

## Carbides crystalline structure of AISI M2 high-speed steel

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### INTRODUCTION

The AISI M2 high-speed steel has a high alloying elements content. For this steel class the alloying elements are V, Cr, Mo, W and C. After casting any further thermo mechanical treatment aims the formation of a ferritic and or martensitic matrix, i.e., in crystallographic words the matrix is pure or near pure iron with bcc structure, and a complex network of metallic carbides. This carbide net is formed by atom migration through the matrix [1].

The macroscopic mechanical properties of the alloys are imposed by the microstructure. Until now, there is not great interest in the study of the crystallographic structures of carbides present in high-speed steels. In the actual context, the cutting tool insert has been used with thin coated layer, e.g., titanium nitride and titanium carbonitride. Hence, the knowledge of these high-speed steel substrate structures has acquired a major importance.

Notwithstanding, the structure determination of these carbides is a very hard work. Since these structures were formed by atom migration it is not possible to reproduce them by a controlled process with a determined chemical composition. The solution of this problem is to obtain the carbide by chemical extraction from the steel.

The aim of this study was to identify the crystallographic structure of the extracted carbides of AISI M2 steel spray formed.

### EXPERIMENT

The chemical composition (mass %) of AISI M2 in this study was Cr, 3.29; Mo, 4.09; W, 6.19; V, 1.87; Si, 0.22; Mn, 0.18; Ni, 0.034; N, 0.034; C, 1.03 and Fe balanced. A 20 cm diameter and 10 cm height billet was spray formed using N<sub>2</sub> as the atomizing gas.

Carbides were extracted by chemical dissolution of the matrix with Berzelius reagent [2]. The microstructure and chemical composition of the carbides were analyzed by scanning electron microscope SEM (Phillips, XL30) fitted with energy dispersion spectrometer EDS. X-ray diffraction was performed with a synchrotron source, with 5.42 keV energy. The Rietveld refinements utilized computer program GSAS.

### RESULTS AND DISCUSSION

The microstructures show differences along of the longitudinal direction of the billet in relation to the atomizing direction. These differences are consistent with the different cool-

ing ratios that arise from the gas atomising process. The billet top is in contact with a stream of particles and gas and the bottom with a ceramic substrate.

In the spray forming plant the top of the billet undergoes a faster cooling rate and during solidification it is formed a microstructure where the MC type carbides are dispersed in the matrix, where M denotes metallic atoms. In the central billet region the slower cooling rate allows the atomic migration promoting the formation of the M<sub>2</sub>C and M<sub>6</sub>C carbide network. In the bottom of the billet this net is analogous to that of the centre, but the cells are smaller. The M<sub>2</sub>C type carbide present a hexagonal structure, which assumed a plate-like shape and are discontinuously precipitated.

Figures 1 e 2 show the sample microstructure at the billet centre, which comprises a ferritic matrix, a net of carbides rich in hard atoms (Mo and W) and a disperse carbides formed by hard and lighter atoms (V and Cr).

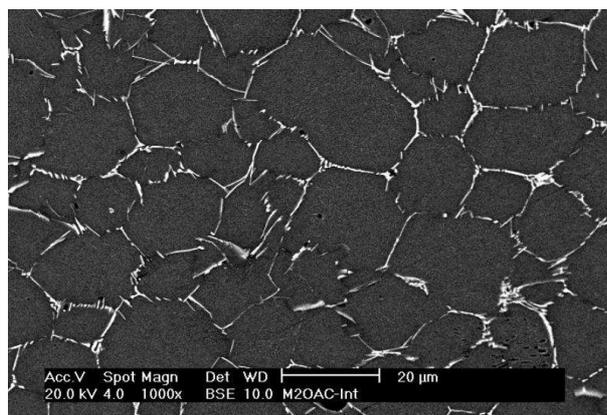


FIG. 1: SEM micrographs of the spray formed AISI M2 high-speed steel showing the carbides cells.

