INVESTIGATION OF INFLUENCE OF THE SCALE FACTOR ON CORROSION STABILITY OF TITANIUM ALLOYS

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ABSTRACT

It is marked, that during investigations of the scale factor, it is necessary to pay particular attention to the object and methodics of testing. Test results of the large-scale specimens from titanium alloys on estimation of their corrosion-cracking resistance in neutral solutions are represented. On the basis of the experimental data the kinetics of the surface corrosion cracks development is shown. The physics and chemical mechanism of the corrosion creeping process is given.

KEYWORDS

Scale effect, corrosion cracking, slow-motion fracture, corrosion creeping.

INTRODUCTION

Display of the scale factor is more often connected with the influence of construction thickness section/Romaniv O.N., Nikifotchyn G.N., I986/. That is why, considering it from the point of view of fracture mechanics, particular attention should be paid to the object and methodics of tests. In particular, investigating the strength to destruction of plate constructions, it is desirable not only keep the natural thickness of rolled metal and condition of its surface, but to observe the constructive-technological similarity, and also the condition of loading.

The Laboratory of Strength of Welded Constructions of Rostov-on-Don Institute of Agricultural Mechanical Engineering has a test equipment complex for investigations of low-sycle and static corrosion cracking resistance of large-scale elements of shellformed welded constructions /Lukyanov V.F. et al.,I986/. The family of test stands of UDR and UDI types gives possibility to carry out tests of discs specimens with the diameter till I300mm on biaxial tension - with thickness till I6mm and on biaxial bending till I00mm.

SCALE FACTOR IN THE FRACTURE OF THICK-PLATE SHELLFORMED CONSTRUCTIONS

With estimation of corrosion cracking resistance of the titanium alloys of BT20 type in neutral chloride solutions, it was noticed, that with the increase of alloy resistance of corrosion cracking/CC/, the area of K_I values appeares, with which the development of corrosion surface crack in the plate element having axis-symmetrical bending, is proceeding unsteady. With the constant level of load, started crack growth is stopped.

To affirm the above mentioned, let's consider two cases from the investigation practise.

On Fig.I the results of tests of disc specimens from the alloy of the BT20 type with the diameter of I3OO mm and thickness of 90 mm are represented. In the centre from the cut with the length of 40 mm the surface crack was formed.

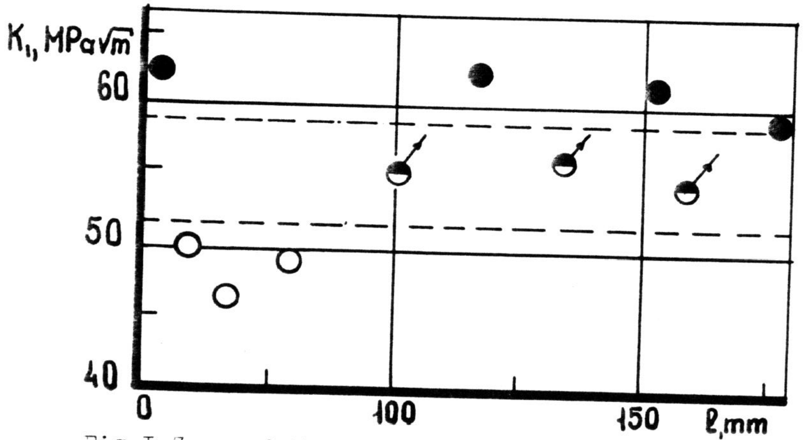

Fig.I Zone of the unstable growth of the surface crack

During tests static and cyclic loads were alternated by steps till steady crack growth has appeared/the left dark point/. The values of K_I, when the growth of the crack under static load was absent, were also fixed /light points/. Reiterating the experiment in the range $K_I = 45...65$ MPa$\sqrt{m}$ we have got zone, in which starting crack growth stopped in 20...30 min./points with arrows/.

Conformably to the thick plate rolling, one of the aspects of the scale factor is the influence of the rate differences of cooling of the surface and inner zones of the plate on their characteristics. Investigation of the effectiveness of cooling conditions of metal, as the method of increase of its corrosion cracking resistance showed, that the improvement of this characteristic is followed by the increase of its unsteadiness. With this, on alloys with high value of K_{Iscc}, with the

growth of load the stable CC is always proceeded by the unstable growth of the crack with the further its stop.

