Large eddy simulation of enclosed rotor-stator flow

W. Lo and C. A. Lin*
Department of Power Mechanical Engineering, National Tsing Hua University,
Hsinchu 30013,TAIWAN
e-mail: calin@pme.nthu.edu.tw
Fax:+886-3-5722840

Introduction

The flow between a rotating and a stationary disk has received much attention due to its relevance to applications in turbomachinery. In the present study, the large eddy simulation technique is adopted to predict the flows within the enclosed rotor-stator. Focuses will be on the predicting capability of the LES model to internal flow fields and the differential levels of turbulence on the stator and rotor walls. Since the LES requires the solutions of three-dimensional time dependent equations, and this requires the usage of parallel computers. Therefore, the implementation of parallel algorithm and its efficiency are also addressed.

Numerical framework and modeling

The framework of the present numerical procedure incorporates the finite volume method and the staggered grid arrangement. The integration method is based on a semi-implicit, fractional step method proposed by Kim and Moin (1987). The non-linear terms and wall parallel diffusion terms are advanced with the Adams-Bashfoth scheme in time, whereas the Crank-Nicholson scheme is adopted for the diffusion terms in the wall-normal direction. Fast Fourier transform method is used to tackle the periodic condition. Since the disk cavity is enclosed, no inlet boundary condition is needed. No slip and impermeable wall conditions are applied, except along the rotor walls, where the rotor tangential velocity is prescribed according to the angular velocity. The subgrid scales are modeled by the Smagorinsky model. A Van Driest damping function is employed for the near wall effects on turbulent length scales.

Near Wall treatment

In order to reduce the computational cost, an economic pressure solution methodology is also employed in the present study. Pressure is assumed to remain uniform in the wall-normal direction within a pre-defined region, a condition similar to that exits inside the boundary layer. This approach assumes that in this region only one pressure node prevails, and therefore, the computational cost of the Poisson equation is dramatically lessened. Unlike the core flow field where continuity is satisfied through the solution of Poisson equation, the mass conservation is enforced by local continuity in the uniform pressure zone,$\overline{v} = -\int_0^y (\frac{\partial \overline{u}}{\partial x} + \frac{\partial \overline{w}}{\partial z}) dy'$, where the wall normal-direction velocity(v) is modified through the balance of parallel components(u,w) thus ensuring the mass conservation.

Results

For the rotor-stator flow, the internal structure is induced by the diffusive transport of the tangential momentum from the rotor into the interior. The instantaneous azimuthal vorticity contours near the stator and rotor show stretching and elongated structure in the tangential direction. Near the rotor, the vorticity line is more coherent; however along its counterpart location at the stator wall, the structure is more chaotic. This shows that the turbulence intensity along the stator wall is much more enhanced compared to that on the rotor wall. A laminar region is also identified near the shaft at small radii. Negligible difference is observed when comparing results with and without uniform pressure zone.

*corresponding author