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TEMPERATURE TROUBLES IN CHOOSING A FILLER METAL FOR BRAZING THE SHAPE MEMORY ALLOYS

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Abstract

Brazing technology requires some demands between the filler metal and parent metal, most of them are related to the strength, corrosion resistance, wettability, melting temperature, etc. One of the main characteristics of the shape memory alloys (SMAs) is in its temperature of martensitic transition, i.e. when such alloy became a "memory alloy". The joining of the SMA sometime becomes necessary. There are a few fusion methods for joining of the SMA; one of them is brazing, but then the relation between the melting temperature of a filler metal and temperature of a martensitic transformation at the SMAs becomes very important. The higher melting temperature of filler metal than the martensitic transition temperature certainly will affect changing the important properties of the SMA. So, the troubles in choosing the melting temperature of a filler metal for brazing any kind of the SMAs will arise. Further, the brazing technology will affect the metallurgical properties not only on the joint, but also on the final product to be made.

Keywords: *SMA, martensitic temperature, brazing temperature, filler metal*

1. INTRODUCTION

The appearance of the SMA in a modern time is pretty well known: at the 1930s, the shape memory materials were firstly discovered in the gold-cadmium alloys, without any applications, but after some 30 years later, the same effect was discovered in the nickel-titanium alloy. There is an opinion that the first using of the SMA in a human history was mentioned in the Bible, when Moses (XIV cen. B.C.) throughout the metal bar on the ground, and this bar was turned into the snake-shape [1]. Nowadays, it is well established that the temperature at which austenite transforms into martensite primarily depends on the chemical composition of an alloy, but also from the thermomechanical treatment. [2,3] Driving force for the martensitic transition could be either from the temperature and load, rarely by the magnetic force in the alloys.

Nowadays, a lot of shape memory materials were discovered, even in plastics. The adhesive bonding, welding and/or brazing, with certain limitations, are available for joining of the shape memory materials with another kind of material.

The problem in brazing, precisely about the level of brazing temperature and martensitic transition temperature of the SMAs will be discussed in this paper. The SMA can be deformed at one temperature, but when heated or cooled, it returns to the original (preformed) shape – it is used to say that they have a "shape memory effect" (SME). At elevated temperature, the SMAs (parent or memory phase) exist as an austenite phase, but after cooling below the transformation temperature, this phase transforms into martensite in many variants, typically in the sheared platelets. The principle of the SME here is demonstrated on a simple way, Figure 1: a) original shape, b) strained wire in cold state, c) heating returns previous shape, and d) another example for heating and returns to the original shape.

a) b) c) d)

Figure 1. *Steps in demonstrating the shape memory effect (SME)*

The basic principle in forming a shape memory alloy is in a position of temperature during the martensitic transformation, Figure 2.

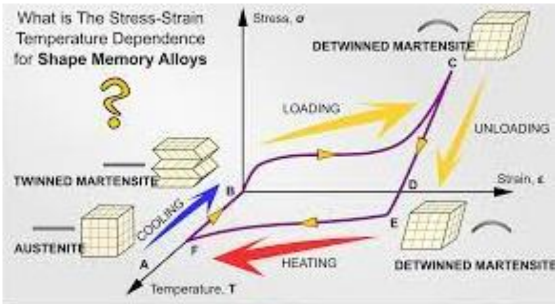

Figure 2. *Loading and heating causes changes during the austenite – martensite transition*

Temperatures of martensitic transition in the SMAs commonly are below 200°C, but they may be at the cryogenic temperatures in some alloys [4]. Almost all the SMAs are based on the next systems: Cu-based alloys, NiTi-based alloys, Ag-based alloys, FePt-alloys and others, Table 1.

Table 1. *Caption of table*

Alloy	Composition	Transformation temperature, °C
Ag-Cd	44/49 at.%	-150 to < -50
Au-Cd	46,5/50 at.%	30 to 100
Cu-Al-Ni	14/14.5 wt.% (3/4.5 at.%)	-140 to 100
Cu-Sn	approx. 15 at.%	-120 to 30
Cu-Zn	38.5/41.5 wt.%	-180 to -10
Cu-Zn-(Si, Sn, Al)	a few wt.% of (Si, Sn, Al)	-180 to 200
In-Ti	18/23 at.%	60 to 100
Ni-Al	36/38 at.%	-180 to 100
Ni-Ti	49/51 at.%	-50 to 110
Fe-Pt	approx. 25 at.% Pt	approx. -130
Mn-Cu	5/35 at.% Cu	-250 to 180

NiTi is the most known and developed the SMA, but the other materials commonly show the poorer mechanical properties and then are less commercially viable.

