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Fast evaluation of sound radiation by vibrating structures with ACTRAN/AR

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The numerical analysis of sound radiation by vibrating structure is a well known and mature technology used in many industries. Accurate methods based on the boundary or finite element method have been successfully developed over the last two decades and are now available in standard CAE tools. These methods are however known to require significant computational resources which, furthermore, very quickly increase with the frequency of interest. The low speed of most current methods is a main obstacle for a systematic use of acoustic CAE in industrial design processes. In this paper we are going to present a set of innovative techniques that significantly speed-up the calculation of acoustic radiation indicators (acoustic pressure, velocity, intensity and power; contribution vectors). The modeling is based on the well known combination of finite elements and infinite elements but also combines the following ingredients to obtain a very high performance:

- a multi-frontal massively parallel sparse direct solver;
- a multi-frequency solver based on the Krylov method;
- the use of pellicular acoustic modes as a vector basis for representing acoustic excitations;
- the numerical evaluation of Green functions related to the specific geometry of the problem under investigation.

All these ingredients are embedded in the ACTRAN/AR CAE tool which provides unprecedented performance for acoustic radiation analysis. The method will be demonstrated on several applications taken from various industries.

1. Introduction

The numerical analysis of sound radiation by vibrating structure is widespread technology used in many industries. Many methods have been developed over the last two decades and are easily available in standard CAE format. In spite of increasing computer technologies and resource, low speed of most current calculation method is a main obstacle for systematic use of acoustics. So, in this paper, we will introduce a set of innovative technology that significantly speed up the calculation of acoustic radiation(AR) problems. Some pictures are presented for easy understanding of ACTRAN features.

2. Features of ACTRAN

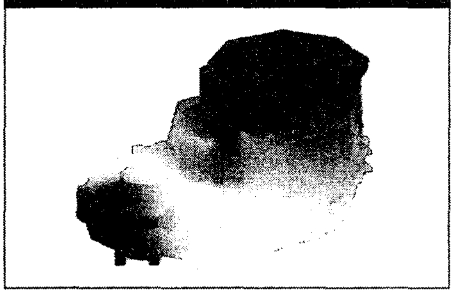
2.1 Acoustic Indicator

To solving acoustic problem is equal to find out the major acoustic indicators. The most common used acoustic indicators are acoustic pressure, velocity, intensity, power, FRF and etc.

2.2 Pre Processor

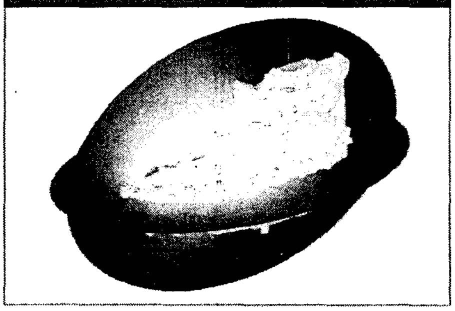
The standard computational process for vibration acoustics is illustrated below.

Fig.1 Vibration computations (Nastran etc)



First, vibrating surface information should be required from structure analysis solver.

Fig.2 Acoustic computations (ACTRAN)



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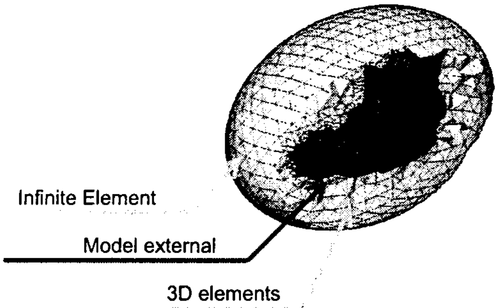
And then, ACTRAN/AR reconstructs the acoustic mesh with fast 3D mesh tools like wrapping functions even if structure and acoustic mesh are unequal. The figure is presented in <Fig.3>



<Fig.3> Acoustic modeling of ACTRAN

2.3 Solving Strategy

ACTRAN allow the direct computation of all frequencies (one matrix resolution with multiple RHS.) and adopt frequency parallelisms available for very large problems. And KRYLOV strategy produces precise result and efficient solving time with MUMPS, SPARSE.

(1) MUMPS (Multi-frontal massively parallel sparse direct solver)

Skyline solver is the first one of ACTRAN that requires renumbering of mesh for good performance (Cuthill-McKee algorithm). But with requiring more powerful matrix ordering technique (AMD, AMF, PORF, METIS), MUMPS solver is now generally used in ACTRAN. It produce hybrid scheduling and can be interfaced with Fotran, C, Matlab.

(2) Krylov strategy

Dynamic equation of a system can be compared with the algebraic equation of the impedance matrix.

$$\left(A_0 + \omega A_1 + \omega^2 A_2\right)x(\omega) = f(\omega) \quad \text{<Eq.1>}$$

For complex system, if the stiffness and damping could be frequency dependent and not strong, then a solution consists in splitting the frequency interval in sub-intervals where the stiffness dependency can be considered as quadratic block like <Eq.2>

$$\begin{aligned} K(\omega) &= K_0 + K_1\omega + K_2\omega^2 \\ C(\omega) &= C_0 + C_1\omega \end{aligned} \quad \text{<Eq.2>}$$

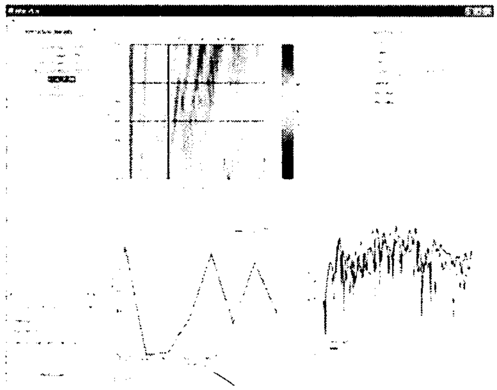
(3) Eigen value solver

Except the direct solver, ACTRAN also can use a specific solver for modal extraction based on a Lanczos method in which matrices should be symmetric and no damping is required.

The others are; thanks to reconstruction capability, the acoustic computation can be uncoupled from the structural computations and allows the smart handling of results for multiple RPM (with different frequencies for each RPM).

2.4 Post Processing

Fig.4 shows post processing example with ACTRAN/VI.



<Fig.4> Post processing of results

You can find and calculate all important acoustic indicators in numeric or graphic or map in ACTRAN/VI and comparison with experimental data is also available.

Acoustic simulation of gearbox example shows that ten times faster run compared with BEM method.

3. Conclusion

Because of easy way of reading large amount of structural data, simply acoustic modeling, and fast solving strategy, ACTRAN is now widely used in many industries, power train and auxiliaries(oil pan, manifold, intake, exhaust ,……) and chassis(tire, dash panel trimmed body,……) especially in automotive, and is clearly applicable for all industrial products (compressor, motor, fan and etc).