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Influence of Heat Treatment and Niobium Content on the Magnetic Properties and Austenite Formation in Maraging 300 Steels

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Introduction

- 18%Ni maraging 300 steels exhibit high mechanical strength achieved through martensitic transformation and precipitation hardening (FLOREEN, 1968);
- Elements such as Ti and Mo form strengthening precipitates(VISWANATHAN; DEY; SETHUMADHAVAN, 2005);
- The partial or complete substitution of Ti with Nb aims to improve mechanical properties and reduce alloy costs (SINHA et al., 1995).

Objectives

This study aims to evaluate the influence of progressive titanium substitution by niobium (0.02, 0.64, and 1.40 wt.%) and different heat treatment conditions, solution annealing at 910 °C and 1100 °C followed by aging from 440 °C to 650 °C, on the saturation magnetization (M_s) and coercive field (H_c) of Maraging 300 steel, in order to indirectly quantify the reverted austenite volume fraction (f_γ) and correlate magnetic hardening with precipitation and phase transformation kinetics.

Methodology

Table 1 - Studied Compositions:

Alloy	Ti (wt%)	Nb (wt%)
A	0.76	0.00
B	0.39	0.64
C	0.00	1.40

Table 2 – Applied Heat Treatments

Treatment Step	Conditions
Solution Treatment	910 °C and 1100 °C for 1 hour, followed by air cooling
Aging	440 °C, 480 °C, 510 °C, 560 °C, 600 °C, and 650 °C for 1, 3, or 4 hours

Magnetic Characterization:

The magnetic characterization of the samples was carried out using a Vibrating Sample Magnetometer (VSM), model Lake Shore 665, located at INMETRO. The analyzed samples were disk-shaped, with a diameter of 3.5 mm and a thickness ranging from 0.1 to 0.5 mm. Measurements were performed with an applied magnetic field of up to 1.5 T. The main magnetic parameters obtained were the saturation magnetization (Ms), which represents the maximum magnetization value reached by the material under a sufficiently strong magnetic field, and the coercive force (Hc), which indicates the material's resistance to demagnetization after magnetic saturation.

Figure 1: VSM Lake Shore, Model 665 – INMETRO

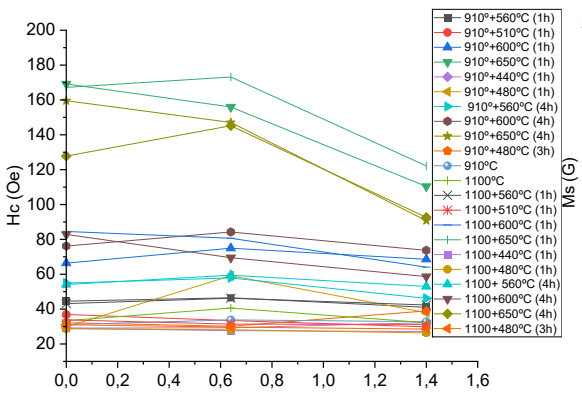
Figure 2: Sample prepared for VSM, disk-shaped

X-Ray Diffraction Analysis:

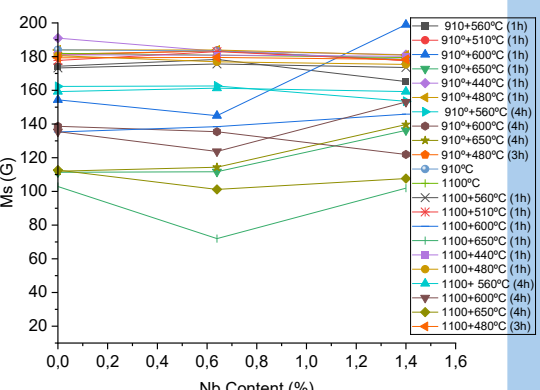
The quantification of the austenite phase fraction was carried out using X-ray diffraction (XRD). This technique allowed the identification and estimation of retained or reverted austenite in the heat-treated samples, complementing the magnetic characterization results.

Results and Discussion

Coercive Force (Oe) vs. Nb Content (%)

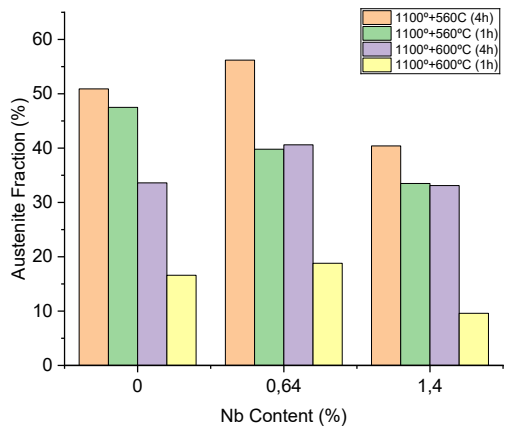


Saturation Magnetization (G) vs. Nb Content (%)



Influence of Nb and aging on coercive force (Hc)

- Hc increases significantly with aging at 650 °C for alloys containing 0.64% Nb;
- The alloy with 1.4% Nb showed reduced Hc values even after aging at 650 °C, indicating that higher Nb content inhibits austenite formation, thus limiting magnetic hardening.



Variation of saturation magnetization (Ms)

- Ms tends to increase after aging at higher temperatures, reflecting the progressive formation of austenite;
In the 600 °C – 650 °C range, the austenite formed may transform into fresh martensite.
- Higher austenite fraction in alloys aged at 560 °C and lower austenite fraction in alloys aged at 600 °C;

- Reduction of austenite fraction in alloys containing 1.4% Nb.

- **Alloy 1 (0.64%Nb)** exhibited the highest (Ms), indicating a predominantly martensitic structure preserved by milder heat treatment conditions;
- **Alloy 2 (1.4%Nb)** showed the lowest Ms, associated with a higher amount of reverted austenite, promoted by the higher solution and aging temperatures.

Nb additions reduced M_s in solution treated samples. Raising the solution temperature from 910 °C to 1100 °C dissolved precipitates and lowered Ms in the 0% and 0.64% Nb alloys (FLOREEN, 1968), whereas 1.4% Nb inhibited dissolution and kept Ms unchanged (SINHA et al., 1995). While aging at 480 °C/1 h caused minor changes, treatments from 560 °C to 650 °C progressively reduced M_s (VISWANATHAN; DEY; SETHUMADHAVAN, 2005) and increased Hc (AHMED et al., 1996) due to reverted austenite formation.

Conclusions

- The addition of Nb affects magnetic behavior: 0.64% Nb promotes magnetic hardening, while 1.4% Nb inhibits austenite formation, reducing both Hc and Ms evolution with aging;
- Saturation magnetization (Ms) decreases with increasing aging temperature, mainly due to austenite formation;
- The reversion of austenite occurred from 560ºC;
- Nb acts by inhibiting austenite formation.

References e Acknowledgements

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