UNSTEADY INCOMPRESSIBLE FLOW IN PUMP IMPELLER WITH OUTLET DISTORTION

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Unsteady incompressible flow computations are more complicated than compressible ones and the appropriate software is not always available for turbomachinery applications. Approximated methods, such as frozen rotor and low Mach number compressible flow calculations, are often introduced to limit the cost and development time.

In the frozen rotor method one assumes that the relative flow is steady in both rotor and stator. In other words the inertial forces, caused by the time variation of the flow, are neglected. The interaction between rotor and stator is calculated by a steady coupling at the interface. The time evolution of the forces and flow is approximated by repeating the calculations at different angular positions of the rotor.

Figure 1 compares the static pressure in the rotor and volute as predicted by the unsteady incompressible flow computations and the frozen rotor method. Results are obtained for 115% of the design mass flow at a given angular position of the rotor. One observes that the frozen rotor method predicts a totaly different flow field than unsteady incompressible flow computations. The pressure distributions around the blades show that in frozen rotor computations, the flow in the impeller passage in front of the tongue, adapts itself to the conditions at the interface and the mass flow in the passage changes. In the unsteady flow computations the pressure distribution changes only at the trailing edge of the blade in front of the tongue. This is due to the potential interaction and the flow in the channel does not have the time to addapt itself.

The variation of the forces acting on the shaft is shown on figure 2 for both methods. It is clear that the frozen rotor method is inappropriate to approximate these forces. The large increase of the force, each time a blade passes in front of the volute tongue is not predicted by the frozen rotor method.

A second approximation of the incompressible unsteady flow is by using a compressible unsteady calculation method at low Mach number. It is based on the observation that the density is nearly constant at low Mach number. However calculations at low Mach number cause the improper computation of the derivatives of the density, because of the numerical accuracy, and a slow down of the convergence, because of large differences in the eigenvalues. Local preconditioning is therefore needed to solve low Mach number flows. For this purpose the 2D Euler code, used previously for incompressible flows, is extended by preconditioning. The code is tested for different cases and satisfactory agreement between analytical and computational results is observed.

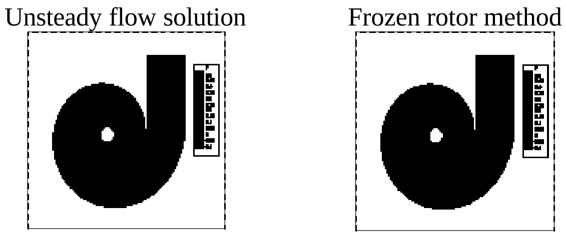

Figure 1: Static pressure distribution at off-design point in a radial pump (ϕ/ϕ_n =1.15)

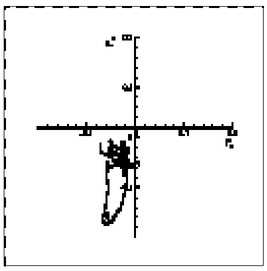

Figure 2: Force variation calculated by using frozen rotor method and unsteady incompressible flow computation at high mass flow (ϕ/ϕ_n =1.15)

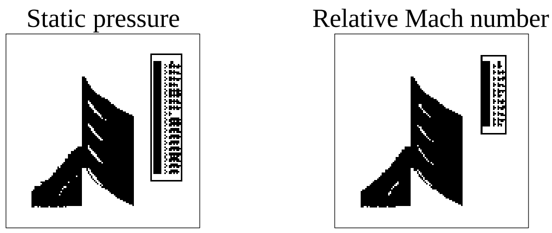

Figure 3: Compressible flow in an axial cascade at low Mach number

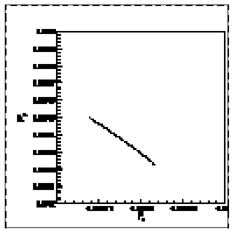

Figure 4: Variation of forces acting on the rotor in an axial cascade flow at low Mach number