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Characterization of a $Ni_{50}Ti_{50}$ shape memory strip produced by twin roll casting technique

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Abstract: An NiTi alloy was produced by twin roll casting technique. Microstructure, thermal behaviour, texture and shape recovery were studied by optical microscopy, differential scanning calorimetry (DSC), X-ray diffraction and elongation measurements. The strip reveals a relatively large thermal hysteresis loop (70 degrees). The crystallization front which proceeds from the outer part of the strip to its centre causes a preferential orientation of the growing grains. In consequence, a texture is formed as a mixture of the fibre <001> orientation and the sheet texture component {001}<100>. The strip shows a good shape recovery.

Keywords: NiTi, Shape memory alloy, Shape memory effect, Twin roll casting

1. INTRODUCTION

The NiTi alloy of near-equiatomic composition has been recognized as the most important shape memory alloy (SMA) from the point of view of numerous applications. The shape memory effect (SME) is strictly related to the reversible martensitic transformation. The diffusionless character of the martensitic transformation demands a cooperative movement of atoms in short distances [1]. Consequently, control of the environment surrounding an atom, creates a possibility to steer the martensitic transformation parameters. There are many known factors, which influence the transformation behaviour in NiTi-based shape memory alloys: the change in nickel content, ageing after solution treatment, thermo-mechanical treatment, thermal cycling, addition of ternary alloying elements and production techniques.

Recently, intensive effort has been put to adopt the non-conventional production techniques such as powder metallurgy, melt-spinning or twin roll casting for manufacturing the NiTi alloys. This creates a wider possibility of the alloy applications. Despite the fact that these techniques have been successfully applied to metals and alloys production [2], their application for SMAs manufacturing is quit new, especially rapid solidification by twin roll casting. One of the advantages of this technique is reduction of cost and time, also avoiding the typical thermomechanical treatment needed after conventional casting.

The paper presents a characterization of the transformation behaviour as well as the shape recovery, in an equiatomic NiTi alloy produced by twin roll casting.

2. EXPERIMENTAL

A bulk alloy with a nominal composition of Ni 50 at.% and Ti 50 at% was induction melted under helium gas atmosphere. Thin strip was prepared by twin roll casting technique with processing parameters given in Table 1.

Table 1.
Processing parameters and thickness of the studied alloy

Material	Melting temp. [^{0}C]	Wheel material	Wheel speed [m/s]	Ejection pressure [MPa]	Thickness [μm]	Width [mm]
$Ni_{50}Ti_{50}$	1600	Cu	0.6	0.025	259	45

Microstructure of the strip was observed using an optical microscope NEOPHOT equipped with a digital camera. The samples were polished following by etching in a solution which consist of: 50ml H_2O_2 + 12ml HNO_3 + 3ml HF.

The transformation temperatures of the martensitic transformation were determined from cooling/heating curves registered using the Perkin-Elmer Differential Scanning Calorimeter (DSC).

The pole figures were recorded on Philips PW1130 diffractometer with a texture goniometer only by reflection mode to the maximum tilting angle 80^0. The Shulz formula was applied for correction of the pole figures intensities.

Shape recovery was studied by the means of elongation versus temperature changes under constant tensile load.

3. RESULTS AND DISCUSSION

3.1. Microstructure

The microstructure of the twin roll cast strip is shown in Figure 1. In the twin roll casting technique, the crystallization front proceeds from both sides simultaneously forming two parts joined by an interface. The interface on the cross-section, remains a straight line separating two symmetrical part of the strip (Figure 1a). The zones which were in direct contact with the

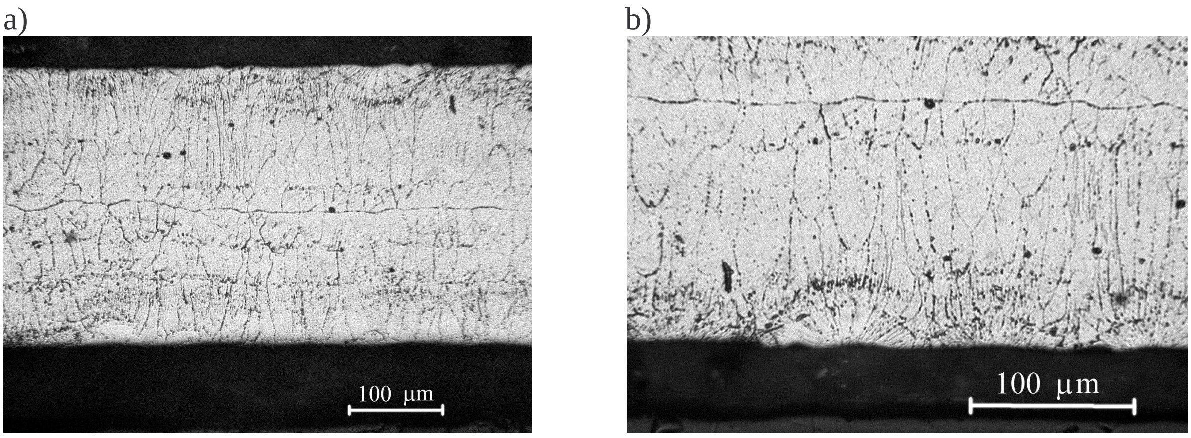

Figure 1. Microstructure of the twin roll cast strip.

rotating wheels reveal shorter grains under which the columnar grains were extending to the centre of the strip. It is due to the cooling rate which is the highest at the place where the melt contacts the wheel surface.

3.2. Transformation behaviour

Preliminary studies of the martensitic transformation were carried out by the DSC measurements. The DSC cooling/heating curves were registered with the rates of 10 deg/min. Only one thermal peak was observed both on a cooling and a heating curve. The transformation temperatures (Table 2) were determined using a slope line extension method.

