A reduced-order model of the Navier-Stokes equations for impeller and seal rotordynamic analysis

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The goal of this project is to improve the prediction of unsteady flows in turbomachinery impellers and seals. By using a time-linearization approach, as an alternative to the time-marching approach, the computational effort needed for rotordynamic analysis was significantly reduced in a previous TRC project. We have shown that using time linearization, the computational time needed for predicting the unsteady flow was approximately 7-8 times more that the time needed for predicting the steady flow, and consequently much less than that needed for the traditional time-marching method.

The time-linearization solver previously developed used the Reynolds-averaged Navier–Stokes equations with a "frozen" Shear-Stress Transport (SST) turbulence model; that is, a turbulence model that was not time-linearized and therefore its dependent variables were not varying in time. In addition, the inlet and outlet boundary conditions were analytically non-reflecting. The objectives of the project during 2018 are to: (1) implement a time-linearized turbulence model, (2) implement numerically exact, far-field boundary conditions, and (3) prepare a user manual for the time-linearized solver. The updated flow solver will then be used to predict the rotordynamic coefficients for two seals previously investigated by Wright (1983) and Nelson et al. (1986).

As the project was awarded after the beginning of the Fall 2017 semester, a graduate student was hired and assigned to the project in January 2018. This report summarizes the work completed so far in 2018. Since the SST turbulence model is a blended model that includes both the $\kappa - \epsilon$ and the $\kappa - \omega$ two-equation models, it was decided to use, in a first step, the Spalart-Allmaras turbulence model. This is a simpler, one-equation model, which proved to be quite successful in predicting the turbulent flow in turbomachinery. The Spalart-Allmaras turbulence model has been integrated in the UNS3D solver and is currently being tested. The report provides the details of this implementation and the planned work for the rest of the year.