STUDY OF INCOLOY 800HT ALLOY TESTED BY HEAT-CYCLING

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ABSTRACT

This paper investigated Incoloy 800HT (UNS N08811) alloy after some heat-cycling tests. The study continues prior tests realized in INR Piteşti concerning utilization of some nickel-based alloys in the heat exchangers and steam generators construction. The thermal-cycling consist in a successive series of heating and cooling with some rates in a range temperature. Technical parameters of thermal cycling: 50 & 200 cycles, 25 C°/minute heating-cooling rate, temperature range 450-1000°C, and argon working medium. The analysis consisted in metallographic examination (microstructure), Vickers microhardness, and traction tests. The average grain size was determined by linear interception method (ASTM E-112). The micro hardness was calculated by the relationship of the device technical book. On the Strength-Deformation diagrams were obtained: tensile strength and elongation. The tested samples were compared with the „as received" material. The results showed a good metallographic and mechanical behaviour of Incoloy 800HT at these thermal-cycling tests.

Key words: Incoloy 800HT, heat-cycling, microstructure, microhardness, tensile strength

Introduction

Incoloy 800HT is a Ni-Fe-Cr alloy with good strength and excellent resistance to oxidation and carburization in high-temperature exposure. Incoloy 800HT will not become embrittled even after long periods of usage in the 1200-1600°F (640-871°C) range where many stainless steels become brittle. Incoloy 800HT have applications in many domains, such as: ethylene furnace quench boilers, hydrocarbon cracking , valves, fittings and other components exposed to corrosive attack from 1100-1800°F (593-982°C), industrial furnaces , heat-treating equipment, chemical and petrochemical processing, super-heater and re-heaters in power plants, pressure vessels, heat exchangers. [1]
The samples (plates & test-pieces) were manufactured of Incoloy 800HT UNS N08811 (Cold Rolled Sheet; Pickled; Solution Treated; 2.0 Thickness x 1200 Wide x 3000 mm Cut). [2]

Experimental Methods

The experiment consisted in the samples testing by thermal-cycling using some scenarios: heating to 1,000°C, then cooling until 450°C, then heating from 450°C to 1,000°C and so further: 50 cycles (Scenario No. 1) respective 200 cycles (Scenario No. 2), with 25 C˚/minute heating-cooling rates. The testing programme included 2-3 samples per situation.
The samples were investigated by Olympus GX 71 optical microscope, OPL tester in automatic cycle, and Walter Bai traction machine.

Metallographic analysis of samples consisted in the microstructure examination and in the average grain size determination by Heyn linear interception method. [3]
Grain size for „as received" Incoloy 800 HT: average grain size by Inspection Certificate [2] is ASTM No. 3.5 (solution treated), and by ASME SB-409 specification [4] shall conform to an average grain size of ASTM No. 5.0 or coarser (annealed alloy).

Material hardness (Vickers microhardness) was calculated with relationship of technical book of device: $MHV = 1854.4\ F/d^2$, [kgf/mm²]
Where: F -force [gf]; *d* -average diagonal of indentation [µm]; 1854.4 -device coefficient for Vickers microhardness. [5]

Tensile strength was calculating of the traction diagrams, representing unitary strength variation σ [MPa] as a function of deformation ε [%]. The following mechanic characteristics were obtained: tensile strength (R*m*) and elongation (*A*).
In Table 1 were presented the values of tensile strength and elongation for „as received" Incoloy 800 HT, in accordance with the Inspection Certificate [2] and ASME SB-409 [4].

Table 1-Mechanical properties, at 20°C

Material	Reference	Tensile Strength, R*m* [MPa]	Elongation on 50 mm, *A*[%]	Heat treatment & hardness
Incoloy 800HT, as received	[2]	567	43.4	Batch & test pieces: 5M 1200°C AC Batch Hv30: 134/142
	[4]	min. 450	min. 30	Annealed; max. 86 Rockwell B

Results and Discussion

The diagram of Figure 1 reproduces Scenario No.1: 50 cycles.
Scenario No.1: 50 cycles, heating-cooling rate 25°C/minute, temperature range 450-1000°C.
Scenario No. 2: 200 cycles, heating-cooling rate 25°C/minute, temperature range 450-1000°C.

