EXPERIMENTÁLNA ANALÝZA ŠÍRENIA SA TRHLINY V TENKOSTENNEJ DOSKE S KRUHOVÝM OTVOROM PRI CYKLICKOM AXIÁLNOM ŤAHU

AN EXPERIMENTAL INVESTIGATION OF THIN-WALLED PLATE CRACK PROPAGATION WITH CIRCULAR CUT-OUT SUBJECTED TO CYCLES AXIAL TENSION

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Abstrakt

Predmetom skúmania je pravouhlá tenkostenná doska s kruhovým výrezom, zaťažená cyklickým axiálnym ťahom. Výsledkom takéhoto zaťaženia je šírenie trhliny s časom, po dosiahnutie kritickej dĺžky. Počas ťahových cyklov vznikajú v doske lokálne vybúlenia ako výsledok membránových napätí vyvolávajúcich aj ohyb. Nárast dĺžky trhliny s časom spôsobuje zväčšenie oblasti ohybu. To má vplyv na hodnoty napätí, vo výsledku na rýchlosť šírenia trhliny a na životnosť. Cieľom článku je kvalitatívna a kvantitatívna analýza horeuvedených fenoméno s ohľadom na kritickú dĺžku.

Doska je vyrobená z polykarbonátu so známymi charakteristikami a fotoelastickými vlastnosťami.

Kľúčové slová: únava, lom, búlenie, fotoelsticita, Moire metóda.

Abstract

The object of investigation constitutes rectangular thin-walled plate with circular cut-out subjected to axial cycles tension. As a result of such loading the crack propagation follows in time, to critical length achieve. In the middle of cycles changing tension the plate sustains the local buckling (wrinkling), as a result apart of membrane stress appears bending state as well. Growth of the crack length in time causes increasing of wrinkling area. It has an influence on the value of the stress, and in result on the speed of crack propagation and fatigue life. The purpose of the paper is qualitative and quantitative analysis of above mentioned phenomena, since assumed an initial length to the critical value.

The plate is made of polycarbonate, known of instantaneous characteristics and photo-elastics properties.

Keywords: fatigue, crack, wrinkling, photo-elasticity, moiré method.

PREFACE

Thin-walled plates and shells belong to elements of the structures of damage endangered for various kinds.The time o life of thin-wall structures is being determined with operational life having basic influence of her elements for integral destruction of load-carrying structure. Local destruction whom a global process is being started from, they are initiating every kind of

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discontinuity, whom slots possess first-class importance among. When plate's thickness is sufficiently small with respect to other dimensions, plates are susceptible to buckling under compression. The buckling phenomena of plate can also occur in the case of tension loading. It is going in situations when the plate contains in its area defects so like cracks or holes. When the buckling load is reached it causes to local buckling in compressed regions located in the proximity of mentioned imperfections.

Existence of the crack in the structure doesn't mean neither its destruction nor too them is posing grounds for limiting of more operating. Showing up cracks in structures require the default observation during operating of the design. At the same time we assume that a critical length is known is following the achievement sudden its increase, in practice leading to total destruction.

In this paper the object of investigation constitutes rectangular thin-walled plate ablated by circular cut-out subjected to cycles changing tension in the range: P_{min}=0, P_{max}=1500 N. As a result of such loading follows the crack propagation in time, all the way to critical length achieve. In the middle of cycles changing tension the plate sustains the local buckling, as a result apart of membrane stress appears bending state as well. Growth of the crack length in time causes increasing of buckling area. It has an influence on the value of the stress, and in result on the speed of crack propagation and fatigue life. The purpose of the paper is qualitative and quantitative analysis of above described phenomenon, since assumed initial length to critical value.

EXPERIMENTAL INVESTIGATION

A thin rectangular plate made from polycarbonate constituted the subject of examinations. Fig.1 presents instantaneous characteristics of the material.

