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Damage and failure processes in structural 347H SS materials

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ABSTRACT

The relationship between microstructure and high temperature strength of 347H SS welded joints was investigated. The materials studied correspond to two preheated furnaces of the petrochemical industry, working at 700 °C and 45 atm (called furnaces A and B). Furnace A presented failures, hot fissure in the Heated Affected Zone, after 60 h operation, whereas furnace B operated for 70000 h. The microstructure research was made by a non conventional replica technique [1], which allowed more accuracy in the nature, quantity, morphology and distribution of the different phases. The probable cause of the remarkable different behaviour of the two materials, although both fulfil the A213/TB/347 H, ASTM standard requirements, has been discussed taking into account the chemical composition of the steels, matrix characteristics, nature of the inclusions, carbides, intermetallic particles and N/Mn, Al/N, C/Nb relationships.

INTRODUCTION

The stress, time, temperature and environment change the metallurgical structure during service, same type of steels but from different heats, will present different structural changes. These structural changes are especially referred to as metallurgical instability such as: recrystallization, carbides, borides, nitrides, intermetallic phases precipitation, delay transformation to equilibrium phase. The structural change influences all type of failures. The accuracy in the prediction of the rupture life depends on a careful study during inspection service of the metallurgical instabilities. It is possible to perform it by the method suggested.

EXPERIMENTAL

347H SS specimens were used with the chemical composition shown in Table I.

Steel type	C	S	Si	Mn	Nb	Ti	Cr
Furnace A	0.0676 ± 0.0002	0.0117 ± 0.03	0.30 ± 0.03	0.38 ± 0.02	0.63 ± 0.02	< 0.1	18.1 ± 0.1
Furnace B	0.0714 ± 0.0002	0.0030 ± 0.0002	0.51 ± 0.003	0.88 ± 0.02	0.60 ± 0.02	-	18.8 ± 0.1
Furnace A	Ca	B (µg/g)	Cu	O	Ni	Al	
	0.0685 ± 0.0004	3 ± 1	0.24 ± 0.02	0.008	9.3 ± 0.1	<0.02 (solub.)	
Furnace B	0.0320 ± 0.0004	2 ± 1	-	0.003	9.5 ± 0.1	<0.02 (solub.)	

Table I. Compositional analysis (Wt %).

Characterization of inclusions, carbides and nitrides:

The size, distribution, morphology, shape and number of particles were studied by conventional light microscopy and scanning electron microscopy (SEM). An unconventional technique (nct) was used to study the chemical composition of the phases that composed the precipitates (1). This is possible only if the inclusions are extracted from the matrix. With this

technique the inclusions, carbides, etc. in the steel were extracted by means of an epoxy organic compound film. The steel surface was previously etched with Br/CH₃OH solution, so that the inclusions were in relief and then covered by an organic film. The particles were then extracted and the microstructure replicated. The conductivity of the sample was obtained by metallic deposition on the precipitate and the phases that composed it were studied by energy-dispersive X ray analysis (EDAX) associated with SEM. The same formalism as the used for thin foil was applied.

RESULTS AND DISCUSSIONS

The most important characteristics of the materials A and B are shown in Table II.

	Furnace A	Furnace B
Grain size (ASTM)	3-8	5-6
Nature inclusion	MnS.Al ₂ O ₃ , 10-100 (μm)	Cr-Galaxite, 1-5(μm)
Inclusion number per metric ton	1.3 x 10 ⁹	1.2 x 10 ¹¹
Localization	at grain boundaries	homogeneous
δ ferrite content (%)	10	5
N in solid solution (% in weight)	0.02	0.13
Mn (% in weight)	completely oxidized	1.5 in solid solution 0.3 as MnO

Table II: Principal characteristics of A and B materials.

Material A:

It shows big alumina inclusions. Cr-Galaxite inclusions in eutectic sulphide matrix formed at grain boundaries (Fig. 1). Besides, within grain boundaries M₆C carbide were observed (Fig. 2). The δ ferrite level is about 10 to 13 %. This high value is related to elements content promotes δ ferrite. The Cu content is approximately 0.2 %. This element is not considered in standard requirements. However, ferrite and σ phase are interrelated, precipitation of δ ferrite ultimately promotes formation of σ at elevated temperatures in austenitic high temperature alloys. The nature, amount, site and shape of the inclusions, carbides and intermetallic phase precipitation determine whether different particles precipitations have some effect on decreased rupture life. Frequently, inclusions, carbides and topologically close/packed (TCP) phases do not act independently, but in this material, the sulphide inclusions were the most deleterious effect on rupture life that produced failure (hot fissure) in the Heated Affected Zone.

Material B:

The material B, before service, presents homogeneous precipitation, carbides, inclusions, nitrides, etc. Fig. 3 shows an austenitic grain boundary free of phase precipitations. Fig. 4 shows a microstructure by (ncr) technique of the furnace B after 70.000 h of service. High NbC precipitate level within and grain boundary was observed. The size is about 5 to 8 μm. Few particles of AlN are present in grain boundary. The manganese content in solid solution is higher than in material B. Perhaps, a convenient ratio to create Mn/N clusters is present, which increases rupture life.

Fig. 1: SEM micrograph showing a big inclusion at grain boundaries in material A. Inclusion type: 34 MnO, 66 Cr₂O₃ in MnS matrix. The specimen was etched with Br/CH₃OH solution.

Fig. 2: SEM micrograph showing (FeCr)₃Nb₃C carbide at grain boundary. Material A etched with oxalic acid.

Fig. 3: SEM micrograph showing the initial microstructure of furnace B. Etched with Br/CH₃OH solution. Small inclusions Cr-galaxite within grain. The grain boundary is free of carbide precipitate.

Fig. 4: SEM micrograph showing the microstructure after 70.000 h operation of furnace B, by (nrt) after 70.000 h in service.

100 μm

CONCLUSIONS

1. Even if the material fulfills the specifications requirements, the life of the component in service cannot be accurately foreseen. The steel quality is an important variable.
2. Residual life greatly depends on the steel quality. "Quality" is only partially defined by specifications.
3. The cost of first quality steels is not relevant when compared to the economical benefits derived from extended component life.

REFERENCES

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