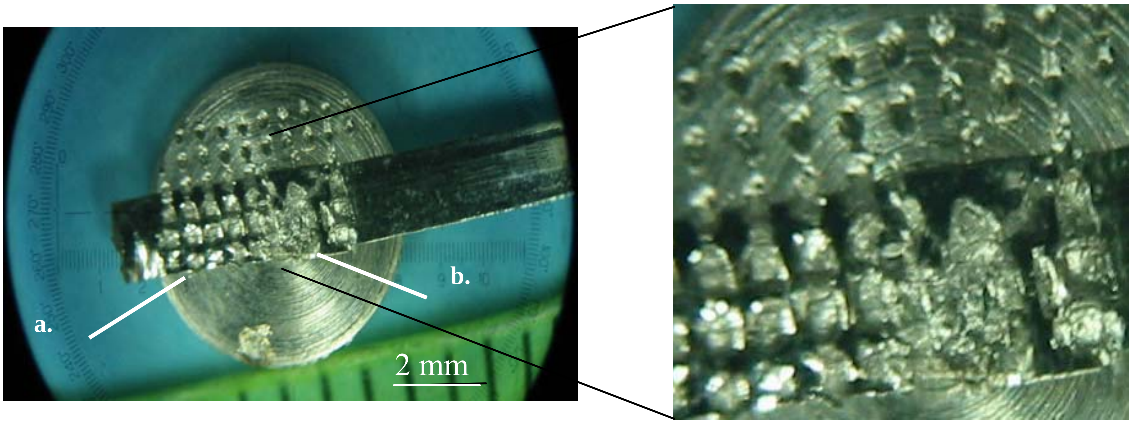
Ultrasonic welding has been selected for study because it implies lower temperatures, localized around the welding spots, thus leading to minor changes in the base materials. The technique is simple, can be adapted to micro-welding processes, can be easily controlled and does not need additional materials which can lead to compositional changes and can deteriorate the welding quality.

2. Macroscopic aspects

Welded joints have been manufactured with Ni-Ti and copper based shape memory alloys using ultrasonic welding. The components were used as bulk and rapidly solidified ribbons.

Figure 1 shows an ultrasonic welding of a Ni-Ti-Cu shape memory alloy ribbon with a Ni_6TiV_4 biocompatible alloy and details distinct areas where the joint resulted in single spots that resulted from the interaction with the sonotrode, but also areas where the ribbons have been deteriorated.

A shape memory alloy ribbon welded between two Ti_6Al_4V disks shows a complex welding capacity, but does not allow the observation of the welding details (fig. 2). Additional microscopic investigations are needed for this purpose.



a. welded joint   b. details of the damaged ribbon

Fig. 1 Ni-Ti-Cu ribbon attached to a bulk Ti_6Al_4V

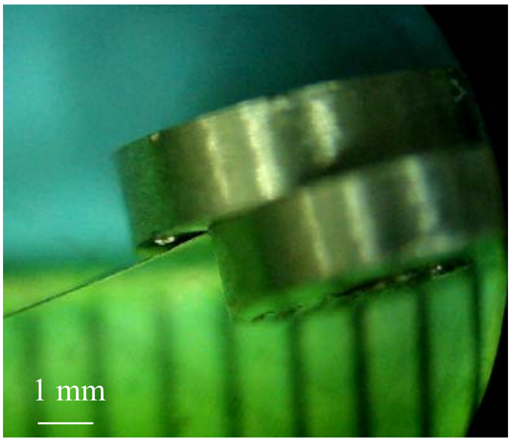
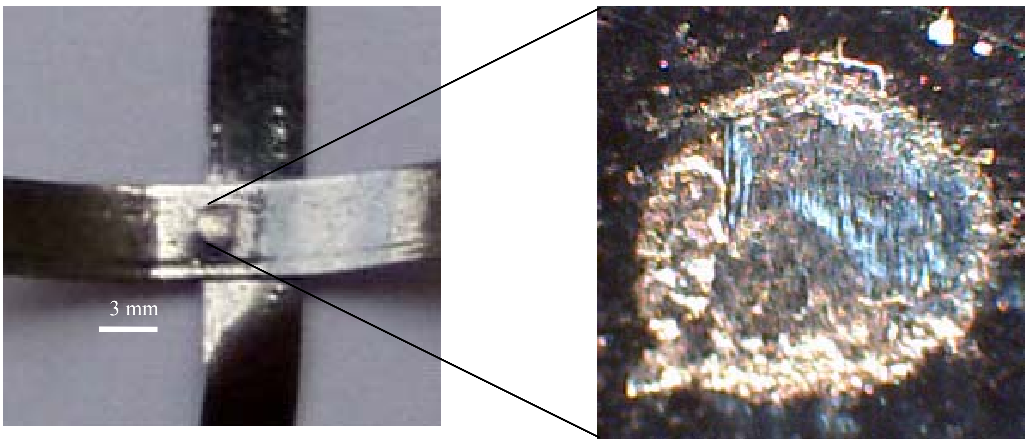


