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LOSS OF STABILITY OF STRUCTURES UNDER GLOBAL TENSION – Modeling and simulation of some typical examples

Franz G. Rammerstorfer[1], Florioan Toth[1] and F. Dieter Fischer[2]

[1] Vienna University of Technology, Gusshausstr. 27-29/E317, A-1040 Vienna, ra@ilsb.tuwien.ac.at, www.ilsb.tuwien.ac.at

[2] Monatnuniversitaet Leoben, Franz-Josef-Str. 18, A-8700 Leoben, Austria, mechanik@unileoben.ac.at, http://mechanik.unileoben.ac.at/de/personal/franz-dieter-fischer

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In structural mechanics, loss of stability of equilibrium, i.e., buckling is generally associated with compressive loading. However, there are several instabilities associated with global tensile loading. The computational treatment of instability phenomena of the latter kind is the content of this presentation.

Necking of a tensile specimen is a well-accepted form of instability under tensile loading. Similar forms of material instabilities under tensile stresses may arise in metal forming of thin plates or shells if certain *"forming limits"* are surpassed. For instance, the formation of periodically arranged necks (localized plastic deformations) during the conical expansion of a thin circular cylindrical shell (similar to flaring of a tube [1]) represents a bifurcation from the trivial, i.e., axisymmetric deformation process.

Thin rectangular sheets with a cut-out (a hole or a transversal crack) may locally buckle when the sheet is stretched. This is due to transversal compressive membrane forces being activated where the free edges, formed by the cut-out, are predominantly oriented perpendicularly to the loading direction. Buckling under global tension is also observed, if a thin square plate, stretched between two corners being opposite to each other in diagonal direction, and the buckling or wrinkling phenomenon appearing if rectangular plates (without any cut-out) if their fully clamped short edges are axially moved in order to stretch the sheet is frequently called *"towel-effect"* [2].

In materials sciences some other, probably less known, but interesting examples of instabilities under global tension can be found. For instance, if a strip consisting of a thin metallic film on a polymeric substrate is stretched the following observations can be made. At a certain global strain the film starts cracking with cracks running perpendicularly to the loading direction. With further stretching the crack density grows up to eventual saturation. During this process local "*film buckling*", accompanied by delamination and progressive uplift of the film from the substrate can be observed. In [3,4] it is shown how from these experimental considerations in combination with numerical simulations interface strength parameters can be deduced.

In addition to the demonstration of the possible appearance of instabilities under global tension, it is the aim of this presentation to show, by means of representative examples, extended modeling techniques and new results, how stability limits and post-critical behaviors for such rather strange stability problems can be calculated by computational methods.

REFERENCES

[1] F.D. Fischer, F. G. Rammerstorfer, T. Daxner, Flaring - An Analytical Approach. *Int. J. Mech. Sci*., Vol. **48** , pp. 1246 – 1255, 2006.

[2] N. Friedl, F. G. Rammerstorfer, F.D. Fischer, Buckling of stretched strips. *Comp. & Struct*., Vol. **78**, pp. 185 – 190, 2000.

[3] M.J. Cordill, F.D. Fischer, F. G. Rammerstorfer, G. Dehm, Adhesion Energies of Cr Thin Films on Polyimide Determined from Buckling: Experiment and Model. *Acta Mater.,* Vol. **58**, pp. 5520 – 5531, 2010.

[4] F. Toth, F. G. Rammerstorfer, M.J. Cordill, F.D. Fischer, Detailed Modelling of Delamination Buckling of Thin Films under Global Tension. *Acta Mater*., Vol. **61,** pp. 2425 – 2433, 2013.