Fluid-Structure Interaction Simulation of a Slender Body in Supersonic Air Flow

Ine Hertens, Jeroen De Ridder, Jan Vierendeels and Joris Degroote

Department of Flow, Heat and Combustion Mechanics
Ghent University (UGent)
Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium
e-mail: {j.deridder,jan.vierendeels,joris.degroote}@ugent.be
web page: http://www.floheacom.ugent.be

ABSTRACT

In industries processing natural or synthetic fibres, a thread is often accelerated using an air or water jet aligned with the thread. This research focuses on air jets, where supersonic flow is typically used to achieve sufficiently high thread speeds. However, this flow contains shocks and expansions, resulting in large variations in force on the thin and flexible thread along its length. Consequently, a complex fluid-structure interaction (FSI) occurs between the supersonic air flow and the thread [1].

In this research, the fluid-structure interaction between a supersonic air flow and a thread is studied numerically using three-dimensional simulations. The thread is represented by a smooth and slender cylindrical body, initially positioned on the axis of a tube in which the air flows. It is clamped at the upstream end. To keep the thread stretched, the air is given a small initial velocity. Subsequently, the pressure at the inlet of the tube is increased using either a measured or a calculated time-dependent boundary condition.

The displacement of the thread is calculated for a given traction on its surface using a finite element structural dynamics code. The compressible flow around the thread is calculated using a finite volume computational fluid dynamics code, using the arbitrary Lagrangian-Eulerian framework to account for the thread deformation. Contact between the thread and the inner wall of the tube (offset by a small distance) is detected. Gravity is currently not included.

In these partitioned simulations, the kinematic and dynamic equilibrium conditions on the fluid-structure interface are satisfied using a coupling algorithm. Several coupling algorithms are compared: from explicit techniques like the conventional serial staggered scheme to implicit techniques like Gauß-Seidel iterations and quasi-Newton iterations [2]. Also the influence of other numerical parameters such as the grid size and the time step size is investigated.

The fluid-structure interaction simulations reveal transversal running waves in the thread. By comparing the speed of these waves with the propagation speed of the shock waves in the tube, it can be concluded that these phenomena are not related.

REFERENCES

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