CREEP AND THERMAL FATIGUE OF ALUMINIUM MATRIX COMPOSITE WIRES

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Summary

The aim of the work is to study the strain induced martensite in austenitic stainless steel (type 304L). Magnetic and hardness measurements have been made to characterize the effect of cold work (rolling and compression) at different temperatures. The effect of heat treatment was also studied. The applied Barkhausen noise measuring method and the ferrite tester were used to determine the amount of α'-martensite. Moreover saturation induction measurement was done to obtain the coercivity of the material.

1 INTRODUCTION

Martensite may form in austenitic stainless steels during cooling below room temperature (i.e., thermally) or in response to cold work (i.e., mechanically)[3]. Two types of martensite can form spontaneously: hexagonal close-packed (HCP) ε-martensite and α'-martensite. The ε-martensite forms on close-packed (111) planes in the austenite and the α'-martensite forms as plates with (225) habit planes n groups bounded by faulted sheets of austenite on (111) planes [4,5].

Deformation induced or strain induced martensite formation is an unique feature of austenitic stainless steels. Strain induced martensite forms at higher temperatures than does martensite, which forms on cooling. The quantity of α'-martensite formed depends on the composition (carbon and nitrogen have a strong effect on austenite stability), degree and rate of deformation and the temperature. [1] The mechanical behaviour during cold working may be described in the following way [1]:

- Normal dislocation glide in alloys with high stacking fault energy
- Planar glide of dissociated dislocation in grades with low stacking fault energy, leading to: HCP ε phase ($T<M_{d30}$), mechanical twins ($T> M_{d30}$), α': $\gamma \rightarrow \varepsilon \rightarrow \alpha'$ or $\gamma \rightarrow \alpha'$

The reverse transformation of ε phase occurs between 150 and 400°C which is followed by the reversion of α' above 400°C [1]. Both the α'- and the ε-phase transform directly into austenitic structure. All austenitic steels are paramagnetic in the annealed, fully austenitic condition. The ε-martensite is paramagnetic in contrast to bcc α' which is strongly magnetic and the only phase in the low carbon austenitic steels [7,8]. Therefore, the cold worked austenitic steel have detectable magnetic properties which can be eliminated by annealing.

2 EXPERIMENTAL

In the present work the appearance of α’ martensite were investigated after cold work and the disappearance of these phase was studied after annealing. The composition of the 304 L austenitic steel is given in table 1.

Fe	C	Mn	P	S	Si	Cr	Ni
Balance	0.030	2.00	0.045	0.030	1.00	19,2	9.40

Table 1. Chemical composition of the austenitic steel used in this work (in mass %).

The original shape of the specimen was a bar in which specimen of the following dimensions were cut: length 60 mm, thickness 7.5 and width 20. These specimen were annealed at 1070°C during 30 min and then water quenched because martensite was present in the original specimen.

The applied measuring methods:

- Vickers Hardness was measured with a load of 10 kg.
- The Barkhausen noise was investigated by using sinusoidal (10 Hz) exciting magnetic field produced by a function generator and a power amplifier. The applied measuring head contains a « U » shaped magnetizing coil and a pick-up coil, which is perpendicular to the surface of the specimen. The signal of the pick up coil was processed by a 1.2 kHz-38 kHz band pass filter and amplified with a gain of 20. KRENZ TRB 4000 computer controlled signal analysing device was used for processing the noise. The Root Mean Square (RMS) value of the noise was used to characterize the microstructural change (appearance of α’ martensite). The applied magnetizing field strength corresponds to the irreversible domain wall displacement of the hysteresis loop.
- Ferrite tester was used to determine the amount of ferromagnetic phase (α’ martensite) and then the percentage of martensite was plot versus the RMS. This plot shows that there is linearity behaviour between RMS and the percentage of ferrite. (annexe fig 1.).
- The coercive force (Hc) of the ferromagnetic α’ phase was measured.
- X-ray diffraction was used to detect the epsilon phase and to determine the amount odd each phase.

3 RESULTS AND DISCUSSION

The specimens were rolled at room temperature up to about 70 %. The figure 1 shows the variation of the RMS and the hardness in function of the deformation. The hardness increases nearly linearly with the elongation. The RMS value increases also with increasing deformation.

Specimens were rolled at different temperatures (liquid nitrogen and dry ice) and at several rate of deformation. The figures 2 and 3 both show that the hardness and the RMS increase when the temperature decrease. So the percentage of martensite increases at lower temperature. In fact, with decreasing the temperature the critical resolved shear stress for slip, i.e., the resistance to slip increases, whereas the resistance to martensite formation decreases. Above a certain temperature the resistance to slip is less than the resistance to martensite formation and therefore slip is the dominating process of deformation [6].

