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CRACK PROPAGATION IN THE TENSION PLATE MADE WITH DIFFERENT KIND OF MATERIALS

ŠÍŘENÍ TRHLINY V DESCE ZATÍŽENÉ TAHEM U ROZDÍLNÝCH DRUHŮ MATERIÁLŮ

Abstract

The paper presents a problem of fatigue crack propagation in thin walled plates on the basis of executed experiments. The tests were made on the rectangular plates with central crack using two kinds of materials: polycarbonate and aluminium alloy. Length of propagated crack vs. number of cycles were measured. In case of polycarbonate material the fields of isochromatics were observed. In order to express an opinion about model similarity the comparative analysis were made.

Abstrakt

Článek se zabývá šířením únavových trhlin v tenkostěnných deskách na základě provedených experimentů. Zkoušky byly provedeny na obdélníkových deskách s centrální trhlinou u dvou druhů materiálů – polykarbonátu a slitiny hliníku. Byla měřena závislost délky rostoucí trhliny na počtu cyklů. V případě polykarbonátu bylo sledováno pole izochromat. Výsledky řešení u obou materiálů byly porovnány.

1 INTRODUCTION

Fatigue crack growth can be characterized by the stress intensity factor. Consider the growing crack in the presence of constant amplitude cyclic stress intensity. A cyclic plastic zone forms at the crack tip, and the growing crack leaves behind a plastic wake if the plastic zone is sufficiently small that it is embedded within an elastic singularity zone, the conditions at the crack tip are uniquely defined by the current K value, and the crack growth rate is characterized by K_{min} and K_{max} .

It convenient to express the functional relationship for crack growth in the following form:

$$\frac{da}{dN} = f(\Delta K, R). \tag{1}$$

The influence of the plastic zone on crack growth is implicit in equation presented above, since the size of the plastic zone depends only on K_{min} and K_{max}. Schematic log-log plot of dl/dN versus ΔK illustrates typical fatigue crack growth behavior (**Fig. 1**).

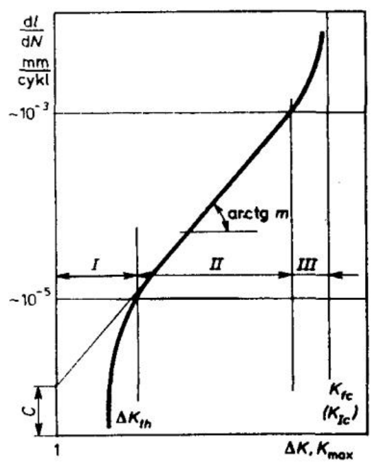

Fig. 1 dl/dN versus ΔK

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2 EXPERIMENTAL INVESTIGATION

If we have curve l = f(N) received from experiment we are able to calculate mentioned sigmoidal curve (esica type curve). Having this kind of curve we are able to determine for given material constants C and m which appear in Parisa-Erdogana equation. Watching similarity of instant characteristics (tension curves) and crack propagation curves for two kinds of materials, metal and plastic (aluminium and polycarbonate) we can suspect that same similarity also characterize sigmoidal curve of logarithmical relation dl/dN versus ΔK.

This paper presents attempt of experimental verification of physical similarity crack propagation process in mentioned before both kinds of materials (metal and plastic). Constructing of similarity matrix for this materials should make shorter fatigue research for constructions with cracks making as plastic models of real metal constructions.

As mentioned before, research were made on samples of two kind of material: optical sensitive plastic – polycarbonate and aluminium alloy. Research were made on cyclic tension of the rectangular plate with a central crack (**Fig. 2**). To retain geometrical similarity of experiment, the test was made on similar size test speciment (**Tab. 1**) but made from different materials. Test was made for one aluminium and three polycarbonate speciments. Polycarbonate speciments were subject of sinusoidal cycling load with amplitudes $\Delta\sigma$ appropriately: 660, 1000 and 1500 N for polycarbonate and 2400 N for aluminium alloy speciment (**Fig. 3**)

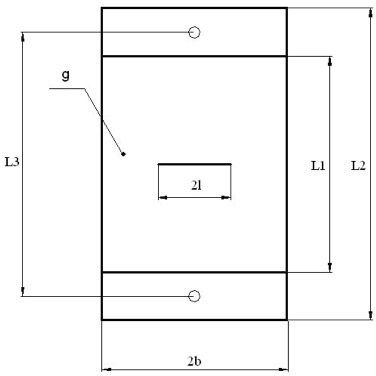


Fig. 2 Specimen size

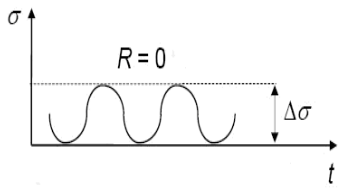


Fig. 3 Cyclic loading

Tab. 1 Size of the test specimen

	Al	*Polycarbonate*		
	2400 N	*660 N*	*1000 N*	*1500 N*
l	*30,0*	*30,3*	*30,0*	*34,6*
b	*125*	*120*	*120*	*120*
	0,3	*0,7*	*0,7*	*0,7*
1	*260*	*190*	*190*	*190*
2	*313*	*242*	*242*	*242*
3	*286,5*	*216*	*216*	*216*

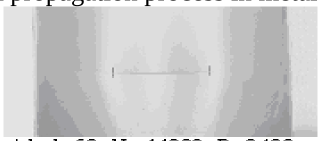
Research were made on special stand allowing realization of programmable load method with assumption that controlling of level load provide solidity of his character and parameters with increasing the crack. Furthermore during tests of elements made of optical active material we made observations and recording of izochromatic field, specially in the front of of crack.

