RELATION BETWEEN NANOPARTICLES AND DISLOCATION DENSITY NETWORK IN THE MICROSTRUCTURE SEVERAL TECHNICAL SYSTEMS

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Introduction

Low – alloy systems on CrMo and CrMoV base successfully work in power energy and chemical industry for last 20 years. Their ferrite matrix is strengthened by very small particles M_2X; V_4C_3 or VCN precipitated on dislocations at tempering. It is evident that between dislocation density and precipitation phase exists narrow relation: Higher dislocation density makes possible to precipitation a great amount very small particles on dislocations in opposite site dislocations are anchored by particles against recovery or formation subgrains during high temperature service. According previous works [2;3;4] when the interparticle spacing is over 2.5 μm intensive recovery is observed [2]. Effective particle number for blocking recovery is 10^5 m^{-3}, under 10^4 μm^{-3} the formation subgrains [4] was observed.
Described criterions don't take into account total dislocation density according to type of structure obtained after heat treatment. Nevertheless dislocation density is depending on cooling rate after austenization. In ferritic structures is about 10^{12} m^{-2} in martensitic or bainitic structures can attain to 10^{14} to 10^{16} m^{-2} level. From this point the level of dislocation density can significantly influence the structure stability during high temperature exposition. Present paper shows a new method for quantitative evaluation of relation bw. secondary phase and dislocation network.

Experimental

Study was made on the low-alloy systems 2.25 Cr - 1Mo and 0.5 Cr –0.5 Mo – 0.3 V type strengthened by Cr_7C_3; M_2X or V_4C_3; VCN particles after N (Q) +T stage. Special test pieces for determination changes in microstructure was anncaled.at 600, 650 and 700°C up to 5000 hours. At several annealing times was provided electronomicroscopy observation on thin foils and extraction carbon replicas for assessment the mean geometric diameter and number of particles and dislocation density. For thin foils was used direct measurement in the case of carbon replicas method of Asby and Ebelling [1; 10].Dislocation density ρ was determined acc. Keh and Weissmann [5]

$$\rho = \left(\frac{n_1}{L_1} + \frac{n_2}{L_2}\right)\frac{1}{t}$$

where :
n_1, n_2..........number of crosspoints dislocation lines with square network of unit segments L_1 , L_2
t ....foil thickness
For determination of interparticle spacing λ was used formula [6]

$$\lambda = (n_V \cdot d)^{-1/2} - \sqrt{2/3} \cdot d$$

where:
n_V ....number of particles in unit volume
d.........mean geometric diameter of particles
Dislocation density in feritic – bainitic structures was determined separately and its mean volume was calculated as weighted average.

Results and discussion

Fig. 1 shows changes in the number and interparticle spacing of secondary phase particles and dislocation density during long term isothermic annealing at service temperature 575 °C. For recounting was used Arrhenius equation with activation energy Q = 330 kJ/mol [7]. There is shown that coarsening processes at high temperature exposition makes significant decreasing number of particles and increasing their interparticle spacing.

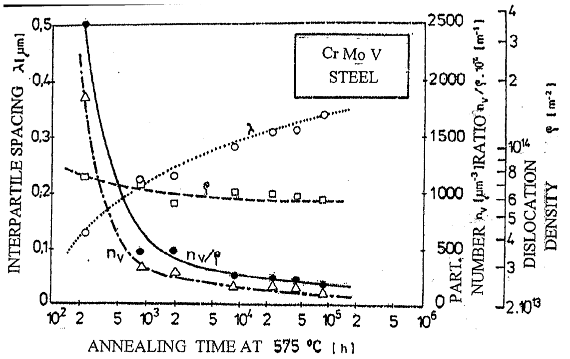

Fig. 1 Changes of dislocation density, criterion K and quantitative parameters of strengthening particles during high temperature exposition.

There we can observe slowly decreasing of mean dislocation density in range from $8 \cdot 10^{13}$ to $6 \cdot 10^{13}$ m^{-2} too. Significant differences are observed for dislocation density ρ in ferrite ~ $3 \cdot 10^{13}$ m^{-2} and bainite $1 \cdot 10^{14}$ m^{-2}. RTG and ELD analyses determined the main strengthening phases in CrMo – as M_2X and V_4C_3 or VCN in CrMoV systems. During long term exposition significant recovery processes or subrain formation have not been observed in testing steels. In comparison with literature data [2] our interparticle spacing is in order lower than criterion ($\lambda < 2.5$ μm). In the other hand our results have not confirmed presentation of recovery processes at the mean level of secondary particles about 10^2 μm^{-3} with composition of Smith criterion 10^4 μm^{-2} [4] but with in order higher dislocation density ~ $1.5 \cdot 10^{15}$ m^{-2}. From this point of view we suggest for evaluation of stability dislocation network the new criterion K :

$$K = \frac{n_v}{\rho}$$

where n_v …… number of particles
ρ ……..mean dislocation density

Criterion K expresses the number of particles for blocking the unit part of dislocation line against recovery. In our systems the value of criterion K gets from $2.5 \cdot 10^7$ to $2 \cdot 10^6$ m^{-1} in ferrite – bainite structure and $7 \cdot 10^6$ m^{-1} in bainitic structure. The same criterion for Smith data gets from $7 \cdot 10^6$ to $2 \cdot 10^7$ m^{-1} with very good agreement to our results. In the Mo alloyed systems recovery process will be influenced by solution of Mo atoms in ferrite matrix with additional beneficial effect on stability dislocation network at high temperatures.

Conclusion

1) During high temperature exposition of CrMo and CrMoV technical systems was observed high level of dislocation network stability. At any case have not been observed intensive progress of recovery with intensive decreasing of dislocation density.
2) The new criterion K enables the evaluation of stability dislocation network against intensive recovery. At ratio n_v/ρ ~ $2 \cdot 10^{-1}$ m and cooperation min. 0.25 % Mo in solid solution it can expect high stability dislocation network in study systems.

References

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