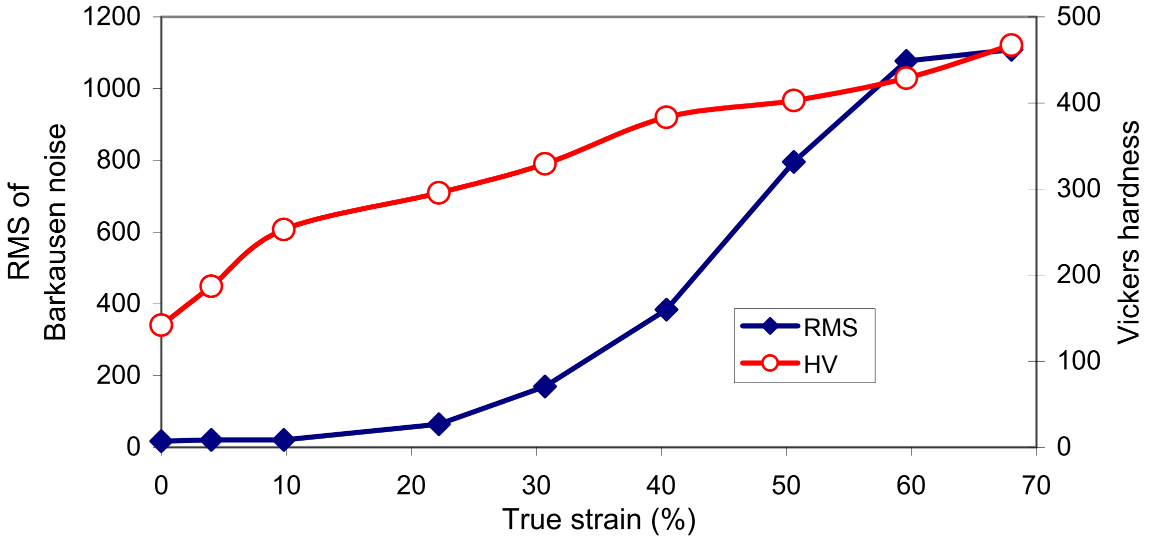

Figure 1. RMS and Hardness in function of the amount of deformation

The magnetic properties of the strain induced α’ martensite phase has been determined. The coercive force of the specimen at a same rate of deformation was measured (table 2) and it can be concluded that the structure of the martensite is different when cold working is done at various temperatures. X- ray spectrometry was done on two samples but due to a strong texture the percentage of phase found is not correct (the lack of precision was evaluated at 20%). Nevertheless, a really small amount epsilon phase (0.20%) was detectable for the specimen rolled at 25% in liquid nitrogen but not for the specimen rolled at 50% at room temperature.

	T = 20°C	T = -96°C	T = -196°C
Hc (A/cm)	120	38	29.5

Table 2: Coercivity at 50% of deformation

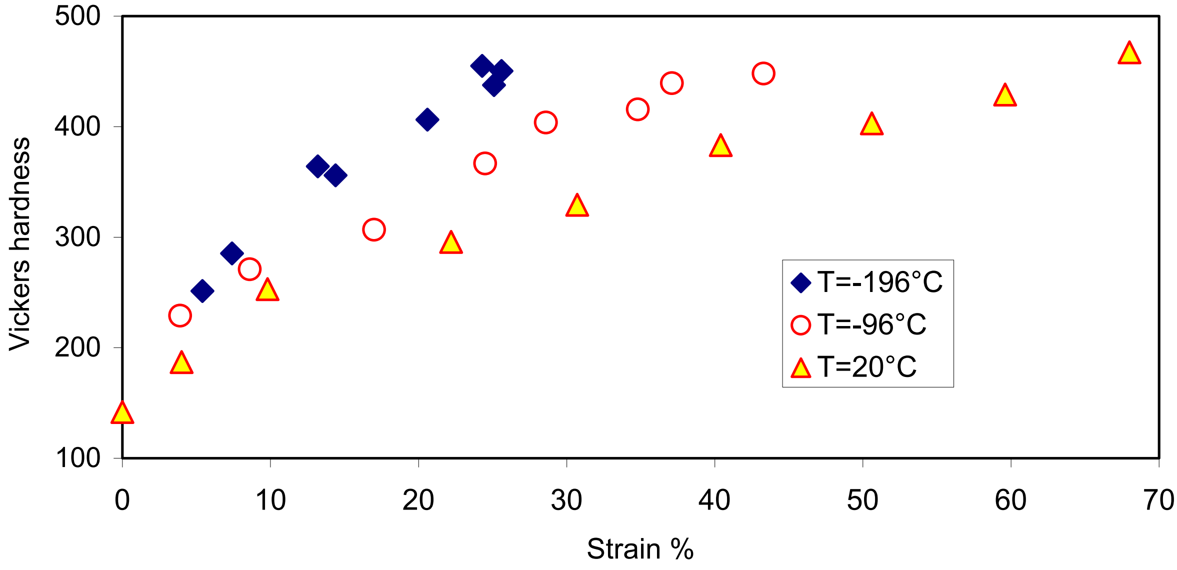

Fig. 2. Dependence of the Vickers hardness on the temperature and on the rate of deformation

