Strain Fields Investigation in Connection with Failure Criteria Analysis

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Low-cycle fatigue strength may be described through deformation-kinetic criteria that present crack development as determined by cyclic and one-side accumulated strain reaching its ultimate value [1], and crack propagation rate - by maximum strain in the crack tip. Accordingly for fracture criteria experimental checking it is necessary to dispose of certain methods providing measurements in the wide range of strain.

In these terms Moire method and the grid method as well as the combination of the two seem to be most advantageous experimental methods. Their application for strain fields measurement in concentration zones under cyclic loading demands definition of change ranges in connection with rasters and grids parametres and also specimen's geometry. As a rule, strain decreasing from maximum to almost nominal values occurs in a certain characteristic region near to the concentrator contour. Maximum strain relative gradient in measurements direction $\mathcal{E}=\frac{\partial^2 u/\partial y^2}{\partial u/\partial y}=\frac{1}{L}$ (with L - standing for certain characteristic region) is to be taken for strain field non-uniformity characteristic [2].

In case of grid method measuring, since grid cutting and measurement errors are under normal distribution law it is possible to find the minimal available for measuring strain from expression

$$\varepsilon_{min} = \frac{330\,\delta_{\Sigma}}{h\Delta u\% + 200\,\delta_{\Sigma}}$$

where δ_{Σ} - integral error;

$\Delta u\%$ - preset measurement accuracy;

h - grid cell dimentions, $h_{min} = L/2$.

Maximum strain, with the grid method applied, is determined in principle by the expression $\varepsilon_{max} = 1{,}65(1-2hG)$ but the upper strain limit being about 70 per cent (Eiler coordinates) due to the grid contrast loss.

In case of Moire method application with usual rasters used, the minimal strain may be measured at the moment when three Moire fringes are formed in the characteristic region according to the expression $\varepsilon_{min} \approx 3{,}3\,\delta/L$, where δ is raster pitch. With differential raster used, the minimal strain is defined by the last interfringe (starting from the maximum displacements zone) width diminution by a certain available for measuring magnitude $[\Delta t]$ and is presented as $\varepsilon_{min} = \left(\frac{\lambda}{\delta/\lambda \, \frac{1}{[\Delta t]} \pm 1}\right)\chi$ where λ - is initial fictitous initial strain and the function $\chi \approx 3{,}3 \pm 2\frac{t_n}{L}$ where t_n - is the last interfringe width /2/. Maximum measured strain corresponds to the decrease of the interfringe width (in the maximum displacements zone) up to a certain available for measuring magnitude $[t]$. Then, in case of usual rasters being used, $\varepsilon_{max} \approx 1{,}12\frac{\delta}{[t]}$ and in case of differential rasters application, $\varepsilon_{max} = \left(\frac{\delta}{[t]} \pm \lambda\right)\varkappa$,

where $\varkappa = 1 \pm 0{,}57\frac{t_1}{L}$

(t_1 - being the first interfringe width in the characteristic region).

In Fig.1 there are curves plotted by these expressions which determine Moire and grid methods measurements ranges versus strain gradient value with grid cells dimentions, raster pitches and preset measurement accuracy given as parametres. As is shown in fig. 1, Moire method provides strain fields measuring under moderate stress concentration in the range of $\varepsilon_{min} \approx 0{,}5\%$ to $\varepsilon_{max} \approx 50\%$. The grid method insures local plastic strain measuring under strain field high non-uniformity conditions (in the characteristic regions at about ten grains). Still, neither of the methods aloue makes the strain fields measuring possible at all the cyclic loading stages the researcher is interested in. Thus it seems advantageously to use both these methods combined for damage accumulation and failure development studies /2/.

In fig.2 are shown equal intensity strain curves plotted from Moire fringes pictures received in low-carbon mild steel specimens with holes testing. These curves represent plastic strain distribution at the initial and before-failure loading cycles. In Fig.3 is shown increase kinetics of maximum one-sidedly accumulated strain. As follows from it, accumulated in the concentration zone ultimate strain magnitude ε_{Σ} in case of quasistatic failure is close to the magnitude of the ultimate failure strain ε_f under static uniaxial tension. Thus the expression $d_s = \int \frac{d\varepsilon_{\Sigma}}{\varepsilon_f} = 1$ is just for accumulated quasistatic damage.

Moire method and the grid method have been jointly used for strain fields research in Al - alloy plates with sharp slit and slit drilled in the tip. Strain measuring in the slit tip vicinity was carried out with the help of the grid method where as the strain measuring in the remaining part of the specimen was made by Moire method. Measurement results under static loading were used for plotting equal strain curves (Fig.4, a – the slit, b – slit drilled in the tip). Analagous results have been established for amplitude strain values. The low-cycle fatigue curves based on these results, that given in Fig.5 (a – the slit, b – the slit drilled in the tip) prove the correctness of the use for fatigue damage calculations of the expression $d_f = 2\int_0^{N_f} \left(\frac{\varepsilon_p}{\varepsilon_f}\right)^2 dN$.

