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STRAIN PLATE STATE OF REINFORCED FIBERGLASS WITH APERTURE AND FISSURE UNDER PULSE LOAD

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Summary. *The process of dynamic fracture of structural elements in the form of plates of transparent composites weakened central hole and isolated by dynamic photoelasticity crack under pulsed load. The changes in the time of stress intensity factors and the speed of the crack tip.*
Key words: *crack, hole, dynamic stress intensity factor, dynamic photoelasticity, composite, fiberglass.*

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Problem setting. The transparent composites usage in the industry is widen annually. The prefabricated elements of modern technique in the form of plates and husks, which are made of fiberglass plastics, with tension thickeners are widely used in the outer space and air building, building, shipbuilding, transport machine building. Under the influence of technological and operational factors, under the action of dynamic loads in the given elements can appear different type cracks. This substantially reduces the strength characteristics and resourceful possibilities either load-bearing members, or the entire construction upon the whole.

Last research and issue analysis. Results, concerning resilient plate dynamic nature investigation, that are weakened by orifices, are given in the works [1-3]. Resilient or elastic analysis of tense strained plate state with fissure under durable static load works are dedicated in [4-8]. Important value for engineering calculation of machine elements, made with diaphanous composite field (fiberglass plastic), has the value tension intensity coefficient distribution in time (TIC) and split movement velocity for the constructive elements in the shape of plates with the central aperture and isolated crack under pulsed load. In the literature numerical data of such investigation aren't proposed.

Work aim. To research changes in time TIC and crack top movement velocity for constructive elements in the form of plates of transparent composite field (glass-fiber reinforced plastic), that are weakened by central orifice and isolated crack by the dynamic photo elasticity method under pulsed load.

Target stating.

Pulse load dynamic nature that appears under striking and explosive power interactions, is one of the main factors, which should be taking into consideration while calculating operational strength. Strain pulse interaction with fissure leads to essential strain load transfer near the top crack and under determined conditions can cause its further development. Consequently, in the solid body under sufficient power pulse impact action, the destroying process arising is possible and under the static strain deficiency. Depending on the nature of strain waves the disturbance areas are divided into primordial and reiterative. Initial is the load wave perturbation area, while it isn't available there are no unload and reflected waves. Accordingly, unload wave and reflected perturbation areas are considered as secondary. They are always in the load wave perturbation area centre and are the areas with the primordial strains and deformations. The load disturbance area arises around this or that force factor immediate action and with the time is widen with the ultimate velocity, equal to the load wave distribution speed. This area is limited by the body surface part (including loaded) and the load wave front surface.

In the suggested work the researched examples form and measures were chosen by the way, that the unload wave impact on the loading process was minimum. Plate parameters are given on figure1.

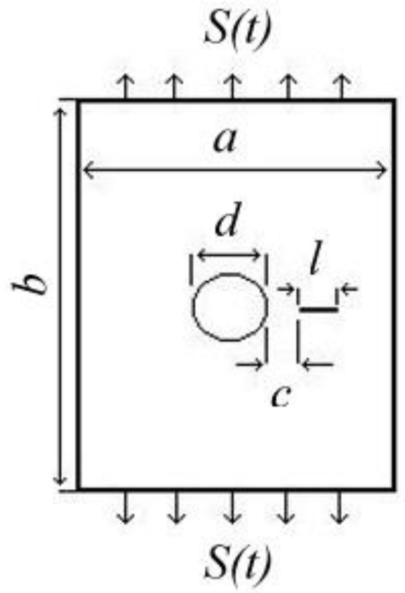

Figure 1. Loading sheme, plate shape and sizes

The patterns were made of transparent composites (fiberglass plastic) on the epoxy resin base ЕД-20, hardened by polyethylene polyamine, and in the role of reinforcing element in which was glass fiber. Such materials production technology and their mechanical and optical properties explore methods are given in the work [10]. The patterns in the shape of plates were investigated with the central orifice with diameter d and isolated crack with length l, that is oriented towards the orifice horizontal diameter direction, coincided with the main orthotropy direction $E_x > E_y$. Pattern measures were: a = 90mm; b = 120mm; c = 11mm; d = 15mm; l = 15mm. To increase the result exactness and authenticity the experiment was repeated on the five or more models of one consignment. Each model under preparation to the experiment was located into the device movable plank slots for the extension pulses excitation [9] and was fastened by the help of epoxy glue (ЕД-20 ПЕПА). Then endure at room (20-21^{o}C) temperature 5 – 6 hours and for further polymerization 14-16 hours in the oven (T=120^{o}C).

