THE STUDY OF THE STRUCTURAL MODIFICATION OF THE TEMPERED HEAVY ALLOYS BASED TUNGSTEN PLASTICAL DEFORMED

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Abstract: *The alloy is characterized by a complex multiphasical structure. The structure of the W-Ni-Fe alloy consists from a refractory phase of the solid solution rich in tungsten and a binder phase, easy inflammable, formed by the solid solution of tungsten and iron in nickel, hardened through dispersion. The behavior of the heavy alloy at plastically deformation and tempering will be determined by the crystalline nature of the phases, by their interaction and by the role of the interphasical limits which are formed at hardening. The aim of this paper is the study of the structural modification of the binder from the easy inflammable phase of the deformed alloy W-Ni-Fe.*

Keywords*: AGW, sintering with liquid phase, composite, metallic powder.*

1. INTRODUCTION

Due to the high demands for the performances of the heavy alloys based tungsten (noted from now on AGW) imposed by the enhancement of their applications, there were developed some methods of mechanical manufacture through plastic deformation, through thermal and thermo-mechanical treatments, to be applied after sintering. These methods have to improve the mechanical properties and especially the toughness and ductility of the AGW, characteristics that are reflected through their tensile; these demands were imposed by the applications from the military field [1].

Examples of the mentioned manufacturing methods are the cold and/or worm plastic deformation, (cold and/or worm forging, lamination, cold and/or worm isostatic pressing, quasi-isostatic pressing), combined or not with aging thermal treatments through deformation or precipitation [2]. Through these manufacture methods an especially place has the dehydrogenating thermal treatment, applied to eliminate the remanent hydrogen from AGW after sintering, because his presence may be one of the causes which determine the fragilisation of the AGW with matrix based Ni-Fe. To be able to apply correctly the methods of post-sintering manufacture of AGW and to obtain maximum efficiency it is necessary to know the behavior at plastic deformation of the two phases which compose the AGW: the hard phase from W grains and the ductile one, made from the matrix in which are included the W grains. The behavior of the two phases together is the answer at the mechanical solicitations of these materials of composite type, which is the heavy alloys based tungsten.

After many experiments there may be said that there exists an important dependence of the yield strength of the tungsten grains by the temperature. These grains are crystallized in system cvc, while the ductile matrix crystallizes in system cfc and has a lower yield resistance, which is mostly independent by the temperature. As a result, deformation of the composite is controlled only by the deformation of the W particles, which are more resistant.

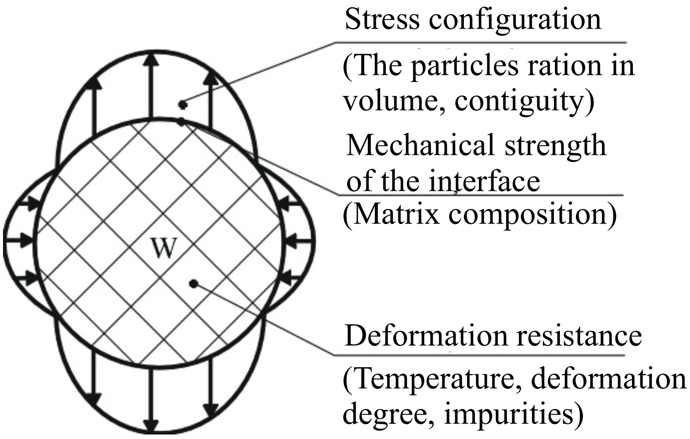

Fig.1. Representation of the stress around the tungsten grains.

The matrix has to be able to rise his strength with the help of the hydrostatic component of the stress until a necessary level of the stress to deform the hardest phase, but to not lead to the earliest fracture of the matrix. This means that the matrix phase has to support a fast hardening through cold working, rising in this way its yield limit at that one of the tungsten grains.

On the other hand, deformation and fracture studies of the composites based tungsten, lead to the conclusions that the composite ductility and its fracture depended on many factors, which are presented in figure 1 [3]. The configuration around the tungsten grains depends on the volume ratio of the tungsten grains; the mechanical resistance of the interface depends on the matrix composition and the yield resistance of the tungsten phase depends on the temperature, deformation degree and purity [4].

The studies of the behavior at deformation were done using an AGW with the nominal composition 90W-7Ni-3Fe. They shown that the deformation of the tungsten grains is very close by the global deformation of the composite in a temperature interval of –25 ^{0}C and +100 ^{0}C. The matrix deformation through cold working is bigger then that one of the tungsten grains; the last one corresponds to the double stresses compared to the nominal stress from the tungsten grains [5]. Using the obtained data it may be said that the fracture take place during the plastical deformation starting from the micro-cracks, which will be open especially between the tungsten grains, after a certain deformation, growing up with the increasing of the deformation degree.

