Numerical simulation of stratospheric balloons deployment by coupled dynamic relaxation and implicit methods

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Abstract

For several years, the French Space Agency (CNES) works on the development of predictive mechanical models to improve the performance of stratospheric balloon envelopes. These inflated structures are used to a large range of physical measure campaigns. Due to the dimensions of the balloons (up to 180m in height) and the flexibility of the envelope materials (the thickness is a few tens of μm), simulations of the inflation of stratospheric balloons combine several non-linear phenomena (material, geometrical and loading) and local buckling phenomena which are characterized by the appearance of wrinkles on the structure. Since 2005, the IRDL laboratory develops numerical and experimental methods to study inflatable structures and more recently stratospheric balloons [1, 2]. The aim of this paper is to propose the use of the combination of two numerical methods to simulate the deployment of the balloons. The so-called dynamic relaxation method is first used in order to determine the global equilibrium. Then, at the end of the inflation, an implicit method is used to balance the stress field in which the repercussions of the presence of wrinkles must be taken into account. In this context, a new method to simulate the wrinkles for any mechanical behavior is first presented. A new dynamic relaxation method allowing the transition between the viscous damping and kinetic damping resolution algorithms is then described to model the first phase of balloon swelling. Finally, a strategy is proposed to improve the convergence by mixing first the kinetic and the viscous dampings, then in the same time step, by passing of the dynamic relaxation method to the classical Newton algorithm with a stabilize method of the transverse behavior of the membranes.

References

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