The experiment was carried out on polarizing and dynamic machinery. Pattern loading was implemented by extension pulse *S(t)* with the time growing $\tau = 30\text{мкс}$, with the electromagnetic inductor help [9]. For the dynamic process registration the parallel radioscopy scheme was used. The model radioscopy direction under such scheme usage, is parallel to the crack plane, and this gives the possibility to record, as strain state near the fissure, and also to fix moving crack top.

Experimental results that contain the data about crack kinetic and about the TIC, were determined with the help of interferential stripe picture analysis. Great interest has wave field change research near the crack top for the case, when the impulse strength load value doesn’t lead to the model ruin. On figure 2 the kinogram fragments with izohrom pictures are given, that correspond to the passing moment by wave front of aperture contour extension and isolated crack top. The isochrome picture analysis showed that the maximum strains around mentioned concentrators arise under their going through the load wave area. Intensity dynamic coefficient maximum value *K(t)*, was $0.59K_c$.

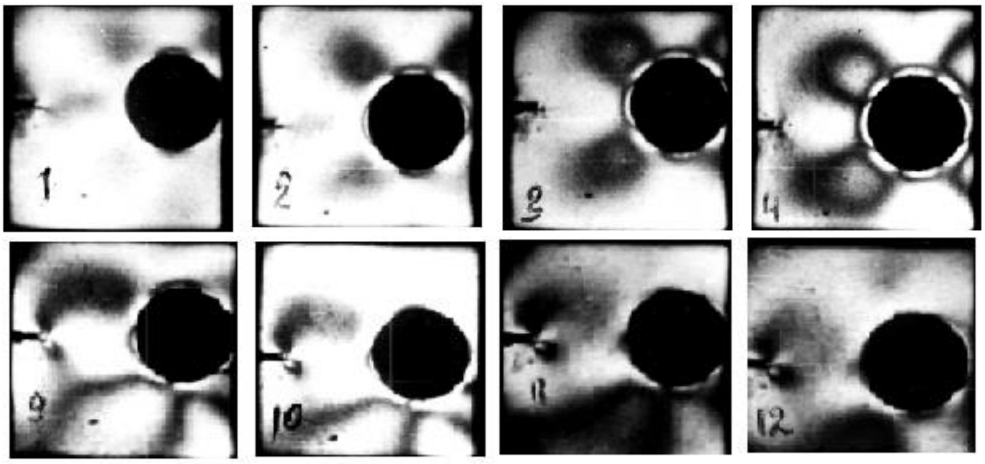

Figure 2. Kinogram fragments with strip isochrome pictures while reaching the fissure top and aperture contour wave front

It should be mentioned, that the straightforwardness of the load wave front when approaching the orifice contour is violated gradually, at the same time areas with strain concentration are formed. The front area, that is located near the sample symmetry longitudinal axis, advances peripheral areas. In the all further experiments, carried out on the models, free of extension static strains, the crack under the extension pulse action was distributed straightforwardly alongside of line that passes through the orifice centre. The strength action energy on the model was appreciated according to the energy, that was stocked up with in the condensers, and for the examples with circular aperture, and isolated fissure made up W = 4, 6 *KJ*. As can be seen from kinogram, the crack movement is accompanied by formation near its top symmetrical relatively to crack plane isochromatic strips. When $\theta = \pi/2$ the nearest to the top cracks isochrome reach the maximum, that is the condition is $\frac{\partial \tau}{\partial \theta} = 0$. This means that, in the induced experiments, in the crack top, the conditions of normal tearing off were realized.

Received result analysis shows, that the crack average velocity via the whole way, gone by the top, had the size 330 – 350 m/s and only at the final distribution stage, at the exit on the aperture contour, somewhat increased. The velocity increasing at the exit on the orifice outline we can explain by the availability of strain zone before the crack top. It was noticed the pulsing nature of fissure growing, that is the changing of movement slowing-down and speeding up. The average velocity measures up its maximum value at the final movement points. The movement slowing time t=3 – 3,5 ms, the speeded movement time t=2 – 2,5 ms.