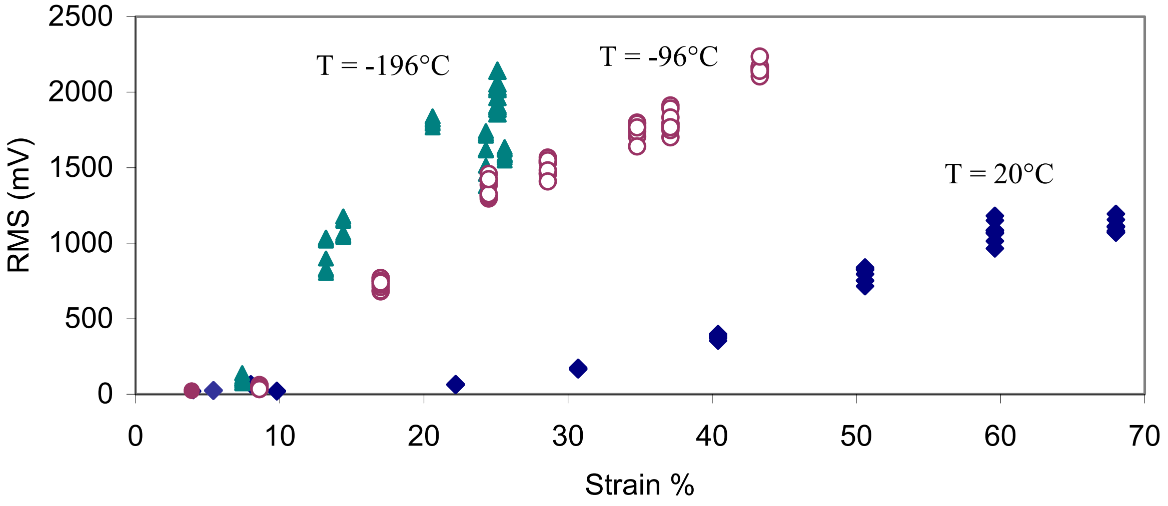

Figure 3. Dependence of RMS on the temperature and on the rate of deformation

The specimens were uniformly rolled at room temperature to the strain 50%. Then they were heat treated between 100°C and 1000°C for 30min. The hardness was measured and ferrite tester was used to determine the amount of martensite (it was supposed that the amount of martensite is about the same of the value given by the ferrite tester).

Fig.4 shows the variation in the percentage of martensite and hardness as a function of the heat treatment temperature. The hardness begins decreasing at 600°C and it will reach the annealed value at 1000°C whereas the amount of martensite begins decreasing at 500°C and it reaches zero at 800°C.

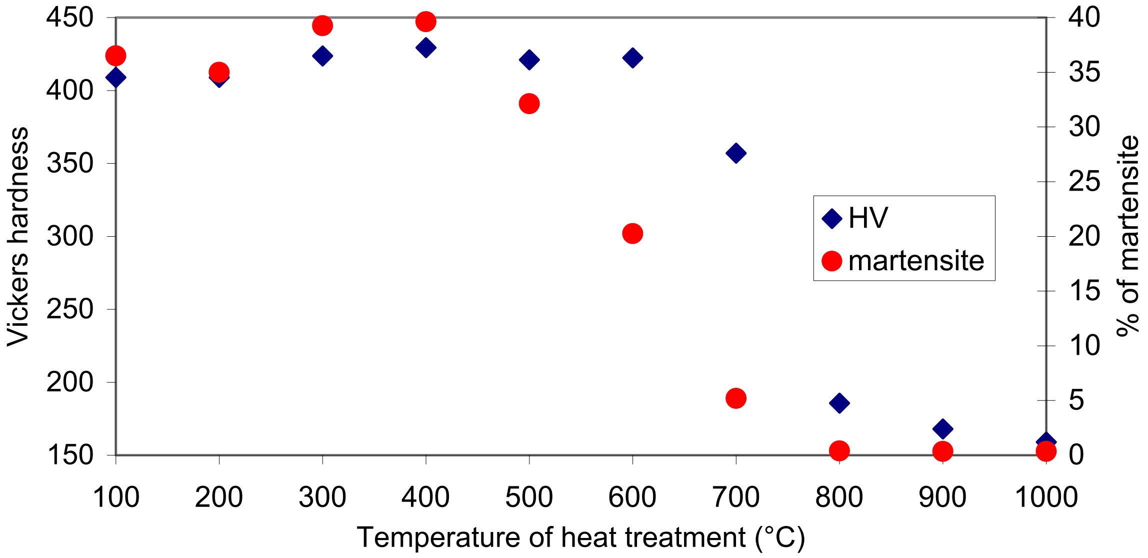

Figure 4. Influence of heat treatment on hardness and the percentage of α’ martensite

