Ram-Air Parachute Aerodynamics With the Space–Time Isogeometric Analysis (ST-IGA)

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ABSTRACT

We present a space–time (ST) computational method for ram-air parachute aerodynamics. A ram-air parachute is a parafoil inflated by the airflow through the inlets at the leading edge. It has better control and gliding capability than round parachutes. Reliable analysis of ram-air parachutes requires accurate representation of the parafoil geometry, fabric porosity and the complex, multiscale flow behavior involved in this class of problems. The key components of the method are (i) the ST Variational Multiscale (ST-VMS) method [1], (ii) the version of the ST Slip Interface (ST-SI) method where the SI is between a thin porous structure and the fluid on its two sides [2], (iii) the ST Isogeometric Analysis (ST-IGA) [3], and (iv) special-purpose NURBS mesh generation techniques for the parachute structure and the flow field inside and outside the parafoil [4]. The ST-VMS method is a stabilized formulation that also serves as a turbulence model and can deal effectively with the complex, multiscale flow behavior. With the ST-SI version for porosity modeling, we deal with the fabric porosity in a fashion consistent with how we deal with the standard SIs and how we enforce the Dirichlet boundary conditions weakly. The ST-IGA, with NURBS basis functions in space, gives us, with relatively few number of unknowns, accurate representation of the parafoil geometry and increased accuracy in the flow solution. The special-purpose mesh generation techniques enable NURBS representation of the structure and fluid domains with significant geometric complexity. The test computations we present are for building a starting parachute shape and a starting flow field associated with that parachute shape, which are the first two key steps in fluid–structure interaction analysis. The computations demonstrate the effectiveness of the method in this class of problems.

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