REFERENCES

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2. Шнейдерович Р.М., Левин О.А. Измерение полей пластических деформаций методом муара, Москва, Машиностроение, 1972.

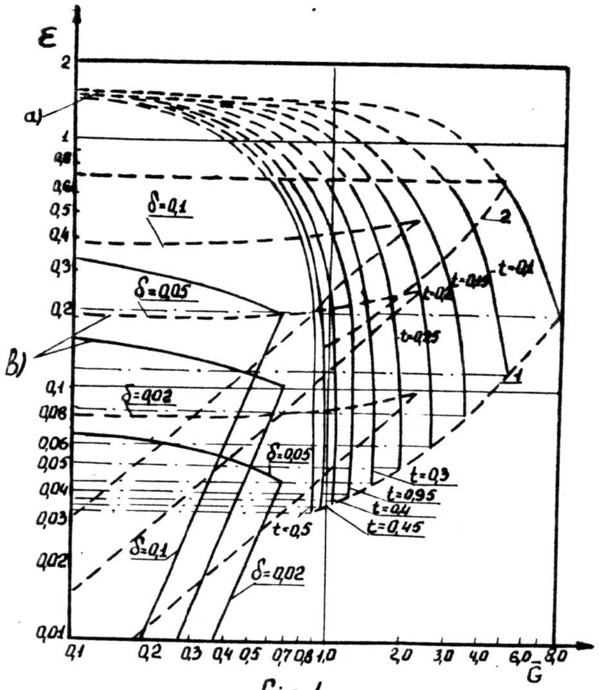

Fig.1

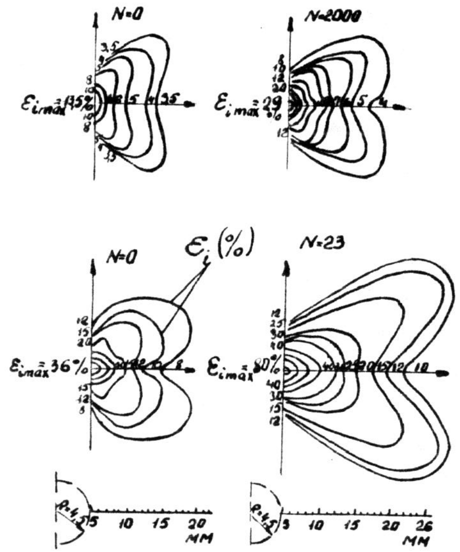

Fig.2

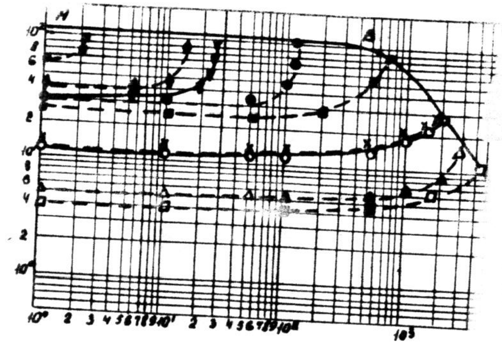

Fig.3

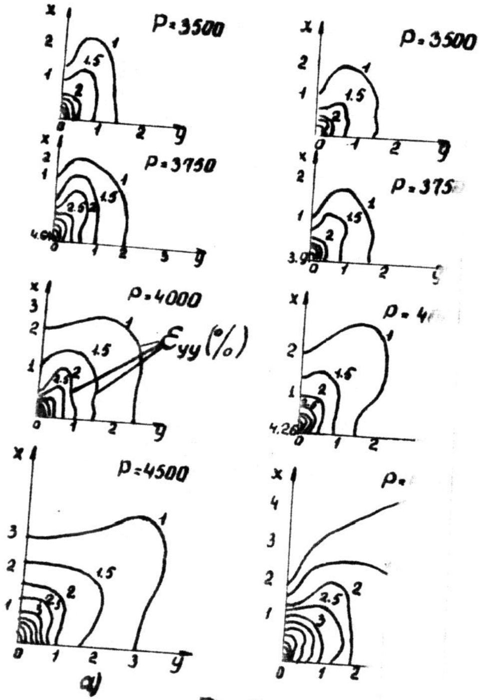

Fig.4

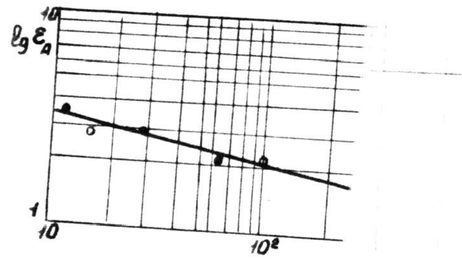

Fig.5