Effect of solution heat treatment conditions on the microstructure of a Ni-Si-B alloy

G. M. Gorito[1] , P. Lacerda[2] , M. Vieira[1,3], L. M. M. Ribeiro[1,3]

[1]Department of Metallurgical and Materials Engineering, University of Porto
[2]FERESPE- Fundição De Ferro E Aço Lda., 4760-485 Fradelos, Portugal
[3]LAETA/INEGI–Institute of Science and Innovation in Mechanical and Industrial Engineering, Porto, Portugal

Introduction

Ni-Si-B alloys are particularly interesting for industrial applications that require oxidation and wear resistance at high temperatures, such as tools, moulds, dies or components for furnaces or nuclear power plants. The Ni-Si-B alloys processed by investment casting, show a complex microstructure, containing dendrites of austenite and hard particles of borides and silicides that confer the required properties [1-3]. However, before being machined the cast components have to be softened by a solution heat treatment to enhance their machinability. The effect of different conditions of heat treatment on the microstructure and hardness have been studied in order to set the best parameters for the solution heat treatment.

Materials and Methods

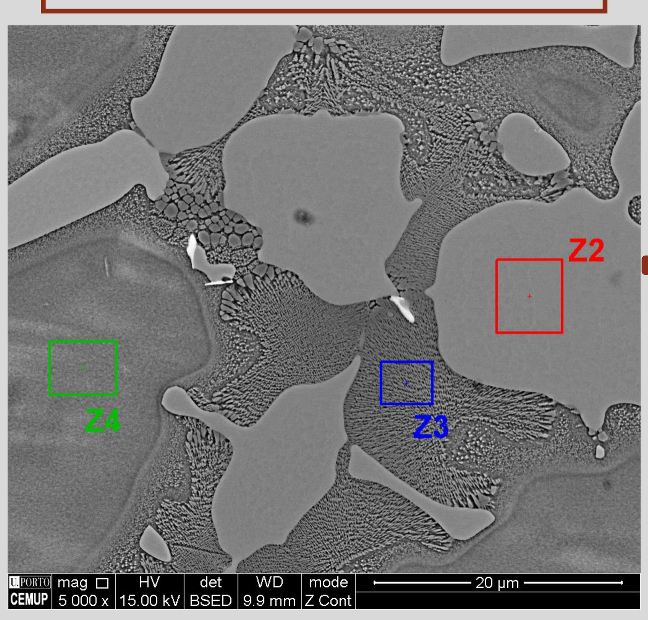
Ni-Si-B alloy specimens were obtained by lost wax investment casting. The nominal chemical composition of the specimens is outlined in Table 1. The solution heat treatments (HT) were carried out in a muffle furnace at 930 and 980 ˚C for 0.5, 1, 2 and 3 hours, followed by water quenching. Samples for microscopy analysis were etched with a solution of 7 g $FeCl_3$, 10 mL HCl and 50 mL H_2O. The microstructural phases were characterized by scanning electron microscopy with EDS, X-ray diffraction (XRD) and low-load Vickers hardness tests.

Table 1. Nominal chemical composition of the Ni-Si-B alloy.

