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B.M.Efros

DEFORMATION TRANSITIONS IN METASTABLE SYSTEMS UNDER PRESSURE

A.Galkin Donetsk Physico-Technical Institute, National Academy of Sciences of Ukraine
R.Luxemburg str., 72, 340114, Donetsk, Ukraine

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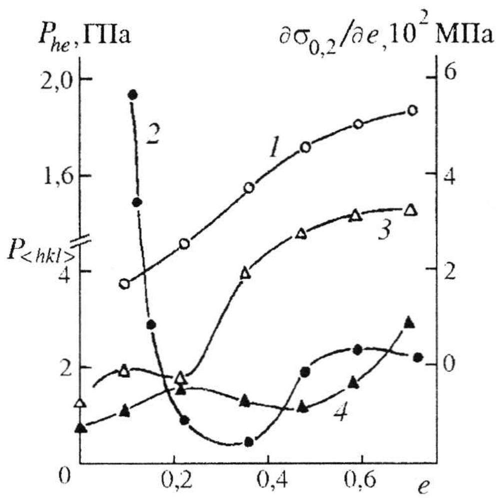
The deformation structural and phase transformations in metastable b.c.c. and f.c.c. materials based on Fe–Ni-, Fe–Ni–Cr- and Fe–Mn–Cr-solid solutions at treatment under high hydrostatic pressure are studied. The realization of these transformations in the investigated metastable systems under pressure is accompanied by the changes of their mechanical properties.

Structural and phase transformation in metastable systems is considerably influenced by elastic stress, plastic deformation below and above critical points (for example, M_d), and uniform hydrostatic pressure. The obtained theoretical and experimental results indicate that a tendency to homogenization of the defect structure is the most typical feature at deformation of stable and metastable systems (metallic materials) under pressure [1,2]. By plastic deformation methods under high hydrostatic pressure (HHP) conditions one can either suppress or intensify the development of the deformation structural and phase transformations and, consequently, obtain the desired properties for metastable materials.

Pressure treatment of b.c.c. metastable materials based on Fe–Ni–Cr- and Fe–Ni-solid solutions

In this paper specific features of defect structure changes at different scope levels, crystallographic texture and mechanical properties of maraging steels 03Cr11Ni10Mo2Ti (chemical composition, by weight %: 0,03C; 11,13Cr; 9,48Ni; 1,96Mo; 0,88Ti; 0,20Si; 0,01P; 0,005S) and 03Ni18Mo4Ti (chemical composition, by weight %: 0,03C; 17,8Ni, 3,91Mo; 1,36Ti; 0,05Si; 0,005P, 0,005S) under hydroextrusion to the logarithmical deformation degree $e = 0–0,7$ are considered [3,4].

The analysis of obtained experimental results enables us to mark some common rules in the character of strain hardening, formation of defect structure and evolution of crystallographic texture at the plastic deformation of the investigated steels under HHP (Figs. 1,2). Thus, in the case of hydroextrusion of 03Cr11Ni10Mo2Ti in the range $e > 0,2–0,5$ where considerable hardening is observed, the active growth occurs only for one selected texture orientation <110> at the background of "carpet" structure and channels of the localized deformation at the mesolevel. The formation of complex two-component texture <110>–<114> (Fig. 1) takes place at intensive hardening stages ($e < 0,1$ and 0,5–0,7). In this case the deformation under HHP conditions with degree $e > 0,5$ is accompanied by both the noticeable hardening and the increasing formation of the characteristic "curly" structure levels with simultaneous increase of the portion of volume occupied by fragmental structure at substructural levels. In the case of hydroextrusion of steel 03Ni18Mo4Ti in the range e = 0–0,7 the stage of strain hardening and its correlation with the evolution of defect structure and formation of crystallographic texture are expressed essentially less pronounced (Fig. 2).



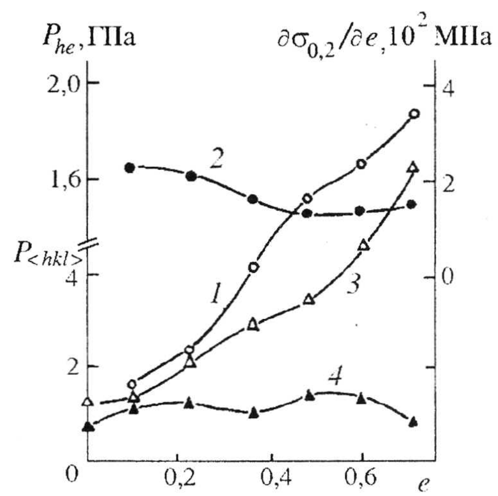


Fig. 1. Dependence of extrusion pressure P_{he} (1), coefficient of deformation hardening $\partial\sigma_{0.2}/\partial e$ (2) and value of polar density $P_{<hkl>}$ of texture <110> (3) and <114> (4) orientations on a degree of deformation at hydroextrusion e of steel 03Cr11Ni10Mo2Ti

Fig. 2. Dependence of extrusion pressure P_{he} (1), coefficient of deformanion hardening $\partial\sigma_{0.2}/\partial e$ (2) and value of polar density $P_{<hkl>}$ of texture <110> (3) and <114> (4) orientations on a degree of deformation at hydroextrusion e of steel 03Ni18Mo4Ti

The obtained relationship found between the formation of defect structure, the evolution of texture and the change of the mechanical properties of b.c.c. metastable materials can be used for obtaining new structural states possessing improved physical and mechanical properties.

