On the receding contact between a homogeneous elastic layer and a half-plane substrate coated with functionally graded materials

Changwen Mi

Jiangsu Key Laboratory of Engineering Mechanics, School of Civil Engineering, Southeast University, Nanjing, Jiangsu 210096, PR China

Loss of contact among neighboring media commonly occurs in multilayered elastic structures and threatens their structural integrity. Recent experimental results show that functionally graded materials are capable of reducing contact deformation and thus delaying the resultant contact damage. In this work, we examine the receding contact between a homogeneous elastic layer and a half-plane substrate reinforced by a functionally graded coating. The material properties of the coating are allowed to vary exponentially along its thickness. Either a rigid indenter or a distributed traction load applied over a finite segment of the layer surface presses the layer and the coated substrate against each other. It is further assumed that the receding contact between the layer and the coated substrate are frictionless. In the case of a rigid indenter, its contact with the elastic layer is also treated as frictionless. In the absence of body forces, Fourier integral transforms are used to the convert the governing equations and boundary conditions of the plane receding contact problem into a system of singular integral equations with the contact pressure and contact size as unknowns. Gauss-Chebyshev quadrature is subsequently employed to discretize both the singular integral equations and the force equilibrium conditions at the contact interface. An iterative algorithm based on the method of steepest descent has been proposed to numerically solve the system of algebraic equations, which is linear for the contact pressure but highly nonlinear for the contact size. Extensive case studies are performed with respect to geometric parameters, material properties and indentation forces. It is interesting to note that as a result of the indentation the elastic layer stays in contact with the coated substrate only over a finite region. Exterior to this region the layer and the coated substrate lose contact. Nonetheless, the receding contact size is larger than that over which the indentation traction is distributed. To validate the theoretical solution, we have also developed a finite element model to solve the same receding contact problem. Numerical results due to finite element modeling and theoretical development are compared in detail for a number of parametric studies and are found to agree well with each other.

Keywords: Receding contact, functionally graded material, multilayered elastic structure, Gauss-Chebyshev quadrature, finite element analysis