Thermochemical Treatments of Alloys 16NiCrMo13 and 23MnCrMo5 : the roles of carbon and nitrogen on metallurgical response to carbonitriding

W. Dal'Maz Silva [1,2] J. Dulcy [1] G. Michel [2] S. Thibault [3]
P. Lamesle [2] T. Belmonte [1]

[1] Institut Jean Lamour, Nancy, France

[2] Institut de Recherche Technologique M2P, Metz, France

[3] Safran Group, Paris, France

21st May 2015

Partners

ASCOMETAL

AIR LIQUIDE

ECM TECHNOLOGIES

AIRBUS HELICOPTERS

faurecia

IRT M2P
INSTITUT DE RECHERCHE TECHNOLOGIQUE
MATÉRIAUX MÉTALLURGIE ET PROCÉDÉS

ArcelorMittal

SAFRAN
AEROSPACE · DEFENCE · SECURITY

UTC Aerospace Systems

PSA PEUGEOT CITROËN

POCLAIN HYDRAULICS

Table of Contents

Introduction

The need of materials combining core toughness and both fatigue and wear resistances has led to the development of several surface treatment techniques.

Although carbonitriding has been known for most of the last century, the role of nitrogen on mechanical properties of treated parts remains still unclear.

The present work seeks for better understanding on the role of this element as well the one of carbon in the metallurgical responses of alloys 16NiCrMo13 and 23MnCrMo5.

Source: Safran Group.

Experimental conditions

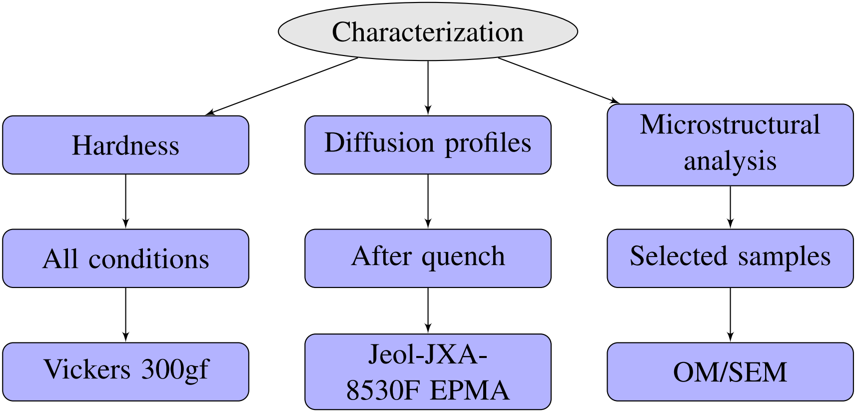
Treatments for alloys 16NiCrMo13 and 23MnCrMo5:

Process		**Steps (hours) at 1173 K.**		
		Carburizing $CO + H_2$	**Diffusion** $N_2 + H_2$	**Nitriding** $NH_3 + N_2 + H_2$
Carburizing	**C0**	2	4 (16NiCrMo13) 3 (23MnCrMo5)	-
Nitriding	**N0**	-	-	3
Carbonitriding	**CN**	2	1 (16NiCrMo13) 0 (23MnCrMo5)	3

Treatments were followed by room temperature oil quench which was continued in liquid nitrogen.

Tempering was carried out during 70 hours at 453 K and also 18 hours at 573 K.

Materials characterization



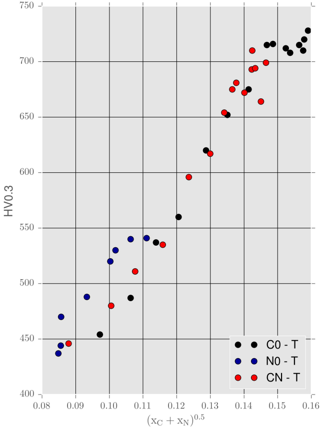
Response to quenching: effect of interstitials

EPMA
↓
Thermo-Calc
↓
Solid solution nitrogen
↓
Hardness $\propto \sqrt{x_i}$

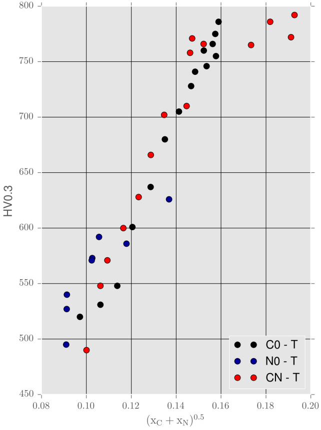
- Thermo-Calc™ was used in order to make an estimation of the solid solution nitrogen in austenite before quenching.
- Linear dependence of hardness after quenching with the square root of the mole fraction of interstitial elements in solid solution.
- Hardness plateau mainly linked to non-transformed austenite (even after liquid nitrogen quenching).