Element	Ni	Si	B	Cr	Fe	Cu	C
(wt. %)	Bal.	3,78	2,11	0,40	0,29	0,03	0,03

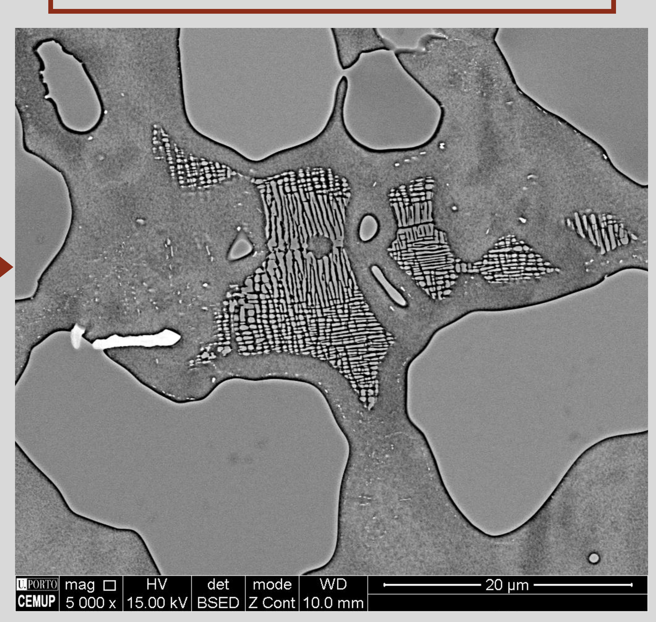
Microstructural and Mechanical Characterization

As-cast microstructure



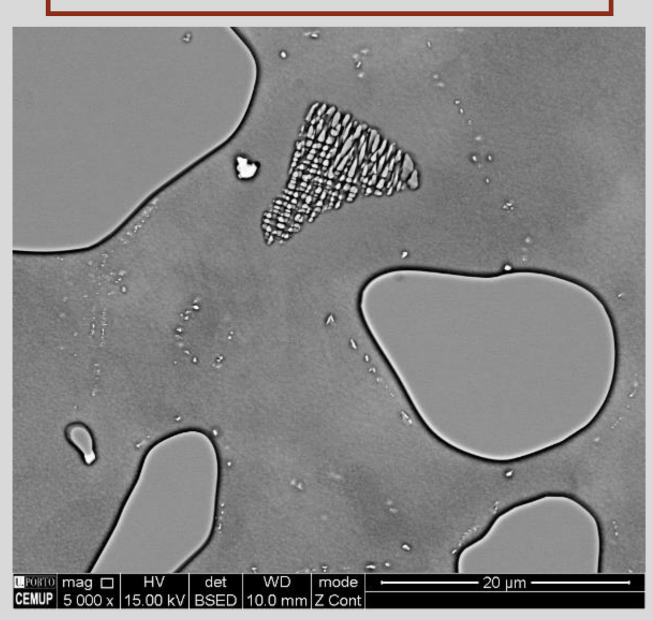
Hardness HV 0.05 and 0.025		
Ni-γ (matrix)	Ni_3B	Ni-γ -Ni_3Si
171 ± 9	[1023-1125]	593 ± 55

HT at 930 ˚C for 0.5 h



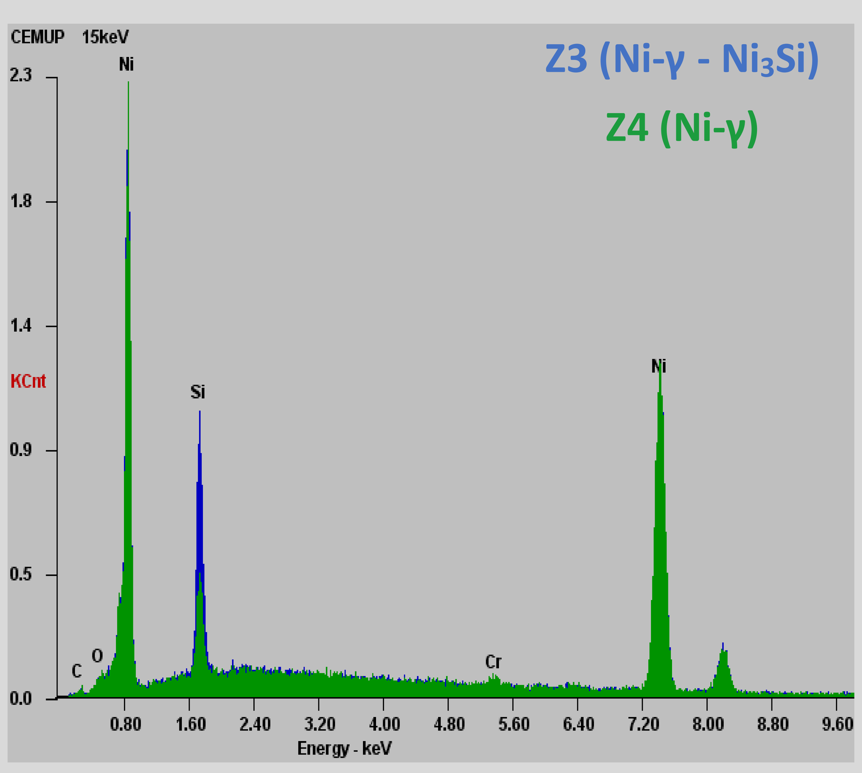
Hardness HV 0.05 and 0.025		
Ni-γ (matrix)	Ni_3B	Ni-γ - Ni_3Si
183 ± 24	[883-1165]	522 ± 66