The crack top maximum velocity, during the speeding up, reached to 600 – 650 m/s, while the fissure speed appeared to be weak sensitive to the changing of coefficient value of strain intensity.

It should be emphasized that, destruction figurative mechanism, connected with the creation by strain waves of net strain of micro cracks and further their confluence [11], that

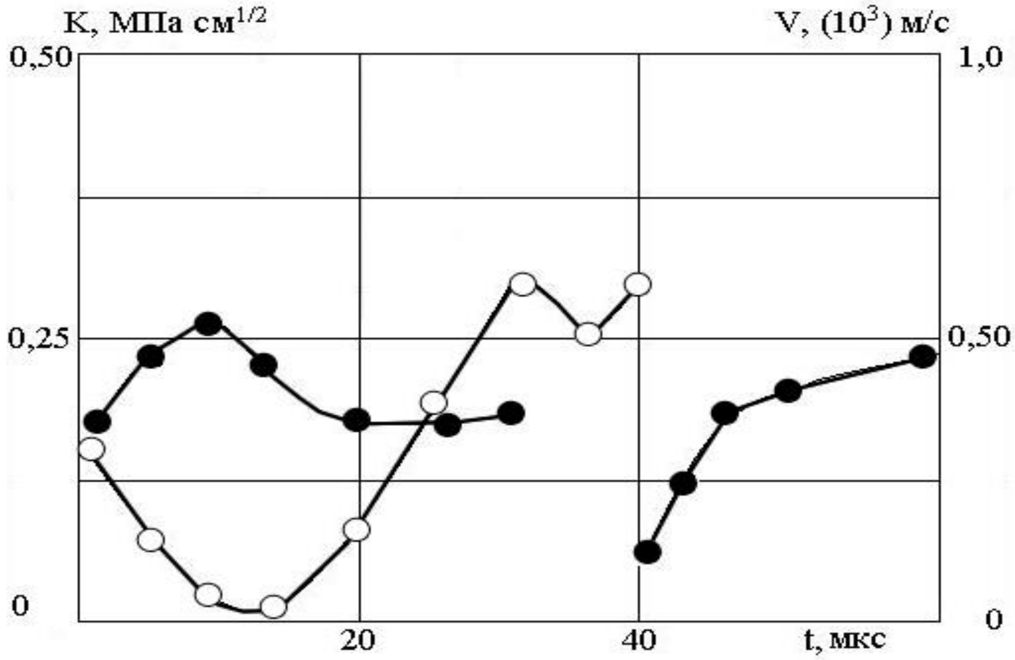

Figure 3. Crack top movement speed changing *V (t)* (●) and tension intensity coefficient *K (t)* (○) from time

leads, as to high speeds of crack growing, and to the stepwise process nature of its movement, in our example wasn't observed. On the picture 3, the changing in time strain intensity coefficient *K(t)* in the plate with round aperture and isolated fissure under the impact of extension pulse is shown.

The growing beginning of the strain intensity coefficient on the top of stationary fissure coincides with the access of load wave front around the fissure and orifice, that time corresponds 29 – 30 ms from the moment of extension pulse application to the plate verge. The intensity coefficient maximum value *K (t)* is observed before the beginning of fissure movement and is in the proposed experiment $K = 3{,}0K_c$. For the average value range, that is determined in the moment of fissure displacement, it was accepted K_c =1,0 к Н/см$^{3/2}$.

The time value changing *K(t)*, many experiments found according to the results, implemented with one and the same energy value of added pulse, eventuated by analogy way and the distinction in the quantity ratio was not more than 5% [12,13]. It is also interesting that the most remote crack isochrom from the top that start from this top, are closed on it. In the given example isochromat, that appeared after the access of strain wave on the crack top, are symmetrical and are closed on it, that affirms about the availability at this time moment conditions of normal breakdown.

Values changing analysis *V* і *K(t)* in time (fig. 3) showed, that any isochrome collars vibrations, and now then, and values *K(t)* are not available. So, top movement stepwise process was accompanied by flowing value changing *K (t)*.

The process of patterns with the central round aperture and fissure ruin (fig. 4), in all cases, was realized at two stages. Firstly the crack development was realized into aperture side and only after the top coming out on the orifice contour via time t_1, the second opposite top movement started to the free model contour side, that ended by crack formation via time t_2. Contrary, concerning the orifice, the sample part wasn't ruined. The ruin phases duration is given in the table.

