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Mechanism of austenitic transformation in the martensitic stainless steel of type PH 15-5

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Abstract : By dilatometric analysis and TEM experiments, the martensite (M)→austenite (γ) transformation and the formation of the precipitates in PH 15-5 alloy were studied between 20 and 1050°C, using heating rate (R_h), and cooling rate (R_c) = 300°C.h⁻¹. For this heating rate the M→ γ transformation develops in two steps. Detailed analysis of the diffusion processes controlling the two stages of the austenite transformation, was carried out, using cumulated thermal cycles between 600 and 1050°C.

I. INTRODUCTION

Martensitic stainless alloys are widely used in the aeronautic and nuclear industries. These alloys contain a small amount of carbon (0.05 % in weight) in order to avoid the formation of carbides or carbonitrides.

Some authors [1], [2], [3] have studied the austenite transformation of martensitic steels of type maraging (Fe Ni Co Mo and Fe Mn Co Mo) according to the heating rate. In these types of alloys they pointed out that the austenite transformation proceeds in two steps if the heating rate is kept moderate (300°C.h⁻¹).

In this work, we studied such phenomena in a martensitic steel of type PH 15-5 with the following chemical composition (in weight %): Balance Fe- 14.8 Cr - 4.87 Ni - 3.10 Cu - 0.75 Mn - 0.30 Nb - 0.28 Si and 0.041 C.

Furthermore, in this study we were able to determine the temperature ranges at which the formation of hardening precipitates (based on Cu) took place in the matrix.

II. RESULTS AND DISCUSSION

The interpretation of this transformation mechanism M→ γ at 300°C.h⁻¹ is based on diffusion processes.

Following this argumentation, we are going to present the mechanism of austenitic transformation in the case described below, i.e. the nominal chemical composition Co and an initial uniform martensitic structure at room temperature (Figure 1):

-during the heating process (300°C.h⁻¹) at a temperature below 442°C, Figure 2, the formation of clusters (Cu) leads to the new composition C_{Mp} of a new martensitic phase, impoverished in elements like Cu and Ni (called M_p).

-between 442°C and 530°C a part of the formed clusters which are not already transformed into stable embryos leading to the formation of precipitates enriched in copper [4], dissolves in the martensitic matrix, leading to an enriched martensitic M_r of composition $C_{Mr} > C_o$ [3].

Figure 1 : Bright field micrograph showing initial uniform martensitic structure at room temperature.

Figure 2 : — Dilatometric curves of PH 15-5 alloy ($R_h = R_c = 300^{\circ}\text{C} \cdot \text{h}^{-1}$).
---- Derivative curve.

The other particles are transformed into stable embryos, the embryos of the precipitates. After a certain growth time the latter show a crystalline structure of the f.c.c. structure [5], called (A) , Figure 3a.

Figure 3 : (a) Alloy aged at 500°C for 64 h ; dark field micrograph showing A type precipitates. The precipitates exhibit a double lobe strain field contrast or a striated contrast.
(b) Alloy aged at 650°C for 64 h ; bright field micrograph showing B type precipitates as rods.
(c) Alloy aged at 700°C for 16 h ; dark field micrograph recorded on C type precipitates.
(d) Alloy aged at 750°C for 64 h ; dark field micrograph recorded on B type precipitates.

At the beginning of the first step of the austenitic transformation, the following processes take place successively :

- formation of an enriched austenite γ_{IT} with the elements of the alloy, in particular the Cu and Ni during the reaction; $M_T \rightarrow M_{TP} + \gamma_{IT}$ [6], accompanied by a decrease of these elements in the neighbouring martensitic zones(Mp).

The diffusion processes are involved in the first step of the austenitic transformation and could be detected as follows :

The obtained Ms values (during the final cooling process) vary as a function of the beginning of the transformation in the heating step; the formed austenite is completely stable at room temperature because no Ms point is observed for $\theta > 20^{\circ}\text{C}$ on the dilatometric curves.

When we increased the maximal temperature reached θ_{Max} (in the heating process), Figure 4 a, b, the corresponding temperatures of the Ms values in the cooling process increased progressively in the same way, Figure 4 c.

Figure 4 : — (a and b) dilatometric curves of PH 15-5 alloy recorded up to various temperatures between 600 and 950°C ($R_h = R_c = 300^\circ\text{C} \cdot \text{h}^{-1}$), --- derivative curves.

(c) Ms values as a function of the maximal temperature reached θ_{Max} .

These results can be interpreted by a progressive impoverishment in alloying elements of the retained austenite (γ_{tr}), in particular in copper and in nickel up to the point where the nominal composition Co is found again.

In the range $600 < \theta_{\text{Max}} < 700^\circ\text{C}$, other processes are superimposed on the formation of the retained austenite :

- on the one hand, the ripening of the first type of precipitates formed takes place before the point A_{cd} (called (B)) Figure 3b.
- on the other hand, the formation of a second type of precipitates (called (C)) with f.c.c. symmetry, is observed [5], as is shown in Figure 3c. The dissolution of precipitates B between 650 and 690°C also takes place.

In the θ_{Max} range between 725 and 800°C , two processes proceed simultaneously :

- the impoverished martensite (M_{rp}) is transformed into a more and more impoverished austenite according to the reaction :

M_{rpp} of concentration $C_{\text{rpp}} < C_{\text{rp}}$ (the concentration of M_{rp}).

γ_{rpr} : austenite more and more impoverished.

During the final cooling process this leads to M_s values higher than M_{s_0} .

- the coalescence of the precipitates (C) $\rightarrow$ precipitates (D), Figure 3d.

At temperatures above 800°C the precipitates (D) dissolve in the austenite matrix γ_{rpr} , which enriches this phase slightly in copper and in nickel. Consequently, during the final cooling process, the transformation values M_s approach progressively M_{s_0} , Figure 4c.

Between 930 and 1015°C , Figure 2, the second step of the austenite transformation takes place according to the reaction $M_p \rightarrow \gamma_p$ (probably a diffusion process of type $M_p \rightarrow M_{\text{pr}} + \gamma_{\text{pr}}$).

III. CONCLUSION

The results obtained by dilatometric study of the transformation mechanisms in the alloy PH 15-5 are summarized as follows.

The transformation $M \rightarrow \gamma$ proceeds in two successive steps, for a moderate heating rate (300°C.h^{-1}) :

-the first step is controlled by diffusion processes whereas the second one is related to the transformation as follows : impoverished martensite (M_p) $\rightarrow$ impoverished austenite (γ) .

-the temperatures of the transformation points A_{cd} et M_s respectively vary with the maximal temperature reached during the heating process (in particular in the intercritical domain).

The martensitic transformation $\gamma \rightarrow M$ is a one step process accompanied by an expansion. The expansion amplitude is considerable if the alloy is homogenized at a temperature above A_{cf_0} (1015°C).

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REFERENCES

- [1] W.A. Peterson, Welding J. 43, 428 (1964).
- [2] C. SERVANT, Thèse de Doctorat-ès-Sciences Physiques Université de Paris-Sud (1972).
- [3] N. BOUZID, Thèse de Doctorat en Science Université de Paris Sud (1987).
- [4] H.R.HABIBI BAJGUIRANI, R.MOLINS, C.SERVANT, J.L.STRUDEL, G. CIZERON, (1993) to be published.
- [5] H.R.HABIBI BAJGUIRANI, C.SERVANT, G.CIZERON. Acta Metall. Mater, vol.41, No.5, pp.1613-1623, (1993).
- [6] N. BOUZID, C. SERVANT and G. CIZERON. Acta Metall, Vol 36, No. 6, pp. 1527-1536, (1988).