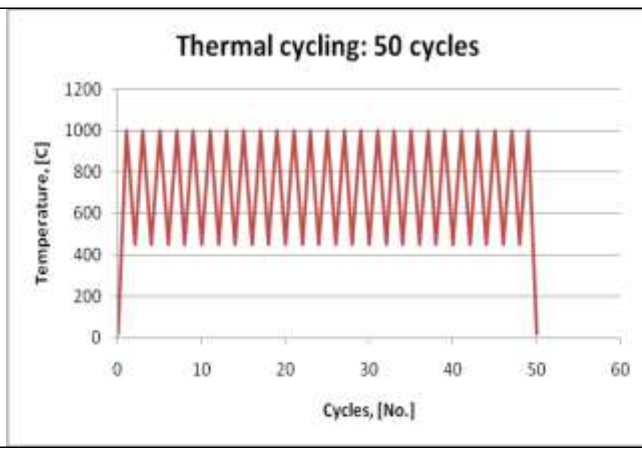

Fig. 1 *Scenario No.1: 50 cycles*

Microstructure

The microstructure was revealed by electrolytic etching with oxalic acid solution (10%), 6.0 V, 20-50 seconds, in cross section (ST).

Initial structure (as-received alloy): Austenite with coarse grains, twin grains and rare carbide particles (black points) present both at the grain boundaries and in the matrix, Figure 2; average grain size: ASTM No. 4.0 to 4.5.

After cycling tests: Austenite with coarse grains, recrystallized grains and carbides uniform distributed present both at the grain boundaries and in the matrix; average grain size for both scenarios (50 & 200cycles) is ASTM No. 4.0 to 4.5 (Figures 3-4).

Note: Grain size conform to [2] ASTM No. 3.5 (106.8 µm), and to [4] ASTM No. 5.0 (63.5 µm) or coarse.

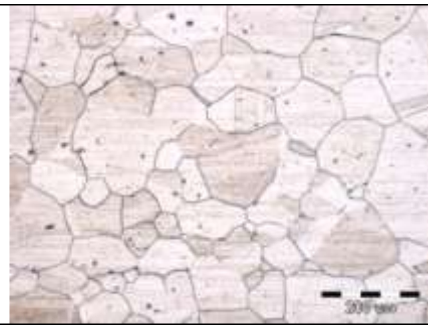

Fig. 2. *Incoloy 800HT - "as received": Austenite & carbides, G=4.0-4.5*

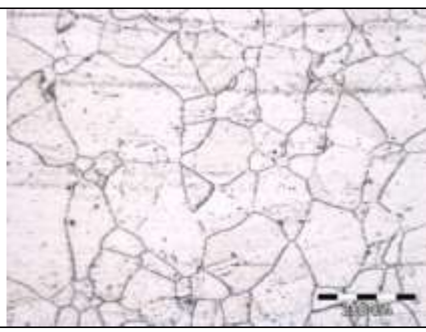

Fig. 3. *Incoloy 800HT - 50 cycles: Austenite & carbides, G=4.0-4.5*

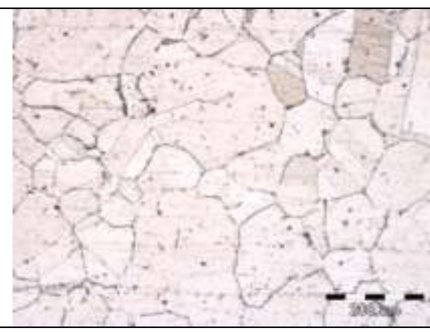

Fig. 4. *Incoloy 800HT - 200 cycles: Austenite & carbides, G=4.0-4.5*

In Figure 5: Average grain size diagram (average diameter, d*m*) depending on thermal-cycling conditions. After cycling tests average grain size is in range of the references.

