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LTAS

Enhancement of in-situ Transformation of M_2C Eutectics Carbides during High Temperature Heat Treatment on a HSS and a Semi-HSS Grades

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Purpose. Describe the kinetics of M_2C eutectics carbides in-situ transformations during annealing of a HSS and a Semi HSS grades and the conditions for such a solid-state transformation.

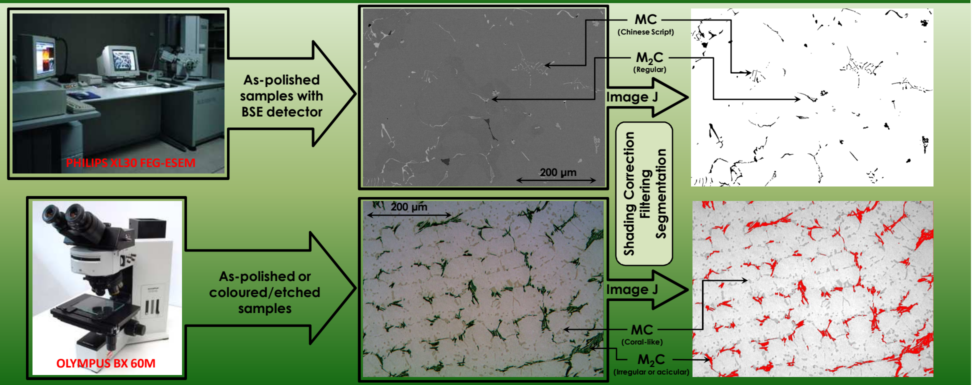
Methodology. Study of the crystallization behavior of both grades through equilibrium simulations with Thermo-Calc® (TC) and non-equilibrium tests by the means of Differential thermal Analysis (DTA), both techniques allowing the determination of critical temperatures prior to heat treatment. Annealing and quenching heat treatments performed in the range]Ac_3, Solidus[, with various temperatures and holding times that allow chemical homogenization, microstructure evolution and carbides stability studies. Microstructure characterization towards light microscope, scanning electron microscope combined with EDS, and bulk hardness measurements. Image analysis for the determination of carbides volume fractions.

Findings. Occurrence of a Cr-rich phase in the vicinity of Mo-rich M_2C eutectic carbides as the driving force for in-situ transformation of such carbides at elevated temperature that remain far below their critical remelting point. M_2C carbides transform themselves into finer V-rich MC and Mo-rich M_6C through a so-called "budding" phenomenon as the later carbides precipitated within the former carbide/matrix interface while leaving a Cr-rich carbide on the parent carbide location. Secondary carbides precipitation depends on the austenitizing temperatures and strongly influences the as-quenched microstructures.

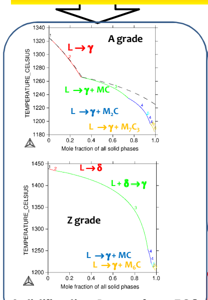
Materials & Experimental Methods

Grades	Alloying elements: C	Si	Mn	Ni	Cr	Mo	V, Nb	Fe
HSS A	1.5-2.0	0.2-1.0	0.6-1.0	0.5-1.5	2.0-6.0	5.0-8.0	3.0-7.0	Bal.
Semi-HSS Z	0.5-1.0				6.0-10.0	2.0-5.0	1.0-3.0	

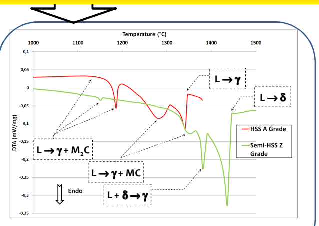
Grades	Austenitizing Temperature (°C)	Holding time (min)	Quenching medium
HSS A	1025, 1060, 1100	20, 60, 180	Calm air
Semi-HSS Z	1025, 1060, 1100		



A Equilibrium (TC®) # Non Equilibrium (DTA)



Solidification Range from TC® simulations



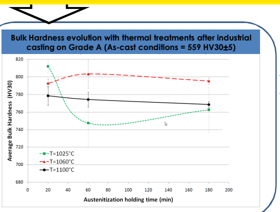
Crystallization Behavior from DTA tests (Cooling rate of 5°C/min)

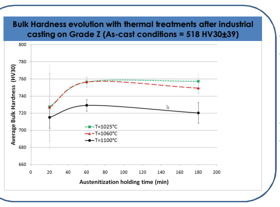
Solidification Range (SR)	A Grade	Z Grade
From TC®	100°C	250°C
From DTA	160°C	290°C

