Advanced Passive Safety Systems for Aircraft: Numerical Simulation of Parachute Inflation

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Abstract

The rapid growth of urban air mobility induces need for the development of advanced passive safety systems for Vertical Take-Off and Landing (VTOL) aircraft. Traditional parachute recovery systems have proven effective for fixed-wing aircraft, but adapting them to VTOL's complex flight profile presents unique challenges. Existing systems work well during horizontal flight due to higher speeds and altitudes. However, the vertical and transitional flight phases require significantly faster parachute inflation to achieve effective deceleration within limited altitude, creating a trade-off between rapid inflation and potentially hazardous opening shocks that can subject passengers to dangerous G-forces.

This study explores the use of numerical simulations to accelerate parachute development for VTOL applications. Traditional methods, such as wind tunnel and drop testing, require the production of physical prototypes, which is both time-consuming and resource-intensive. This research proposes Fluid-Structure Interaction (FSI) analysis as a viable alternative. Previously the FSI analysis of the parachute was conducted using custom FSI solvers developed for example by TAFSM group [1] and others. LS-Dyna was used for parachute simulation employing the Arbitrary Lagrangian-Eulerian (ALE) approach by Tutt [2], which is more relevant to supersonic parachutes. Utilizing ANSYS LS-Dyna software with an Incompressible CFD (ICFD) solver is more suitable for subsonic parachutes. The possibility of using this solver was confirmed by LeGarecc [3]. Simulation in this study utilized ICFD solver and an implicit structural solver, which cooperated using two-way strong coupling to accurately model the dynamic interaction between the parachute and the surrounding air.

A detailed workflow for finite mass analysis was developed to predict parachute inflation with variable descent velocities, based on the generated drag forces. The canopy was modelled as a fabric material developed for airbag modelling, ensuring realistic deformation and performance characteristics. The suspension lines were treated as cables to accurately represent their mechanical properties and behaviour during deployment. The parachute prototype used in this study is currently under development at our institute, and the simulation results showed sufficient correlation with existing experimental data.

Reference

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