ANALYSIS OF INCOLOY 800HT ALLOY TESTED IN THERMAL TRANSIENT CONDITIONS

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ABSTRACT

This paper investigated Incoloy 800 HT alloy after following thermal transient tests: fast heating rates (50° and 90°C/minute) up to 1,000°C, maintaining this temperature level (0 and 60 minutes), furnace-cooling until 220°C, and then air-cooling. This alloy is one of the candidate materials for construction of the steam generators of the future NPP reactors. The analysis consisted in metallographic examination and traction tests. The samples were investigated using the Olympus GX 71 optical microscope, the OPL microdurometer with automatic cycle and WALTER BAI traction device. The average grain size was determined by linear interception method. The micro hardness was calculated by the relationship from the device technical book. On the traction diagrams were obtained: strength resistance (Rm), elongation at rupture (A) and elastic modulus (E). The tested alloy was compared with the „as received" material, and the results showed a good behavior of this alloy in the presented conditions.

Key words: Incoloy 800HT, thermal transient, microstructure, micro-hardness, strength resistance

Introduction

Incoloy 800 HT is one from among nickel-based alloys. These alloys make part of the candidate structural materials which are study for to be used in the construction of the steam generators of the future Nuclear Power Plants which must operate in severe conditions (i.e. high temperature, thermo-mechanical stress, and aggressive media). The „as received" material studied in this paper is conform to Inspection Certificate No. 1187537/28.10.1999 - Special Metals Wiggin Limited, Product: Incoloy 800HT; Cold Rolled Sheet; Pickled; Solution Treated; 2.0 THK X 1200 WIDE X 3000 MM CUT. Specification ASTM B 409 IIS 96A, UNS N08811. Packing & Marking to BIBUS 20 [1]

Experimental Methods

The experiment consisted in the testing of the samples in thermal transient conditions using some thermal stress scenarios: fast heating rates with 50°C/minute and 90°C/minute up to 1,000°C, maintaining this temperature level 0 (zero) minutes, slowly furnace-cooling until 220°C, and then fast air-cooling (Scenarios 1 and 2); fast heating rates with 50°C/minute and 90°C/minute up to 1,000°C, maintaining this

temperature level 60 minutes, slowly furnace-cooling until 220°C, and then fast air-cooling (Scenarios 3 and 4). [2]

Metallographic analysis of samples consisted in the microstructure examination and in the average grain size determination by linear interception method (Heyn). [3]

The average grain size for „as received" Incoloy 800 HT (solution treated), conform to Inspection Certificate No. 1187537/28.10.1999 - Special Metals: ASTM 3.5 [1] and ASTM G=5.0 or coarser. [4]

Material microhardness (Vickers) were calculate with relationship of technical book of device (Microduromètre O.P.L. à Cycle Automatique, France): $MHV = 1854.4\ F/d^2$, [kgf/mm²]

Where: F -force/charge [gf]; *d* -average diagonal of indentation [μm]; 1854.4 -device coefficient for Vickers microhardness (load: 0.1 kgf). [2]

The strength resistance were calculate of the traction diagrams, representing unitary strength variation σ [MPa] as a function of elongation ε [%]. The following mechanic characteristics were obtained: breaking resistance (R*m*) and elongation at rupture (*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 No. 1187537/28.10.1999 - Special Metals [1] and ASME SB-409[4].

Table 1 *Mecanical properties as received material, conform to [1] and [4*]

Material	Temperature Tests [°C]	Tensile Strength, R*m* [MPa]	Elongation on 50 mm, *A*[%]	Heat treatment & hardness [1]
Incoloy 800HT, as received	20	567 [1] / 450 [4]	43.4 [1] / min. 30 [4]	Batch & test pieces: 5M 1200°C AC Batch Hv 30: 134/142

Samples description, preparation and notation

From the #2 mm sheet "as received" material, were cutting the samples: 30 x 15x 2.5 mm (plates) and 44x10x2 mm (test-pieces). Notations: **Iy 800** or **Y**= Incoloy 800 alloy; ST = cross section. [2].

In **Figures 1-2**: Macroscopic aspects of the samples after thermal transient tests. [2]

Figure 1. *Plate samples after thermal transients tests*

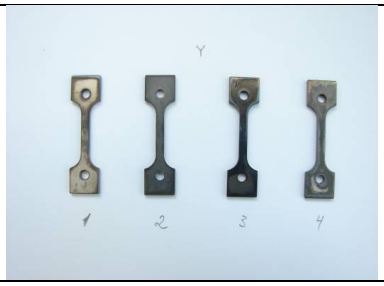

Figure 2. Test-piece samples after thermal transients tests

Results and Discussions

In the diagrams of **Figures 3-6** were presented the used thermal transient conditions/scenarios.

