Comparison of fixed and deforming fluid grid approaches for simulation of fluid-structure interaction between yarn and supersonic flow

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ABSTRACT

In air-jet looms, supersonic air flow in the main nozzle is used to launch the weft yarn into the shed. In addition to this longitudinal motion, also deformation of the yarn transversal to this insertion direction can be observed, caused by the traction of the air. Conversely, the yarn slows down the air flow compared to an empty main nozzle as presence of the yarn occupies a significant fraction of the main nozzle's cross section and as the yarn exerts a reaction force on the flow. Consequently, fluid-structure interaction (FSI) occurs between the yarn and the supersonic flow in a main nozzle of an air-jet loom.

The focus of this work is on the beginning of the insertion, with the yarn still clamped at one end. Transient FSI simulations are performed, starting when the valve opens and considering the acceleration of the air flow in the main nozzle until supersonic conditions occur. Due to the low bending stiffness of the yarn, it moves considerably and impacts the inner walls of the main nozzle, which is challenging to simulate. Therefore, only a limited number of studies on FSI with yarns is available [1]. In this work, fixed grid and deforming grid approaches for the fluid grid in two-way FSI simulations are compared.

In the fixed grid approach, a three-dimensional yarn simulation [2] is coupled with a two-dimensional axisymmetric computational fluid dynamics (CFD) simulation. The CFD simulation provides tractions to the yarn simulation and the reaction force of the yarn is included as a momentum source term in the CFD simulation. In addition, a rigid free-slip cylinder with the same diameter as the yarn is added on the axis of the main nozzle to take the volume occupied by the yarn into account.

In the deforming grid approach, a three-dimensional finite-element structural simulation is coupled with a three-dimensional CFD simulation. The arbitrary Lagrangian-Eulerian (ALE) formulation is applied for the deforming fluid grid, with fictitious springs between the grid nodes. A small gap between the yarn and the inner wall of the main nozzle is preserved by reduction of the main nozzle's diameter for the contact calculation in the structural simulation.

REFERENCES

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