Spring-mass-damper modelling of out-of-plane-bending versus in-plane-membrane resistance of parachute canopy

L. Gérardeaux[††], M. Charlotte*[†] and C. Espinosa[†]

[†] Université de Toulouse, Institut Clément Ader,
CNRS UMR 5312 ISAE-SUPAERO/INSA/UPS/Mines Albi
3 Caroline Aigle, 31400 TOULOUSE Cedex 04, France
*e-mail: miguel.charlotte@isae-supaero.fr

[††] ISAE-SUPAERO
10 Avenue Edouard Belin - BP 54032 - 31 055 TOULOUSE Cedex 4, France

ABSTRACT

Thin, flexible fabric-like structures interacting with fluids (parachutes, airbags, biological skins etc.) have behaviors that are not representable as simple membranes that conventionally work only in stretch and shear. As very often observed in fact, these structures can form wrinkles (and folds) that are due to small and medium resistances to out-of-plane bending and to micro-buckling in shear and compression in the tangent plane of the structure [1, 2]. In the classical Finite Element Methods, this passage between membrane forces and out-of-plane is done with models of shells and plates which connect the rotations of the edges of a surface element with the flows of internal membrane forces, via functions of interpolation and derived from the elastic strain expression. In a networked Mass-Spring-Damper System (MSDS), there is no longer such interpolation features. Being proven that the flexural strength of these structures has an important role in the interaction with the surrounding fluids, it is impossible with these MSDS to represent these relations between bending and membrane effect without additional corrective internal forces (or moments). The problem is that, depending on the method used to take these compensating forces into account, differences of force fluxes (i.e. equivalent stresses) in the response of the structure are obtained. As a prerequisite for the optimal identification of parameters from intrinsic effective values, this communication aims at presenting comparisons between different strategies based on MSDS [3-9] in order to subsequently propose an adapted choice. Our numerical investigation notably shows the location and amplitude of the bending moments generated by the addition of out-of-plane internal forces which can lead to overestimating the forces in common areas of tissue, or to underestimating them in the connection areas, and which could mislead designers or induce unrealistic coupling reactions in Fluid Structure Interaction simulations.

REFERENCES

[1] E. Oñate and B-H. Kröplin, eds. Textile composites and inflatable structures. Vol. 3. Springer Science & Business Media, 2005.

[2] Y.W. Wong and S. Pellegrino, "Wrinkled membranes I: Experiments", *J. Mech. Mater. Struct.,* vol. 1 (1) pp. 1-23. (2006).

[3] R. Bridson, S. Marino and R. Fedkiw, "Simulation of clothing with folds and wrinkles". In Proc. of *ACM SIGGRAPH/Eurographics symposium on Computer animation*, pp. 28–36, (2003).

[4] K. J. Choi and H. S. Ko. "Extending the Immediate Buckling Model to Triangular Meshes for Simulating Complex Clothes". In *Eurographics* (Short Papers) (2003).

[5] Choi, K. J., & Ko, H. S. (2005). Stable but responsive cloth. In ACM SIGGRAPH 2005 Courses, pp. 1-es.

[6] A. Garg, E. Grinspun, M. Wardetzky and D. Zorin, "Cubic shells". In *Symposium on Computer Animation*, pp. 91-98, (2007).

[7] E. Grinspun, A. Hirani, M. Desbrun, P. Schröder, "Discrete shells". In SCA '03, pp. 62–67 (2003).

[8] K. Lu, J. W. Leonard, M. L. Accorsi, K. R. Stein, and R. J. Benney. "Pseudo-flexural elements for parachute simulation". *Computers & Structures*,vol. *78*(1-3), pp. 257-269, (2000).

[9] P. Volino and N. Magnenat-Thalmann, "Simple linear bending stiffness in particle systems". In : *Proceedings of the 2006 ACM SIGGRAPH/Eurographics symposium on Computer animation*. pp. 101-105 (2006).