Fig. 2 Ribbon attached between two bulk disks

Ultrasonic welding of two Ni-Ti-Cu ribbons is shown in fig. 3 and a reduced influence of the welding area is observed, as well as the ribbon deterioration around the welding spot.



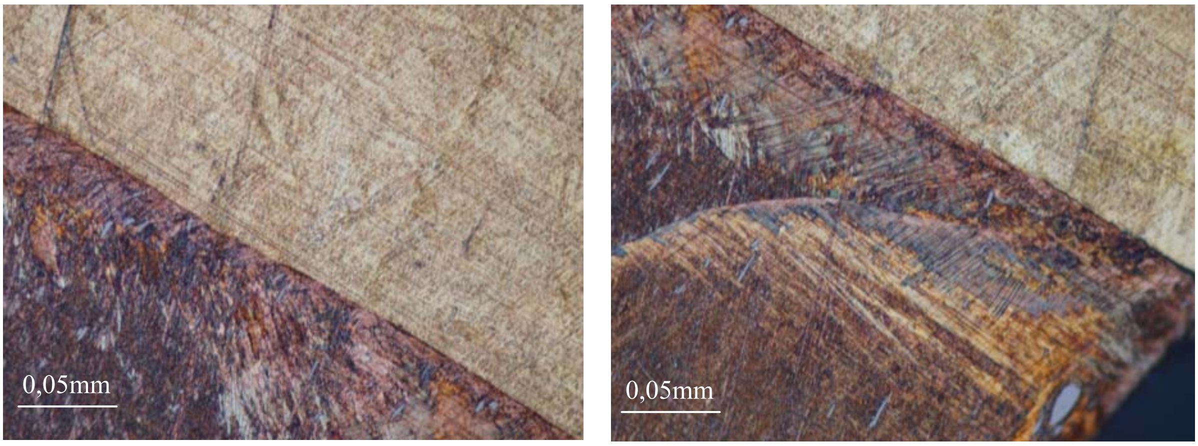
a. asembled joint   b. detail of the welded spot

Fig. 3 Macroscopic images of the Ti-Ni-Cu welded ribbons

3. Microscopic aspects

The preparation for microscopic analysis was made on samples included in epoxy resins followed by usual preparation activities such as: polishing and metallographic etching.

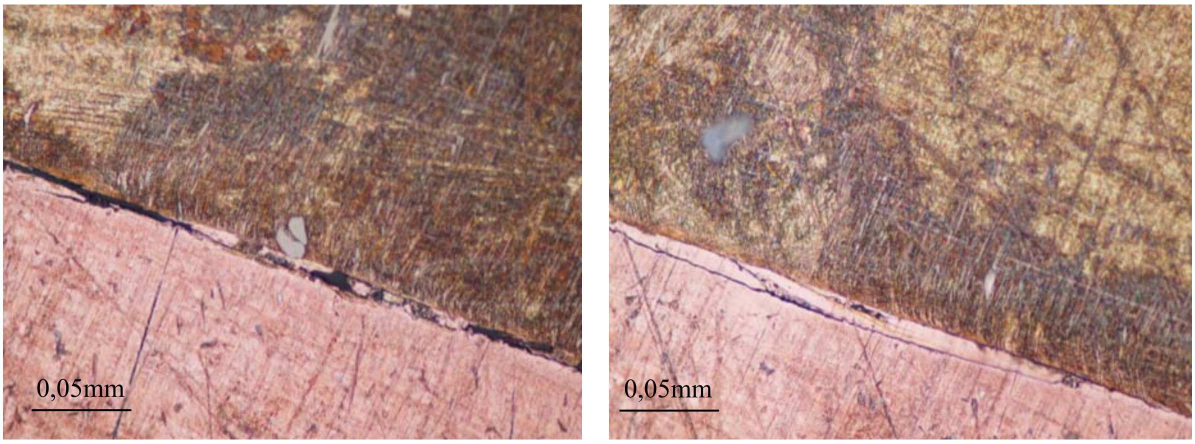
The microscopic aspects of the welded area of bulk Cu-Zn-Al and Cu alloys are shown in fig. 4 showing an area without discontinuities and a martensitic structure (b) and an area including the interface which does not appears to be affected by the welding process.