The specimens were deformed by compression up to about 50% at room temperature. The hardness was measured and ferrite tester was used to determine the amount of martensite (it was supposed that the amount of martensite is about the same of the value given by the ferrite tester). Thanks to the figures 5 and 6, it can be concluded that the mode deformation (rolling or compression) has no effect on the martensitic transformation at room temperature.

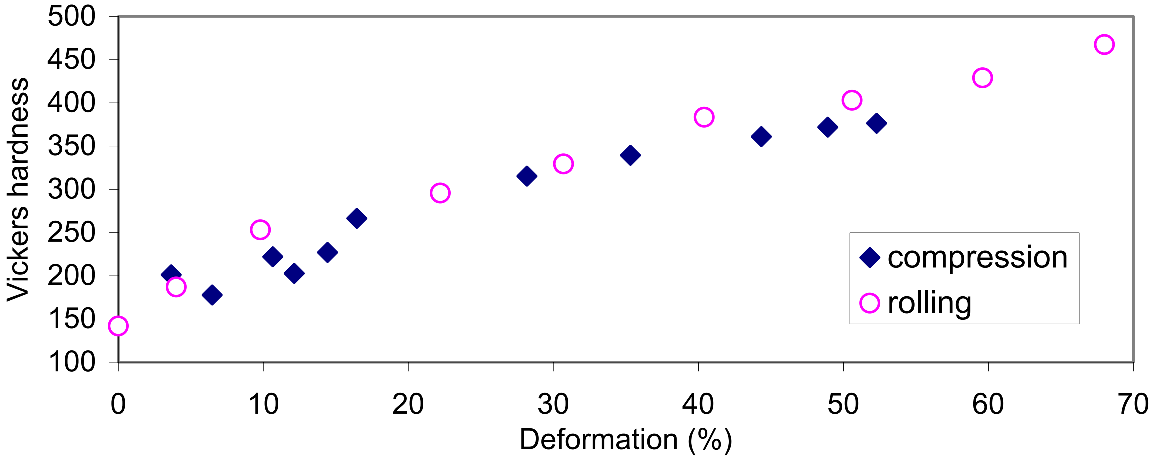

Figure 5. Effect of the mode of deformation on the hardness

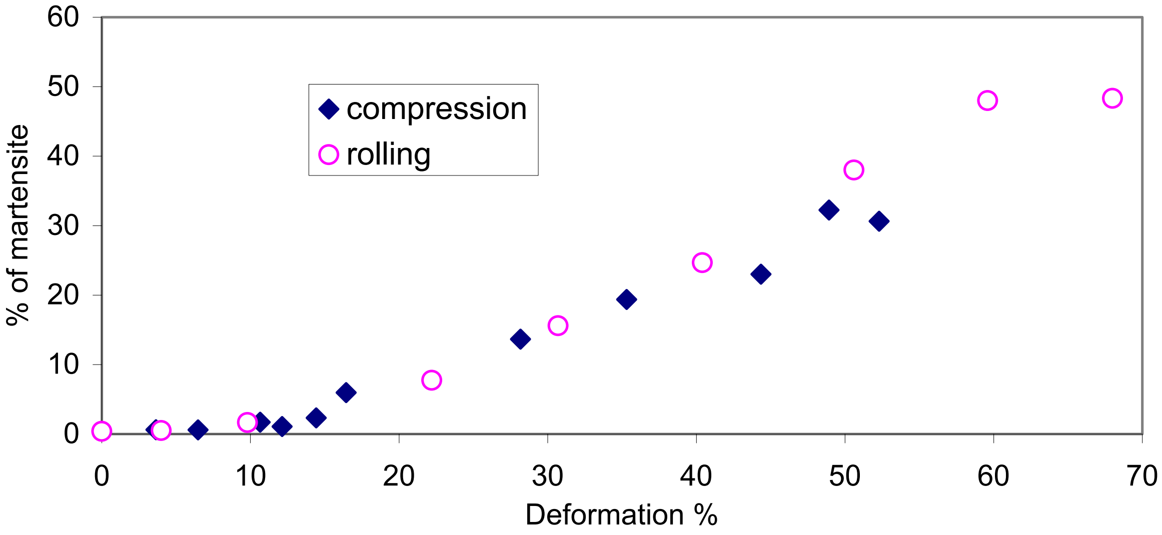

Figure 6. Effect of the mode of deformation on the percentage of martensite

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