Simulation of Acoustic Noise Suppression in a Liner Element

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Introduction

The continual progress in ecological standards places increasing restrictions on permissible rate of noise from commercial aircraft. One of the methods of noise suppression is the usage of acoustic liners that are integrated into the walls of the engine nacelle. Physically, the liner is composed of face-sheet with holes. Optimal design of acoustic liners for maximum suppression requires exhaustive understanding of mechanisms of noise absorption in liners but due to the small size of liner's holes (the typical dimension of aircraft engine liners is about 1mm) the experimental investigation of this problem is cute difficult.

The processes of noise propagation and suppression in a liner can be completely described by the compressible Navier-Stokes equations can be investigated by direct numerical simulation methods. Direct numerical simulation of acoustic liner problem is enough expensive especially in case of high-Reynolds number so the usage of high performance parallel computer systems looks cute natural.

In this paper a direct numerical simulation is employed for simulation of acoustic noise suppression in a liner element. All calculations are carried out on the massively parallel computer system MVS 1000.

Problem formulation

The physical mechanism of acoustic noise suppression in a liner construction is studied well enough. It is generally believed that in case of low sound intensity the friction at the entrance hole is in charge of the dissipation of acoustic energy and plays the dominant role in noise suppression. At high level of noise, the flow through the hole is usually considered as turbulent jet. In this case the most part of energy loss results from the turbulence. Usually the mechanism of dissipation investigated by experiments using much larger size hole and believe that the mechanism is the same as in case of a small one. In the present work the predictions are made on the base of complete system of non linear Navier-Stokes equations.

The geometric parameters

The geometric parameters of the liner under consideration are shown at the Fig. 1. d=1mm, R=7.5mm, H=5R, L=1mm.

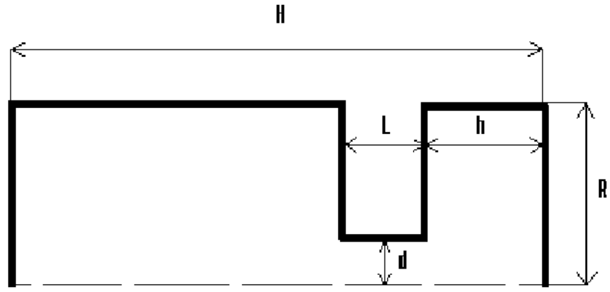

Fig. 1. The geometric parameters of the liner element.

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The boundary conditions were the following. At the solid boundary

$$v = \frac{\partial u}{\partial n} = \frac{\partial p}{\partial n} = \frac{\partial \rho}{\partial n} = 0 .$$

At the left free boundary a one mode artificial source was placed. The law of the source had the following form

$$u_n = A\sin(2\pi ft), \quad v_n = 0, \quad p_n = p_0 + A\sin(2\pi ft), \quad \rho_n = \rho_0 + A\sin(2\pi ft),$$

where A=150Db.

Parallel realization

The domain decomposition technique, namely, its simplest variant is used for parallelizing. In doing so, the whole computational domain is divided into a set of subdomains in accordance with a number of processors available. The data exchange is realized only along the subdomain boundaries. In order to provide processor load balancing, the subdomain configuration is chosen by requiring an approximate equality of nodes number.

Numerical technique

In the current research the Dispersion Relation Preserving (DRP) finite difference scheme was used. DRP scheme was proposed by Tam [1] and his colleges specially for aeroacoustic problems. The way of construction of this scheme provide of it with superior dispersion characteristics. For the DRP method the usual finite difference approximation is taken

$$\left(\frac{\partial f}{\partial x}\right)_l \approx \frac{1}{\Delta x} \sum_{j=-N}^{M} a_j f_{l+j} . \qquad (1)$$

Fourier transformation of the stencil leads to relation between the exact wave number and the effective wave number. The Fourier transform of (1) is

$$ikf \approx \frac{1}{\Delta x} \sum_{j=-N}^{M} a_j e^{ikj\Delta x} f .$$

The effective wave number is

$$k \approx \frac{-i}{\Delta x} \sum_{j=-N}^{M} a_j e^{ikj\Delta x} .$$

The coefficients a_j from (1) can be obtained by minimizing the difference between the effective and exact wave number.

At the beginning the applicability of this scheme was limited as it was applied only on Cartesian uniformly space grids but modern modifications of DRP scheme [2,3] overcome these problems.

Conclusion

Computed liner impedance for several configurations shown a well agreement with experimental measurements.

References

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