HT at 930 ˚C for 3 h

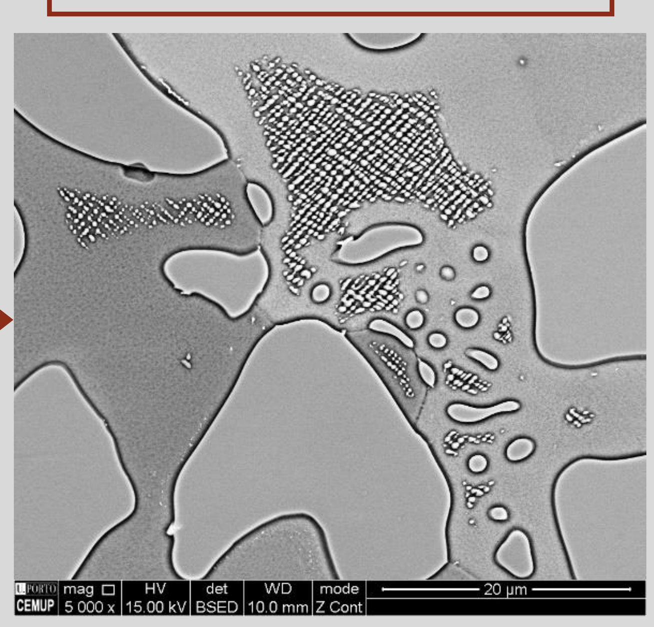


Hardness HV 0.05 and 0.025		
Ni-γ (matrix)	Ni_3B	Ni-γ - Ni_3Si
195 ± 12	[765-1177]	-

