



Phase Composition and Microstructure of Fe-12% Mn and Fe-20% Ni Alloy after Hot Plastic Deformation

Stoyan PARSHOROV¹, Evgeni MACHEV¹, Petar PETROV², Stefan VALKOV²

¹ Institute of Metal Science, Equipment and Technologies with Hydro- and Aerodynamics Centre
“Acad. A. Balevski” at the Bulgarian Academy of Sciences, Sofia, Bulgaria
e-mail: s_parshorov@gmail.com

² Institute of Electronics at the Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract

The subject of investigation are iron-based alloys with manganese content 12% Mn and 20% Ni. The samples were tested after complete annealing and after controlled rolling in the austenitic area at a temperature interval of 1050-980 °C with a degree of deformation of 41-43%. The influence of the content of alloying elements – manganese and nickel and hot plastic deformation on the amount of residual austenite and the micro-structural parameters of austenite was determined by X-ray diffraction. The plastic deformation has been found to influence the phase composition and the formation of substructure in austenite, which is subsequently inherited from martensite.

Keywords: manganese steels, hot plastic deformation, micro-structural parameters

1. Introduction

The alloys Fe-20% Ni and Fe-12% Mn, according to their state diagrams [1], at room temperature, have a predominantly martensitic structure. When cooled from the austenitic area the reactions, respectively, $\gamma \Rightarrow \alpha$ -martensite in nickel and $\gamma \Rightarrow \varepsilon$ -martensite in manganese, take place. The purpose of the present work is to determine, by X-ray structural studies, the effect of hot plastic deformation in the austenitic area on the phase composition and micro-structural parameters of solid solutions at room temperature.

2. Materials and method

Object of investigations are binary alloys on ferrous base of 20%wt nickel and 12%wt manganese, respectively. The alloys are produced in vacuum furnace. The cast sample bodies were rolled repeatedly up to a thickness of 4 mm, then a controlled rolling was carried out in the austenitic region in the temperature range 1050-980 °C with a degree of deformation of 41-43%. Some of the samples were reheated to a temperature of 1050 °C and, after holding for 1 hour at this temperature, were cooled with the oven. The final size of the x-ray plates 15x15 mm was obtained after electro-spin cutting in a water bath. This eliminates the structural and phase changes in the specimens resulting from their preparation.

The X-ray structure analysis is performed by standard apparatus “Philips” of Co-K α emission. The full spectrum of the examined alloys is taken in the range of doubled reflection angles from 40 to 140° and austenite (111) γ line and martensite (110) α line by decreased step of 0,02°/min and rate of 20 sec/step. For references, there are used samples of armco-iron and stainless steel after full annealing.

The quantity of the residual austenite %A is calculated by standard method [2] on the basis of the intensity of the diffraction maximums I_{(111) γ} and I_{(110) α} of the austenite and martensite.

For the sake of comparison, the amount of residual austenite was calculated by replacing the intensities with the areas of the respective diffraction lines A (111) γ and A (110) α .

The microstructure parameters of the austenite and martensite solid solutions – size of the domains – D and the micro deformation of the crystal lattice – ϵ , are studied by the so called “single line analysis”. This method allows calculating the microstructure parameters of austenite and martensite on the basis of one reflection line, for every one of the phases [3-8]. The reflection lines (111) γ and (110) α are examined as in compliance with the analysis principles reflection lines are studied at low values of the angles where the widening caused by the presence of a duplicate in them is negligibly small. It is considered that an accurate description of the reflection line profiles could be achieved by the so-called pseudo-Voigt function, which is a combination of the Gauss and Cauchy functions.

For practical processing of the experimental data by the “single line” analysis, we have used the capabilities of the program “Origin 5.0 Pprofessional” with calculation method of the program Excel. On their basis, the values of the solid solution microstructure parameters are obtained.

3.Results and discussion

Figures 1 a), b) and 2 a), b) show the diffraction lines of reflection of martensite and austenite, respectively – (111) γ and (111) α for the studied alloys. Table 1 shows the values of the microstructural parameters of austenite and martensite and that of residual austenite, calculated on the basis of the methods described above.

Table 1 – Size of the domains D, lattice micro deformation ϵ (strain) and quantity of the residual austenite – A in %wt, calculated by intensity – I / by area of maxim

sample №	Alloy	2w (°2 θ) (FWHM)	β_{integr}	D(crystallite/ domain size) x 10 ⁻¹⁰ [m]	ϵ (strain)	Residual austenite A %
1.	Fe-12%Mn-anneal. (110) α	0,23471	0,362	39,71521004	0,000180671	-
2.	Fe-12%Mn-deform. (110) α	0,43854	0,486	1788,290819	0,003887757	-
3.	Fe-20%Ni-anneal. (111) γ	0,33445	0,4288	61,385534	0,002303695	30,5% / 25%
	Fe-20%Ni-Anneal. (110) α	0,36429	0,4498	76,97610176	0,002651967	-
4.	Fe-20%Ni-deform.(111) γ	0,4654	0,5216	326,7934148	0,004107357	68% / 69,8%
	Fe-20%Ni-deorm.(110) α	0,38378	0,472	74,30479676	0,002822613	-

The presence of two types of martensitic transformations in the alloys under consideration is defined by the thermodynamic, crystallographic and other features of the two alloys. The determining parameter for this is basically the austenite stacking fault energy /SFE/, from which the corresponding martensitic phase has evolved. Fe-Ni alloys are known to exhibit relatively higher SFE compared to manganese. The Fe-12% Mn alloy is characterized by SFE, in the order of 18 erg/cm², suggesting the formation of ϵ -martensite. The higher SFE value of the Fe-20% Ni – 50 erg/cm² double alloy guarantees a martensitic transformation of the $\gamma \Rightarrow \alpha$ type [9].