a. free defects area b. martensitic structure

Fig.4 Cu-Zn-Al and Cu alloys welding spots

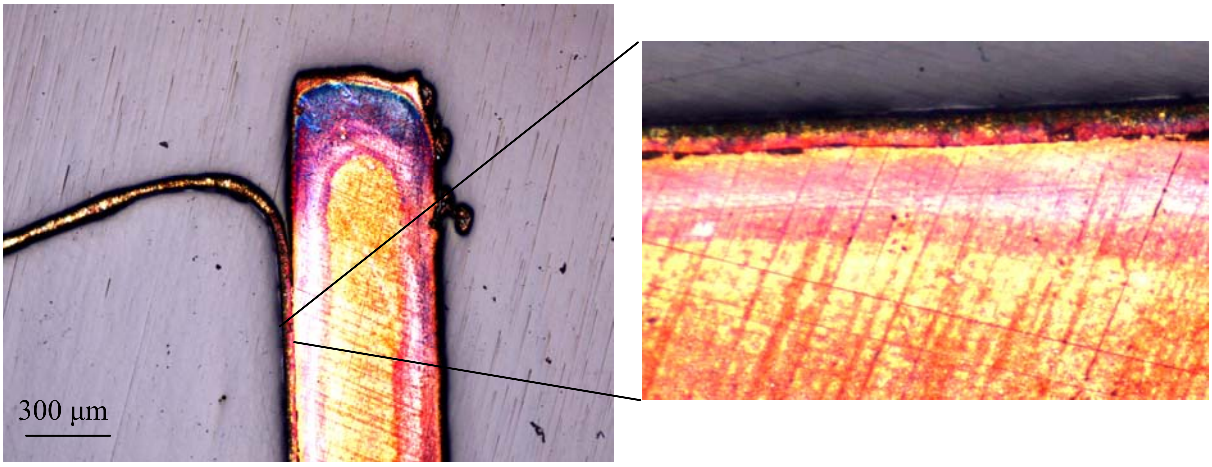
At the interface level deteriorations have been observed as localized ones or as interfacial cracks (fig.5) that seems to have as starting point pre-existing defects in the welded material (fig. 5b).



a. punctual deteriorations b.delamination area

Fig. Defects at welding interface

For an ultrasonic welded joint based on Cu-Zn-Al bulk shape memory alloys (fig. 6) one could observe areas assembled without plastic deterioration of the ribbon (fig. 6a), as well as the martensitic structure in the welded joint.



a. details of the bulk-ribbon welded joint   b. the martensitic structure of the ribbon

Fig.6 Cu-Zn-Al with Cu_{99} ultrasonic welded joint

Deteriorations of the welded ribbon have also been observed when Ni-Ti-Cu has been welded to bulk Ti_6Al_4V. The ribbon has been attached by welding to the bulk (fig. 7), but some area show fractures of the ribbon during the process (b).