EDS results

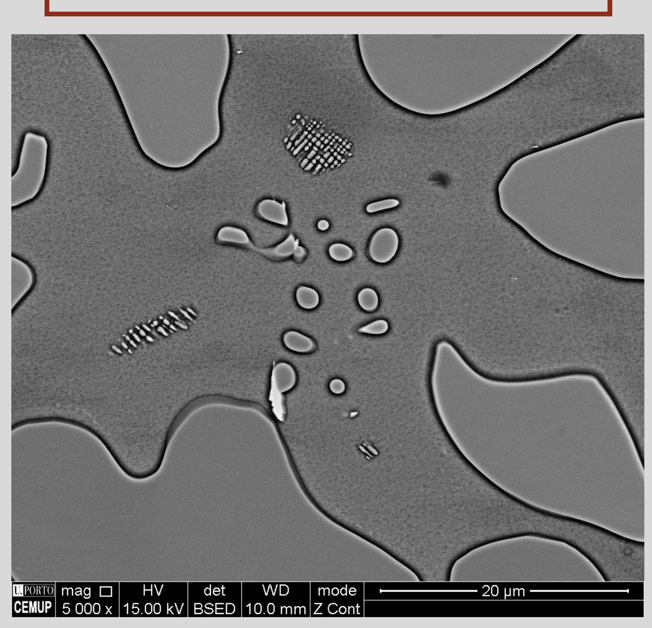


HT at 980 ˚C for 0.5 h



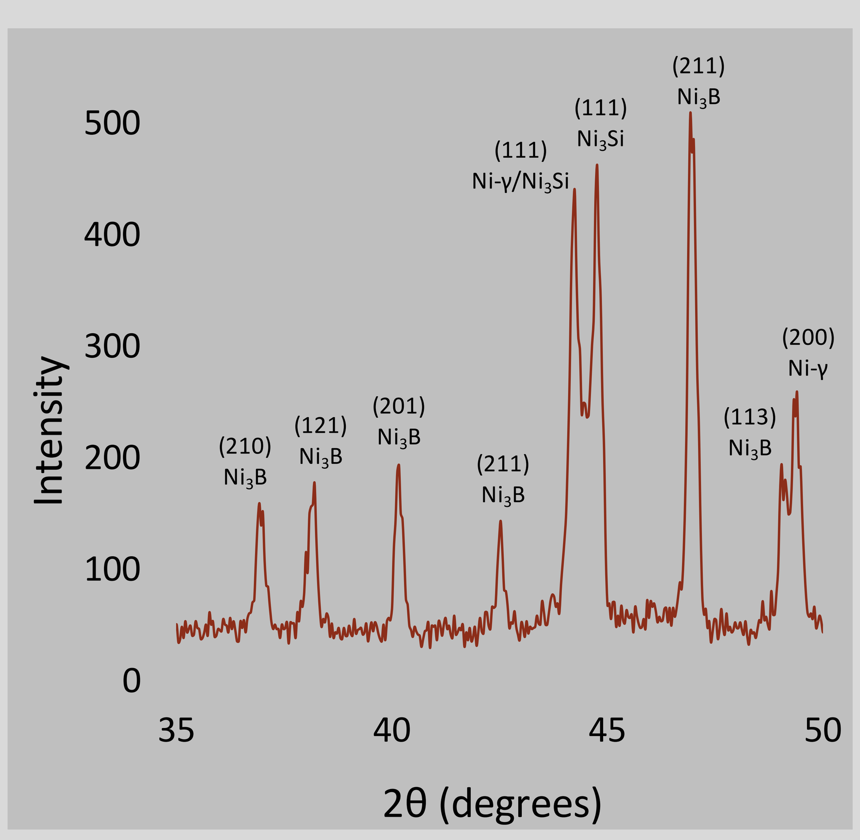
Hardness HV 0.05 and 0.025		
Ni-γ (matrix)	Ni_3B	Ni-γ - Ni_3Si
207 ± 15	[892-1270]	483 ± 28