Table 2.
Transformation temperatures of the strip

Material	Martensite start temp. M_s [^{0}C]	Peak temp. on cooling M_p [^{0}C]	Martensite finish temp. M_f [^{0}C]	Austenite start temp. A_s [^{0}C]	Peak temp. on heating A_p [^{0}C]	Austenite finish temp. A_f [^{0}C]
Strip A	-70.0	-78.4	-88.5	-33.1	-24.3	-18.9

Relatively large hysteresis loop, calculated as a difference between M_p and A_p (almost 54 degrees), and lack of irregularities on the DSC curves suggest that the parent phase B2 transforms directly to the monoclinic martensite B19'. Moreover, a regular shape of the thermal peaks confirms that the chemical composition of the strip is homogenous.

3.3. Texture

For texture analysis, the pole figures for {001}, {011} and {112} parent phase planes were registered. Samples for the pole figure measurements were fixed in a holder in such a way that the RD direction at a pole figure corresponds to the wheel rotation direction. From the obtained pole figure data the orientation distribution function (ODF) was calculated. The pole figure for the as-cast strip reveals pole density concentration around a ring of <001> orientation as well as clustering around the orientation of the {001}<100> sheet texture component (Figure 2). The texture of the studied strip is relatively strong. Maximum of the pole density reaches fourteen levels for the {011} pole figures, whereas for {001} pole figure

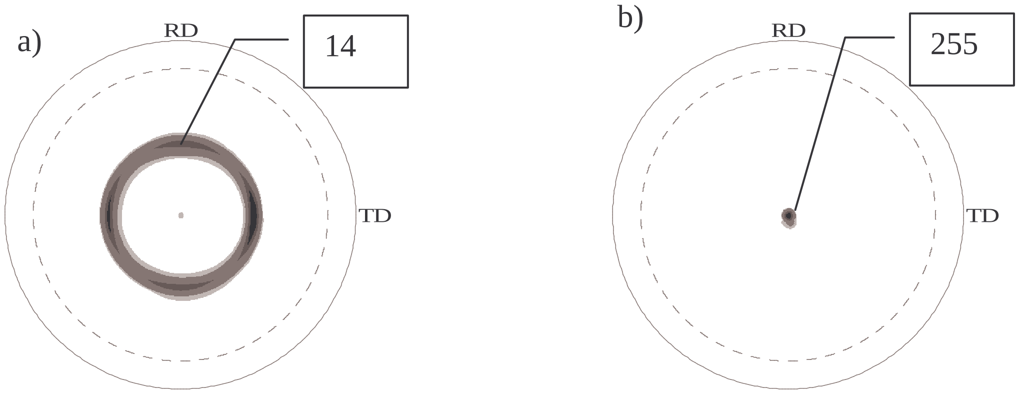

Figure 2. Pole figures registered for strip: {011} (*a*) and {001} (*b*).

it exceeds 255 levels. It is worth to point out, that despite of a relatively high cooling rate almost 66% of the grains were oriented along the fibre <001> texture component and 18%

with {001}<100> sheet texture component. It means that less than 16% of the grains were randomly oriented.

3.4. Shape recovery

Shape memory recovery was studied by means of elongation measurements under constant tensile stress. A completed hysteresis loop of the shape recovery was registered in the temperature range between M_f - 40^0 and A_f + 40^0. Then the tensile load was increased of 10 MPa and a next hysteresis was obtained. This procedure was repeated until plastic deformation appeared (80MPa). The stress was applied along the ribbons. Figure 3 shows results of a shape memory recovery registered for the studied strip.

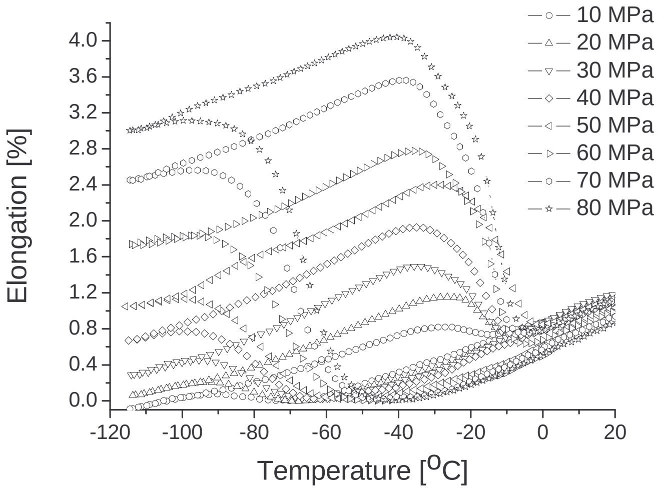

Figure 3. Shape recovery under constant tensile stress

In shape memory NiTi alloys the transformation from B2 parent phase to B19' monoclinic martensite occurs by a short-distance atom movement in every second {110} plane in the <110> direction followed by the monoclinic distortion. Despite the fact, that the texture component {001}<100> does not support the martensitic transformation, the maximal elongation has reached 3.5% under constant tensile load of 70 MPa. It seems to be a good result if one considers general fact that the twin roll cast strip reveals poorer mechanical properties than the bulk due to the higher concentration of macroscopic defects.

4. CONCLUSIONS

- The NiTi twin roll cast strip reveals reversible martensitic transformation B2↔B19' and shape recovery.
- The high cooling rate used during the solidification results in formation of texture with fibre <001> and sheet {001}<100> components.

REFERENCES

1. K. Otsuka, C .M. Wayman, Shape Memory Materials, Cambridge University Press, Cambridge, United Kingdom, 1998.
2. M. Yun, S. Lokyer, J.D. Hunt, Twin roll casting of aluminium alloys, Materials Science & Engineering, A280, pp. 116-123, 2000.