2. THE EXPERIMENTAL PART

There were elaborated samples from the alloy W-Ni-Fe using the methods of powder metallurgy. From this mixture there were pressed samples with their exterior diameter of 20 mm and high of 60 mm; sintering with liquid phase at 1475 ^{0}C, for 1 h, in hydrogen. After sintering the samples were manufactured through turning at an exterior diameter of 15 mm, high of 50 mm and then introduced in dies of steel; the ensembles part-die were pressed at different reducing degree, between 2-50 %, figure 2. After deformation the parts were treated at different tempering temperatures between 600 ^{0}C and 1300 ^{0}C, 1 h, to study the recrystallization of the tungsten phase, and between 300 ^{0}C and 1200 ^{0}C, 1 h, for the matrix phase. The control parameter of the material microstructure evolution was the hardness.

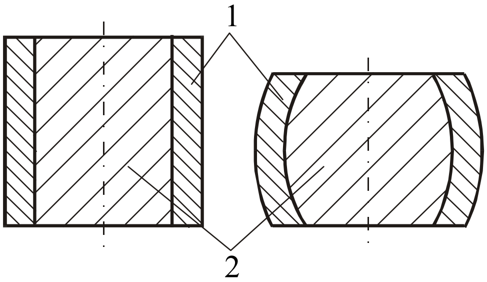

Fig. 2. Steel dies with samples:
1 - die, 2 - samples.

3. RESULTS AND DISCUTIONS

The material cold worked during the plastical deformation process is characterized by a surplus of free energy. The increasing of the free energy through deformation is tied by the material nature, by the type and repartition of the crystalline net's defects, by the conditions of the deformation process. The structure of the heavy alloy 90W-7Ni-3Fe sintered with liquid phase at 1475 ^{0}C, 1h, can be seen in figure 3.

In figure 4 there are presented the microhardness variations of the phase's constituents versus the deformation degree, which reveal the cold working character. The result of the microhardness measurement demonstrates that the degree of the deformation through cold working of the binder phase it is considerably

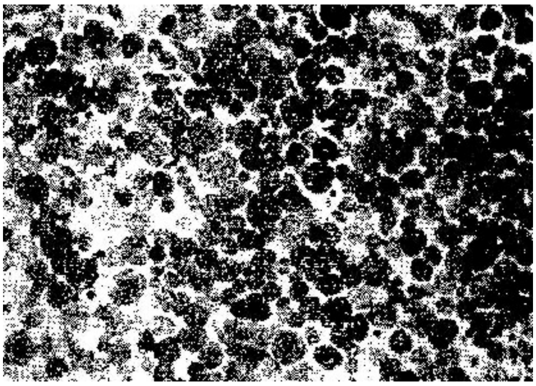

Fig. 3. Initial structure of the heavy alloy 90W-7Ni-3Fe (500 x).

greater than for the tungsten at small degree of deformation. The micro-hardness of the easy inflammable component riches, already, a deformation degree of 10 %. This value is the limit, which doesn't modify through the rising of the deformation degree. The level of the free energy is the energy of the remanent deformations and it determines the character and the speed of the structural modifications into the alloy during the tempering. Because of the interval, of the deformation degree and of the heating temperatures, there were pursued the most important steps of the structure's modifications from the alloy during the tempering.

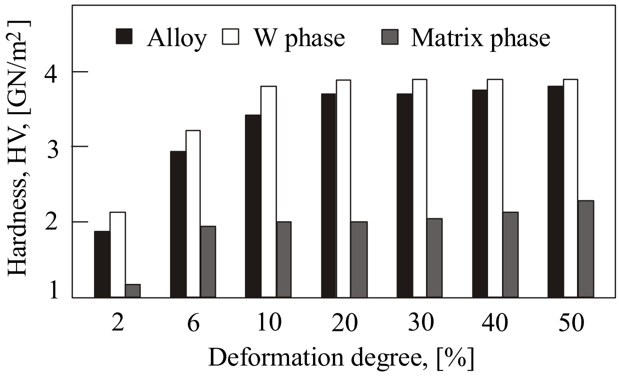

Fig. 4. The variation of AGW 90W-7Ni-3Fe hardness and phases microhardness versus the deformation degree.

As it results from the microhardness measurement, a tempering of the alloy at temperature relatively low determines a diminishing of the binder phase hardness, figure 4. The tempering process of the mechanical properties from the binder phase depends on the preliminary degree of the cold deformation and it intensify with its rising. The hardness diminishing is determined by the relaxation degree too. The diffusion and especially self-diffusion, tied by the vacancy migration determine the relaxation. To the relaxation belongs also removal and annihilation process of the isolated vacancies, of recombination and annihilation of different vacancy aggregates.

The presence of a quantity of vacancy great enough and of the possibility of their migration through the rising of the tempering temperature permits to the dislocations to do a drag. This process generates most of the mutual annihilation actions of the dislocations with contrary sign. The dislocations with the same sign which remained in surplus rally into the walls which are perpendicular on the first slip surfaces, as called suborders, limits between the blocks of bend type which done small angles. The migration of dislocations in surplus determines the mechanism of polygonization process, which take place at high temperatures and ensure the improvement of the deformed structure.