Scenario No.1: heating rate 50°C/minute up to 1,000°C, maintaining this temperature level 0 (zero) minutes, then slow furnace cooling until 220°C, and then air cooling.

Scenario No. 2: heating rate 50°C/minute up to 1,000°C, maintaining this temperature level 60 minutes, then slow furnace cooling until 220°C, and then air cooling.

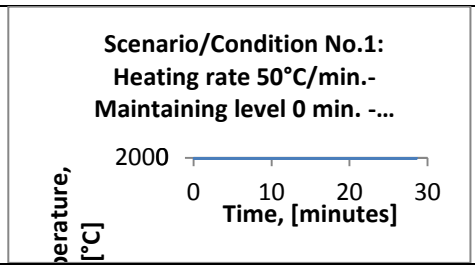

Figure 3 *Scenario No.1: 50-0-slowly cooling*

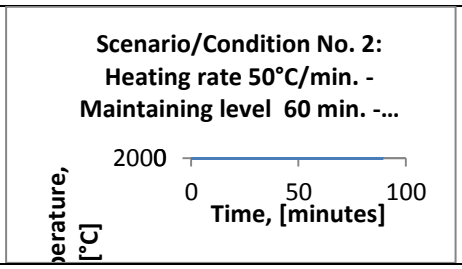

Figure 4 *Scenario No.2: 50-60-slowly cooling*

Scenario No.3: heating rate 90°C/minute up to 1,000°C, maintaining this temperature level 0 (zero) minutes, then slow furnace cooling until 220°C, and then air cooling. **Scenario No. 4**: heating rate 90°C/minute up to 1,000°C, maintaining this temperature level 60 minutes, then slow furnace cooling until 220°C, and then air cooling.

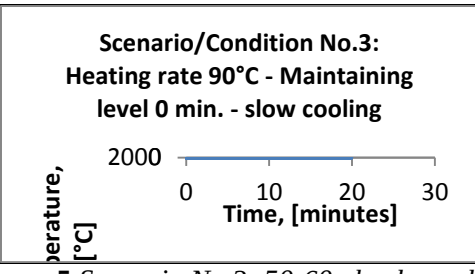

Figure 5 *Scenario No.3: 50-60-slowly cooling*

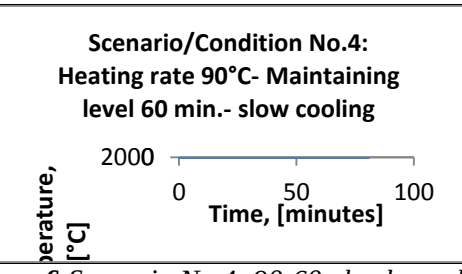

Figure 6 *Scenario No.4: 90-60-slowly cooling*

Microstructure (micrographs)

Electrolytic etching: oxalic acid (10%), 6.0 V, 20-50 seconds. ST-cross section.

The structure. Initial (as received): Austenite with coarse grains, twin grains and rare carbide particles (dark), **Figure 7** (in ST); average grain size: ASTM 4.0-4.5. After the transient tests, **Figures 8-12** (in ST): Austenite with coarse grains, recrystallized grains and carbides uniform distributed; average grain size: ASTM 4.0-4.5 [2]

In **Table 2** - The determined values for average grain size after thermal transient scenarios.

Table 2 *Average grain size after thermal transient tests, in S.T.*

Material (notation)	Scenarios: Heating rate [°C/minute]-Maintaining level [minute]-Cooling	Average distance $\bar{l}$ [μm]	Number ASTM
Incoloy 800 HT (Y)	as received*	74.4	4.0-4.5
	Scenario No.1: 50-0-slow	68.7	4.5
	Scenario No.2: 50-60-slow	73.8	4.0-4.5
	Scenario No.3: 90-0-slow	73.9	4.0-4.5
	Scenario No.4: 90-60-slow	66.4	4.5

