Numerical Simulations of a Subsonic/Supersonic Coaxial Jet for an Efficient Design of Experimental Setup

Daniel Guariglia[1], Christophe Schram[1]

[1]von Karman Institute for Fluid Dynamics, Sint-Genesius-Rode, Belgium

Abstract

An efficient design of a new experimental facility in fluid dynamics often requires an iterative procedure. Several steps must be followed, if we want to obtain the maximum number of benefits, at the minimum cost. One of this step is for sure the feasibility study with the use of a commercial software like COMSOL Multiphysics®, which gives the possibility to explore the problem from different point of view, at low cost in terms of money and time.

The problem under investigation is the study of the noise generated by a coaxial jet with the inner flow being subsonic and the outer flow being supersonic in under-expanded conditions. This particular configuration lead to the formation of shock-cells between the inner and the outer shear layer which generate tonal and broadband noise. These are both an issue for the environment and a cause of fatigue stress for aeronautic structures.

We will use the High Mach Number Flow physics interface of COMSOL Multiphysics® to have reliable prediction on the topology of the flow, which appear to be quite complex (see Fig. 1). The results will be used to design the experimental setup, which will include aeroacoustic and optical measurements. We will test several pressure ratio configurations in order to define the most interesting ones to be investigated.

After this, we will couple the High Mach Number Flow physics interface with Heat Transfer in Solids physics interface with the aim to verify possible influences of the heat transfer in the nozzle itself on the boundary layer development, which is an important factor in the shock-cell noise formation. In Fig. 2 we can see that the ΔT between the inner and the outer flow is of the same order of magnitude of the total temperature. This could also lead to a more appropriate choice for the nozzle material.

Finally, we will use the Structural Mechanics module to verify to don't have permanent deformations in the nozzles due to the combined stresses of the boundary layer, pressure and thermal stress.

The combined results given by an appropriate use of COMSOL Multiphysics® will be used to design efficiently an experimental setup for optical and aeroacoustic measurements on a

subsonic/supersonic coaxial jet. This will consent to save time and money in the realization phase and more over in the testing phase, avoiding critical mistakes and addressing the work of the researchers to the right direction, since the beginning.

Reference

Introduction to Comsol Multiphysics 4.4;
COMSOL Multiphysics 4.3 User Guide;
G. M. Carlomagno, Elementi di Gasdinamica, Liguori Ed. (2009);
C. Tam, N. Pastouchenko, and K. Viswanathan. Broadband
Shock-Cell Noise from Dual Stream Jets. In Aeroacoustics Conferences. American
Institute of Aeronautics and Astronautics, May 2008;
S. A. E. Miller, J. Veltin, P. J. Morris and D. K. McLaughlin, Assessment of Computational Fluid Dynamics for Supersonic Shock Containing Jets, AIAA Journal, 47(11), pp. 2738-2746, 2009;
Y. Abdelhamid and U. Ganz, Prediction of Shock-Cell Structure and Noise in Dual Flow Nozzles 13th AIAA/CEAS Aeroacoustics Conference (28th AIAA Aeroacoustics Conference). May 2007

Figures used in the abstract

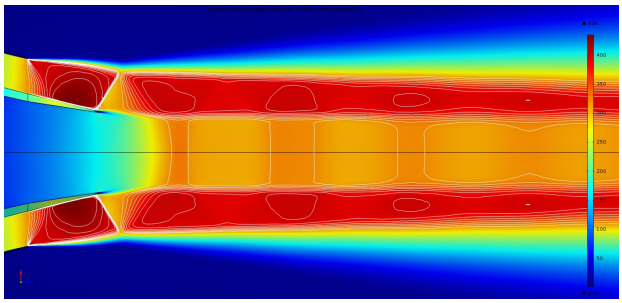

Figure 1: Detail: velocity field with M>1 isolines.

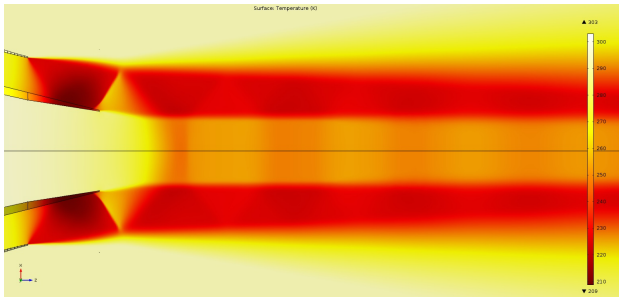

Figure 2: Detail: Temperature field.