THE INFLUENCE OF THE THERMAL CYCLING ON GRAINS SIZE AT THE NICKEL –BASED ALLOYS

[1]S C VULPE*, [1]M ABRUDEANU, [2]D OHAI, [2]D BENGA, [1]G PLAIASU
[1]University of Pitesti, str. Targul din Vale, nr.1,cod 110040
[2] Institute of Nuclear Research Pitești, str. Câmpului, nr.1, cod 115400

ABSTRACT

The proposed Generation IV nuclear energy systems are aimed at making revolutionary improvements in economics, safety and reliability and sustainability. Because the materials will be used under high pressure and temperatures, the requirements for cladding materials are: good mechanical properties, corrosion resistance, resistance to neutron irradiation, low susceptibility to stress corrosion cracking and micro structural stability.
Of the candidate alloy systems that could be considered for high temperature applications, nickel-based alloys were selected as promising material based on experimental results.
This paper shows the changes of grain size nickel based alloys suck as: Incoloy 800HT, Inconel 617, 230 and 718 that appear after a thermal treatment like thermal cycling.
One sample of each alloy was meekly at a thermal cycling of 25 cycles. The parameters which were choose for this treatment was: the maxim temperature of a cycle 700°C and the minim temperature of a cycle 400°C.
In the as received Incoloy 800 HT has the biggest grain size, fallowed by Inconel 230 and Inconel 617. Inconel 718 has the smaller grain size, even 4 time smaller then Incoloy 800HT and 3 times smaller then Inconel 230.
It could be observe a big decrease of the grain sizes of all the alloys after the thermal cycling treatment of 25 cycles. For the first tree alloys Incoloy 800HT, Inconel 617 and Inconel 230 it's detected a decrease ten time higher compared to the values of the grain size of the alloys on the as received.
For Inconel 718 appear a smaller decrease of the grain size after thermal treatment compared with the as received appear.
During the thermal cycling process, materials are alternately cooled and (sometimes) heated until they experience molecular reorganization. That's way after the thermal cycling of 25 cycles it could be observed that the hardness of the alloys increase and the grain sizes decreased. This reorganization "tightens" or optimizes the particulate structure of the material throughout, relieving stresses and making the metal denser and more uniform (thereby minimizing flaws or imperfections).

KEYWORDS

Nickel alloy, Incoloy 800HT, Inconel 617, Inconel 230, Inconel 718

INTRODUCTION

Generation IV reactor are promising advanced nuclear systems due their high thermal efficiency and plant simplification. One of the major issues is to propose performance materials for the fuel claddings and the core components. The proposed generation IV nuclear energy systems are aimed at making revolutionary improvements in economics, safety and reliability and sustainability. Because the materials will be used under high

pressure and temperatures, the requirements for cladding materials are: good mechanical properties, corrosion resistance, resistance to neutron irradiation, low susceptibility to stress corrosion cracking and micro structural stability (1).
Of the candidate alloy systems that could be considered for high temperature applications, nickel-based alloys were selected as promising material based on experimental results. (2)
Because of this important properties that the materials must have, in this article we want to observe the differences that appear between the grain sizes of the at the nickel based alloys in as receive and after the thermal cycling at 25 cycles.
Thermal cycling is a temperature modulation process developed to improve the performance, strength and longevity of a variety of materials. Probably best described as "advanced cryogenics", thermal cycling has been applied chiefly to metals to-date, although the process is also beneficial to certain plastics, polymers and composites. It is currently used by a number of industries where enhanced material performance is desired.

EXPERIMENTS

The interest alloys are: Incoloy 800HT (UNS N08811) (3), Inconel 617 (UNS N 06617) (4), Inconel 230 (UNS N 06230) (5) and Inconel 718 (UNS 07718) (6).
The materials used in this study were commercial with a measured chemical composition listed in Table 1.

