Composite/textured surfaces

Problem presentation

Titanium alloys are heavily used in aeronautical components which undergo fretting, such as turbine blades. A desired reduction in wear and friction can be achieved through surface engineering, by a combination of surface texturing and the application of a coating layer of solid lubricant. The sputtered lubricant is coated on a material, whose surface has been previously textured. The lubricant fills the dimples and forms pockets. This combination was proofed to reduce friction and to improve the durability of the coating. When the coated textured surface is loaded against a metallic counterpart, the contact area is characterized by regions of metal to metal and regions of lubricant to metal contact, each one characterized by a local coefficient of friction. The textured surface behaves thus as a composite surface with a global behaviour that can be determined from the local coefficients of friction and the mechanical properties of the metal and the lubricant.

These composite surfaces are represented using both, 2D plane strain meshes. The Ti6Al4V is described using an linear elastic constitutive material model, whereas the lubricant inclusions are considered to be elastic. Sliding friction is taken into account using Coulomb friction, with different local coefficients of friction, in order to describe metal to metal and metal to lubricant contact. The influence of different texturing parameters on global friction, such as dimple geometry and density. Fig. 1. shows geometrical model of contact between ball and composite surface. In this model, dimples are fullfilled by MoS2, ball and substrate are titanium. The material behaviour for both materials is linear elastic. In this contact problem we apply vertical and horizontal displacements.

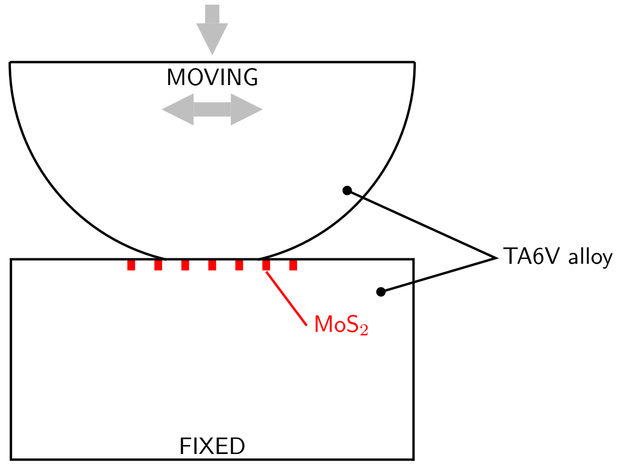

Fig.1 : Contact of composite surface with ball

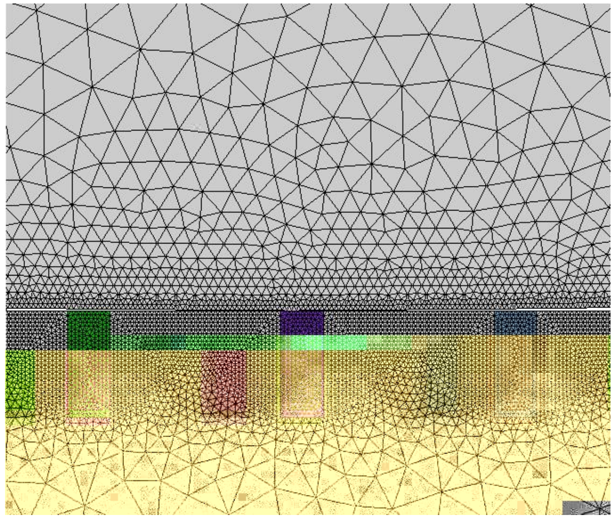

Fig.2 : FE model of composite surface

Files available for FE computations

The files are given in a series of directories. The directory *2_substrate* corresponds to a contact between a sphere and a composite surface where depth of dimples is equal to 2 micrometers. The first number shows the depth of the dimples. In the main directory, there are 3 subdirectories *2_text_surf*, *10_text_surf*, *20_text_surf*. Each subdirectory has 4 directories with different length of the dimples. For example, subdirectory *2_text_surf* has directories *20_length*, *40_length*, *60_length*, *80_length*. It means that depth of the dimples is equal to 2 micrometers and that the ratio between solid and lubricant in contact is equal to 20%, 40%,60%,80%.