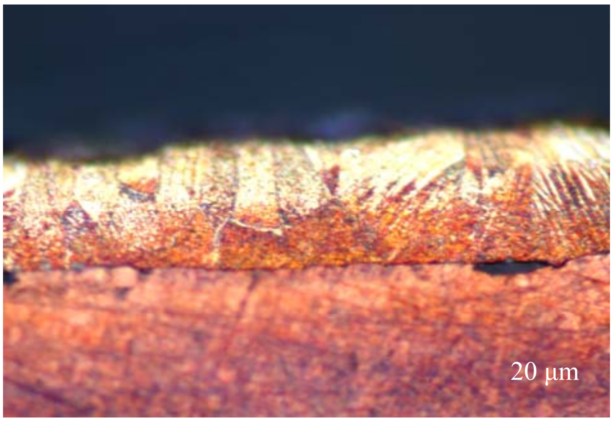
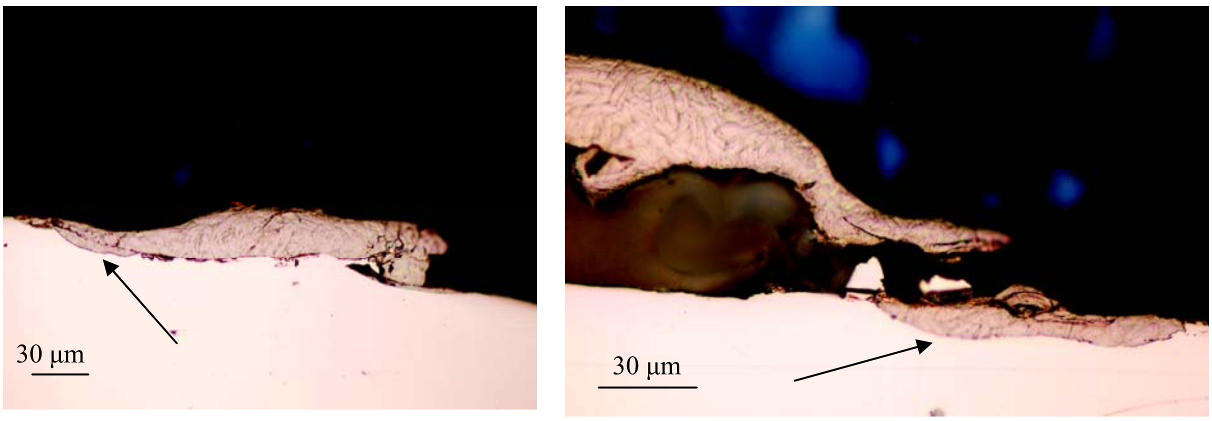


Fig.7 Ni-Ti-Cu with Ti_6Al_4V ultrasonic welded joint

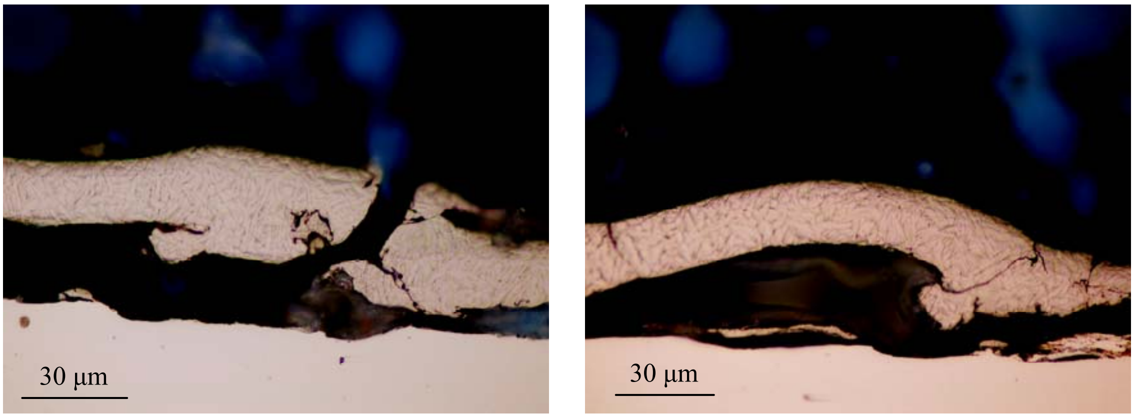
The welded area has a limited surface (fig. 8) and the ribbon remains partially attached and a larger welded area shows a delamination of the ribbon from the bulk alloy.



a. partially attached ribbon   b. welded area and detached ribbon

Fig. 8 Ni-Ti-Cu ribbon welded to a biocompatible Ti_6Al_4V bulk alloy

Typical examples of the shape memory alloy deteriorated ribbons are shown in figs. 9.



a b

Fig. 9 Deteriorari ale benzilor din aliaj cu memorie a formei in asamblarile sudate cu ultrasunete

4. Conclusions

The experiments performed allowed the evaluation of a series of aspects that can influence the quality of the ultrasonic welding. For both bulk and ribbons we observed deteriorations of the welded surfaces but no or limited thermal influence around the welding.

The results on bulk alloys are promising, but for ribbons there is a need to further design specific sonotrodes that would address the thickness issue and welding parameters that would reduce the risks for deterioration (the ribbon when welded with bulk alloys and the ribbons when they are welded together).

Further research will focus on the optimization of the welding technologies in order to achieve the best assemblies, with minimal deterioration of the welded parts and with maintaining the functionality of the welded structure.

Acknowledgements

The results have been obtained as part of the activity funded by the Romanian Ministry of Education and Research through the National Research Grant Programme.

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