Response to quenching: effect of interstitials

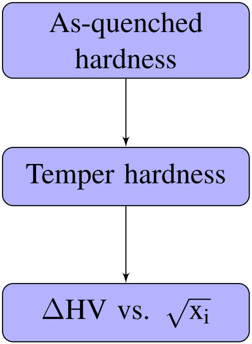
Alloy 16NiCrMo13



Alloy 23MnCrMo5



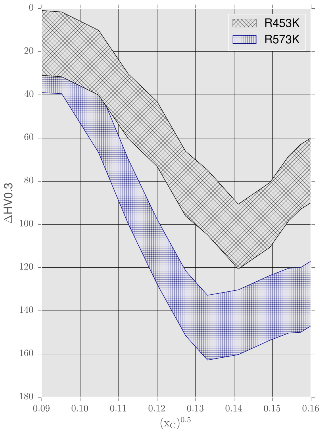
Tempering effects: role of carbon and microstructure



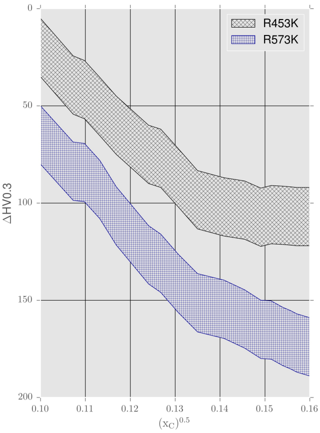
- Alloy 16NiCrMo13: retained austenite decomposes into ferrite + carbides which leads to a maximum hardness loss below surface.
- Contributions of both microstructure and composition are taken into account, although plots are obtained as a function of composition.

Tempering effects: role of carbon and microstructure

Alloy 16NiCrMo13

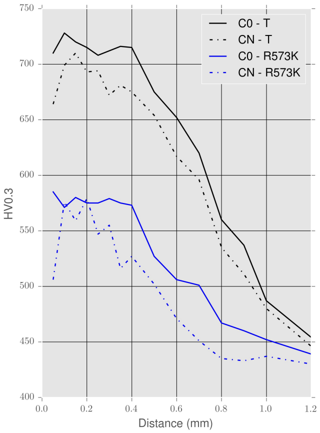


Alloy 23MnCrMo5

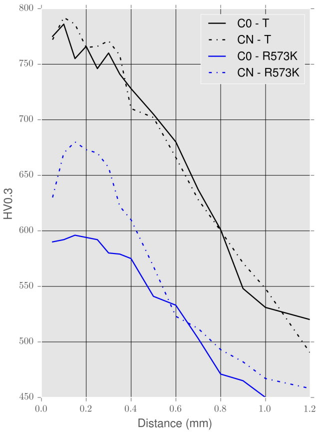


Carburizing vs. Carbonitriding

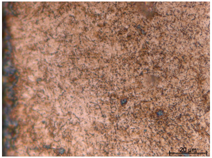
Alloy 16NiCrMo13

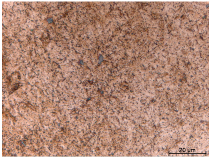


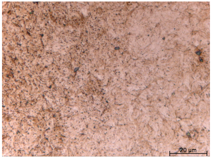
Alloy 23MnCrMo5

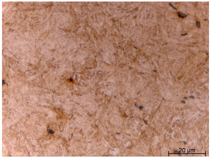


Carbonitriding: behavior of alloy 23MnCrMo5







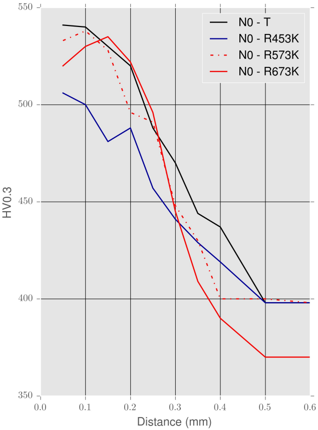


0.05 mm	0.15 mm	0.25 mm	0.45 mm
0.90 % wt N	0.75 % wt N	0.37 % wt N	0.05 % wt N

Institut Jean Lamour
PENSER LES MATÉRIAUX DE DEMAIN

Secondary precipitation: nitriding of alloy 16NiCrMo13

- Hardness drops when tempering is conducted at 453 K for long duration (70 hours) but at 573 K, as-quenched hardness is almost preserved in surface after 18 hours of tempering, although decreases steeper to the core.
- Even at 673 K (hold during 18 hours) surface hardness is kept, although important core hardness decrease is measured.



Conclusion and perspectives

Hardening responses as a function of total **interstitial content** led to the critical amount of these elements implying **non-transformed austenite** in alloy 16NiCrMo13 even after cryogenic treatment. Working below these levels is suggested as a mean to possibly achieve better fatigue performance.

Alloy **23MnCrMo5 shows higher remaining hardening after temper** when highly enriched in nitrogen. The mechanism which lead to this performance needs further investigation.

Although the effect of nitrogen could not be directly identified from carbonitriding, **nitriding** results suggest that TEM analyses may allow the identification of **secondary precipitation** leading to better understanding of carbonitriding for the studied alloys.

Institut Jean Lamour

PENSER LES MATÉRIAUX DE DEMAIN

Thank you for your attention!