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Sonic boom modeling: aspects, numerical methods and optimisation

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ABSTRACT

This presentation gives a synthesis of the sonic boom study realized by INRIA in HISAC European project.

In the first part, we introduce the physical problem and the difficulty to model it due to the large variations of the considered scale going from the millimeter scale on the aircraft to the kilometer scale in the atmosphere. Then, we briefly discuss all aspects of the sonic boom studied in the HISAC European project [2]. They concern physical aspect, i.e. meteorological impact and atmosphere turbulence, and numerical sonic boom prediction.

The second part focusses on the numerical sonic boom modeling and its assessment. The physical phenomena is simulated by coupling adaptive CFD techniques and waves propagation methods in the atmosphere. The near field is modeled by the Euler equations discretized by a high-order finite volume method. To ensure a valid coupling between CFD and the propagation, the use of mesh adaptation is mandatory to have an enough accurate signal far from the aircraft. Mesh adaptation employes advanced techniques producing adaptive anisotropic tetrahedral meshes [3]. Practically, the coupling is assumed valid, in the sense of the Whitham theory, if the solution is locally axi-symmetric. Then, the near field signal is provided to a propagation code based on the wave form parameters method [5] which compute the sonic boom signature. This method propagates the acoustic signal in the atmosphere from the near field to the ground by taking into account meteorological data, such as the wind for instance. A multi-pole approach is used to rebuild a Whitham function from the near field pressure distribution interpolated on a cylinder around the aircraft to obtain a more accurate input [4]. This approach ensure a valid coupling closer to the jet. This coupling has been validated by matching the CFD signal and the one obtain by the propagation 2 kilometer below the aircraft.

The third part is concerned with the difficult problem of shape optimization for sonic boom reduction. Indeed, there is no conventional shape to reduce the boom. This purpose is illustrated by showing a large variety of shape proposed by NASA or HISAC project. We point out that to get an efficient cost function an accurate solution must be obtain far from the aircraft. Therefore, it requires to couple mesh adaptation with shape optimization to guarantee a significant reduction of the objective function.

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