The definition of the analysis is provided by the various sections after the line `****calcul)` : the role of each section can be found in its name (`***resolution`,`***bc` (the boundary conditions), `***contact`, `***material`, `***output`).
Section `***resolution` is used to specify the algorithm. `**sequence 2` specifies that two loading sequences are prescribed – to load and unload. The evolution of the applied force during loading and unloading is linear. The full loading path is achieved after 2 seconds (`*time 2.`).
In section `***bc`, the boundary conditions are defined. The keyword `**imposed_nodal_dof` allows to prescribe the displacement of node sets. The prescribed value is obtained by multiplying the base value by the value contained in the table.
In section `***table`, the table that represents the loading path is defined. This table is used for the definition of the boundary conditions (in `***bc`).
The contact conditions are given by `***contact`, with a subsection concerning the contact algorithm (`solver_method`) and a subsection concerning the definition of the contact zone (`**zone`). Zones are modeled by a node set acting as the impactor (`slave`) surface which may come in contact with a target (`master`) surface area, defined by a line in twodimensional problems. The coefficient of friction is defined by `*friction`.
In section `***material`, the materials are associated with element sets.

All the `calcul.inp` files have in common a mesh file and three material files, located in the directory. In this directory, the file `union.geof` defines the nodes, the elements and the various groups used for applying the boundary conditions. The mesh can be displayed by means of the command `Zmaster mesh.geof`.
The files `solid.mat` and `lubricant.mat` contain the mechanical behaviour of the two materials presented in the problem.

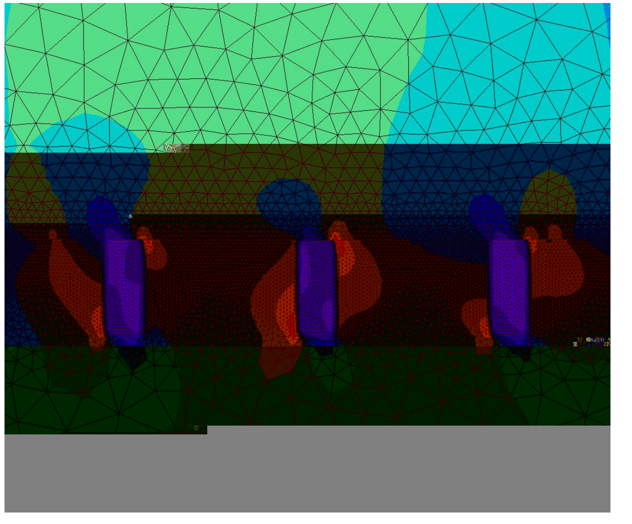

Fig 3 : Von Mises stresses. Contact.

FE computations for various depths of the dimples

Go to every directory and type `Zrun calc.inp`. Once the simulation is performed, go to next directory. When all calculations are finished, you should run `./calc.py` in main directory. Then go to subdirectories and you will find there `friction.dat` files. Use information from `friction.dat` file in order to plot all FEM results. The analytical solution can be used in order to compare with FEM results. The solutions are as follows :

– Under uniform strain :

$$p_i = C_i \varepsilon_{yi}$$

$$C_i = \frac{E_i}{1-\nu_i^2}\frac{(1-\nu_i)^2}{(1-2\nu_i)}$$

$$\mu = \frac{\sum \mu_i C_i f_i}{\sum C_i f_i}$$

– Under uniform contact pressure :

$$\mu(x) = \frac{\sum \mu_i f_i}{\sum f_i}$$

Discussion

The synthesis of the computations should be done having in view the following questions :

– How depth and length of the dimples do influence the global coefficient of friction of composite surfaces ?
– What is the position of the FE results with respect to the analytical friction curves ?