Modeling of thermal process in elements of structures with poles with the record of recovery

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Abstract The proposed work deals with the problem of finding the geometric dimensions of a cavity-type defect by measuring the thermal fields. As a structural element, a plate with a rectangular cavity is considered.

1. Introduction

The proposed work deals with the problem of finding the geometric dimensions of a cavity-type defect by measuring the thermal fields. As a structural element, a plate with a rectangular cavity is considered. The method of solving this problem is based on the optimization approach. Optimization is carried out using methods of finding extremums without calculating the derivative, in this paper this is the Hook-Jeeves method. The results of solving this problem make it possible to improve the accuracy of determining the location of the defect and show the advisability of generalizing the problem under consideration to more complex structural elements. The results obtained in this paper can be used in problems of thermal non-destructive testing.

2. Mathematical model

The model problem of thermal diagnostics in the following formulation is considered. Heat flows are studied in this article [1—3]. An element of a product of aerospace engineering in the form of a plate with a cavity of rectangle type is considered. The plate on one side is heated by a stationary flow, the two sides of the plate are thermally insulated, and the thermal imager measures the thermal flux of radiation from the fourth side. The boundary conditions [2-6] on each side are recorded.

![Figure 1. Type of plate boundary conditions](image-url)
The problem under consideration reduces to a parabolic equation with nonlinear boundary conditions and taking into account reradiation. Let’s consider the mathematical formulation of the stationary problem.

\[ \Delta u(x) = 0, \ x \in \Omega \] (1)

\[ K \frac{\partial u(x)}{\partial n} = 0, \ x \in \Gamma_1 \text{ or } \Gamma_3 \] (2)

\[ K \frac{\partial u(x)}{\partial n} + \alpha (u(x) - T_c) + \sigma (u(x)^4 - T_c^4) = 0, \ x \in \Gamma_2 \] (3)

\[ q(x) = \sigma u(x)^4 - \int_\gamma G(x, \xi) q(\xi) d\xi \] (4)

\[ K \frac{\partial v(x)}{\partial x} + a q(x) = 0, \ x \in \gamma_1 \cup \gamma_2 \cup \gamma_3 \cup \gamma_4 \] (5)

\[ K \frac{\partial u(x)}{\partial n} + q^*(x) = 0, \ x \in \Gamma_4 \] (6)

Where \( q(x) \) – heating temperature

An approximate solution of the problem posed will be sought by the finite difference method. The optimization methods are studied in these articles [4—5]. To do this, it is necessary to formulate a grid problem and indicate a method for solving it. The grid problem corresponding to the set and iterative method for its solution with small changes corresponds to the grid problem.[1]

The results of solving this problem make it possible to improve the accuracy of determining the location of the defect and show the advisability of generalizing the problem under consideration to more complex structural elements.

The obtained results showed the importance of accounting for reradiation in solving the problem of restoring geometric dimensions and location of defects in the plate.

3. Formulation of the inverse problem

The inverse problem is to restore the geometric dimensions of a plate with a cavity-type defect. This problem reduces to an optimization problem with four parameters (Figure 2).
4. The coordinated problem of heat exchange by radiation and thermal conductivity

Of greatest interest is the problem of taking into account reradiation for non-convex bodies, when it is necessary to take heat transfers into the body. Here, such a coordinated problem of taking into account heat transfer by radiation and thermal conductivity is considered under the conditions of the two-dimensional problem for the next model area (Figure 1).

5. The results of solving the inverse problem

The Hook-Jeeves method was programmed in C++ in Visual Studio. The geometric dimensions of the cavity were restored. Figure 3 shows the results. Blue contour - the present location of the cavity.

6. Conclusion

The results of solving this problem show the importance of taking into account reradiation and allow increasing the accuracy of defect location and show the expediency of generalizing the problem under consideration to more complex structural elements. The results obtained in this paper can be used in problems of thermal non-destructive testing.
Acknowledgments

The work was carried out with support of state task of Ministry for Science and Education № 9.5387.2017/БМ

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