11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

A SIMULATION TOOL FOR PARACHUTE/PAYLOAD SYSTEMS

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Key Words: *Parachutes, Aeroelasticity, Potential Flow, Membranes, Rigid bodies.*

A simulation tool for design of parachute systems is presented. The current design practice of parachute manufacturers relies mostly on empirical methods. This is largely due to the extremely complex aeroelastic behaviour of parachutes, which makes the numerical treatment difficult [1]. Some of the most challenging aspects of the problem are:

- Lack of bending stiffness of the canopy and suspension lines which makes the mechanical response of the system severely nonlinear. Moreover, the wrinkling behaviour of the fabric must be accounted for, otherwise an unrealistically high stiffness would be predicted.
- Geometric changes due to the structural deformations severely impact the aerodynamic loads. This leads to a strong coupling between the fluid and solid fields.

The mathematical complexities of the dynamical behaviour, combined with the niche market character of the industry, have led to the present situation where the application of computational mechanics to design tasks is marginal at best. Based on suggestions from parachute manufacturers a fully coupled solver has been developed. The code provides a level of fidelity adequate for preliminary design purposes while being efficient enough to achieve short run times (well under an hour) in current desktop hardware.

The focus of interest of the present work is on parafoil systems. For this kind of parachutes large areas of separated flow are not expected under nominal flight conditions. Therefore, to achieve a fast solution of the flow field an unsteady panel solver has been chosen [2,3]. The unsteady aerodynamic code allows for simulation of transient response (e.g. manoeuvres) as well as steady flight conditions. A large part of the computational effort associated with panel methods comes from the assembly of the influence coefficients matrix. This is a task that lends itself very well to parallel processing, as the coefficients of the matrix are independent from each other. Therefore, important speedups can be achieved using multi-core or multi-processor computers. The aerodynamic solver offers a choice of direct and iterative parallel solvers to better adapt to the different flow regimes (direct solvers are more suited for steady simulations and abrupt changes in the flow field while the iterative solution is more efficient in the case of slowly changing unsteady problems)

A dynamic explicit solver has been selected for the structural filed. This kind of solver is highly insensitive to the non-linear effects caused by the very large displacements encountered and the material asymmetric behaviour due to wrinkling (zero compression stiffness). There is no degradation of the radius of convergence due to such effects, as the allowable time step is controlled only by the stability limit of the time integration algorithm [4,5]. A very robust solution is thus achieved. In addition to cable and membrane elements for modelling of the parachute, the structural solver includes general 3D solids and arbitrary rigid bodies for simulation of payloads. For those cases where deformations of the payload are not relevant (during the design of the canopy, for example) the use of rigid bodies greatly speeds up the computation. Each rigid body has only 6 degrees of freedom and does not impose any constraints of the stability limit. Therefore, rigid bodies can be added to the model without any noticeable increase in computational cost.

The mathematical foundations of the numerical algorithm are explained first. Next, examples of parachute simulations in both steady-state and transient conditions are presented. The good computational efficiency of the software is illustrated.

REFERENCES

[1] E. Ortega, R. Flores and E. Oñate, *Innovative numerical tools for the simulation of parachutes*, CIMNE publication Nº341 (2010).

[2] J. Katz and A. Plotkin, *Low-Speed aerodynamics. From wing theory to panel methods,* McGraw-Hill (1991).

[3] E. Ortega, R. Flores and E. Oñate, *A 3D low-order panel method for unsteady aerodynamic problems*, CIMNE publication Nº343 (2010).

[4] T. Belytschko and W.K. Liu, *Nonlinear finite elements for continua and structures*, John Wiley & Sons (2000).

[5] R. Flores, E. Ortega and E. Oñate, *Explicit dynamic analysis of thin membrane structures*, CIMNE publication Nº351 (2011).