ACCELERATED OPTIMIZATION FOR MULTI-DISCIPLINARY OPTIMIZATION OF TRANSONIC AND CONTRA-ROTATING TURBOACHINERY COMPONENTS

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The design of innovative turbomachinery components for compact high-speed propulsion flight vehicle or for limited fuel burns of current aircrafts requires to reduce the number of stages to save weight, while increasing the efficiency of every single component. A reduction of the size of the machine for the same power output leads consequently to increase the load on each single component. The related design challenges are inherently multidisciplinary. Trade-offs between flow efficiency and structural integrity have to be found and optimization strategies provide promising perspectives.

Compared to traditional design strategies, optimization techniques, such as Evolutionary Algorithms, enable to augment the explored design space and to consider simultaneously several conflicting requirements. To speed up the most expensive CFD evaluation of an aero-structural design problem, parallel computations could be performed, typically using several Central Processing Units (CPU). Alternatively, much work has recently been focused on Graphics Processing Units (GPU) and applications of GPU in aerospace highlighted the potential acceleration of computing time from 10 to 20 times faster. The present project proposes in a first part to investigate GPU-accelerated CFD. A first 2D Euler code would be implemented and assessed on a transonic turbine case. Based on the lessons learned from this initial work, more advanced techniques will be progressively implemented.

Optimization techniques are then applied to investigate innovative design methodologies for turbomachinery configurations involving demanding fluid and solid requirements. In particular, high-pressure turbines operate in the transonic regime leading to strong shock interactions between the vanes and the rotors. To limit the risk of high-cycle fatigue on the rotor blades, the vanes could be designed for limited downstream distortion. A design approach with steady-state evaluations to reduce the shock waves propagation downstream of the vane is proposed. The impact on the stage would be evaluated by computing the unsteady forcing on the following rotor.

The design of transonic fans requires also fluid and solid considerations. While conventional fans produce a pressure ratio of about 1.6, many research trends focus on much higher loads. A design methodology to achieve highly-loaded fan is investigated. As an alternative to traditional 1-D parametric studies, an optimization of the flow path would be performed to initiate the aerodynamic design of the fan. To bypass two-dimensional sub-optimal results, a three-dimensional optimization would be directly processed, including several section profiles along the span, as well as lean and sweep. High-fidelity CFD and finite element structural analysis would be employed to guaranty the flow efficiency and the structural integrity of the finalized design. This methodology would be applied to the design of a transonic and a contra-rotating fan.

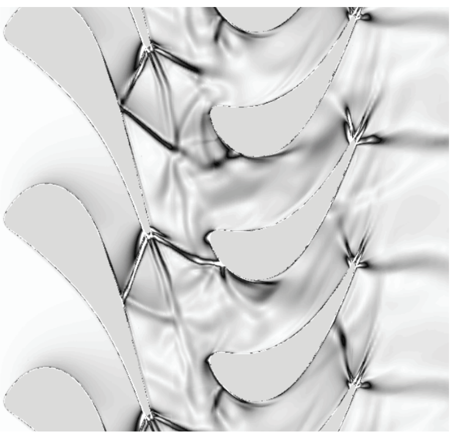

Figure1: Shock Interaction in High-Pressure Turbine

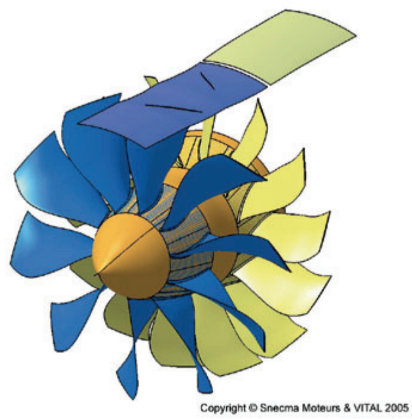

Figure 2: Example of Contra-Rotating Fan configuration