* Conform to [1]: ASTM 3.5

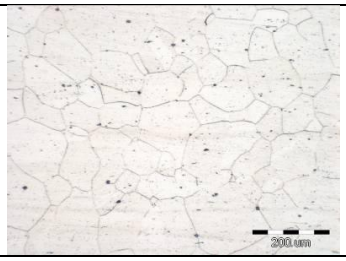

Figure 7 *Iy 800HT "as received"*

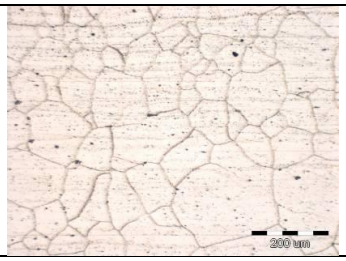

Figure 8 *Iy 800HT-Scenario 1: 50-0-slowly cooling*

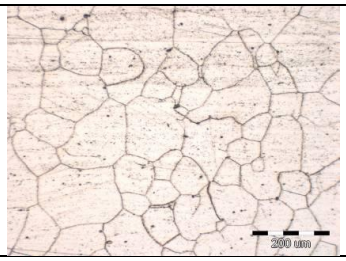

Figure 9 *Iy 800HT-Scenario 2: 50-60-slowly cooling*

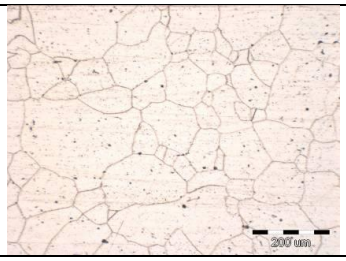

Figure 10 *Iy 800HT-Scenario 3: 90-0-slowly cooling*

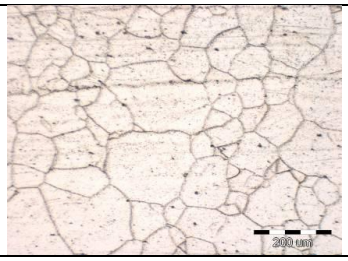

Figure 11 *Iy 800HT-Scenario 4: 90-60-slowly cooling*

In the **Figure 12**: Diagram of average grain size depending on thermal transient conditions.

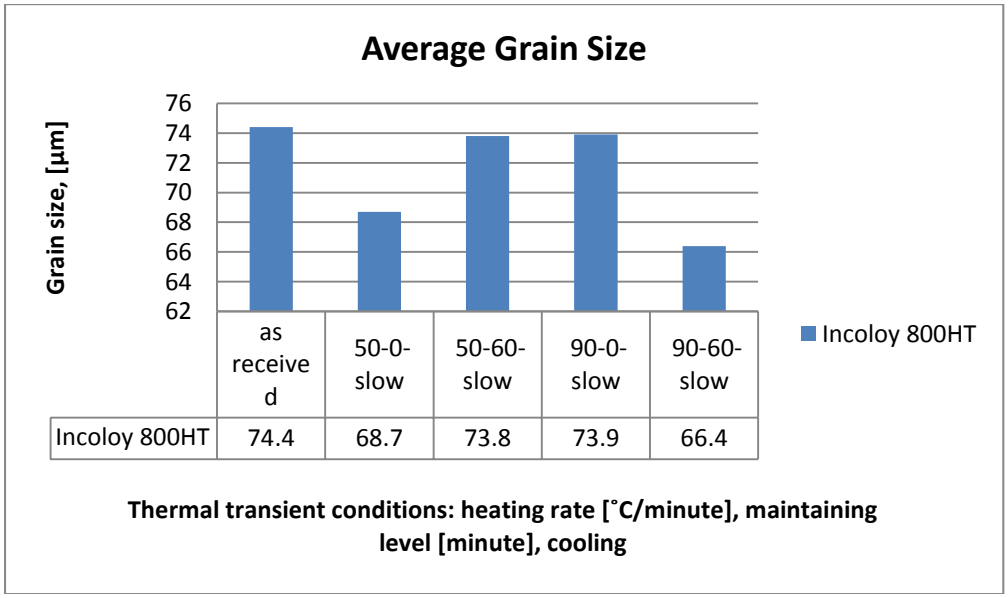

Figure 12 *Average grain size diagram*

Vickers microhardness

In **Table 3** - The determined values of Vickers microhardness after the transient tests.
In general, the Vickers microhardness increase 0-13 units comparative with initial material. The increase of maintaining time at temperature (1,000˚ C), from 0 at 60 minutes, influence the Vickers microhardness in decreasing sense with 9-12 units.

In the **Figure 13**: Diagram of Vickers microhardness depending on thermal transient conditions.
In the **Figures 14-17**: Microhardness imprints examples.

Table 3 *Vickers microhardness after the transient tests*.