From the point of view of the linear fracture mechanics such behaviour of the crack is considered to be the anomaly. For considered examples the surface growth of corrosion crack with static loading with forming of the so called "tongue", when the crack front from the stable condition is going to pass on to equilibrium, is characteristic. As a result, near the upper part of the crack, in the area of the flat stress condition the zones of intensive plastic deformation appear /the so called "IPD zones", which fracture energy capacity is high. This, and also the increasing bending of the "tongue" front are factors, keeping up the crack growth in the length /in the direction of a big axis of half ellipsis/. Its further behaviour is determined by the possibility of development into the depth /in the direction, perpendicular the sheet surface/. With the growth of the sheet thickness such possibility increases, because, thanks to the greatest constraint of deformations, here favourable conditions for CC passing are created. With the crack deepening the "tongue" bending decreases and the growth of K_I value in this area leads to CC resuming in this zone, the surface sign of which is the growth and further fracture of "IPD zones". It lasts so till the moving fracture forces exceed braking forces.

The experimental confirmation of this mechanism of the development of corrosion surface crack may serve the results of testing on axis-symmetrical bending of disc specimen with thickness of IOO mm with the visual fracture control and acoustic emission /AE/ with the help of "Amur - D4" instrument. The use of triangulation principle lets us not only single out a signal from the fracture zone, but determine the running coordinates of these zones. On Fig.2 the received results are compared with the results of fractographic analysis of the specimen fracture surface. It is evident,that on the first stage /a/ during cyclical loading the crack grows uniformly along the whole front. On the second stage /b/ during static loading maximum AE is situated in the centre of the crack, that is it grows mainly into the depth in the most favourable for CC direction. It was affirmed also by the analysis of fracture surface. Later on, during cyclical loading /c/ the crack is striving to restore the steady form at the expense of "IPD zones" fracture and growth in the length, AE maximums with this are close to the visible ends of the crack. During the repeated static loading /stage d/ the area of fracture is moving to the centre of the crack again. CC is spreading with the visible minimum crack lengthening. Inspite of the fact, that the depth of the crack makes up about 40% of the plate thickness at this period, the lowering of the working K_I value in the centre, owing to the gradient of fracture surface stresses appeared to be less important to CC process, than braking by the development of plastic deformations in "IPD zones". Further cyclical loading /e/ intensively lengthened the crack with its minimum growth in the centre, where stress intensive factor range by this time was sharply shortened.

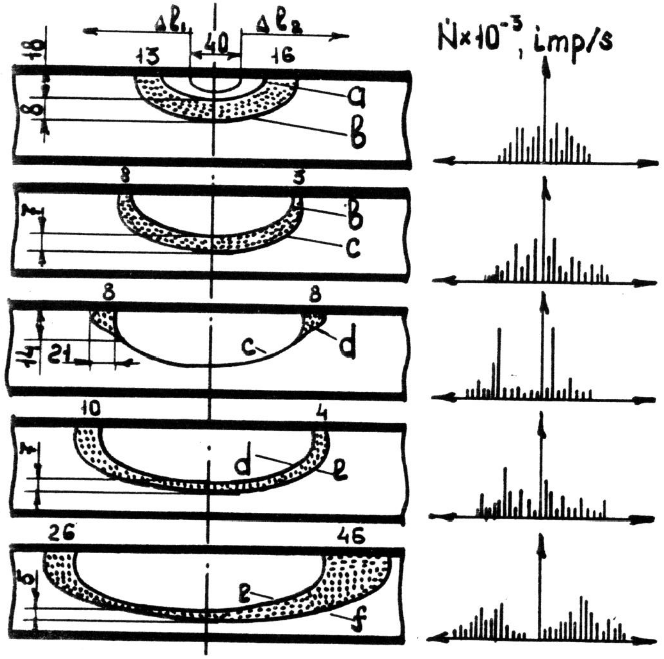

Fig.2 Development of the surface crack in various types of loading.

The described character of changing of the front form of the surface crack gives possibility to make the following conclusion.

Firstly, with the increase of the relative length of the surface crack $K_I$scc threshold values grow a little. This is confirmed in the additional experiments with the specimens of 30 mm thickness.

Secondly, the interchange of cyclical and static loading, increases crack growth rate /CGR/ of the surface crack, even if its visible growth is absent with constant loading.