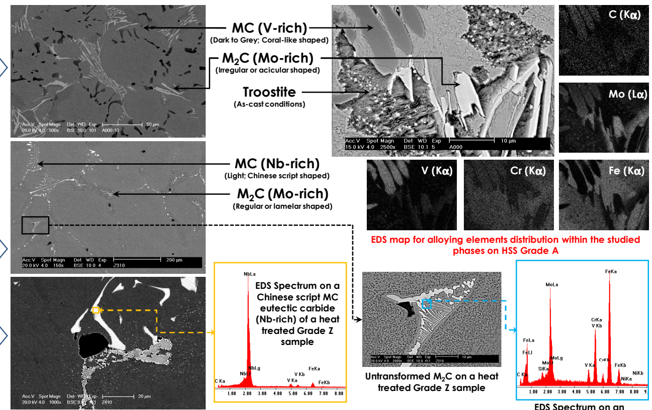
Carbides Volume Fractions

Grades	MC	M_2C	M_7C_3	M_6C
TC® simulations (%)				
A	42.0	21.0	4.0	2.0
Z	15.0	3.0	1.0	5.0
Quantitative Metallography on as-cast and heat treated samples (%)				
A	[5.6 -8.3]	[3.3 -5.7]	Not observed	
Z	[1.5 -2.5]			

B Heat Treatments







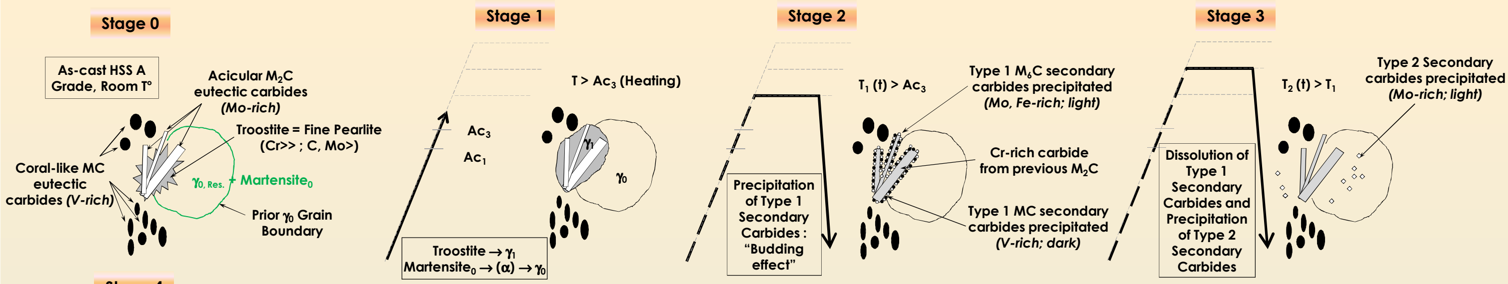
EDS map for alloying elements distribution within the studied phases on HSS Grade A

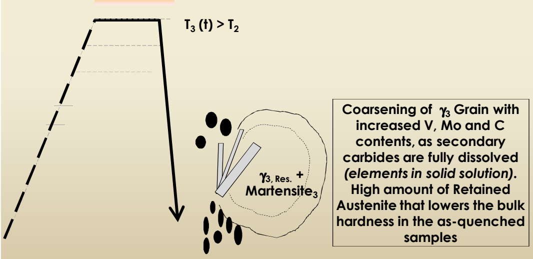
Untransformed M_2C on a heat treated Grade Z sample

EDS Spectrum on an untransformed lamelar M_2C eutectic carbide (Mo-rich) of a heat treated Grade Z sample

In-situ transformation of M_2C carbide through a « Budding » phenomenon, on a heat treated Grade Z sample

C Sketch Map for in-situ transformation mechanism of eutectic M_2C carbides: M_2C + Cr-rich phase → M_6C + MC + M_xC_y (Cr-rich)





Conclusions

- (A) Solidification ranges are larger in Non Equilibrium conditions (DTA) than those obtained from Equilibrium conditions (TC®)
- (A) Nature of predicted Mo-rich eutectic carbide in Equilibrium conditions (M_6C) is different from the M_2C type obtained after DTA tests. Furthermore the carbides volume fractions given by TC® are always higher than the carbides amounts found after both DTA tests and industrial casting.
- (B) Stability of M_2C carbide evaluated towards appropriate heat treatments leads to the enhancement of an in situ phase transformation with a diffusion control destabilization phenomenon.
- (C) A complete mechanism of M_2C carbides destabilization can be suggested, this mechanism being conditioned by the occurrence of a Cr-rich neighboring matrix in the vicinity of the M_2C carbide (e.g. troostite), and being promoted by austenitizing temperature and holding time.