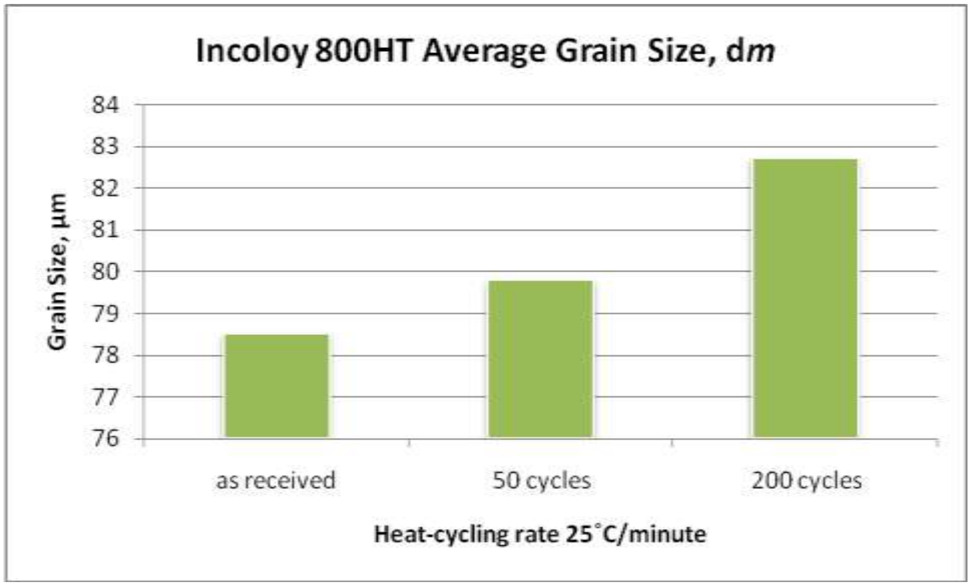

Fig. 5 *Average grain size diagram*

Vickers microhardness

In general, the Vickers microhardness increases 5-6 units comparative with initial material.
In the figure 6: Diagram of Vickers microhardness depending on thermal cycling conditions.
In the figures 7-9: Vickers microhardness MHV0.1 imprints examples.
Note: Vickers hardness conforms to [2] is 134÷142 Hv 30.

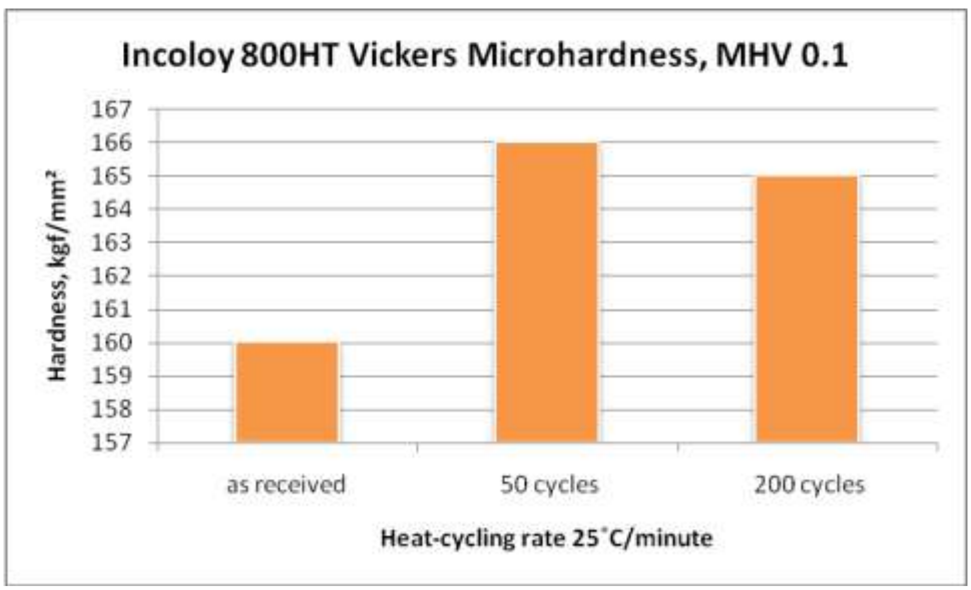

Fig.6 *Vickers microhardness diagram*

The Vickers microhardness increased too little comparative with initial material.

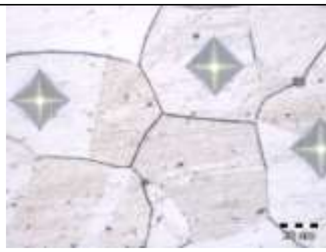	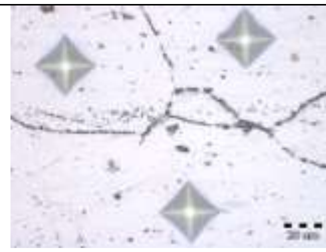	
Fig.7. *Incoloy 800HT “as received”*	**Fig.8.** *Incoloy 800HT: 50 cycles*	**Fig.9.** *Incoloy 800HT: 200 cycles*

Traction tests

In Figures 10-11 were presented the diagrams of some mechanical characteristics determinate before and after heat-cycling tests.

In general, after the cycling tests the tensile strength values maintaining in near of received material (572 MPa), for Scenario 1 increase with 8MPa, and for Scenario 2 decrease 2 MPa. Also, the determined tensile strength was superior to tensile strength of Inspection Certificate of the producer (567 MPa) and ASME SB 409 (min. 450 MPa), showing a good behaviour of this alloy at these cycling tests.