The given effect is conditioned not only by periodical change of the crack form with "IPD zones" fracture, but mutual stimulating influence of mechanical and corrosion stages of fracture /Fedotov N.A. et al., 1986/. This doesn't give possibility to use Wei - Landes hypothesis in the case of its corrosion - fatigued fracture.

KINETICS OF SLOW-MOTION DEVELOPMENT OF THE SURFACE CORROSION CRACK

During investigation of influence of heat treatment on corrosion cracking resistance of titanium alloys the comparative tests of disc specimens with the diameter of 550 mm and thickness of 30 mm from alloy of the BT20 type of two modifications were carried out. The specimens were made from the surface /modification A/ and middle /modification B/ zones of the plates with thickness of 70 mm. With similar mechanical properties of metal of these zones, their corrosion cracking resistance differed considerably because of the different cooling rate after rolling. Tests on axis-symmetrical bending included interchanging cyclical and static loading. The initial crack was grown in the centre of the disc from the surface cut.

Test results prove, that in the large range of the cracks lengths and KI values on the alloy with high corrosion cracking resistance, steady but slow-motioned fracture is observed with static loading and practically constant rate of the crack growth 40...60 times lower, than that, typical for CC.

Taking into account keeping up influence of "IPD zones", it was supposed, that in the given case CGR is controlled by the process not depending from CC. By static tests of disc specimens in the open air the possibility of the slow-motion growth of the surface crack was confirmed, with this CGR appeared to be considerably lower, than with the presence of corrosion environment which proves the stimulation of this process to corrosion cracking.

The described peculiarities of kinetics of development of the surface cracks gives possibility to suppose, that mechanism of the slow - motion fracture in the corrosion environment is in proceeding of the two conjugated in time processes: corrosion cracking and slow - motion fracture, mutually stimulating each other. On Fig.3, illustrating this mechanism, both processes, for clearness, conditionally are shown passing by turn. From initial fatigued crack of the stage I,CC is developing. But, because of the above described reasons, the crack growth stops after forming the "tongue" and "IPD zones"/stage II/. Intensive plastic deformation of metal in the area of "IPD zones" creates favourable conditions for the development in the surface layers of the process of low temperature creeping. This process is going with much lower rate, than CC. Fracture of "IPD zones" /stage III/ equals the crack front, creating conditions for further CC as in the direction of thickness, so and in the length, with forming of new "IPD zones"/stage IV/. Such simultaneous double process will go on till K_I value, acting on the outline of the crack near its ends will not become lower for some reasons, than KIscc or the threshold value of the low temperature creeping. In the given case it is the last process, that controls CGR. The described process of the slow - motion fracture in the corrosion environment we called "corrosion creeping". It is obvious, that it is possible not only in the case of the surface cracks, but

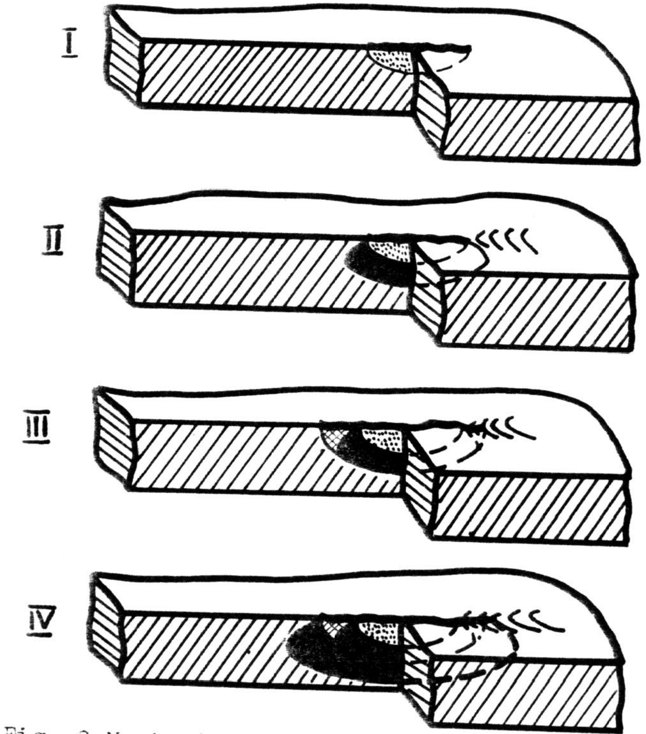

Fig. 3 Mechanism of corrosion creeping development

everywhere, where on the outline of the corrosion crack it is possible to single out separate zones of CC going and slow - motioned fracture of metal. Apparently, this mechanism of the crack growth is specific for any test objects, having bigger cuts and it may be considered as one of aspects displaying the scale factor.