Table № 1

Ruin stages duration

Model	*W* (10^3 J)	*V* (m/s)	t_1 *(mks)*	t_2 *(mks)*	t_3 *(mks)*
№1	4,8	330-350	40	30	–

The analysis of izochrom pictures changing after the fissure creation between the aperture and free plate contour showed, that the dynamic strains intensity is decreasing in time, and izochromatic buttonholes fluctuations near the aperture are caused by own fluctuations of two cantilever girders, correspondent to two halves of half-ruined sample. These fluctuations are followed by crack margins contact interconnection.

For the got experimental results authenticity estimation ruined unvaried type models analysis was realized.

On the figure 4 ruined plates samples with central circular orifice and transparent isolated crack external view is induced. Ruined surfaces factor graphic analysis and the process development in time in each unvaried type model indicated on dynamic processes high repetition in them.

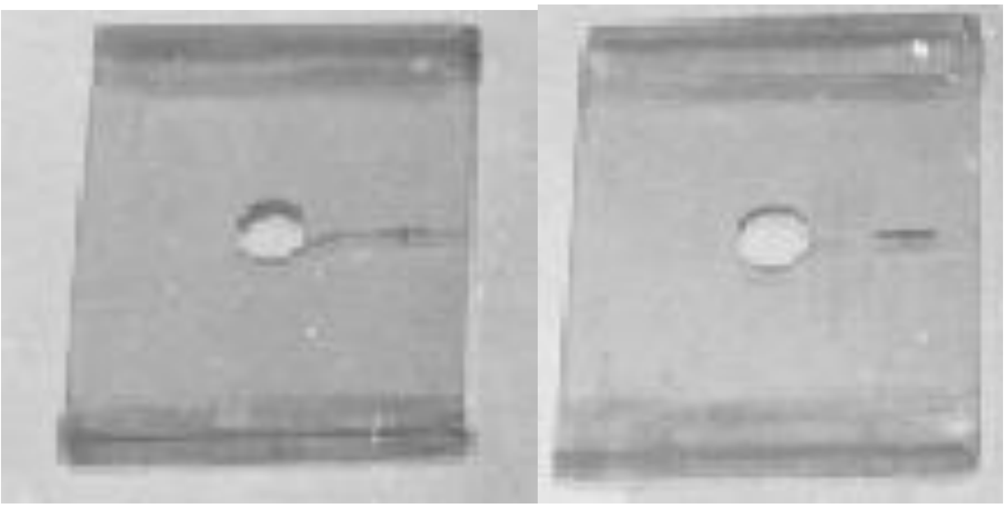

Figure 4. Ruin samples view

Conclusion. Result analysis shows, that the average crack velocity via the whole way gone by the top was 330 – 350 m/s and only at the final distribution phase, while inletting into the aperture contour a little increased. The fissure top extreme velocity while speeding up, was 600 – 650 m/s, the crack velocity appeared to be weak sensitive to the tension intensity coefficient value modification. Dynamic intensity coefficient extreme value $K(t)$, formed before crack movement $3K_c$.

Dynamic model ruin occurs at the weakened area extension coming time by the primordial wave. Wave front straightforwardness while it is approaching to the aperture outline is distorting at the same time the strain concentration areas are formed, that influences further on the ruin process. The separate constructional elements at the samplers ruin process is divided into phases, their availability and time intervals are determined by non-straightforwardness of wave front extension.

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НАПРУЖЕНИЙ СТАН ПЛАСТИН ІЗ СКЛОПЛАСТИКУ З ОТВОРОМ ТА ТРІЩИНОЮ ПРИ ІМПУЛЬСНОМУ НАВАНТАЖЕННІ

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Резюме. *Розглянуто процес динамічного руйнування конструктивних елементів у вигляді пластин із прозорих композитів, що послаблені центральним отвором та ізольованою тріщиною методом динамічної фотопружності при імпульсному навантаженні. Вивчено зміни в часі коефіцієнтів інтенсивності напружень та швидкості руху вершини тріщини.*

Ключові слова: *тріщина, отвір, динамічний коефіцієнт інтенсивності напружень, динамічна фотопружність, композит, склопластик.*

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