Engineering Fracture Mechanics 100 (2013) 92–107

Contents lists available at SciVerse ScienceDirect

Engineering Fracture Mechanics

journal homepage: www.elsevier.com/locate/engfracmech

Solutions of dissimilar material contact problems

Y.Y. Yang

IAM – IZBS, KIT Karlsruhe, 76131 Karlsruhe, Germany

ARTICLE INFO

Article history:
Available online 28 September 2012

Keywords:
Stress singularity
Dissimilar materials contact problem
Thermal and mechanical loading
Singularity exponent
Angular function
Regular stress term
Friction free contact
Contact with friction
Stress distribution near singular point

ABSTRACT

In this paper, the stress distribution near the singular point in a two dissimilar materials contact problem will be considered, in which the interface is friction free or with friction. The loads may be thermal or mechanical loading. For the type of r^{ω} singularity the stress distribution near the singular point is given by

$$\sigma_{ij}(r,\theta) = \sum_{n=1}^{N} \frac{K_n}{(r/R)^{\omega_n}} f_{ijn}(\theta) + \sigma_0 f_{ij0}(\theta)$$

The first term is the singular term, and the second term is called the regular term which is especially important for thermal loading. The solutions for determination of the stress exponents, the angular functions and the regular stress term for a friction free interface and an interface with friction will be presented. Finally, the general behavior of the stress exponents for various geometries and material combinations will be discussed.

1. Introduction

In many technical areas two or more dissimilar materials have to be joined together to take the advantage of the properties of the different materials. The joining of ceramic to metal to combine the ceramic's wear resistance, high temperature strength, and low thermal or electrical conductivity with the ductility of the metal is especially important. Examples of the application of ceramic - metal joints are heat engines [1], turbocharger rotors [2], and nuclear fusion components [3]. Another example of materials joint is a coated structure for thermal protection, wear resistance, and corrosion resistance. In the electronic field many dissimilar material layers are joined together as chips.

With increasing use of bonded joints, their behavior is of interest in many engineering disciplines. Both mechanical and thermal loading at fabrication or in service are relevant. For the reliable design of such components, and for choosing a material combination and a joint geometry, a stress analysis is required for elastic, elastic–plastic or viscoplastic material behavior. In particular, the effect of residual stresses caused by thermal mismatch of the joined components needs to be investigated, because these residual stresses may lead to fracture of joints directly after the fabrication due to cooling from high temperature.

Due to the mismatch of the material properties of the joined components after a homogeneous temperature change or under a mechanical loading, very high stresses occur near the intersection of the interface and the outer surface, or near the intersection of two interfaces. For most material combinations and joint geometries, there exists even a stress singularity. This intersection point is called singular point. These high stresses may cause fracture of the joint. Therefore, the investigation of the stress situation near the singular point is of interest.

E-mail address: yyy8888@hotmail.com

0013-7944/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.engfracmech.2012.09.015

In a dissimilar materials joint, the boundary and interface conditions may be different. The following boundary conditions may be assumed: (a) the edge is stress free (see Fig. 1); (b) the edge is loaded with tractions (see Fig. 2); (c) the edge has a given displacement. At the interface there may be a perfect bond or sliding with friction. The Author has studied the problem with perfect interface in many papers [4–9]. In this article a special case, the two dissimilar materials contact problem, will be analyzed.

For a two dissimilar materials contact problem, in which the interface is friction free or with friction, still stress singularity exists for most material combinations and contact geometries. The stress singularity can also be described by $r^{-\omega}$. Dempsey and Sinclair [10] have given the equations to determine the stress exponent ω for interfaces with and without friction. Adams and Bogy [11,12] have studied the friction free contact problem in semi-infinity bodies, in which the stresses can be determined by solving singular integral equations. Dundurs and Lee [13] have considered the friction free contact problem with the contact geometry $\theta_2 = 180^\circ$ and θ_1 being arbitrary, in which the dependency of the stress exponent on the Dundurs parameter α is given. In [14] experimental results are presented for the contact geometry corresponding to that one used by Dundurs and Lee. Gdoutos, Theocaris [15] and Comninou [16] discussed the contact problem with friction as well.

In this paper, the stress distribution near the singular point in a two dissimilar materials contact problem will be considered, in which the interface is friction free or with friction (see Fig. 3). The loads may be thermal or mechanical loading. For the type of r^{ω} singularity the stress distribution near the singular point is given by

$$\sigma_{ij}(r,\theta) = \sum_{n=1}^{N} \frac{K_n}{(r/R)^{\omega_n}} f_{ijn}(\theta) + \sigma_0 f_{ij0}(\theta) \tag{1}$$

The first term is the singular term, the second term is called the regular term and is especially important for thermal loading. The determination of the stress exponent and the angular functions for a friction free interface and an interface with friction

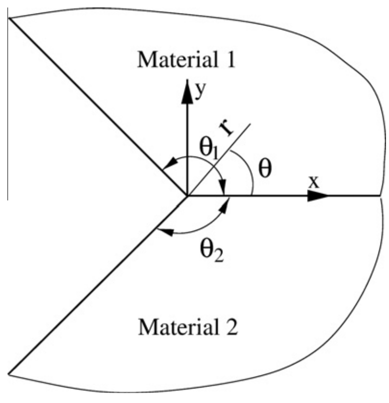

Fig. 1. A general two dissimilar materials joint with free edges.

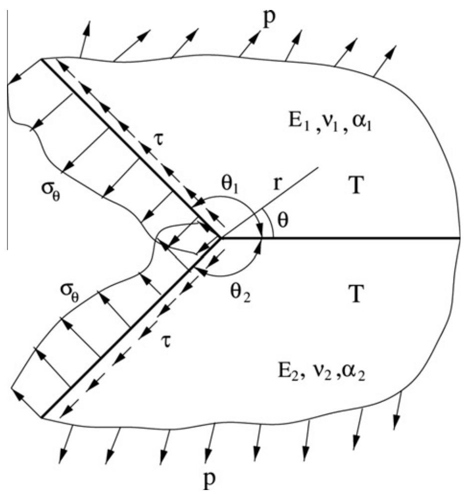

Fig. 2. A joint with edge tractions.