DIVIDING GRIDS METHOD IN EXPERIMENTAL FRACTURE MECHANICS

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ABSTRACT

Possibilities of dividing grids method implementation in fracture mechanics are discussed. Examples of elastic-plastic fracture toughness determination for different materials and different technological factors' affect on it are given. A perspective of dividing grids method implementation for fracture criteria determination of real construction is shown.

KEY WORDS

Fracture mechanics, fracture criteria, dividing grids method, J_c - integral, CTOD.

Fracture mechanics' (FM) features display the stress-strain state (SSS) at the crack tip on different stages of specimen's and construction element's deformation and fracture. Because of that the information about SSS in the crack tip lets us consider the FM features.

Most of standard methods of fracture toughness definition are based on the using of generalized indirect information about the behavior of specimen with initial crack. This information can be presented in deformation and fracture diagrams. It is difficult to get such information when you use construction full scale elements tests and whole complicated loading.

We consider the using of experimental methods in the crack tip zone of real construction and specimens for SSS characteristic investigation to be the most interesting. These methods are: dividing grids, moire interferometry, golography interferometry and others. (Kang and Kobayashi, 1988; Dodds and Read, 1990).

We used dividing grids method to get criteria characteristics of elastic-plastic fracture mechanics: J_c - integral, crack tip open displacement δ_c, strain intensity factor k_{Ie}, J_R resistance curves.

Let's take the especial features of J_c- integral defining by dividing grids method. J_c - integral for specimen with a crack fluent and slow loading in detailed will be the following:

$$J = \int_c \{\omega\cos\theta - [(\sigma_x\cos\theta + \tau_{xy}\sin\theta)\, du/dx + (\tau_{xy}\cos\theta + \sigma_x\sin\theta) dv/dx]\}\, ds \qquad (1)$$

where $\omega(\varepsilon_{mn}) = \int_0^{\varepsilon_{mn}} \sigma_{ij}\, d\varepsilon_{ij}$ - is a specific work of deformation; u,v - components of shifting according axis x and y, θ - angle between normal to the element of contour ds and axis x, c - integration contour.

We used the deformation theory of plasticity and grid cells unit coordinates of deformed dividing grid around crack tip to get FM components from equation 1. J_c- integral value is got by integration on contours, which cover crack tip and crossing plastic deformed zone directly near the crack tip (Fig 1). We used base of the dividing grid cell as integration contour element (Matvienko and Goltsev, 1982, 1983). While getting J_c- curves integration contour was prolonged on crack expanding value to the base of the dividing grid cell.

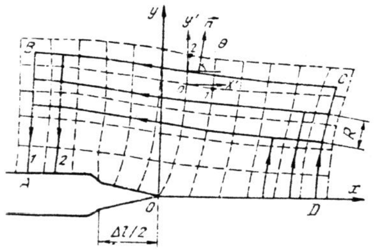

Fig. 1.Tensile specimen with counter crack.

We can say that dividing grids method makes it possible to define criteria characteristic of elastic plastic fracture mechanics, basing only on theoretical knowledge about J_c - integral (Parton and Morozov, 1989).

We compared J_c- integral for different materials defined by dividing grids method and standard methods (according the fracture diagram load-displacement loading force point). It was showed that dividing grids method reduced mistakes and disperse for J_c- integral calculation (Matvienko and Goltsev, 1985a).

Crack tip opening is measured according the displacement of registration points near crack tip. For registration points we took the dividing grids nodes .

Strain intensity factor k_{Ic} was got from experimental analyses of intensity of elastic-plastic deformations distribution at the crack tip on the line of its continuation. For example

dependence deformation intensity of crack tip on line of its continuation for steel 09X16H15M3Б is shown on Fig 2.

We can discuss the using of dividing grids method implementation for solving of the experimental fracture mechanics tasks.

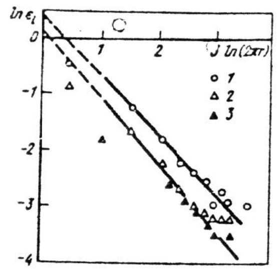

Fig.2. Deformation intensity at the crack tip distribution on the line of its continuation for 09X16H15M3Б steel: 1,2,3 - points on the figure: t=0,8; 0,4; 0,4 mm; l_0=8; 8; 15 mm appropriately.

The well-known demands to specimen dimension, which guarantee getting of reliable values of J_c, are automatically implemented in the case of plane stress state. But our results of investigation of J_c- integral and zone of plastic deformation near crack tip show that these demands for thin-sheet materials can be less strict. Optimal specimen dimension for which the values of J_c are reliable do not depend on specimen geometry are established in the following way:

$$k(b - l_0) >= \frac{10\, t}{t - t^*}\, \delta_c \qquad (2)$$

We used k = 1 for bend specimens and tensile specimens with eidge crack and k = 5 for tensile specimens with center crack, t - specimen width, t* - specimen width in fracture.

We carried on investigations of construction-technique factors affection on fracture toughness of some designed steels and alloys. The affect of increasing preliminary deformation degree upon mechanical properties and fracture toughness features 09X16H15M3БP steel at the test temperature of 823 K is presented in Table 1 (Goltsev and others, 1985, Goltsev and Matvienko, 1987, 1991).

Table 1.Mechanical properties and Fracture toughness of 09X16H15M3БP steel at 823 K.

orientation of specimen	degree of prelimi-nary strain by rolling	$\sigma_{0,2}$ MPa	σ_B MPa	δ %	σ_{co} MPa	δ_c MM	J_c KH/M
transversal	annealing	150	420	35	265	0,35	210
	20 %	532	575	7,2	610	0,15	150
	30 %	600	610	4,8	710	0,05	30
	40 %	650	665	4,6	675	--	24
longitudinal	20 %	410	452	5,1	525	0,1	110
	40 %	610	620	4,2	560	--	20

We can notice considerable reduce of elastic-plastic fracture toughness when we increase the degree of preliminary material deformation. More over the value of fracture toughness is greater when the crack plane is oriented along the rolling direction then when it is oriented perpendicularly the rolling direction.

Carbonation of this very steel in sodium environment (modelling of work conditions of steel material in sodium heat transfer medium of fast neutrons reactor) lead to the important steel embrittlement (Fig.3.) (Vasiliev and others, 1986).

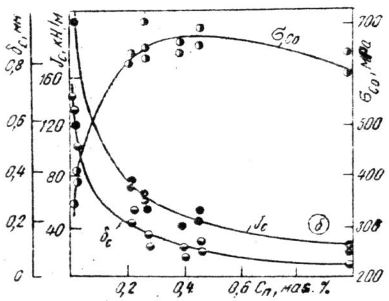

Fig. 3. 09X16H15M3Б steel embrittlement dependence on carbon concentration on the specimen C_n after carbonation in sodium.

Technology of determining J_c- integral for loading static conditions of the specimen with a through crack was used for determination the elastic-plastic fracture toughness on the stage of dynamic crack initiation J^D_c and crack arrest J_α for the thin-sheet plastic specimens with surface center notch (Goltsev and others, 1987). Dynamic loading conditions are performed by immediate crosspiece fracture, it means turning nonthrough surface notch into through central crack and releasing elastic energy by specimen unloading. This energy makes depend on dynamic loading of specimen with a central through crack. We showed the elastic-plastic fracture toughness both on the stage of crack dynamic initiation and crack arrest is less then static fracture toughness J_c using dividing grids method.

CONCLUSION

We discussed the perspectives of using dividing grids method in the experimental fracture mechanics for both specimens and construction elements regardless of loading conditions. We consider using devide grids method in natural element's fracture resistance investigations to be the most perspective

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