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is required. These vibrations are caused by an intricate interaction between structural dynamics and aerodynamics.

The basic idea of the four-dimensional solution algorithm [1] is that a time-periodic problem can be considered a steady problem in the sense that after one time period the next period shows the same phenomena. This is formalised by solving the time-dependent equations simultaneously in both space and time for the complete period of the problem. The equations are solved on a four-dimensional space-time grid.

The main advantage of the solution algorithm lies in the fact that it transforms a time-dependent problem into a steady-state problem. This has several advantages:

- the final solution is independent of the solution process;
- local grid refinement can be extended to the time dimension;
- no dynamic load balancing problems on parallel machines;
- time-accurate coupling with other physics models is straightforward.

These four points show that the solution algorithm is excellently suited for aeroelastic simulations of rotor systems in forward flight. The aeroelastic coupling, the rotor trimming procedure, and the local grid refinement process for improved vortex capturing are combined in an elegant way, without one of the processes jeopardizing the efficieny of the other processes.

At the presentation, results for an aeroelastic simulation of the four-bladed BO105 +M296 rotor in forward flight will be shown.

[1] H. van der Ven and O.J. Boelens. Towards affordable CFD simulations of rotor in forward flight - a feasibility study with future application to vibrational analysis, 59th AHS Forum, Phoenix, USA, May 6-8, 2003.

A Space-Time Discontinuous Galerkin Method for Wet-Chemical Etching

J.J. Sudirham (University of Twente), J.J.W. van der Vegt (University of Twente), R.M.J. van Damme (University of Twente)

Thursday, 11:00–11:30, Hall 5

Wet-chemical etching is a manufacturing technique which is well suited for the machining of complicated small devices. An etching fluid is used to dissolve the material, while the rest of material is protected by an impenetrable mask. This technique is attractive for micromachining, because it is a fast room temperature process and the production process is independent of the complexity of the design. The control of the etching process is, however, not fully understood. This results in inacccuracies in the product of the etching process. In order to improve the understanding of the wet-chemical etching process, there is a strong need for accurate mathematical models. Recently, we have developed a space-time discontinuous Galerkin finite element method for parabolic problems with moving boundaries. In this presentation we will summarize the finite element discretization and discuss the modelling of the transport of the etching fluid concentration, which we assume is governed by an advection-diffusion equation. The finite element method is adaptive, therefore it is well suited for the wet-chemical etching process, as the behaviour of the process requires the accurate capturing of the silicon-etchant interface, thin boundary layers and corner singularities. As an example, we apply the method to etching of a slit and the results are compared with analytic studies and other numerical experiments.

Discontinuous Galerkin Method for Duct Acoustics

R. Hagmeijer (University of Twente), C.P.A. Blom (University of Twente), H. Ózdemir (University of Twente)

Thursday, 11:30–12:00, Hall 5

The present paper deals with the analysis of duct acoustics by means of the Discontinuous Galerkin finite element method. It summarizes part of the work done within two research projects at our department [1], [2]. The industrial problem considered is that of acoustic radiation from a vibrating wall segment inside an infinite rectangular duct. The objective is to compare numerical with analytical results in order to identify the relevant phenomena and to verify the numerical algorithms employed.

We employ the Discontinuous Galerkin (DG) finite element method. The currently used implementations are upto fourth order accurate in space and time. We use tetrahedral [1] or hexahedral [2] elements.

We present detailed analytical solutions for two specific cases: (i) plunging rigid wall segment, and (ii) an harmonically deforming (in space and time) wall segment. All of the analytical work presented is taken from [1].

We have obtained good agreement between analytical and numerical solutions, although evaluation of the analytical results is a challenge in itself. Due to the large number of integrals over infinite domains that have to be calculated, we have therefore, at various stages, taken the leading term only. It appears that these leading term already captures most of the characteristics of the solution.

[1] C.P.A. Blom, Discontinuous Galerkin Method on Tetrahedral Elements for Aeroacoustics, Ph.D.-thesis, University of Twente, September 2003.