EFFECT OF HYDROGEN ON DELAYED FRACTURE OF MARAGING STEELS

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Introduction

The products from maraging steels (MAS) have tendency to delayed fracture (DF) at the work. This tendency to DF increases sharply from vacuum to air and aqueous solutions tests [1, 2]. That's why the resistance to delayed fracture is one of the criteria to be determined to estimate the structural strength of MAS.

The paper investigates MAS for tendency to DF in various corrosive media, as well as the influence of thermoplastic-treatment parameters on corrosive-mechanical properties and character of fracture of steels under investigation.

Experimental results

The investigated were commercial steels of quality 03H18M4T, 03X11H10M2T and 03H18K3M3T with known chemical compositions.

Cobalt-free steels were subjected to double quenching after 30-min holding from 920 and 820^0C in water in the both cases. Samples of steel 03X11H10M2T were deformed under high hydrostatic pressure (HHP) by hydroextrusion method with the reduction ratios ε=0-30%. The tendency of steels to DF was estimated in air, distilled water and 3.5 % aqueous solution of sodium chloride.

The DF and impact elasticity tests were done by using prismatic samples, 10mm thick of Charpy – type with section reduced by fatigue crack. The DF tests were done by the scheme of pure bending under constant load (the Brown methods [3]). Fracture ration was estimated by time dependences of nominal stress in sample cross-section and by values of relative drop of the strength calculated from the curves and by the average velocity of crack propagation found by the procedure described in [4]. Fracture of the tested samples was studied by the method of scanning electron microscopy using the instrument of "SUPERPROB JCXA-733" type.

The obtained results evidence that the steel shows the highest tendency to fracture during the test in water. The calculated relative drop in strength (%) under load $(\sigma_K-\sigma_\tau)$ $100\%/\sigma_K$,), were σ_K average value of chart-term strength; σ_τ-average value of strength under load during time τ, for the testing duration of 500 h, makes 16, 79 and 92% for air, sodium chloride solution and water, respectively.

Fractographic analysis of subcritical crack growth (SCG) during the DF in the investigated steels having the lath martensite structure has shown that under the short- and long –term tests in air the viscous dimple fracture is observed. It should be, in this case, noted that during the holding under load (i.e. under the DF), the fracture is preceded by a considerable local deformation.

On the fractograms of the samples tested in sodium chloride (τ=70 hs) there are regions of both viscous fracture and quasi-spalling of the size similar to that of the lath.

During steel testing in water, a change in fracture mechanism is observed. In this case, the crack propagates mainly by boundaries of the initial austenite grain. This phenomenon is commonly related to the "dynamic impact" during the growth of martensitic crystals under the hardening against austenite grain boundary resulting in the initiation of high local micro-stresses [1, 2]. There is another viewpoint [2, 4] by which the tendency to DF is due to the influence of hydrogen present in steel. Hydrogen atoms, when diffusion onto the boundaries of austenite grains; slacken the intergrain adhesion and make the formation and development of the inter-crystallite cracks easier.

Micro- and macrofractography of fracture patterns of the investigated steels has shown that in water the DF crack develops mainly by boundaries of the initial austenite grains. After the short-term strength tests (τ=0) on the fracture pattern of quenched samples one can see a viscous groove-like fracture. On the patterns of samples aged at Tag higher than 400°C (steel 03H18M4T) and at 350°C (steel 03H18K3M3T) and tested for short – term strength there are no grooves. This may imply that the mechanism of plastic deformation has changed.

At early stages of the SCG (τ >0), in steel 03H18M4T, along the direction of crack motion, the regions of viscous groove-like fracture (similar to fracture in air under the impact strength and short –term strength tests) are changed by regions

of brittle intergrain fracture. With increasing the time of loading ($\tau >> 0$) the share of viscous component, in the zone of SCG, decreases. The increase of aging temperature acts the same as the increase in holding under load (the both factors are accompanied by increase of the level of stresses in steel): the mixed discrete fracture is changed by the continuous brittle one. The boundary of this transition is in the range of Tag ≈ 400-450°C.

The mechanical tests have shown that for MAS the character of fracture under dynamic tests (KCT) varies with the growth of Tag, the same as during the short-term strength tests. This is also confirmed by the similar-dependence of σ_k and KCT results on aging temperature. As the results have been obtained in air and the steels maximally tend to DF in the same range of Tag, it can be assumed that the processes responsible for the embitterment in air also condition the fracture of steels in water.

The influence of chemical composition as well as causes of increased sensitivity of MAS to DF in the range of aging temperatures was studied in articles [2,4,5]. The obtained results show that titanium influences the DF the most; the less is the influence of cobalt; molybdenum practically has no influence on DF. It is believed that in the aged MAS, the DF may result from high internal stresses originating due to the formation of intermetallic compounds of Ni_3Ti type or from the redistribution of internal (metallurgical) hydrogen under the influence of processes of hardening-phase segregation during the aging.

According to the results of this work and to the analysis of literary data [2,4,5] changes of medium (air by sodium chloride solution and by distilled water) the same as changes of loading conditions (increase of loading duration), as well as presence of structural transformations in MAS in the low-temperature region of aging result in the increase of the level of local internal microstrsses facilitate the motion of dislocations during the origination of microcracks, which , when accumulated in the zone of preliminary fracture, result in the development of principal crack.

It should be noted that among possible reasons of the tendency of MAS to DF during the testing in air there may be "external" diffusion-active hydrogen formed during the interaction of adsorbed atmospheric moisture with chemical elements that are steel components [6].

Conclusions

Basing on the comparison of temperature and deformation dependences of the relative drop in strength, average velocity of crack propagation as well as of threshold stress values it should be noted that the steels tend to DF the most after aging at T≈400-430°C and after the hydrostatic extrusion with the percent reduction ε≈5 and 20%. Difference in the behavior of MAS at the SCG becomes apparent from the mechanism of stress relaxation at tip of the crack in the "hydrogenised" state. Hydrogen induced degradation of MAS structural state is a complex problem of materials science, chemistry and mechanics of metals.

References

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