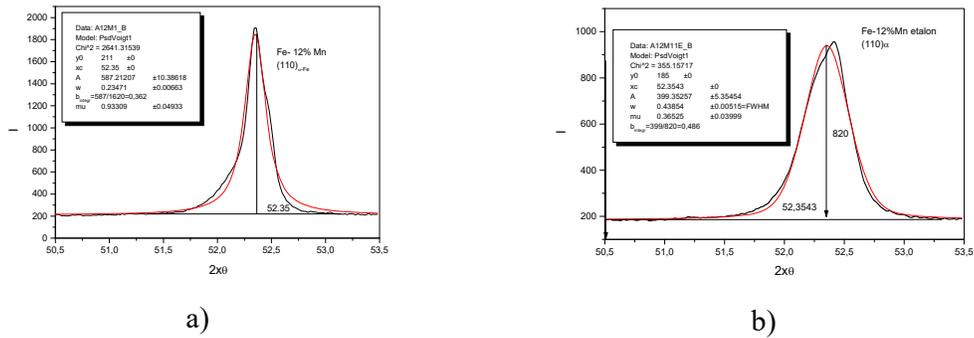


Figure 1. Diffraction line (111) α – Fe-12% Mn alloy, a) annealed; b) hot deformed

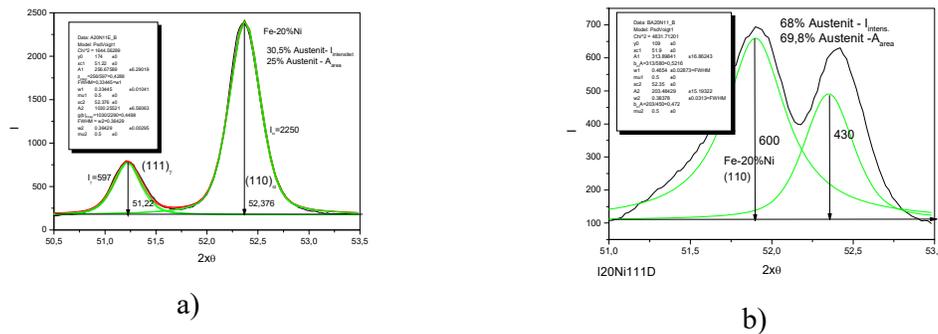


Figure 2. Diffraction lines (111) γ and (111) α – Fe-20% Ni alloy a) annealed; b) hot deformed

The results obtained show that the Fe-12% Mn alloy does not form residual austenite. The presence of residual austenite is known to be triggered by the high internal stresses that the austenite undergoes from the growth of martensitic lamellae or needles. The absence of residual austenite indicates that the formation of ϵ -martensite is associated with the passage of strong relaxation processes leading to a decrease in the value of internal stresses. Confirmation of this is the experimentally obtained by us the very low value of the micro-deformations of the martensite lattice.

Residual austenite is not recovered after hot plastic deformation. This indicates that hot deformation treatment does not alter the relaxation nature of the conversion mechanism.

The results also showed that hot plastic deformation changes the values of the micro-structural parameters of the martensite – the values of the micro-deformation of the lattice and the size of the crystal domains increase dramatically. In our view, this is caused by structural changes occurring during hot plastic deformation, which lead to the formation of a substructure in austenite, which is subsequently inherited from martensite.

The nickel alloy is characterized by the presence of residual austenite, the amount of which increases after hot plastic deformation almost 2.5 times – samples 3 and 4 fig. 3-4. This, as noted above, is due to the higher internal voltages in the interphase spaces. Interestingly, the hot plastic deformation does not change the micro-structural parameters of the converted

martensitic phase, and within the error of the experiment these values are the same as those of the annealed specimen. Similar to manganese alloy, hot plastic deformation increases the values of the microstructural parameters of austenite associated with the formation of substructure in the matrix austenitic phase. Probably as early as the process of hot plastic deformation, substructural grains are formed in the austenite, cleared of dislocations, which is also inherited from the residual austenite. This also guarantees the high values of crystal domain lengths.

4. Conclusions

X-ray diffraction studies of Fe-20% Ni and Fe-12% Mn alloys showed that:

1. The Fe-12% Mn alloy does not form residual austenite, even when hot plastic deformation is applied in the austenitic region, due to the low value (SFE) of this alloy and the formation of ε -martensite. The conversion is related to the strong relaxation of the stresses in the solid solution.
2. The nickel alloy is characterized by the presence of residual austenite, the amount of which increases after hot plastic deformation. This is due to the higher internal voltages in the interphase spaces.
3. The hot plastic deformation dramatically increases the lattice micro-deformation values and the size of the crystal domains of the martensite in the Fe-12% Mn-alloy and the residual austenite in the Fe-20% Ni alloy. Structural changes occurring during hot plastic deformation lead to the formation of a substructure in austenite, which is subsequently inherited from martensite and residual austenite.

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