THERMOELASTIC PROBLEMS FOR A BIMATERIAL WITH DEFECTS/SINGULARITIES

Vera E.Petrova
Voronezh State University of Architecture and Civil Engineering, 394006 Voronezh, Russia

Summary. The paper presents a method for the solution to 2D thermoelastic problems for a bimaterial with singularities/defects, like cracks, dislocations as well as a heat source. A number easy-to-use formulas, in particular, for the stress intensity factors evaluation is presented.

Bimaterial compounds are often used in different electronic devices, which are undergone to thermal loading. Interface fracture is commonly observed in such structures [1]. The interface crack problems have a long history many models have been developed up to now. The interaction problem of singularities, in particular, edge dislocations, with a bimaterial interface or an interface crack in isotropic and anisotropic materials were solved by Suo [2]. In the work by Petrova and Herrmann [3] the analogous relations have been obtained for the corresponding thermoconductivity and thermoelasticity problems. On the basis of these expressions for the complex potentials a solution is constructed for the problem of the system of internal cracks and an interface crack.

This paper presents a method for the solution to 2D thermoelastic problems for a bimaterial with internal singularities/defects, like cracks, dislocations. A bimaterial interface is either virgin or contains an interface crack. The bimaterial is subjected to thermal loading caused by a uniform heat flux, applied at infinity normal to the interface, or a heat source of intensity Q acts at a point z_0^s, as shown in Fig.1.

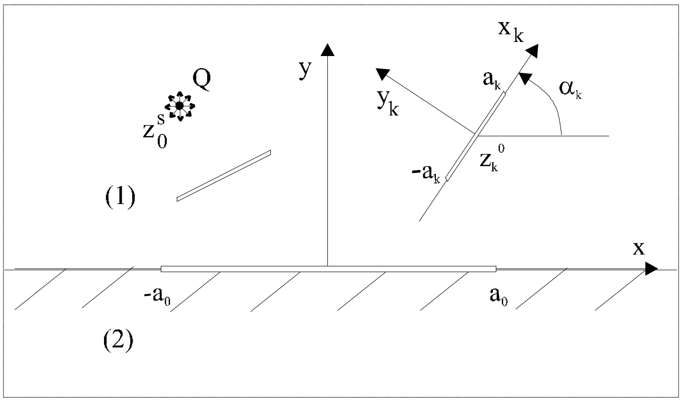

Fig.1. Cracks and a heat source in a bimaterial.

The geometry of the problem for defects-cracks is depicted in Fig.1. A bimaterial composes of two different isotropic semi-infinite media (1) and (2) with thermoelastic constants μ_i , α_{ti} , k_i , ν_i (i=1,2). The crack position is determined by an angle α_k to the x-axis and the defect midpoint coordinate z_k^0 $(k = 0,1,..., N)$.

In the previous studies by Petrova and Herrmann (see [3]) the thermoelastic fracture problems are considered for a bimaterial with perfectly bonded interface in exception of an interface crack. In this work the common method for the construction of the solution is presented and different types of interfaces are considered in accordance with boundary conditions on the interface line.

The uncoupled, quasi-static thermoelastic theory is applicable to this problem so that the solution consists of the determination of the temperature distribution, and the determination of the thermal stresses. The cracks are supposed to be thermal insulated and traction free, whereas, the interface is partially thermal conductive.

The method is based on
- the well-developed theory of complex potentials,
- analytical continuation theorem and
- superposition technique

and leads to singular integral equations for the problems in hand.

Due to the superposition principle the main temperature and thermoelastic problems decompose into a series of simple subproblems each of them contains either an internal crack or an interface crack. The general parts of the scheme of the solution are presented in the Table. The full temperature T* consists from the perturbation temperature T, caused by defects, and the temperature T^0 for the undamaged bimaterial. If a heat source is acts in a bimaterial then the solution is more complicated because of the heat source is a singularity and it causes stresses in the undamaged bimaterial (see the scheme II in the Table).

As examples of the effectiveness of this technique the solution of subproblems are presented and discussed. It should be noted that the well-known solutions for singularities in an infinite homogeneous medium are used for construction of these problems. These particular solutions also verify the validness of the method.

Table

FULL TEMPERATURE in a bimaterial with cracks $T^{*}=T+T^{0}$		
I	II	III
PERTURBATION TEMPERATURE PROBLEM (T) Determination of the temperature jumps on the crack lines	TEMPERATURE PROBLEM (T^0) for an undamaged bimaterial with a heat source	TEMPERATURE PROBLEM (T^0) for an undamaged bimaterial influenced by a heat flux. T^0 doesn't cause stresses in an undamaged bimaterial so that only perturbation solution (I) is needed
THERMOELASTIC PROBLEM for a bimaterial with cracks Determination of the stresses caused by the perturbation temperature	THERMOELASTIC PROBLEM for an undamaged bimaterial. Determination of the stresses on the crack lines ($\sigma_k - i\tau_k$)	
	ELASTIC PROBLEM for a bimaterial with cracks The edges of cracks are loaded by stresses with opposite signs, $-(\sigma_k - i\tau_k)$	

For internal cracks interacting with an interface crack the systems of singular integral equations are constructed for the temperature and thermoelastic problems, as well as antiplane problem. If the typical size of the internal cracks is much smaller then the size of the interface crack a small parameter method is used [4] for the solution. The small parameter is equal to the ratio of the length of the microcrack *2a* to the length of the interface macrocrack $2a_0$, i.e. $\lambda=a/a_0$. The solution of the problems is obtained up to λ^2 , which taking into account the interaction between the interface crack and each of microcracks. The closed form expressions for the temperature distribution in the bimaterial with cracks is obtained and then the stress intensity factors at the interface crack are derived. Further, the effect of the location of micro- defects as well as the influence of the material combination on the stress intensity factors at the interface macrocrack tip are investigated.

References

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