Table 1
Chemical composition (wt %) of the Incoloy 800HT, Inconel 617, Inconel 230, Inconel 718

Alloy	Fe	Ni	Cr	S	C	Mn	Al	Cu	Ti	Mo	Co	Si	Nb	P	W
Incoloy 800HT	45.19	31.22	20.06	0.001	0.077	0.71	0.51	0.41	0.52						
Inconel 617	1.72	52.98	22.99	0.001	0.09	0.07	1.14	0.04	0.22	9.70	11.19	0.06		0.005	
Inconel 230	0.97	60		0.002	0.10	0.50	0.31	0.04	0.01	1.24	0.30			0.005	14.22
Inconel 718	17.44	53.61	19.03	0.001	0.027	0.06	0.48	0.02	1.04	3.05	0.16	0.07	5.0		

Although thermal cycling is a process which is effective on a number of different types of materials including composites, ceramics, and plastics, it is most commonly associated with its beneficial effect on metal parts, that's way it's interesting to observe the differences that appear before and after the heat treatment.
One sample of each alloy was meekly at a thermal cycling of 25 cycles. The parameters which were choosing for this treatment were:
- Heating speed 5°C/min
- Cooling speed 5°C/min
- The maxim temperature of a cycle T_{max}= 700°C
- The minim temperature of a cycle T_{min}= 400°C

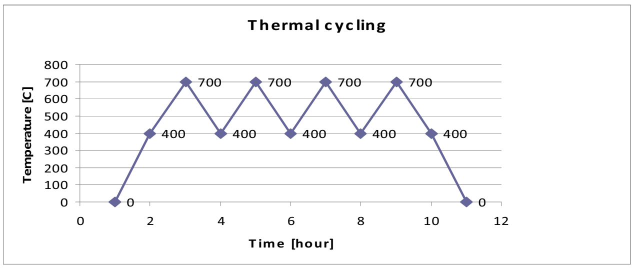


Fig. 1 The thermal cycling process

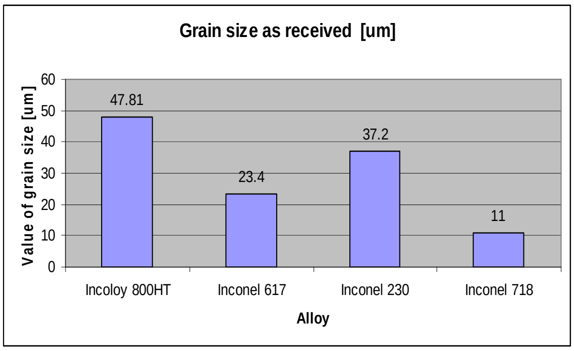
The investigations were conducted on samples of Incoloy 800HT, Inconel 230 and 617 of 15x30x2mm and Inconel 718 15x30x2.5mm size materials. The treatment has been realized using a Guss oven.

RESULTS

In the as received state the grain sizes of the alloys are presented in Table 1:

Table 1 Grain size in as received

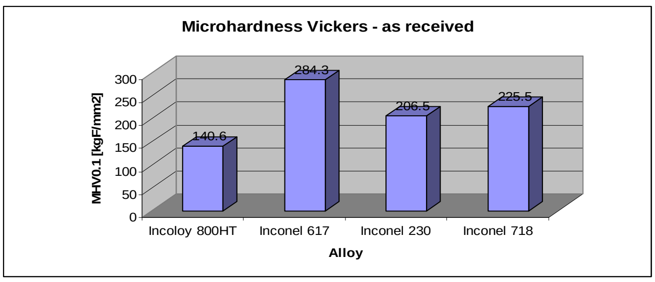
Alloy	As received
	Grain size $\bar{l}$ [µm]
Incoloy 800HT	47.81
Inconel 617	23.4
Inconel 230	37.2
Inconel 718	11.0



Incoloy 800 HT has the biggest grain size, fallowed by Inconel 230 and Inconel 617. Inconel 718 has the smaller grain size, even 4 time smaller then Incoloy 800HT and 3 times smaller then Inconel 230.
Micro hardness Vickers of the alloys at as received is presented in Table 2:

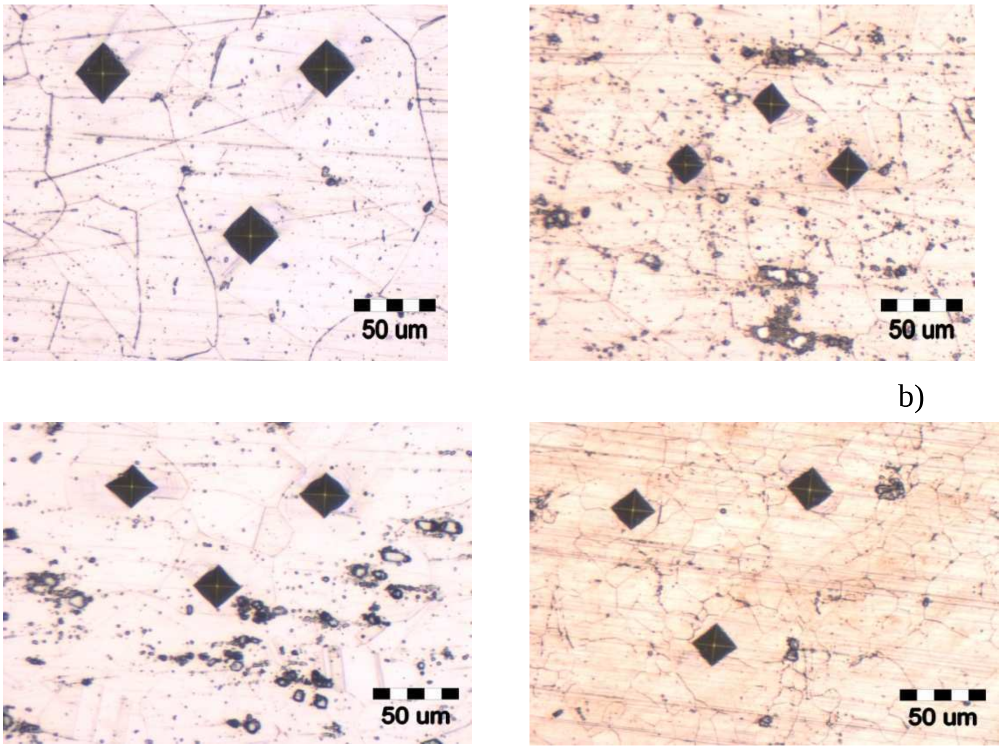
Table 2 The micro hardness Vickers for the samples as received

Alloy	$MHV_{0.1}$ [kgF/mm^2]
Incoloy 800HT	140.6
Inconel 617	284.3
Inconel 230	206.5
Inconel 718	225.5



$$MHV_{0.1} = \frac{\sum_k^n MHV}{n}$$

$MHV_{0.1}$ – The micro hardness Vickers with a force of pressing F= 100 kgF
MHV– The micro hardness Vickers, n- Number of grain



a) b)

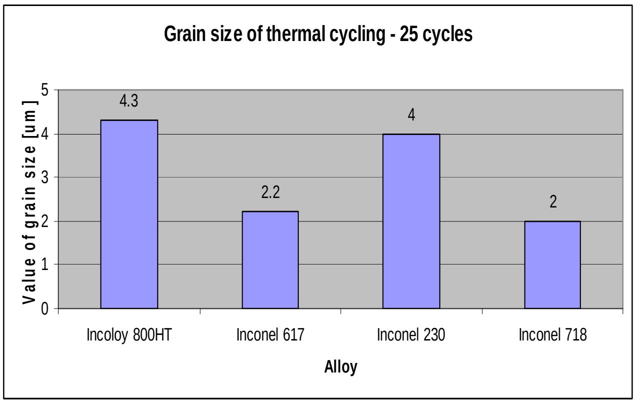
c) d)

Fig.2 The print of micro hardness Vickers x500: a) Incoloy 800 HT; b) Inconel 617; c) Inconel 230; d) Inconel 718

In the as received state Inconel 617 is the hardest alloy from all, followed by Inconel 718, 230 and Incoloy 800HT.
After the thermal cycling of 25 cycles at the temperature 400-700°C the values of grain sizes decrease sharply. The grain sizes of the alloys after the thermal cycling of 25 cycles are present in Table 3.