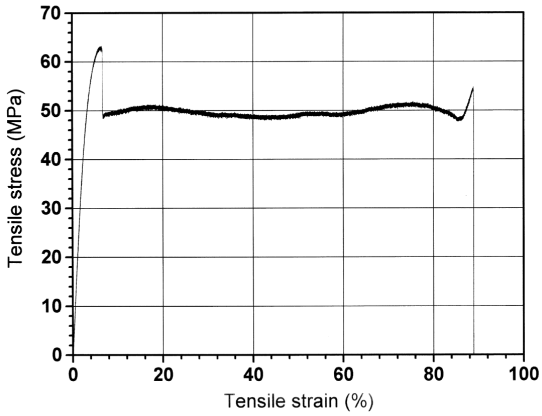

Fig.1 Instantaneous characteristic of material

The material demonstrates the clear zone of visco-elastic deformations. In the face of the short times, like in the case of the fatigue test, these deformations are being treated as a plastic. Examinations were carried out in the stand making the realization of the assumed pulsing load and boundary conditions (see Fig.3) The load was being realized on the hydraulic device, the increase ensuring the constant value of the load amplitude to the crack increasing in time.

The level and the character of the loading and the length of the crack in the function of the number of cycles was being controlled during examinations. Dimensions of the tested plate, crack location and the loading method (Fig.2) are: L= 250mm, 2w=240mm, a=30mm.

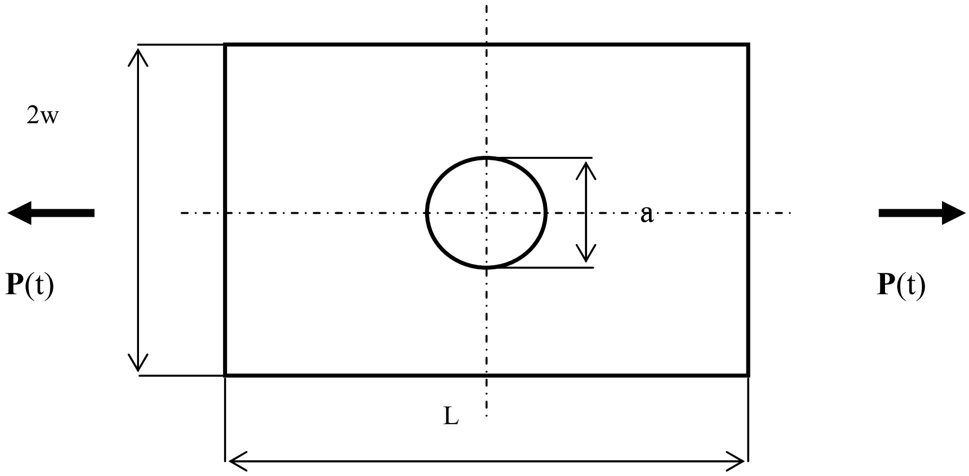

Fig.2 Dimensions, circular hole location and loading of the plat

Station to the fatigue examination of the plate presents Fig.3.