PHYSICS AND CHEMICAL MECHANISM OF THE PROCESS OF CORROSION CREEPING

Only from the positions of fracture mechanics it is hardly possible to explain all peculiarities of corrosion creeping process. Kinetics of corrosion processes was studied on the specimens of outer central tension, made from the same plate, from which were discs made. Methodics of investigation envisaged registration of loading, opening and length of the crack AE electrode potential and PH of solution in the crack cavity. Fracture kinetics looked like that observed on discs. The crack "tongue" and, correspondingly, "IPD zones" had

less sizes. CGR fluctuated in the limits of $/2...5/\cdot IO^{-4}$ mm/s. Kinetics of electrode processes, as well as the intensity of mechanical fracture, considerably differed from the typical for CC. On Fig. 4 are given characteristic kinetic bends CGR, of electrode potential φ and histogramme of the AE intensity.

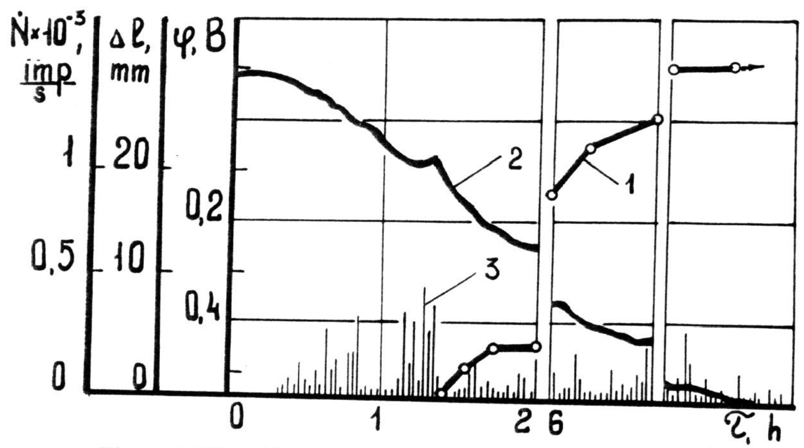

Fig. 4 Kinetics of parameters of fracture of the BT20 type alloy

AE character and also φ fluctuations point out, that incubative period of fracture was not longer, than half an hour, inspite of the absence in the first I,5...2 hours, seen crack growth. Apparently, the first hour of testing is the stage of CC going in the central part of the cut with forming of the crack "tongue". Later on, the process of fracture is controlled by the creeping mechanism, for which gradual improvement of φ till positive values and low, AE episodic character are characteristic. Solution in the crack cavity is gradually acidulated till pH = 2,5...3 with keeping these values during several days after the stopping of the crack, that principally differs this process from typical CC, with which the intensive alkalation of solution in the crack cavity is observed.

Detailed comparative analysis of electro-chemical fracture mechanism with CC and corrosion creeping is given /Fedotov N.A. et al., I986/. Here we mark, that if CC develops autocatalitic mechanism, with which the stages of mechanical fracture and anode dissolution mutually stimulate each other, then corrosion creeping is proceeding in the conditions of mutual "braking" of these two stages and the moving force of the fracture process in these conditions is high level of the reserved energy of elastic forces, providing the proceeding of low temperature creeping in close to surface layers near the crack top.

CONCLUSION

Specificity of development of the surface corrosion crack influences the results of comparative tests of elements and constructions and in its turn it depends on the material properties: the higher its corrosion cracking resistance, the more considerable is its positive influence on the peculiarities of the surface crack growth. With the low $K_{I}scc$ level, CC is developing, autocatalitic mechanism of the process providing CGR growth till the catastrophic fracture. With the $K_{I}scc$ high level the crack behaviour depends on the alloy tendency to slow fracture in the inert environment. With this, the crack is steadily developing on corrosion creeping mechanism with control of CGR process of creeping. The exclusion of the possibility of influence on the result of indicated peculiarities of the surface crack development provides certain estimation conservatism, expedient, apparently, in the case of using titanium alloys, differing by hightened unsteadiness of properties.

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