8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

An Interface Model for the Analysis of Anisotropy of Friction and Wear of Contact Surfaces

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Key Words: *interface, frictional anisotropy, wear.*

ABSTRACT

For a large number of mechanical problems the contact between bodies represent a crucial aspect to take in account in order to properly describe the overall response of the structure. The contact surfaces represent singular surfaces with reference to the displacement field (strong discontinuity) and are the source of different phenomena like opening (jump of displacement component in the direction normal to the nominal contact surface) and/or sliding of the two bodies (jump of the displacement components on the tangent plane to the nominal contact surface) when the limit friction condition is reached local wise. In particular the accurate modelization of the frictional behaviour of the contact surface is required in different cases [1] A detailed and rigorous description of contact response can be provided by asperities-based models which are developed on microscale analysis of deformation and relative sliding of surface asperities. This class of models is based on the idea reported in [2] that the contact surfaces are rough and formed by asperities interacting over discrete small areas. This class of models are called ”asperity models”. Extensions of the asperity models to microcontact deformations involving elasto-plastic effects were introduced by Hisakado [3], [4] and [5]. An innovative asperity model has been proposed by Mróz and Giambanco [6] which was mainly focused to the development of sliding between asperities and to dilatancy effects. In particular, the model considers the contact surfaces topography composed by asperities of two different size scales: small or high-order asperities represented by contacting spheres and large or primary asperities represented by a curvilinear, periodically repeated profile, including dilatancy and additional hardening or softening contact response. The interface frictional model herein presented associate the anisotropy of friction and wear with the roughness anisotropy of the contact surface. An anisostropic surface roughness is then a surface in which highs and hollows in the surface are clearly oriented. The primary asperities are modelled assuming an initial shape represented by an hyperboloid of two sheets. Due to the development of sliding, the contact point changes and the primary asperity shape is expressed by the following equation:

$$f\left([u_1]^s,[u_2]^s\right)=\sqrt{\left(tg\alpha_1[u_1]^s\right)^2+\left(tg\alpha_2[u_2]^s\right)^2+g^2} \tag{1}$$

where $[u_1]^s, [u_2]^s$ are the component of the discontinuity displacement vector at the contact layer on the tangent plane, g represents a constant that defines the initial shape of the primary asperity, i.e. when

irreversible displacement discontinuities was not developed. In particular, for $g = 0$ the primary asperity degenerates in an elliptical cone that in 2D problem represents the classical saw-tooth Patton model and for $g \to \infty$ in a flat surface. The angles α_1 and α_2 represent the actual values of the surface slopes in the directions 1 and 2 respectively. Due to the wear process is assumed that these values modify according to the following evolution laws:

$$tg\alpha_1 = tg\alpha_{01} e^{-\frac{W_1}{W_{01}}}; \qquad tg\alpha_2 = tg\alpha_{02} e^{-\frac{W_2}{W_{02}}}; \tag{2}$$

where W_{01} and W_{02} are two parameters reflecting the sensibility of the surface to the wear and W_1 and W_2 are the specific friction works of tangential contact stresses for unit surface in the 1 and 2 direction respectively:

$$W_{1,2} = \int_0^t \tau_{1,2} [\dot{u}_{1,2}]^s dt \qquad . \tag{3}$$

The secondary asperities are modelled assuming a spherical shape and an uniform distribution along the primary one. The elastic stiffness matrix could be calculated on the base of elastic properties of the material constituting the asperities. The sliding limit condition used is the classical Mohr-Coulomb one with a non associative flow rule.

In order to test the capabilities of the proposed interface model, the finite element method has been chosen as general tool of numerical analysis. The interface element has been written according to the procedure proposed by [7] and incorporated in a finite element code (OOFEM) [8]. An iterative procedure of Newton-Rhapson type is performed to solve the discretized version of equilibrium equation obtained by space discretization via the finite element method. The iterations take place inside the generic load step given by the time-discretization of the assigned load history employed.

Different set of test problems [9] were performed and the principal results are shown.

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