11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

OPTIMIZATION OF GEOMETRY OF ADHESIVE JOINTS

Andrey Yu. Fedorov*, Natalja V. Sevodina

Institute of Continuous Media Mechanics of Ural Branch of RAS
1, Acad. Korolev Str., Perm, Russia, 614013
fedorov@icmm.ru, *natsev@icmm.ru*

Key words: *Adhesive Joints, Stress Singularity, Finite Element Analysis, Elasticity Theory, Compound Shape, Joint Design, Geometry Optimization.*

In problems of the theory of elasticity the existence of singular solutions should be related to the presence of infinite stresses at particular points (lines) of the domain, known as singular points (lines). Among these points are the points on the body surface where the surface smoothness condition is violated, the type of boundary conditions changes, and different materials come into contact or the internal points where, for example, the condition of smoothness of the contact surface between different materials is violated. Singular solutions usually indicate that the simulated object incorporates stress concentration areas.

The analysis of design diagrams of adhesive joints shows that the adhesive joints contain singular points, in the vicinity of which the stress concentration occurs under loading conditions.

There are various ways to reduce the stresses in the adhesive joints. One of them is to change the shape of the external surface of the adhesive layer at the ends of the contact area. Out of others, the most effective way is to change the shape of the external surface of the adherend(s) near the ends of the contact area or to change the shape of the contact area itself.

The most common type of adhesive joints is a lap joint. The adhesive lap joint with a straight edge surface of the adhesive layer, which is obtained by removing the excessive adhesive from the edges of the contact area, is characterized by the non-uniform stress distribution over the contact surface and strong stress concentrations at the ends of the contact area. Changes in the rectangular shape of the adhesive layer end faces by forming an external excess adhesive (spew fillet) allows the load to be distributed over a larger area and thus ensures a more uniform stress distribution. It was shown in that the use of spew fillets at the ends of the contact area of adhesive joints decreases the stress concentration both in the adhesive layer and in the adherends.

Changing of the geometry of spew fillet, external surface of the adherend(s), or contact surface itself leads us to the problem of geometry optimization. A mathematical formulation of the optimization problem is as follows. Near a boundary of the contact surface we must find such a geometry of the piecewise-homogeneous elastic body that provides the minimum value of the functional determining the optimal stress state. In the framework of the optimization problem under consideration, different variants of functionals can be used. For example, the functional

$$F\left(S_t\right) = \max_{S_k} \sigma_u \tag{1}$$

defines the maximum value of stress intensity near the contact area S_k of adhesive joint; the functional

$$F\left(S_t\right) = \int\limits_{S_k} \left[\sigma_{\mathrm{o}} - \frac{1}{S_k} \int\limits_{S_k} \sigma_{\mathrm{o}} ds\right]^2 ds \tag{2}$$

defines the root-mean-square deviation of the preset components of the stress tensor from their averaged values generated at the specified area (or boundary) S_k. Here σ_{u} is the stress intensity, σ_{o} is the specified combination of components of the stress tensor (for example, the normal stresses at the contact surface), S_t (V_t) is the part of the surface (of the volume) of the examined compound body in the vicinity of a singular point. On the surface S_t and region V_t we can impose different constraints in the form of equalities and inequalities.

The specific feature of the numerical implementation of the stated optimization problem is that the solutions are found for a limited class of surfaces. As a generatrix of such surfaces we can use a piecewise-polynomial or some other functions defined by the values of coordinates or derivatives of these functions at the finite number of nodal points. In this case, the optimization problem for the chosen functional reduces to a classic problem of non-linear mathematical programming. The computation of the functional at each step of numerical procedure was done by the finite element method.

Different variants of searching for optimal geometries (of spew fillet, contact surfaces of dissimilar materials, or external surface of compound body) in the vicinity of singular points were considered. The analysis of results of solutions supports an earlier conclusion that the optimal geometries in the vicinity of singular points have one common feature [1]. For the corresponding singular point without regard to the chosen functional, the optimal geometry in its vicinity defines the boundary between singular and non-singular solutions.

REFERENCES

[1] S.M. Borzenkov,V.P. Matveenko. Optimization of elastic bodies in the vicinity of singular points. *Bulletin of RAS. Mechanics of Solids.* 93–100, 1996. [in Russian]