The phases (Cr<sub>15.58</sub>Fe<sub>7.42</sub>)<sub>23</sub>C<sub>6</sub> e V<sub>8</sub>C<sub>7</sub> were identified in the top and the bottom regions of the billet. In the central region another phase (Cr<sub>15.58</sub>Fe<sub>7.42</sub>)<sub>23</sub>C<sub>6</sub> is present as an unknown phase with very high X-ray diffraction peaks intensities and the VC phase. The difference phases found in the billet can be related to the cooling ratios at the particular billet region.

The VC non-stoichiometric carbides occur in the fcc structure (space group, *Fm* -3 *m*), where the vacancies are randomly distributed among the non-metal sites. The V<sub>8</sub>C<sub>7</sub> is a long range ordered phase, which is also cubic (space group, *P* 43 3 2) [4] and has an approximately eight times larger elementary cells than the VC phase. The difference between their X-ray diffraction patterns is the satellite peaks of very low intensity. In the central region of the billet this peaks were not

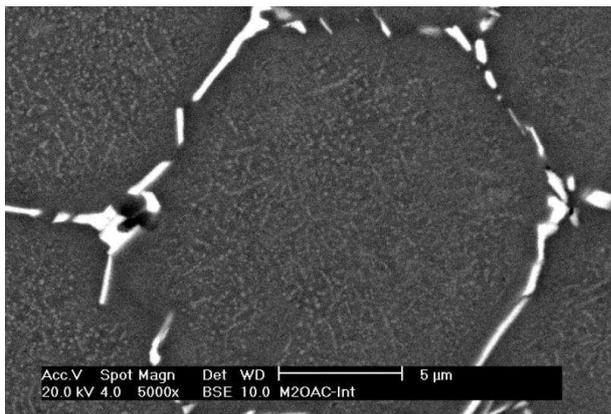


FIG. 2: SEM micrographs of the spray formed AISI M2 high-speed steel showing the intracell carbide precipitation

identified.

The hexagonal or orthorhombic crystalline structure of the  $M_2C$  carbides is function of the ordered or random distribution of the carbon in metallic carbides that is determinate by the cooling temperature, the kinetic of transformation and carbon concentration.

The orthorhombic phases can be identified through the distortion of the metallic sublattice, which induces a splitting of some peaks, which may be detectable, by synchrotron measurements.

The space group  $Pbcn$  (orthorhombic structure,  $\xi Fe_2N$  type) was used for Rietveld refinement of unknown phase [3]. The agreement between the measured and calculated intensities is illustrated in Figure 3. The observed intensity data is plotted in the upper field as points. The calculated pattern is show as a solid line. The solid line curved below x-axis represents the difference between observed and calculated intensity. The differences observed are attributed at the preferential orientation due to the particles shapes.

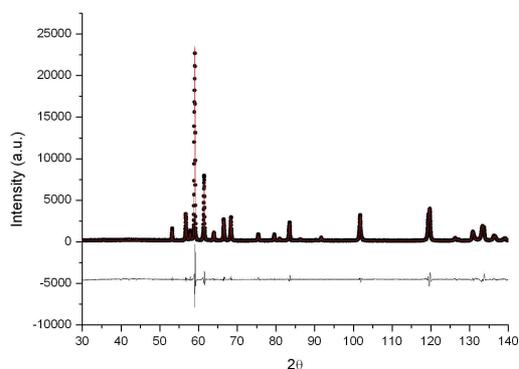


FIG. 3: Rietveld refined diffraction pattern of the extracted carbides.

The differences observed are attributed at the preferential orientation due to the particles shapes and the presence of the amorphous phase.

The lattice parameter calculated for the unknown phases is  $a=0.4649636$  nm,  $b=0.674553$  nm and  $c=0.5116704$  nm. Since, this phase is isomorphs at  $Mo_2C$  the differences between these parameters are assigned by the substitution of the Mo by another alloy atoms [5]. The orthorhombic structure of this carbide is commonly accepted as a disordered structure in transition at a hexagonal structure. The presence of this structure in this material is coherent with the thermodynamic history.

## CONCLUSION

Using the Rietveld refinement, it was confirmed that de unknown phase found in central region of the billet is an orthorhombic structure. For this carbide type the usual structure is hexagonal, this structured can be attributed the thermal treatment of this particular sample.

## ACKNOWLEDGEMENTS

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