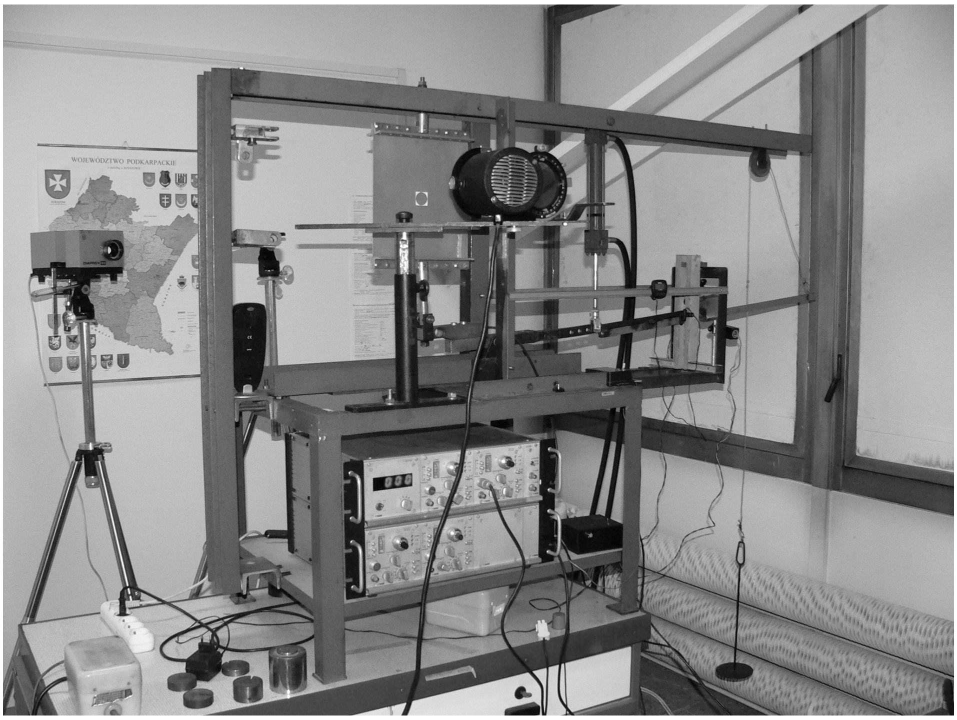

Fig.3 Station to the fatigue examination of the plate

Using the reflective polariscope the field of isochromatics in zones of the crack front was being watched. For the purpose the tested plate was one-side painted with the layer of the fluorescent paint. It was making the default observation of the effective stress distribution in accordance to the Tresca theorem and observation of the plastic zone at the crack front. Fig.5 presents the field isochromatics in the successive stages of propagation process.

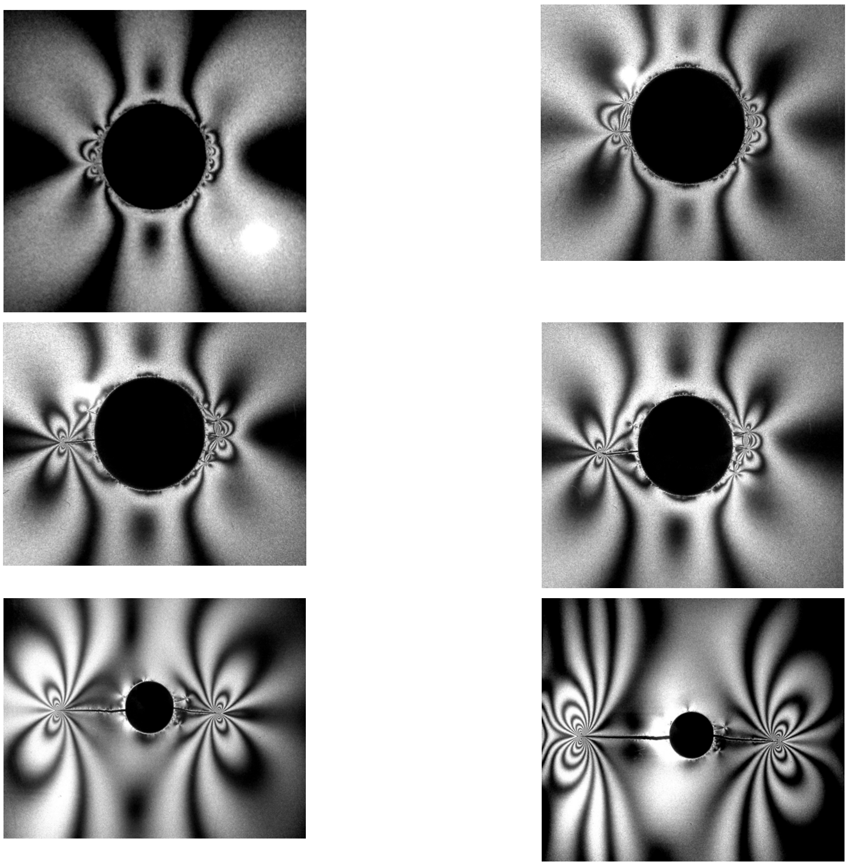

Fig.4 Field of isochromatics in the successive stages of propagation process.

The crack length increase executed the change of the plate rigidity, moderately to increase of the loading cycles numbers. It was manifesting itself in the form of local wrinkling, successively to the growing amplitude.

In order quantitative determining of the state of transverse deformation being the consequence showing up of local wrinkling, examinations of deflection distribution were carried out applying the shadow moiré method.

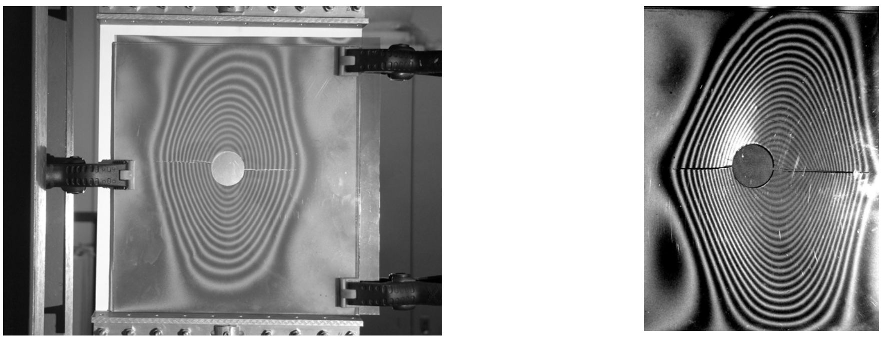

Fig.5 Moiré fringes illustration Quantitative of deflections in proximity of the crack