Table 3 The grain sizes of the nickel based alloys after the thermal cycling of 25 cycles

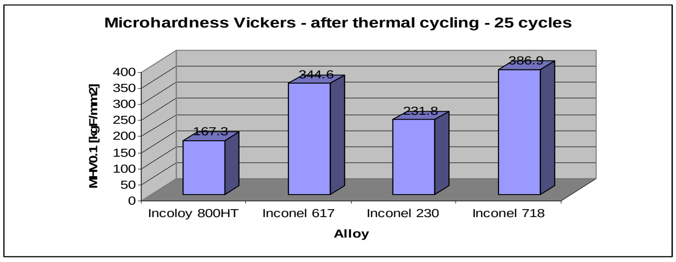
Alloy	Thermal cycling of 25 cycles, temperature 400-700°C
	Grain size $\bar{l}$ [μm]
Incoloy 800HT	4.3
Inconel 617	2.2
Inconel 230	4.0
Inconel 718	2.0



Incoloy 800 HT has the biggest grain size, fallowed by Inconel 230, 617 and 718.
Micro hardness Vickers after the thermal cycling of 25 cycles is present in Table 4.

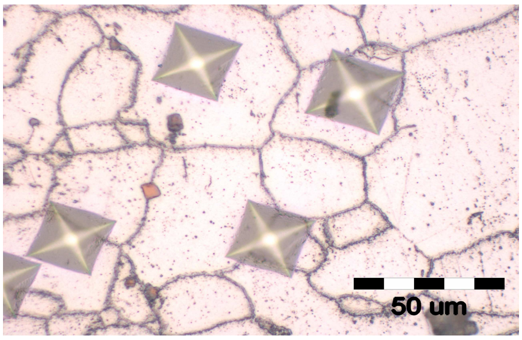
Table 4 The micro hardness Vickers for the samples after the thermal cycling of 25 cycles

Alloy	$MHV_{0.1}$ [kgF/mm^2]
Incoloy 800HT	167.3
Inconel 617	344.6
Inconel 230	231.8
Inconel 718	386.9

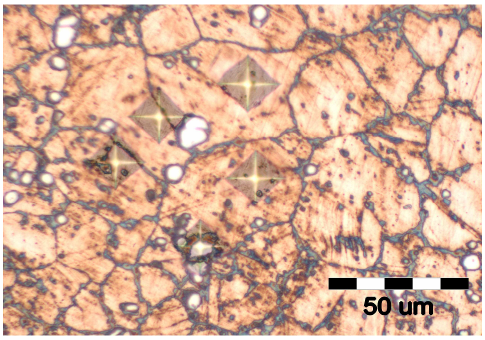


After the thermal cycling Inconel 718 is the hardest alloy although in the as received state the first place was occupied of Inconel 617 with was the hardest alloy from all.

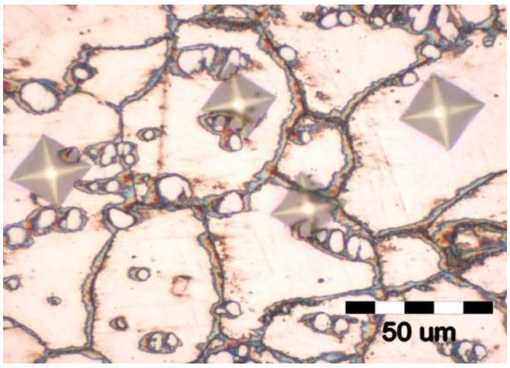
In Fig. 3 are presented the print of micro hardness Vickers x500.



