Phase equilibria of the Fe-Co-Mo ternary system in the iron-rich side above 900 °C

Annie Antoni-Zdziebucki, Naveen Aruchamy, Paolo Galimberti, Thierry Commeau

1 Univ. Grenoble Alpes, CNRS, SIMAP, Grenoble INP, Grenoble, France
2 Eurotungstene Metal Powders, 9 rue André Sidibelas, Grenoble, France
33-40

PREPARATION OF ALLOYS

One Co/Fe/Mo diffusion multiple was prepared by inserting a piece of pure Mo into Co powder, then sintering the binary couple, polishing one broad side, and sintering Fe powder onto that side. It allows to obtain extensive information on the ternary diagram from a single specimen and it was supplemented by investigating homogenized alloys with predetermined compositions. The as-cast alloys were prepared by melting cold pressed powders of high purity in a medium frequency induction furnace under purified Ar. Specimens were sealed in silica capsules and equilibrated at 930 °C in a horizontal furnace under vacuum for 28 days then quenched. At 1250 °C, samples were annealed in a horizontal furnace under He for 7 days and then quenched. The samples produced were observed by optical microscopy and SEM, and characterised by chemical analysis (ICP), EPMA and X-ray diffraction.

INTRODUCTION

The Fe-Co-Mo system is likely to provide technologically appealing alloys, in view of the significant improvements of the mechanical properties, such as hardness and ductility, attainable by aging treatments [1]. A thorough knowledge of the phase equilibria is required for the development of new alloys, processed in the liquid state and requiring a strict control of solidification conditions. However, there is a lack of experimental data concerning liquid-solid phase equilibria, making the calculations conjectural. The main objective of the present study is to carry out an experimental work to achieve the constitution of phase equilibria involving the liquid phase in the iron-rich side of the ternary system.

ISOThERMAL SECTIONS at 930°C and 1250°C [2]

At 930°C:
➢ The three-phase fields boundaries \( \alpha/\gamma \) and \( \gamma/\mu \) were determined experimentally. The \( \alpha/\gamma \) tie-triangle is shifted to lower Co contents and the \( \gamma/\mu \) tie-triangle expands to a lower range of Co compositions in comparison with the calculations.
➢ The solubility of Mo in Fe solid solution is about 8 to 15 mass.% Mo and is found to be higher than in the calculations.

At 1250°C:
➢ The \( \gamma \) layer formed next to the \( \gamma \) layer is very narrow. The \( \alpha/\gamma \) phase boundary was specified and is found to be higher than in the calculations.
➢ The solubility of Mo in Fe solid solution is about 20 mass.% Mo and is found to be higher than in the calculations.
➢ The \( \alpha/\gamma \) tie-triangle is shifted to higher Co compositions and extends to a higher range of Mo compositions as compared to the calculations.

INVESTIGATION OF AS-CAST ALLOYS

Schematic representation of the liquidus projection with the invariant equilibrium of the binary systems [4,5,6].

As-quenched microstructures characterization by SEM/EDX and liquidus temperature evaluated from DTA measurements lead to preliminary map of primary phase fields.

LONG TERM ANNEALING TREATMENTS

Choice of key alloys compositions

➢ As a first step, a preliminary calculation of the liquidus projection of the ternary system has been obtained by introducing ternary excess parameters into the thermodynamic functions. The latter are estimated by using the previous experimental data.
➢ As a guide to choose key alloys compositions for liq/sol. long term annealing treatment: the aim is to locate the composition of the invariant point and to determine the liq/sol. lines just above and below the four-phase plane.

HEATING / COOLING EXPERIMENTS using DTA

➢ Marking of peritectic transformation by precipitates.
➢ For alloys composition located in the primary field of Fe solid solution, several phases show primary solidification morphologies: dendrites of Fe solid solution (dark contrast) and coarse intergranular phase (white contrast).
➢ A third population of intergranular phase is formed by solidification.
➢ The precipitate free periphery of the dendrites could correspond to \( \gamma \) phase. In the center of the dendrites, \( \gamma \) phase has precipitated. Transition between \( \gamma \) dendrites and \( \gamma \) is marked by strings of \( \mu \) precipitates.
➢ A ternary quasi-peritectic reaction: \( L \rightarrow \gamma + \mu \) has been observed at 1300 ± 2 °C

PERSPECTIVES

This investigation should be completed by an experimental study of the ternary system states involving the liquid phase. Annealing treatments involving the liquid phase will be performed at selected temperatures by means of electromagnetic phase separation technique [8].

The integration of all these new data in a thermodynamic evaluation should allow a refinement of the description of the Co-Mo system.