Pressure treatment of f.c.c. metastable materials based on Fe–Cr–Mn-solid solution

The paper studies the influence of hydrostatic extrusion at room temperature with reduction ratio ε = 0–50 % ($\varepsilon = [(D^2 - d^2)/D^2]$ 100%, where D – diameter of the sample in the initial state, d – diameter of the sample after deformation) on structure, phase composition and mechanical properties of metastable steel Cr13Mn21 (chemical composition, by weight %: 0,02C; 12,8Cr; 20,7Mn; 0,20Si; 0,004P; 0,005S). The degree of stability of austenite in the initial state (hardened) has been controlled in the studied steel by carbon and nitrogen alloying.

The mechanical properties of Cr–Mn steel samples in the hardened state (1050°C) were as follows: $\sigma_{0.2}$ = 310 MPa, σ_B = 740 MPa, δ = 65 % and Ψ = 68 %. The level of mechanical properties of this alloyed with carbon and nitrogen steel in the initial state depends on value of hardening temperature (and time of annealing at this temperature) [5,6].

The plastic deformation of Cr–Mn steels under pressure at room temperature in the range ε = 0–50 % results in considerable growth of resistance to high and low ε which is shown by the example of Cr–Mn steel with 0,4 % C and Cr–Mn steel with 0,4 % N (Fig. 3,a). Strain hardening degree of Cr–Mn under hydroextrusion depends on the relationship of the alloyed elements and, as a rule, it is higher when the concentration of these elements grows.

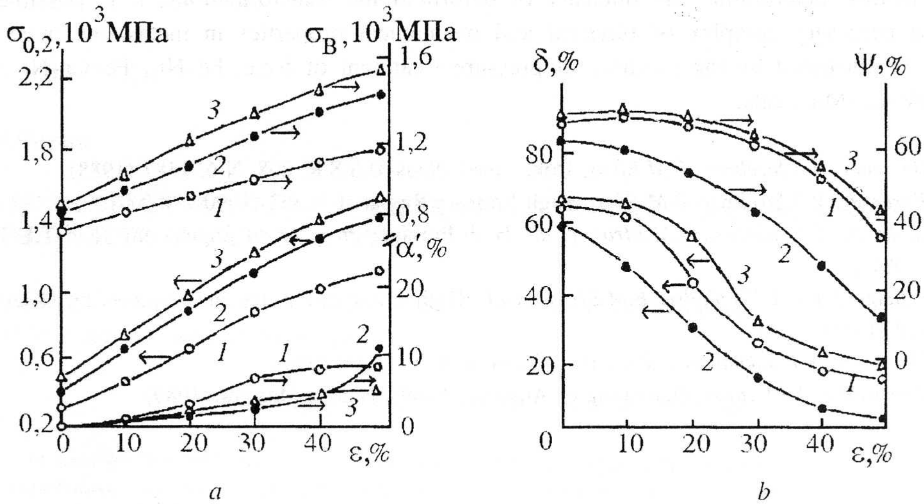


Fig. 3. Effect of hydroextrusion under the room temperature on mechanical properties and quantity of deformation α'-martensite in steels: *1* – Cr–Mn-based steel; *2* – Cr–Mn steel with 0,4 % C; 3 – Cr–Mn steel with 0,4 % N; *a* – $\sigma_{0.2}$, σ_B, *b* – δ, ψ

With the increase of percent reduction ε (especially at ε > 40 %) the $\sigma_{0,2}/\sigma_B$ ratio increases considerably which is accompanied by degradation of plastic characteristics (Fig. 3,*b*). Value of ε, above which the intensity of δ and Ψ lowering increases essentially, shifts towards higher value ε for extrudates of Cr–Mn–N as compared to the base steel. For the extrudates of Cr–Mn–C steel this shift is of the opposite sign. The observed character of mechanical property changes in steels under investigation considerably depends on the number of defects of crystal structure and their distribution within the matrix as well as the intensity of twinning and appearance of deformation phases (deformation α'-martensite) at the background of supersaturated γ-solid solution decomposition at the given Δε (Fig. 3).

Studies of microstructure have shown that in the above mentioned steels both the homogeneous and discontinuous (to a less degree) decomposition in austenite grain as well as precipitation of hardening phase at grain boundaries take place depending on parameters of deformation-heat treatment under high hydrostatic pressures.

The obtained experimental results are the basis for the development of optimal modes of hydropressing treatment of chromium-manganese steels alloyed with carbon and nitrogen. A desirable complex of the mechanical properties can be finally formed by the subsequent aging of extrudates of this quality.

Conclusion

The purposeful study of the effects accompanying structure and phase transformations at deformation under HHP is the prospective trend which is used to develop techniques of pressure treatment of metastable materials for obtaining the states with a high complex of physical and mechanical properties. The obtained experimental data show that the character of deformational transformations and, thus, the quantity of structural and phase components are defined by both the internal (chemical composition, structure, etc.) and external (scheme and degree of deformation, pressure, temperature, etc.) factors. Therefore, in the end, with these factors, determining the intensity of deformational transformations, it is possible to form a necessary complex of physical and mechanical properties in metastable materials which is illustrated by the example of pressure treatment of b.c.c. Fe–Ni-, Fe–Cr–Ni- and f.c.c. Fe–Cr–Mn-steels.

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