Simulation of Parachute Inflation Dynamics Using an Eulerian Computational Framework for Evolving Fluid-Structure Interfaces in High Speed Turbulent Flows

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ABSTRACT

Today, there is significant evidence that the supersonic flow regime has a profound effect on the performance of a parachute [1]. A parachute that performs well in subsonic airstreams suffers a rapid fall off of drag performance at supersonic speeds. Causes for even greater concern are the many canopy failures observed in flight tests conducted over the past four decades, which typically occurred during inflation, and the limited number of tests that can be performed for developing a better understanding of how to avoid such failures. Yet, most if not all relevant computational efforts have focused on developing Computational Fluid Dynamics (CFD) and Fluid-Structure Interaction (FSI) parachute models for the much easier to simulate *post-inflation* regime; few predictive high fidelity simulations of the dynamics of a parachute during its inflation have been reported.

Inspired by the success achieved in the simulation of a closely related FSI problem, namely, the deployment of an airbag inside a vehicle [2], some investigators have lately used the commercial finite element code LS-DYNA to model the problem of parachute inflation in the low Mach number flow regime [3], and more recently, in the high Mach number flow regime [4]. However, they have ignored the initial folded state of the parachute – and therefore its influence on the inflation process and final stress state of the parachute fabric – and assumed a laminar flow as well as a host of other simplifications, which led to numerical results for the inflation time and aerodynamic drag that are only qualitatively consistent with available experimental data.

To this effect, this talk will begin with a short presentation on the development of an Eulerian computational framework for evolving fluid-structure interfaces in high speed turbulent flows whose design is motivated by the need to simulate parachute inflation dynamics. The framework is built around an Eulerian computational model for FSI that has proven itself for the simulation of the failure analysis of submerged structures subjected to explosions and implosions [5, 6]. It incorporates in the computations a suitable material failure model, captures the effects of strain rate and temperature, and accounts for the various interactions between the fluid subsystem, the nonlinear parachute subsystem and the forebody. It resolves all self-contact effects of the parachute during its inflation and tracks and resolves all evolving boundary layers using a combination of adaptive mesh refinement and corotational transformations [7]. Next, the talk will proceed with the discussion of a set of preliminary simulations of a parachute's opening process performed using this computational framework, initiating from a folded state of the parachute pre-inflation to the fully inflated state. Finally, the talk will conclude with an original idea about modeling different folding patterns to numerically predict the influence of the folding pattern on the inflation process and initial, intermediate, and final stress state of the fabric when the parachute survives the inflation dynamics.

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