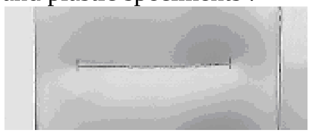
2.1 Research results

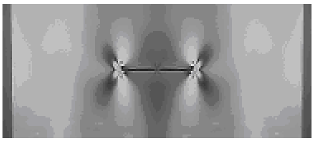
Results were documented in form of two kinds of pictures. First kind presents length of cracks versus of fatigue cycles numbers. Second concern only plastic models (speciments made of optical active material) and illustrate izochromatic field for determinate length of the crack.

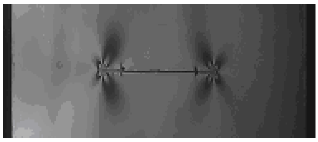
Pictures below show the crack propagation process in metal and plastic speciments .


Al., l=30, N=0, P=2400


Al., l=52, N=44300, P=2400


Al., l=81,1, N=46305,


PW, l=32, N=1620, P=1000


PW, l=45, N=7776, P=1000

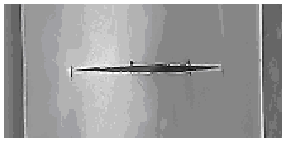
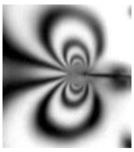
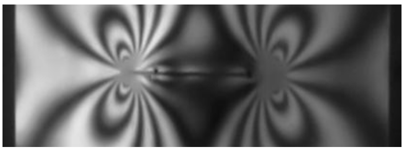

PW, l=69, N=9080, P=1000

Fig. 5 Izochromatic field in the crack front in polycarbonate speciments

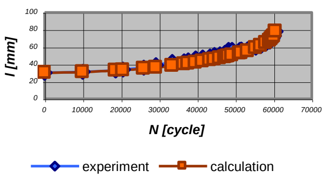

N = 0, P_{max}= 1000 N, l_0 = 30 mm


N = 7776, Pmax= 1000 N, l = 45.7 mm

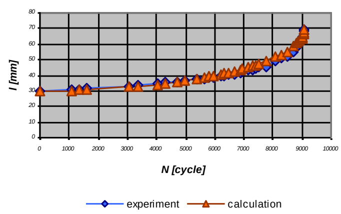

N = 9080, P_{max}= 1000 N, l = 69,6 mm

Fig. 6 Izochromatic field for determinate length of the crack

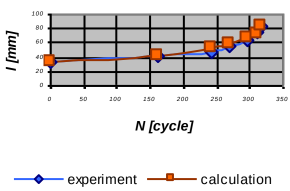
Based on research results below graphs present relations of increasing crack length versus of fatigue cycles number l=f(N) and propagation speed versus ΔK (Fig. 7)



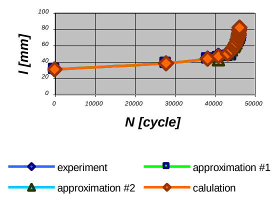
Polycarbonate, P_{max}=660 N



Polycarbonate, P_{max}=1000 N



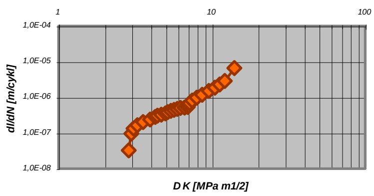
Polycarbonate, P_{max}=1500 N



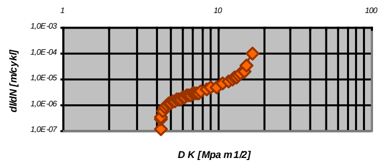
Aluminium, P_{max}=2400 N

Fig. 7 The crack length versus of fatigue cycles

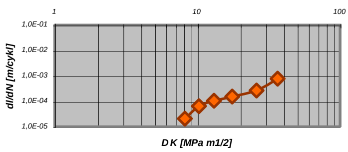
On graphs presented on the **Fig. 7** we can see curves received directly from experimental measurement (curves marked on blue) and heir estimations (curves marked on orange). Estimated curves were used to make graphs dl/dN=f(ΔK), which are graphical presentation of Paris law (**Fig. 8**.)



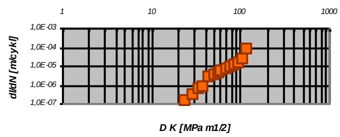
Polycarbonate, P_{max}=660 N



Polycarbonate, P_{max}=1000 N



Polycarbonate, P_{max}=1500 N



Aluminium, P_{max}=2400 N

Fig. 8 Propagation speed versus ΔK

3 CONCLUSION

Based on research constants mp and Cp which appear in Paris law were determined. Their values are appropriately:

	PA7		*Polycarbonate*		
	240 daN	*wg Germana*	*66 daN*	*100 daN*	*150 daN*
C_p	$1,7x10^{-12}$	$7x10^{-11}$	$1,14x10^{-8}$	$4,89x10^{-8}$	$1,84x10^{-6}$
m_p	*3,495*	*4,0*	*2,187*	*2,0803*	*1,521*

- The clear quality similitude were stated in course of both experiments, whitch allow to optimistic prediction of research results moving possibility. It still require further investigations.
- Experimentally confirmed, that the stress state in the crack tipe realise finite value represented by isochromatic field.

REFERNCES

[1] GERMAN J. *Podstawy mechaniki pękania*, Politechnika Krakowska, 2005.
[2] NEIMITZ A. *Mechanika Pękania*, PWN, 1999.
[3] RICE J. R.& PARIS P. C., MERKLE, J. G. *Some further results of J-integra analysis and estimates*, ASTM STP 536, pp. 213-245, 1973.
[4] TREBUNA, F. *Principy, postupy, pristroje v metode photostress*. Typopress Kosice 2006.

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