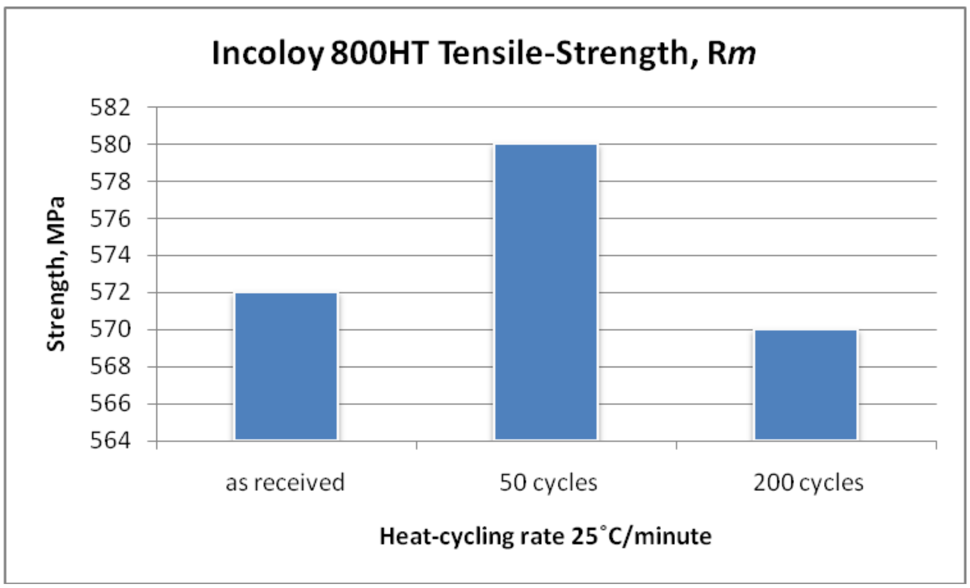

Fig. 10 *Tensile Strength diagram*

Tensile strength after cycling tests is in proximity to as received material, but superior to the references (producer Inspection certificate and ASME SB 409).

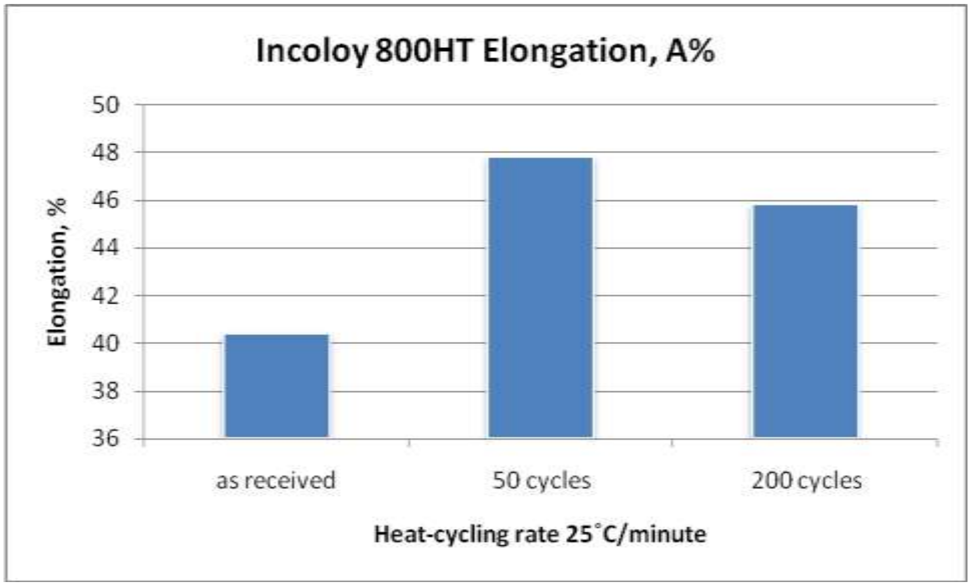

Fig. 11 *Elongation diagram*

Note: Conform to [4] R*m* = 450 MPa, *A*= min. 30%; Conform to [2] R*m* =567 MPa, *A* = 43.4%

Conclusions

Microstructure: Comparatively with as-received alloy (twin-grained austenite and carbides), the structure obtained after the cycling tests consists of a recrystallized-grained austenite with carbide particles present both at the grain boundaries and in the matrix. Also, average grain size is in range of the references and initial grain size.

Vickers microhardness: After the transient tests, small changes in Vickers microhardness occur comparatively with as-received alloy, increasing with 5-6 units.

Traction tests: Comparatively with as-received alloy, small modifications in tensile strength occur after transient tests. Also, elongation is superior to as received material. In all cases the determined tensile strength is superior to tensile strength of the references.
In conclusion, the results show that Incoloy 800HT alloy has a good mechanical and metallographic behaviour at these heat-cycling scenarios.

References

[1] Mega Mex-„Specialty Metals on Demand”-Texas, 2010
[2] Special Metals Wiggin Limited, Holmer Road, Hereford, England HR4 9SL: Inspection Certificate nr. 1187537/28.10.1999 – Product: Incoloy 800 HT - Customer BIBUS METALS AG-Hertistrasse 1 CH-8304 Wallisellen Switzerland.
[3] ASTM E 112-96 (2004), Standard Test Methods for Determining Average Grain Size.
[4] ASME SB-409: Specification for Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip.
[5] *Microduromètre O.P.L. à Cycle Automatique, France (technical book).