Into the samples deformed with small deformation degree (2 %), the recrystallization begins at 1000 ^{0}C. In the same time with the deformation increasing, the recrystallization beginning removes in the domain of lower temperatures, thus at a deformation of 50 % the recrystallization begins at 600 ^{0}C. At high degrees of quasi-isostatic deformation appear important gradients of free energy at the limit of the distortion and undistorted area of the crystalline net. The difference of the energetic level determines the diminishing of the recrystallization temperature. This effect may be seen on the diagram of the binder metal cold worked at the samples of heavy alloy quasi-isostatic deformed. Into the samples deformed with small degree of deformation the relaxation process may be explained through the fact that the time necessary for the disappearance of the pointshaped defects and of the dislocations at relaxation is smaller then the average period of incubation of the formation into the deformed material of the recrystallization centers. During the relaxation process, which accompany the successive modification of the mechanical properties at recrystallization, the hardness of the alloy diminishes suddenly, as the micro-hardness of its phase components, figure 5. For the samples strongly deformed there appears many centers of recrystallization; their rising is burdened by the intersection with other recrystallized grains. For small degrees of deformation, closely to the critical ones, appear little centers of recrystallization, which succeed to grow up until significant dimensions and intersect other recrystallized grains. For the critical deformation degree, the average size of the recrystallized grains grow up from 15 μm at 875 ^{0}C, at 35 μm at 1300 ^{0}C. Once with the growing of the tempering temperature, the size of the critical deformation removes in a lower domain. At the tempering temperature of 875 ^{0}C the deformation critical degree rich 6 % and diminish at 2 %

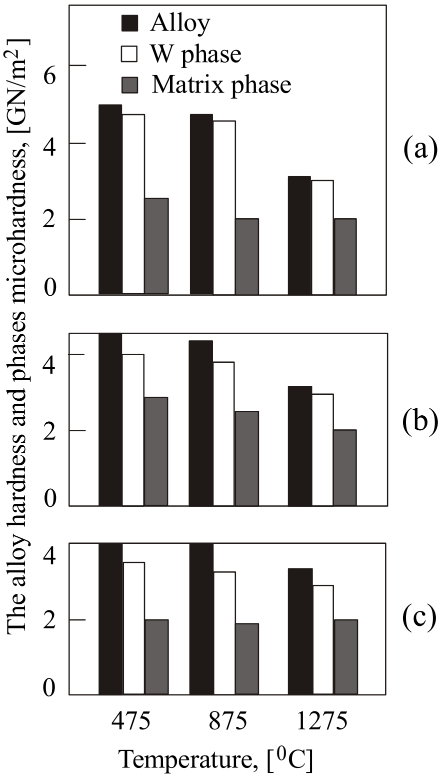

Fig. 5. The variation of the hardness and microhardness of the same AGW from fig. 4, versus the tempering temperature and different deformation degree: (a = 50 %; b =10 %; c = 2 %).

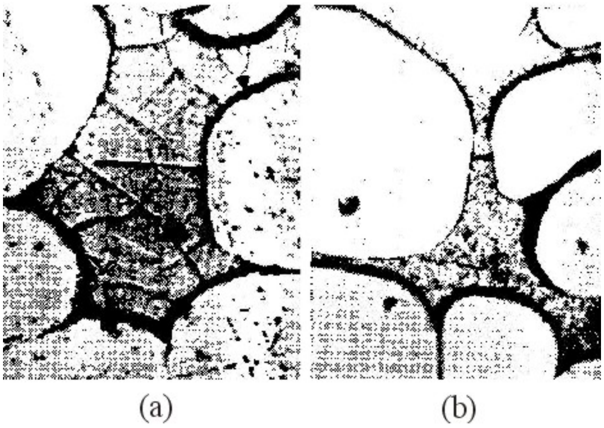
(a) (b)

Fig. 6. The structure of the binder phase: (a) - deformation 10 %, tempering temperature 1275 ^{0}C; (b) - deformation 6 %, tempering temperature 1275 ^{0}C.

for a tempering temperature of 1275 ^{0}C. The recrystallization for all deformation degree through tempering for 1h, ended at 1075 ^{0}C. The alloy structure with phase slow recrystallized is presented in figure 6. The growing of the recrystallized grains take place, mainly, in the limits of the initial grains (fig. 6 a) and only for the critical deformations and for that one near the critical ones, the grains dimension outruns the initial one (fig. 6 b).

4. CONCLUSIONS

- The beginning temperature of the binder phase recrystallization in the heavy alloy 90W-7Ni-3Fe depends on the alloy initial cold deformation degree and it diminish from 1100 ^{0}C at 400 ^{0}C in the same time with the deformation increasing from 2 at 50 %.
- At low tempering temperatures and small deformation degree, into the phase take place, mainly, a relaxation process tied to the tempering and polygonization. For the intermediate deformation, these processes take place in the same time, overlapping.
- The size of critical deformation depends on the tempering temperature and diminishes from 6 to 2 % simultaneous with the temperature rising from 800 at1300 ^{0}C.

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