Characterization and simulation of carbide precipitation during tempering of low silicon AISI H11 hot-work tool steel

S. MAURIES[a], P. MICHAUD[a], D.DELAGNES[a], P.LAMESLE [a], E.KOZESCHNIK [b]
[a]Ecole des Mines d'Albi Carmaux, Campus Jarlard, Route de Teillet, F-81 013 Albi Cedex 09, France
[Bi b]Institute for Materials Science, Welding and Forming, Graz University of Technology, Austria

INTRODUCTION

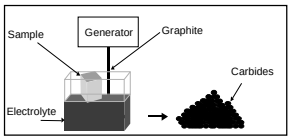
Hot-work tool steels withstand severe and complex thermo-mechanical loading in service. Generally, heat treatment is performed to obtain a good hardness and/or tensile strength with a required ductility. The microstructure parameter controlling well-balanced mechanical strength/toughness properties is the secondary precipitation and more precisely the nanometric carbides formed during tempering. The precipitation of secondary carbides during tempering of low silicon AISI H11 hot-work tool steel is investigated by transmission electron microscopy observations, X-ray diffraction and small angle neutron scattering. The experimental results are compared with results obtained by modelling precipitation sequence using a new model developed at Graz University for nucleation, growth and coarsening in multi-component multi-phase systems.

EXPERIMENTAL METHODS

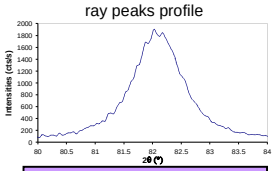
⇨ Low silicon AISI H11 : 0,35%C, 0,28%Si, 0,35%Mn, 0,06%Ni, 5.11%Cr, 1,21%Mo, 0,47%V

X-Ray Diffraction

Carbides extracted by dissolution of matrix



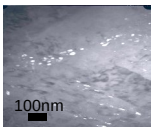
WHM and WAM methods based on X-ray peaks profile



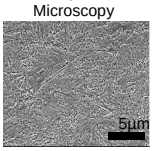
Chemical nature of carbides | **Dislocation density**

Electronic Microscopy

Transmission Electron Microscopy



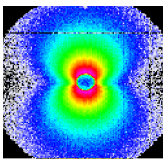
Scanning Electron Microscopy



Possible carbides Nucleation sites | **Grain size Subgrain size**

Small Angle Neutron Scattering

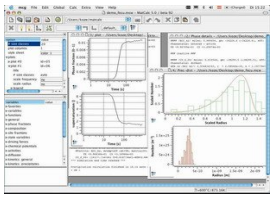
Adjustment of the intensities diffused using a model with double distribution of size of spherical precipitates
Scattering vector range : 0.05 to 1.6 nm^{-1}



Input parameters

Thermodynamic and precipitation kinetics modelling

- Calculations of precipitation sequences during heat treatment in multi-component multi-phase systems with MatCalc
- Based on mean field approximation: Onsager principle



Volume fraction of carbides
Average radii of carbides

RESULTS

Microstructure and precipitation

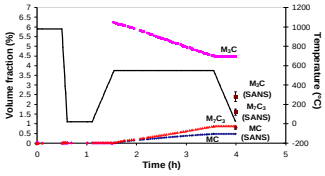
⇨ Two populations of secondary carbides were identified by small angle neutron scatterring :

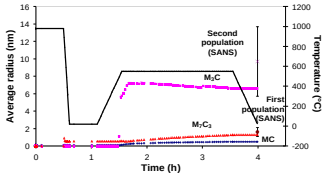
- Small carbides with a radius around 1.6 nm ± 0.5nm : M_7C_3 and MC.
- Larger carbides with a radius 9.7 nm ± 4nm : M_3C and M_7C_3.

Simulation

⇨ Input parameters :

- Dislocation density: $\rho=3.10^{15}$ m^{-2}
- Grain size = primary austenitic grain size = 10µm
- Subgrain size = martensite lath size = 2µm





⇨ The tempering occurs in two steps:

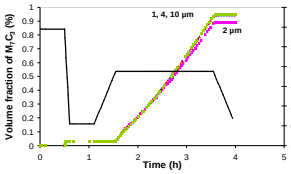
- Rapid precipitation of paraequilibrium M_3C at the beginning of tempering : the depletion of matrix in carbon exactly follows the increase of M_3C volume fraction.
- Then dissolution of M_3C which releases its carbon to allow the precipitation of M_7C_3 and VC.

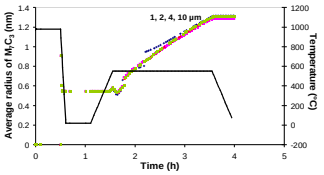
⇨ Comparison between calculation and experimental results :

- Same evolution of both first (MC and M_7C_3) and second population (M_3C).
- Significant discrepancies between volume fraction and average radii measured by SANS and obtained by modelling.

INFLUENCE OF INPUT PARAMETERS

Subgrain size

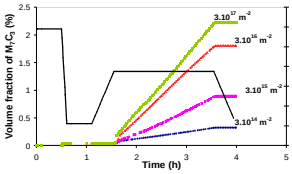


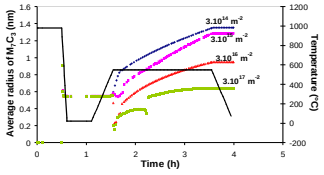


⇨Slight influence on volume fraction and radii of carbides.

⇨Measurement by scanning electron microscopy : 2µm is adopted for simulation.

Dislocation density





⇨The increase of dislocation density raises the volume fraction of M_7C_3 carbides, and consequently enhances the dissolution of M_3C .

⇨Low accuracy in the dislocation density determination (factor of 10) induces scattered simulation results.

CONCLUSION

⇨Discrepancies between experiments and simulation results can be due to an inaccurate determination of input parameters : dislocation density, shape of carbides, interfacial energy carbide/matrix.

⇨The value of subgrain grain size has only a slight influence on precipitation of carbides.

⇨ A variation of dislocation density has a significant influence on volume fraction and radii of carbides. Low accuracy in the dislocation density determination (factor of 10) induces scattered simulation results.

FUTURE WORK

⇨ Volume fraction and radius of M_3C have to be determined by small angle neutron scattering considering needle shaped carbides.

⇨ Improve thermodynamic database in order to better calculate the interfacial energy carbide/matrix.

⇨ With the up to date experimental techniques dislocations density can be adapted by a factor of 10.

⇨ Improve the simulation of MC carbides precipitation : volume fraction as well as radius are still under evaluated.