2. SOME IMPORTANT FACTS ABOUT BRAZING TEMPERATURE

The SMA could be joined by different techniques, and the low strength, sometimes the increased brittleness will appear in most of them, usually as a result of forming an intermetallic compound. The temperature of joining plays an important role in the phase transition, of course in the shape memory effect. Much less reactions of molten metal with gases may be expected during brazing in comparison to the welding, which is obviously provided at higher temperatures [5-9]. Brazing, according to the definition, is provided at temperatures above 450ºC. Brazing filler metal should fulfill the gap, s shown in Figure 3A, while the base metal stayed un-melted and only heated-up, Figure 3B.

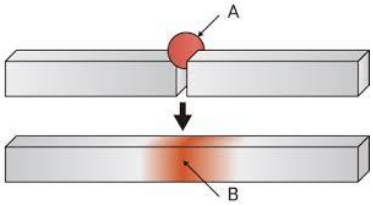

Figure 3. *Filling a narrow gap with brazed metal A), and heating-up in neighboring brazing zone B)*

Choosing of a filler metal here represents a serious job, from metallurgical and also economic reasons. In comparison the temperatures of the SMA martensitic temperatures to the brazing temperatures, it is clear that the use of brazing will be faced to some troubles.

For brazing one of the most known SMA type, as TiNi to stainless steel, is used commonly as a kind of silver-base filler metal, from alloys 68% Ag, 10-30% Cu, 12-20% Zn and 0-10% Sn, all wt. %. Their melting temperatures of brazing alloys are far away from the martensitic transition temperature from a lot of the SMAs. Brazing is available using many techniques [6-10], but it seems that heating with a narrow beam (as by laser) for the SMAs is more effective than for example using a gas torch.

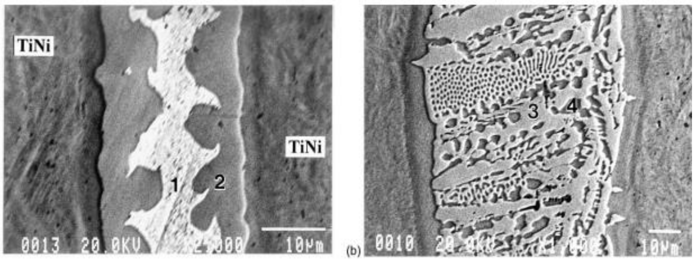

Figure 4. *Two examples of brazing TiNi using the different filler metals, SEM photos*

Intermetallic compounds may have a degradation effect on the mechanical properties of joint. Two examples of different intermetallic distribution when brazing is provided, using two filler metals [1], are given in Figure 4.

In a wide literature, one can find the using vacuum or other atmospheres and temperatures above 1100ºC for brazing of TiNi [8]. From that point of view, the technological schedule in making the SMA product must be programmed that brazing of such components could not be the last step, so that the SME will not disturb. Because the degradation of SME may occur due to the required high brazing temperatures, the solution must be achieved using (very little metallurgical) additives which will prevent such formation of brittle compounds.

3. CONCLUSION

Joining of the SMAs leads to some problems as the low strength, brittleness (due to an intermetallic compound formation) and changes the shape memory effect. Variations in those properties lie in an inadequate temperature position, from the austenite-martensite transition (below 200ºC) and brazing (above 450ºC). The fusion bonding, including brazing, represents a critical step in joining the SMAs, and could be applied only when is unavoidable.

An inert atmosphere for brazing always is desired, but either of this the brittle intermetallic compounds may be formed according to the expecting metallurgical reactions during brazing. So, the brazing of SMAs must be conducted carefully, in choosing the proper filler metal and processing temperature with minimum risks for degrading the SME.

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