Material (notation)	Scenarios: Heating rate [°C/minute]-Maintaining level [minute]-Cooling	Vickers microhardness, $MHV_{0,1}$ [Kgf/mm^2], in S.T.
Incoloy 800 HT (Y)	as received*	142
	Scenario No.1: 50-0-slow	155
	Scenario No.2: 50-60-slow	143
	Scenario No.3: 90-0-slow	151
	Scenario No.4: 90-60-slow	142

*Conform to [1]: Hv 30 = 134/142

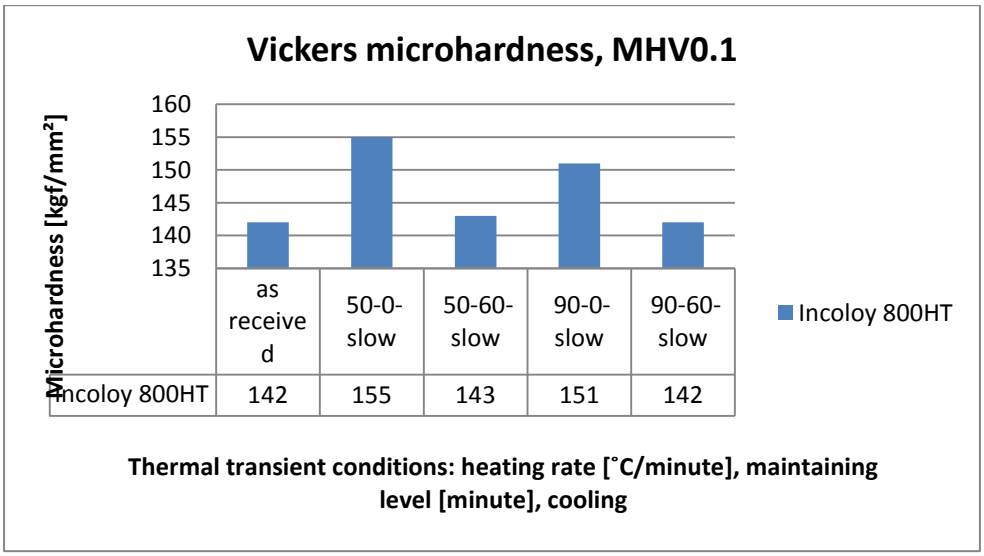

Figure 13 *Vickers microhardness diagram*

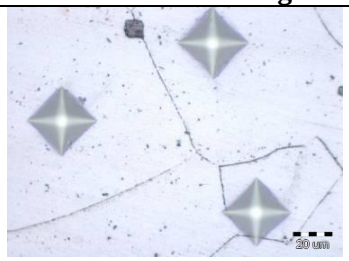

Figure 14 *Iy 800HT-as received*

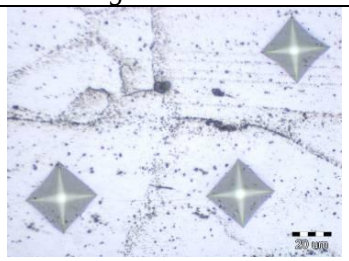

Figure 15 *Iy 800HT-Scenario 4: 90-60-slowly cooling*

Strength resistance

In **Table 4** - The determined values of strength traction and elongation after the transient tests.

In **Figures 16-17** were presented the diagrams of some mechanical characteristics determinate before and after the transient tests.

Table 4 *Strength traction and Elongation after the transient tests*.

Material (notation)	Scenarios: Heating rate [°C/minute]-Maintaining level [minute]-Cooling	Strength traction, R*m* [MPa]	Elongation, *A*%
Incoloy 800 HT (Y)	as received*	577	40.4
	Scenario No.1: 50-0-slow	586	39.8
	Scenario No.2: 50-60-slow	583	39.2
	Scenario No.3: 90-0-slow	579	41.4
	Scenario No.4: 90-60-slow	578	40.2