Fig.6 is presenting the contour lines of the constant deflections in proximity of the crack. Distance between adjacent contour plane in our case is equal 0.26mm. And so they are maximum value of deflections respectively: 5,98mm.

Examination results are permitting to present of the dependence between crack length and number of cycles up to structure collapse (Fig.7).

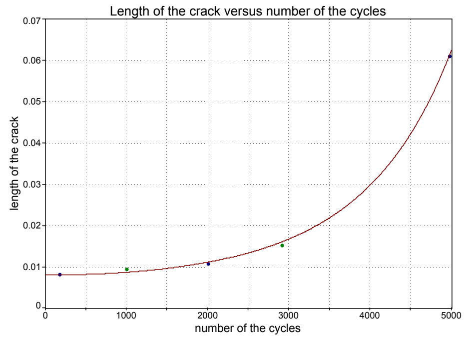

Fig.6 Dependence length of the crack vs number of cycles

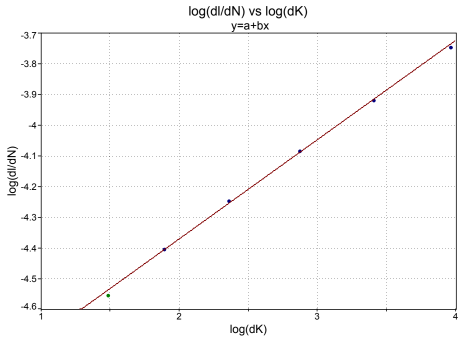

Fig.7 Dependence $\log\dfrac{da}{dN}$ versus ΔK

where

$$\Delta K = K_{\max} - K_{\min}\,, \qquad K_{\max} = \sigma_{\max}\sqrt{\pi \cdot a}\cdot\beta\,, \qquad K_{\min} = \sigma_{\min}\sqrt{\pi \cdot a}\cdot\beta \tag{1}$$

$$\beta = \left[1 + 0.128\frac{a}{w} - 0.288\left(\frac{a}{w}\right)^2 + 1.529\left(\frac{a}{w}\right)^3\right] \tag{2}$$

The linear range of the above dependence (presented in logarithmic scale) can be described by Paris - Erdogan equation

$$\frac{da}{dN} = C(\Delta K)^m \tag{3}$$

Here C and m denote constants material.

On the basis of the presented plot we are able to determine both material constants. For considered polycarbonate were received:

$$C = 9{,}56\ 10^{-6}\,, \tag{4}$$

$$m = 0{,}32382\,. \tag{5}$$

After integrated eq. 3 we obtain the number of cycles, necessary to receive the crack equal a^* :

$$N_f = \frac{2}{(m-2)C(\Delta\sigma)^m \pi^{0.5m}} \left[\frac{1}{a_0^{0.5(m-2)}} - \frac{1}{a^{*\ 0.5(m-2)}} \right] = 6850 \text{ cycles} \tag{6}$$

Here a^* =115 mm - denotes the critical length of crack.

CONCLUSION

Examinations carried out made it possible to formulate few conclusions - how it is appearing - about significant cognitive importance and utilitarian. The proposed methodology relying on making the analysis of stress and strain state in the area of the crack propagation during fatigue tests with simultaneous registration of the isochromatics field and of transverse deformation in this area is enables to make detailed analyses and estimations of both quality and quantitative page examined phenomena. It refers to the estimation of correctness of the model in the main measure and of adequacy of numeric procedures, accepted for the solution of the considered physically and geometrically nonlinear problem. Effects of experimental examinations make identification of material constants, necessary to determine the time of safe life structure, with the simultaneous usage of constitutive equation, for example of Paris - Erdogan. law [8]. Usefulness bases to take up of work above the issue of widening of results of the fatigue investigation for objects executed from other kind of the materials than considered one, but about similar instantaneous characteristics with affirming rights of the model similarity.

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