# 6. INTERNATIONAL CAPPADOCIA SCIENTIFIC RESEARCH CONGRESS

*August 10-12, 2024, Göreme / TÜRKİYE*

## THE PROCEEDINGS BOOK

## EDITOR

Prof. Dr. Serap GÖNCÜ

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# RESEARCH OF THE FUEL TANKS DESTRUCTION DURING TRANSPORTATION

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## ABSTRACT
Paper aims to develop advanced numerical methods to analyze stress in structures containing crack-like defects. The innovative aspect of the proposed research is to involve hypersingular integral equations to solve a benchmark test. The benchmark test employs both boundary and finite element methods. The investigation involves fatigue analysis under finite amplitude cyclic loads, revealing a significant increase in service life, ensuring successful transportation of the intact structure. However, placing a penny-shaped crack in the zone of maximum stresses results in a notable decrease in the expected service life before failure. For practical applications, short-distance transportation is deemed sufficient, as long-distance transport may induce fatigue crack propagation within the shell, leading to depressurization and eventual failure.
**Keywords:** crack-like defects, hypersingular integral equations, liquid transportation, boundary element method, finite element method.

To determine the stress-strain state of an elastic body, a system of equations of the elliptic type in partial derivatives of the second order have been applied

$$\mu\Delta U_j + (\lambda+\mu)\frac{\partial\vartheta}{\partial x_j} = 0, \qquad \Delta = \frac{\partial^2}{\partial x_1^2}+\frac{\partial^2}{\partial x_2^2}+\frac{\partial^2}{\partial x_3^2}, \quad \vartheta = \mathrm{div}U, \quad j=1,2,3. \quad (1)$$

where μ - shear modulus, $\lambda=E\nu/[(1+\nu)(1-2\nu)]$ - the Lamé coefficient, $E$ - Young's modulus, $\nu$ - Poisson's ratio, U - displacement vector. It has been introduced the differential surface tension operator of the elasticity classical theory as

$$\mathbf{T}^{n(x)}\,U = 2\mu\frac{\partial u}{\partial n} + \lambda n\,\mathrm{div}U + \mu(n\times \mathrm{rot}U), \qquad (2)$$

where n – unit external normal to the surface.

A boundary value problem for a three-dimensional body bounded by a region is formulated $\Omega$ and weakened by incisions $S_i$ (i = 1,...,n), to determine the displacement vector U

$$\Delta U_j + (\lambda+\mu)\frac{\partial\vartheta}{\partial x_j},\ j=1,2,3,\ U_i(\mathbf{x})=u_{i1}(\mathbf{x}), \quad \mathbf{x}\in\Omega_1,.\mathbf{T}^{n(x)}\mathbf{U}(\mathbf{x})=\mathbf{X}(\mathbf{x}),\ \mathbf{x}\in\Omega_2, \ (3)$$

$$(\mathbf{T}^{n(x)}\mathbf{u}(x)\cdot\mathbf{n}(x)) = N_{3i},\ (\mathbf{T}^{n(x)}\mathbf{u}(x)\cdot\tau_k(x)) = N_{ki},\ \mathbf{x}\in,\ i=1,2.$$

The solution of the boundary value problem (3) could be found using various numerical methods. Among them, it is worth noting the method of finite elements [1] and boundary elements (BEM) [2]; both are based on the use of the weighted error method.

Further, the formulation based on the boundary element method has been used. One of the key features of this method is the use of singular trial functions that satisfy the differential equation (1) everywhere except for one singular point. Thus, fundamental and singular solutions of equation (1) are used as trial functions. The fundamental solution of the theory of elasticity is obtained by solving equation (1) with the right-hand side in the form of a delta function and is presented in the following matrix form

$$\Gamma_{ij}(x\text{-}y) = \frac{\lambda+\mu}{8\pi\mu(\lambda+2\mu)}\left[\frac{\lambda+3\mu}{\lambda+\mu}\frac{\delta_{ij}}{|x\text{-}y|} + \frac{(x_i\text{-}y_i)(x_j\text{-}y_j)}{|x\text{-}y|^3}\right]. \qquad (4)$$

Using representation (4) in the case of an isolated circular crack, a hypersingular integral equation in the form [3] has been obtained

$$\frac{1}{4\pi}\iint_S \frac{\alpha_3(y)}{|x\text{-}y|^3} dS_y = Mq(x),\ \ M = \frac{1\text{-}\nu}{\mu}, \qquad (5)$$

where $q(x)$ – function to characterize the external load.

