

THE METALS DEGRADATION IN HYDROGEN  
ATMOSPHERE AT THE PLASTIC STRAIN

A.V.Fishcoit

One of the most injurious phenomena of hydrogen degradation is the cracks generation on the surface of metals during plastic strain in hydrogen atmosphere. These cracks arise in stress concentration places at the first loading or as a low cycle loading result. Then, they can grow at the small fatigue stresses influence at the presence or absence hydrogen effect. In this paper the analysis of the hydrogen transfer on the surface of metal, which have been subjected to the plastic deformation, was executed and the metal degradation theoretical model was proposed.

INTRODUCTION

At present two points of view on the degradation mechanism of metals in hydrogen atmosphere exist. Some of the scientists think, that degradation is defined by penetration of hydrogen in surface layer of metal as a result of equilibrium dissolution and "drawing" of it by dislocations from surface. Other ones believe that degradation is the consequence of material surface energy decrease because of hydrogen adsorption is present, that facilitates surface cracks generation. The given hypotheses do not explain the series of important aspects of hydrogen degradation in particular its amplification at reduction of strain rates (1). In this connection the development of degradation models of metals at their plastic strain in hydrogen atmosphere remains urgent task.

Central Institute of Aviation Motors, Moscow

MAIN PART

The assumption have been made (2) that the solution process of chemisorbed ions is activated by the metal surface atomic bonds rupture energy. The quantity of the bonds rupture is proportional to the quantity of the dislocations and vacancies, which go out to the surface, - that is elastic deformation rate. Consequently, soluted hydrogen ions flow density is

$$J = k \dot{\epsilon} \theta \dots\dots\dots(1)$$

Soluted hydrogen transfer in metal takes place in the main by means of dislocation transport. It depends on the effective diffusion coefficient,

$$D \approx k D \dot{\epsilon} \dots\dots\dots(2)$$

The hydrogen concentration in metal may be calculated by means of the diffusion equation solution with coefficient  $D^*$  (2) and the boundary condition (1). It depends from  $\theta$  and elastic deformation value  $\epsilon$  only. As the destruction condition we choose

$$F(\epsilon, C) = F_c \dots\dots\dots(3)$$

As  $C = C(\epsilon, \theta)$ , so  $F(\epsilon, C) = F(\epsilon, \theta)$ . Consequently, the metal hydrogen degradation degree (the ratio of critical value  $\epsilon$  in air and in hydrogen) is determined in the main by  $\theta$ .

Using the constants values which determine the adsorption and diffusion processes rate (3) it is possible to calculate  $\theta$  for different temperatures -  $T$ , pressures -  $P$  and deformation rates (Fig.1,2).

On the base of these calculations next conclusions are made :

1. The metal degradation at the elastic strain in hydrogen takes place at the temperatures not below 100...150 K .
2. The degradation level increases with the deformation rate reduction.
3. The degradation level increases at the growth of hydrogen pressure to 10...20 MPa . At the further growth to 100 MPa the degradation level changes insignificantly.

The conclusions what the hydrogen degradation of metals is absent at the temperatures below 100...150 K and, what the hydrogen degradation increases with the

deformation rate reduction, confirmed by the numerous literature datas (1). Executed recently the experimental works confirm also what the nickel alloys hydrogen degradation level strongly depends from pressure to 20 MPa, but practically there are no changes in the interval 20...100 MPa.

Evaluations were made for nickel, but the conclusions, apparently, are true to other metals and alloys, which absorb the hydrogen endothermically.

Thus the proposed model describes the main experimental established phenomenons of the metal degradation at the plastic strain in hydrogen atmosphere.

## SYMBOLS USED

- $\dot{\epsilon}$  = the deformation rate.
- $\theta$  = the degree of the chemisorbed hydrogen surface covering.
- $D$  = the true hydrogen diffusion coefficient.
- $D^*$  = effective hydrogen diffusion coefficient.
- $C$  = hydrogen concentration.
- $\epsilon$  = plastic strain.
- $F(C, \epsilon)$  = is the convex function, which depend on  $C$  and  $\epsilon$ .
- $F_c$  = is the critical value of this function.
- $T$  = temperature.
- $P$  = pressure of hydrogen.
- $k, \eta$  = a constants.

## REFERENCES

- (1) Kolatshev, B.A. "Hydrogen degradation of metals". Metallurgia, Moscow, U.S.S.R., 1985.
- (2) Fishoit, A.V. Fisiko-himitsheskaya mekhanika materialov, 1989, N 3, pp.12-16.
- (3) "The constantes of metals-gas interaction" (reference book). Edited by B.A.Kolatshev and J.V.Levinski, Metallurgia, Moscow, U.S.S.R., 1987.

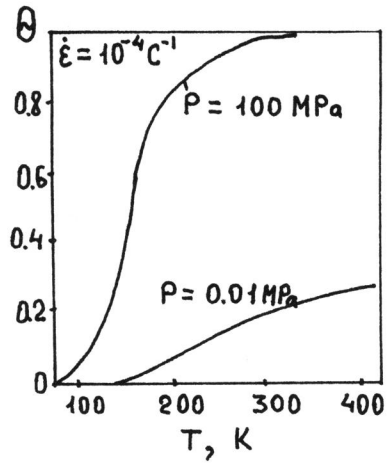


Fig.1.  $\theta$  - value dependence on nickel from temperature .

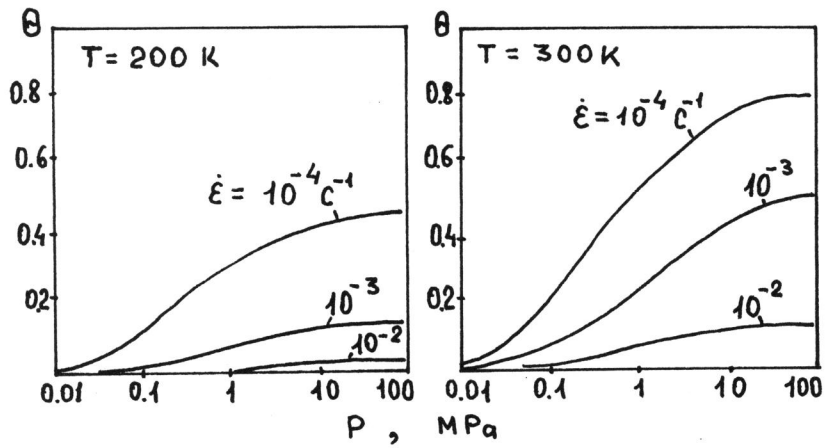


Fig.2.  $\theta$  - value dependence on nickel from pressure.