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Influence of Mo content on Tungsten Heavy Alloys for Die Casting Applications

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Tungsten heavy alloys containing Mo are widely used on the Al die casting industry for several decades. Obtained through solid-liquid sintering from a compacted mixture of prime materials at the powder state, some aspects of these alloys, notably with respect to the influence of a small variation on the Mo content are unknown. Present investigation evaluates the influence of Mo not only at the bulk properties of tungsten heavy alloys but most importantly at the surface level, where alloy will interact directly with the solidifying liquid cast. Usual investigations were performed and a complementary ToF-SIMS was performed, characterizing the very first few layers of the material.

Keywords: *tungsten heavy alloys, Mo content, sintering, mechanical resistance, Aluminiun die casting*

1. Introduction

Recent previous works [1-5] described correspondingly mechanical and thermal properties of two available trademarks from Plansee tungsten heavy alloys: Densimet D185 © and Densimet D2M © (the latter, alloy containing Mo as an alloying element). In the present study, efforts were concentrated on the Mo role of at Densimet D2M © material, notably at the assessed microstructure for variations on Mo concentration with some perspectives for an improved Densimet D2M ©. According to the literature [6], the presence of Mo will play a role on tungsten solubility at the binder. Therefore, the increasing concentration of Mo shall reduce the total solubility of W during solid liquid sintering [5]. Authors supposed that at higher concentrations (more than 10%), the kinetic growth of W grain will be slower and better mechanical properties can be then obtained by grain refinement. Such high Mo concentration can be though industrially critical because of the possible presence of brittle intermetallics, particularly the ones described on the Ni-Mo system.

The Mo concentration effect was then evaluated by a very specific surface analysis technique, the ToF-SIMS. Time-of-Flight Secondary Ion Mass Spectroscopy (ToF SIMS)[7] is a very sensitive analytical technique which uses a pulsed ion beam to remove both atoms and molecules from the sample surface (< 4 atomic layers). ToF SIMS machine offers the opportunity to perform chemical mapping of element or molecules with a high lateral resolution (< 100 nm). By combining depth profile with 2D imaging, it is possible to reconstruct 3D images.

2. Experimental

2.1 Sample preparation

Standard Densimet D2M© and 4 prototypes were elaborated according to the alloying composition listed on Table 1. (cf. Table 2).

Table 2- Standard Densimet D2M and prototype composition

Alloy	Ni/Fe	Mo	W
Densimet D2M©	2	4	balance
Prototype A	0.5	4	
Prototype B	2	2	
Prototype C	3	2	
Prototype D	2	6	

They were then isostatic pressed in cylinders in a cylindrical shape with approximately 12 mm of diameter. Sintering step took place under pure H_2 atmosphere, aiming the chemical reduction of oxide layers. Samples were then machined, cut and polished using SiC paper of different mesh and then finished using ordinary alumina polishing. They were cleaned on US bath and dried on desiccator before usual and TOF-SIMS analysis

2.2 Results

All density values were superior to 17,0 g/cm^3. In terms of microstructure analysis, the first striking point was the perceptible presence of intermetallics on Prototypes A, B and D. Indeed, the presence of various intermetallic phases associated with the intense variation on the Mo content and the different Ni/Fe ratio might generate brittleness for those compositions.

Rather interesting results were obtained on prototype C. This relatively low density alloy (around 17.3 g/cm^3) showed an overall consolidated structure,

similar to the classical Densimet D2M © alloy. Samples were then deeply investigated on ToF-SIMS analysis, notably prototype C, as shown at the images below (Figure 4 and Figure 5). A representative surface of 100µm^2 from the sample was scrutinized by the device, with respect to each one of the constitutional elements. This chemical mapping enables the observation of rich or depleted zones on the material according to the elements, including W and Mo distributions.

As previously observed [2], Fe and Ni will be mainly restricted to the binder (cf. Figure 4). Some past results [6,8] pointed out the possibility that the levels of Ni evaluated inside the W phase are higher than the ones predicted by the Ni-W phase diagram. It is though not observed any trace of either Fe or Ni on the nodular domains. The nodular domains are mainly evaluated with respect to Mo and W. Figure 5 shows some surprising results with respect to the nodules: some of the: are showing depleted Mo zones. Those results are in contrast with previously obtained microstructure in which Mo core surrounded by W were observed by some authors. Also, in small scale on the binder, some zones are also Mo deprived.

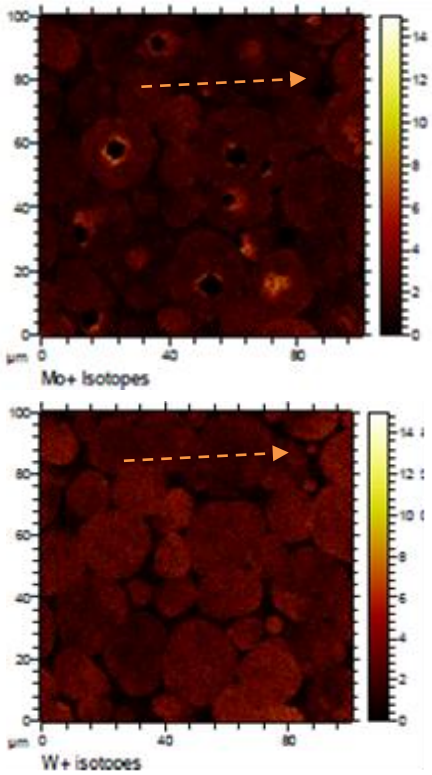

Figure 5- Images obtained with ToF-SIMS analysis (prototype C) with W and Mo mapping.

The chemical mapping is related with W and Mo occurrence. The arrows on Figure 5 indicate the existence of a depleted Mo zone. Also, several nodular phases are showing Mo depleted areas in their core.

3. Conclusions and perspectives

Prototype C has the highest Ni/Fe ratio and less Mo than other compositions. In a first observation, it showed similar microstructure with respect to the standard industrial alloy. ToF-SIMS analysis though put in evidence some depleted Mo zones in that alloy. Observed microstructure is similar to the existent industrial alloy.

Even though some results showed drawbacks in t terms of homogeneity, tungsten heavy alloys containing Mo remain as the ideal material for die casting application. A better control on Mo distribution will undoubtedly lead to an optimized alloy which must be verified in application.

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