Efficient aeroelastic analysis of wind loads on inflatable hangars

Roberto Flores*, Enrique Ortega[a]

*International Center for Numerical Methods in Engineering (CIMNE)
C. Gran Capitán s/n, 08034 Barcelona, Spain
rflores@cimne.upc.edu

[a] Serra Hunter professor at Escola Superior d'Enginyeries Industrial, Aeroespacial y Audiovisual de Terrassa, Universitat Politècnica de Catalunya, Spain

Abstract

Inflatable structures offer an attractive alternative to traditional construction for temporary or semi-permanent aircraft hangars. Pneumatic structures can be deployed in a short time due to their light weight and ability to be quickly packaged in small volumes. Furthermore, they do not require deep foundations and can be assembled from standardized modules. This makes them especially attractive for emergency relief operations and any application where time constraints are dominant.

Due to reduced mass and limited stiffness, wind loads play a crucial role in the design of inflatable hangars. Design loads from safety regulations can be used for structural sizing, but they overestimate the real aerodynamic forces. While conservative, this approach leads to overbuilt structures and increased costs. Thus, a more accurate estimation of wind loads is desirable. Unfortunately, inflatable hangars have intricate geometries and massive flow separation is expected over the leeward face of the structure. Conventional CFD approaches (e.g. LES) struggle with the complexities of the flow field and remain impractical due excessive computational cost.

We present a cost-efficient tool for the aeroelastic analysis of inflatable structures. It is based on the PARACHUTES code (http://www.cimne.com/parachutes) originally developed to simulate parachute/payload systems [1,2]. It uses a staggered solution scheme with an explicit finite-element structural solver and potential flow aerodynamics. To account for large areas of separated flow typical of blunt shapes, a semi-empirical correction is applied to the inviscid solution. The streamlines of the potential solution are computed and, for each one, the separation point is predicted with Stratford's criterion [3]. Next, an empirical correction is applied to the inviscid pressure field over the separation zone. Finally, the aerodynamic loads are transferred to the structural solver to update the displacements. The process is repeated until a fully-coupled equilibrium configuration is found.

We present validation benchmarks as well as a real life application example. The predicted aerodynamic forces show a large improvement over the design loads from civil engineering regulations. Over the majority of the flow field, the pressure field agrees well with high-fidelity computations (e.g. LES), yielding similar global loads for structural sizing. This is achieved with a small fraction of the computational effort required by conventional CFD approaches. The methodology is thus attractive for inflatable hangar manufacturers who, due to limited resources, cannot afford the cost and lead times of traditional CFD for routine design applications.

References

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