Equation (5) has been considered for a crack in a circle with a radius $R$ under uniform stretching $\sigma$. Thus, $q(x)=\sigma$. Area of integration $S$ divided into $N$ flat triangular and quadrilateral elements. The hypersingular integral over the approximated surface has been considered and a system of linear algebraic equations was obtained

$$\sum_{k=1}^{N} H_{kj}\alpha_{3k} = f(x_{0j}),\ \ j = 1,2,\ldots N. \qquad (6)$$

where the elements of the matrix $H_{kj}$ are calculated by formulas

$$H_{kj} = \frac{1}{4\pi}\sum_{i=1}^{m}\frac{([l_i \times r_i]\cdot n)}{|[l_i \times r_i]|^2}\left[\frac{(l_i\cdot r_{i+1})}{r_{i+1}} - \frac{(l_i \cdot r_i)}{r_i}\right] . r_k = (x_k\text{-}x_0, y_k\text{-}y_0, z_k\text{-}z_0),$$

$$l_i = (x_{i+1}\text{-}x_i, y_{i+1}\text{-}y_i, z_{i+1}\text{-}z_i), i = \overline{1,m}\ ,$$

$$n = (n_1, n_2, n_3),\ x_{m+1} = x_1,\ y_{m+1} = y_1, z_{m+1} = z_1,\ r_k = |r_k|.$$

Since the domain in equation (5) is a circle, the two-dimensional hypersingular equation reduces to a one-dimensional one [3]. A cylindrical coordinate system has been used, therefore $x = \rho\cos\varphi, y = \rho\sin\varphi$, $x_0 = \rho_0\cos\varphi_0$, $y_0 = \rho_0\sin\theta_0$. It has been introduced the following notations: $a = \rho^2 + \rho_0^2 + (z\text{-}z_0)^2$, $b = 2\rho\rho_0$, and there have been got a one-dimensional hypersingular integral equation

1𝜋0𝜋𝛼3(𝜌)𝜌E(k)d𝜌𝜌+𝜌0𝜌-𝜌02=1-νG. (7)

Numerical implementation has been done by the method [4].

For a crack in the shape of a circle with a radius $R$, that is under the influence of load $\sigma$, the boundary element method has been used, while the crack is considered in an unlimited three-dimensional space. Thus, there are two solution options with hypersingular integral equations. The first option is related to the two-dimensional integral equation (5), while the second concerns the axially symmetric formulation according to equation (7). In numerical simulations, it has been selected values $R$=0.005м i $\sigma$=1 MPa. The total number of planar triangular and quadrilateral elements when using equation (5) was $N$ = 9284. Segment [0, $\pi$] was divided into $N_1$=100 one-dimensional boundary elements. The analytical solution of equation (7) with the right-hand side obtained in [3] as $\alpha_3(\rho) = 4\sqrt{R^2\text{-}\rho^2/\pi}$. The most important parameters of destruction are stress intensity coefficients. They are successfully used to analyze crack propagation and structural failure. In the considered case, only the coefficient $K_I$ is needed to adequately describe the deformed state around the crack. Its analytical expression for a circular crack with radius $R$ under load $\sigma$ looks like KI=2𝜎𝜋R/𝜋 [3,5]. Table 1 provides a comparison of analytical and numerical results obtained by different methods for different polar angles φ. The finite element mesh consisted of 43674 elements.

Table 1. Comparison of numerical and analytical results

| φ | Analytical value | Two-dimensional equation | One-dimensional equation | FEM |
|---|---|---|---|---|
| 10 | 1.12827 | 1.13217 | 1.12988 | 1.14217 |
| 30 | 1.12827 | 1.12945 | 1.12837 | 1.14207 |
| 50 | 1.12827 | 1.12876 | 1.12830 | 1.14204 |
| 70 | 1.12827 | 1.12842 | 1.12828 | 1.14203 |
| 90 | 1.12827 | 1.12830 | 1.12828 | 1.14200 |

The results presented in Table 1 testify to the accuracy and reliability of finite and boundary element methods, which will be used in the future in the analysis of the possibility of fuel tanks destruction with initial micro-defects during transportation.

**References**

1. K.V. Avramov, E.A. Strelnikova. “Chaotic vibrations of plates two-sided interacting with flux of moving fluid”, Int. Appl. Mech, Vol. 50, P. 329-335, 2014.

2. O. Sierikova, E. Strelnikova, V. Gnitko, K Degtyarev, “Boundary Calculation Models for Elastic Properties Clarification of Three-dimensional Nanocomposites Based on the Combination of Finite and Boundary Element Methods”, IEEE 2nd KhPI Week on Advanced Technology (KhPIWeek), P. 351–356, 2021.DOI: 10.1109/KhPIWeek53812.2021.9570086

3. V. Gnitko , A.Karaiev, K. Degtyariov, I. Vierushkin, E. Strelnikova, “Singular and hypersingular integral equations in fluid–structure interaction analysis”,. WIT Transac-tions on Engineering Sciences, 2022, Vol. 134, P. 67-79, DOI:10.2495/BE450061.

4. A. Karaiev, E. Strelnikova, “Axisymmetric polyharmonic spline approximation in the dual reciprocity method”. Z Angew Math Mech. 101, e201800339, 2021, DOI:10.1002/zamm.201800339.

5. Sierikova O., Strelnikova E., Degtyarev K., 2022. Srength. Characteristics of Liquid Storage Tanks with Nanocomposites as Reservoir Materials. 2022 IEEE 3rd KhPI Week on Advanced Technology (KhPIWeek): 151-157. doi: 10.1109/KhPIWeek57572.2022.9916369