* Conform to [1]: R*m* =567 MPa; *A* = 43.4%

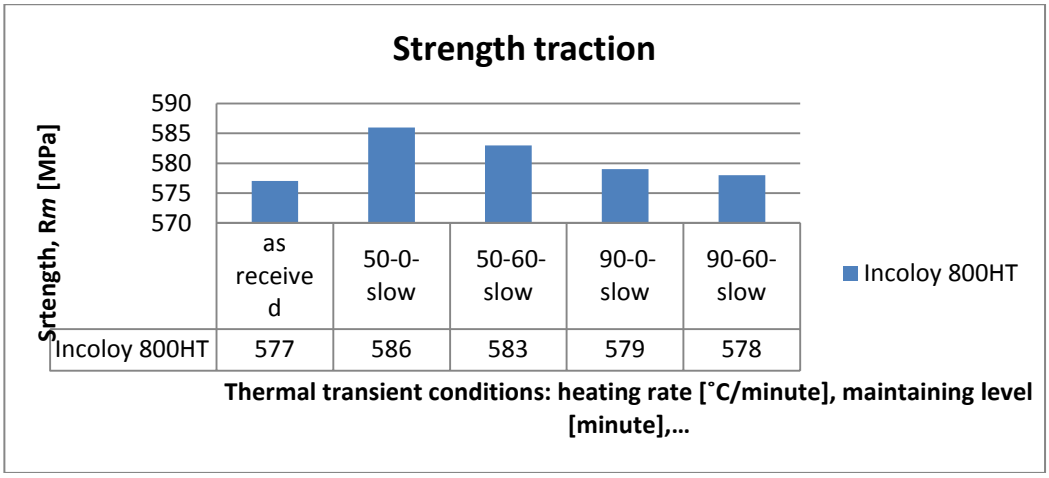

Figure 16 *Traction strength diagram*

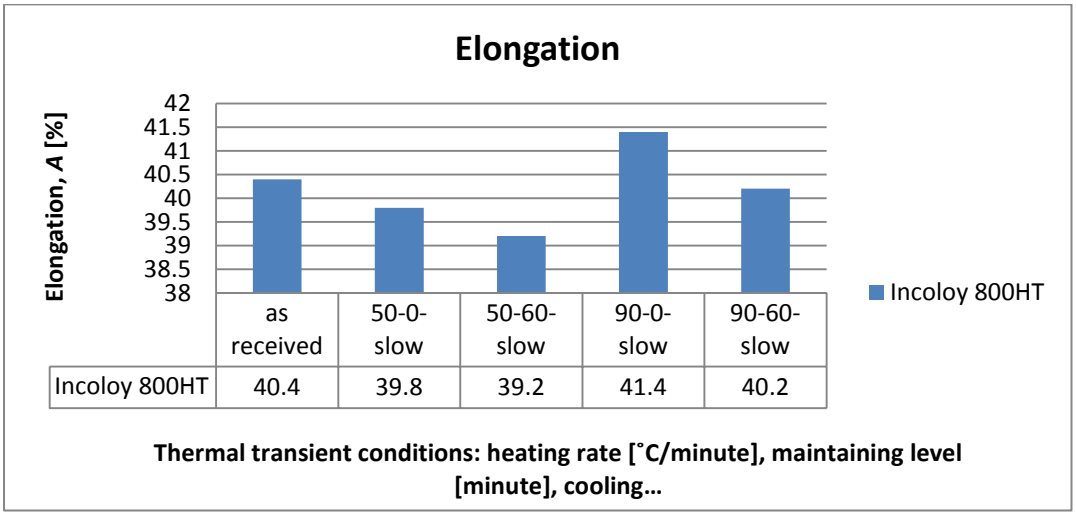

Figure 17 *Elongation diagram*

In general, after the transient tests the tensile strength values increase (with 1-9 MPa) comparative with the value as received material (577 MPa). Also, in all cases the determined tensile strength were 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 transient tests. [2]

Conclusions

Microstructure. Initial ("as received"): Austenite with coarse grains, twin grains and rare carbide particles; average grain size: ASTM 4.0-4.5. After the transient tests: Austenite with coarse grains, recrystallized grains and carbides uniform distributed. Average grain size, ASTM 4.0-4.5, is in range ASTM 3.5 - ASTM 5.0.

Vickers microhardness. After the transient tests, in general, the Vickers microhardness increase 0-13 units comparative with initial material. Also, the increase of maintaining time at temperature, from 0 at 60 minutes, influence the Vickers microhardness in decreasing sense with 9-12 units.

Traction tests. After transient tests, in general, the tensile strength values increase with 1-9 MPa comparative with the value as received material. Also, in all cases the determined tensile strength were superior to tensile strength of the producer Inspection Certificate (567 MPa) and ASME SB 409 (min. 450MPa).

The results show that Incoloy 800HT have a good behaviour at these thermal transient tests/scenarios.

References

[1] 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.

[2] L.Velciu, Thermal Transient Tests on Incoloy 800HT and Inconel 718 Alloys for Heat Exchangers Generation IV Reactors – RI 99xx/2013, ICN Piteşti, p. 20, 22-23, 25-26, 32-33, 35-36, 38-42

[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.