HT at 980 ˚C for 3 h

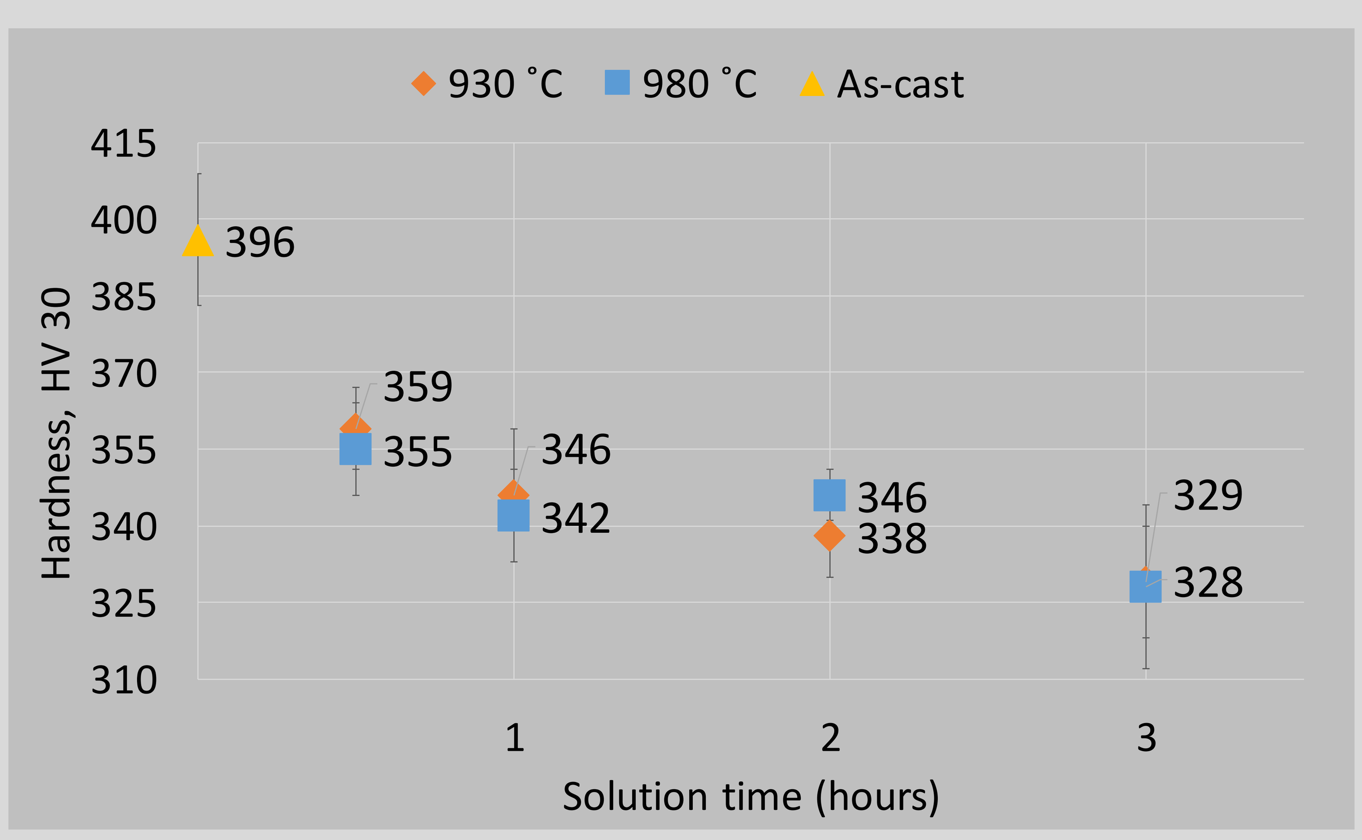


Hardness HV 0.05 and 0.025		
Ni-γ (matrix)	Ni_3B	Ni-γ - Ni_3Si
209 ± 28	[842-1274]	-

XRD results



Evolution of the hardness as a function of solution time



Discussion

The as-cast microstructure consists of dendrites of Ni austenite (Ni-γ, Zone Z4) and a large volume fraction of eutectic constituent (Ni-γ - Ni_3Si, Zone 3) and borides (Ni_3B, Zone 2), based on SEM/EDS analysis and XRD patterns.

SEM images show that the increase of solution time leads to a high variation in the microstructure, promoting the dissolution of the eutectic constituent (Ni-γ - Ni_3Si). This kinetics of dissolution is faster for 980 ˚C.

The hardness of the nickel austenite increases with the solution time, due to the increase of silicon in solid solution that came from the eutectic constituent. On the other hand, the dissolution process induces a considerable decrease in the hardness of the eutectic constituent, even though the hardness of the borides does not change significantly. Therefore, the microstructural changes result in a significant decrease of the alloy's bulk hardness, and an improvement in machinability can be expected.

Conclusions

The solution heat treatment at 930 ˚C and 980 ˚C allows the dissolution of the silicides (Ni_3Si) present in the microstructure, with faster dissolution kinetics at 980 ˚C.

After 3 hours at 980 ˚C, only traces of the eutectic constituent are detected, resulting in a decrease in hardness from 396 HV 30 to 328 HV 30 (17%).

Referencies

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