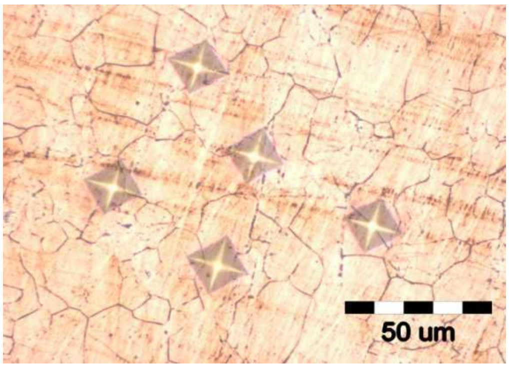
a)



b)



c)

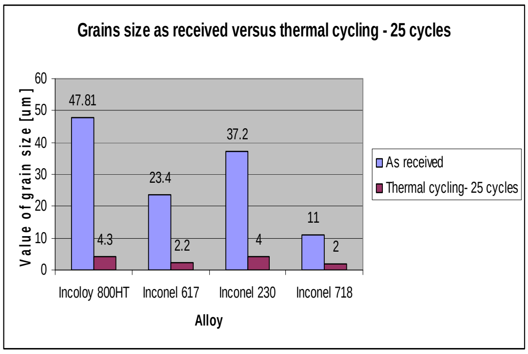


d)

Fig.3 The print of micro hardness Vickers x500: a) Incoloy 800 HT; b) Inconel 617; c) Inconel 230; d) Inconel 718

In Table 4 are presented the differences between the grain size in as received state and after the thermal cycling of 25 cycles of the nickel based alloys

Alloy	As received	Thermal cycling of 25 cycles; temperature 400-700°C
	Grain size $\bar{l}$ [μm]	
Incoloy 800HT	47.81	4.3
Inconel 617	23.4	2.2
Inconel 230	37.2	4.0
Inconel 718	11.0	2.0



It could be observe a big decrease of the grain sizes of all the alloys after the thermal cycling treatment of 25 cycles. For the first tree alloys Incoloy 800HT, Inconel 617 and Inconel 230 it's detected a decrease ten time higher compared to the values of the grain size of the alloys on the as received.

For Inconel 718 appear a smaller decrease of the grain size after thermal treatment compared with the grain size of as received.

Also for the Incoloy 800HT and Inconel 230 the grain sizes are very closed (4.3-4.0) after the cycling treatment and also Inconel 617 and Inconel 718 (2.2-2.0) have almost the same values of the grains sizes.

CONCLUSION

During the thermal cycling process, materials are alternately cooled and heated until they experience molecular reorganization. That's way after the thermal cycling of 25 cycles it could be observed that the hardness of the alloys increase and the grain sizes decreased.

This reorganization "tightens" or optimizes the particulate structure of the material throughout, relieving stresses and making the metal denser and more uniform (thereby minimizing flaws or imperfections). The tighter structure also enhances the energy conductivity and heat distribution characteristics of the material.

Thermal Cycling minimizes "hotspots", enhances cooling and impedes the ability and tendency of metals to vibrate. Significantly reducing vibration as a factor in metal fatigue slows down the metal's eventual failure or breakage. Corrosion resistance is enhanced as a result of molecular uniformity because the metal's ability to impede oxidation and chemical degradation is strengthened.

REFERENCES

(1) G.S. Was, S. Teysseyre, J. McKinley, Corrosion and stress corrosion cracking of iron and nickel-based austenitic alloys in supercritical water, in: Proceeding NACE's Annual Conference, Corrosion, New Orleans LA, Paper 04492, 2004.
(2) J. Gan, J.I. Cole , T.R. Allen , S. Shutthanandan , S. Thevuthasan , Irradiated microstructure of alloy 800H, 2006, Journal of nuclear materials
(3) ASTM B409 ISS 96A UNS N08811
(4) SAEAMS 5889B; ASME SB 168 UNS N 06617
(5)ASME SB435; AMS5878B UNS NO6230
(6) ASTM B 670 ISS 02 UNS N0718

ACKNOWLEDGEMENTS

This work was partially supported by the strategic grant POSDRU/88/1.5/S/52826, Project ID52826 (2009), co-financed by the European Social Fund – Investing in People, within the Sectoral Operational Programme Human Resources Development 2007-2013.