Conference track «Theory of elasticity»

Simulation of Crack Initiation and Propagation in Solid Square Plate Using Fatigue Fracture Method

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In this research, numerical simulations are performed to identify the initiation and propagation of crack inside a solid plate using the fatigue fracturing method. A two-dimensional case is considered in this study. The study uses a novel methodology involving the overset grid, an approach that diverges from the conventional use of conformal meshes. In the domain of computational solid dynamics, particularly in the context of handling complex geometries, overset or chimera meshes have emerged as the prevailing advanced techniques. The overset grid's capacity to manage such geometries is noteworthy, underscoring its importance in advanced computational solid dynamics applications. The study utilizes a grid characteristics method, using a third-order approximation scheme to ensure precision in the analysis. The dimensions of the solid square plate are 7.8 cm in length and width, and the radius of the hole is 1 cm. The linear elastic model is used [1]. The model equations (1) are solved using the internal build code RECT, developed in the C++ programming language. The fatigue fracturing method is implemented in Python. The maximum principal stress is used to define the equivalent stress on the computational grid based on the Smith-Watson-Topper method.

(1)

Here, , are the pressure wave and shear wave velocities that can be computed from Young's modulus and Poisson ratio ( ) and is the density of the material. The different modes of the cyclic loading are defined on the basis of the equivalent stresses ( ) [2] . Firstly, if equivalent stresses are less than ultimate strength of the material and higher than low classical fatigue limit, then the stresses are in the region of low cyclic mode. Secondly, if equivalent stresses are less than the low classical fatigue limit and greater than the high classical fatigue limit of the material, then the stresses are in the region of the high cyclic mode. The destruction function and cyclic loading are dependent on each other. The value of the destruction function is always between 0 and 1, where 0 indicates no destruction in the plate and 1 indicates full destruction. The total time required for the initiation and propagation of the crack on the solid surface exceeds six hours. The velocity boundary condition is implemented at the upper and lower sides of the plate, while the force-free boundary condition is used along the lateral edges of the plate. Additionally, the force-free boundary condition is implemented along the inner edge of the plate. The temporal interval is determined through the implementation of a stable numerical scheme, under the condition that the courant number is less than one and the cell size is less than the 10-times radius of the hole. Simulations are performed at a frequency of and at a velocity amplitude of . The zone of destruction and stress field are illustrated in Figure 1.

To produce large crack in the plate cycles loading is required as is seen in Figure 1. As we set the maximum value for destruction must be less than 0.96, it is visible at Figure 1 (a) and

(b) that equivalent stress ( ) are higher than the low classical fatigue limit and it is in low cyclic mode. The gradual decrease in the properties of the material leads to the crack in the solid square plate. In summary, the propagation of the crack is observable.

References

1) Khalid, W., Golubev, V., Nikitin, I. et al. Simulation of Cycling Damage under High-Frequency Loading with Grid-Characteristic Method on Overlapping Meshes. Math Models // Comput Simul .2024, vol16 (Suppl 1).
2) I. S. Nikitin, N. G. Burago, and A. D. Nikitin, Damage and Fatigue Fracture of Structural Elements in Various Cyclic Loading Modes // Mech. Solids. 2022, vol. 57, no. 7.

Illustrations

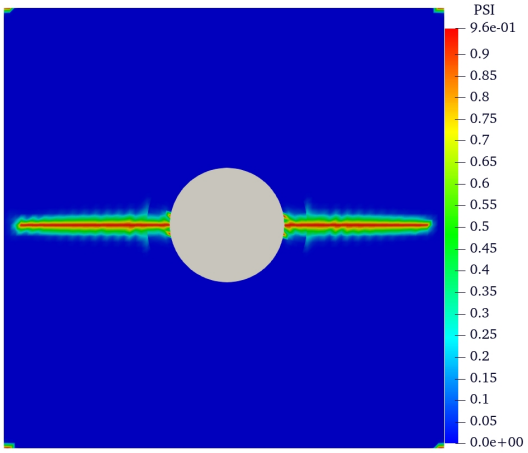

Рис. : shows the destruction function ()

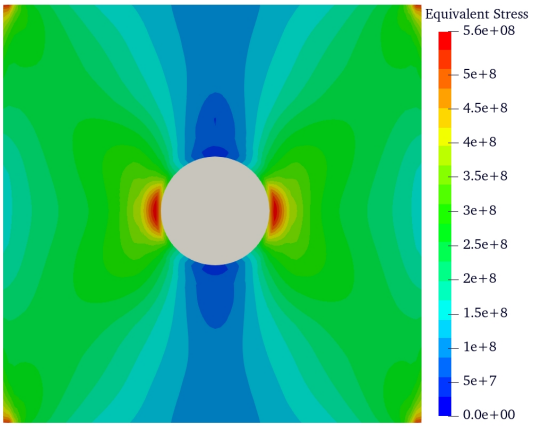

Рис. : the equivalent stress [U+3016] ([U+3017]$_e q$)*atthecomputationaldomain*