TRC CONTINUATION PROPOSAL 2016- 2017

CFD Prediction of Gas and Liquid Dynamic Forces in Impeller and Seal Passages

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INTRODUCTION AND JUSTIFICATION

API 617 level-II analysis requires detailed computed rotordynamic coefficients if level-I criteria fails. Thus, calculating more accurate rotordynamic dynamic forces and coefficients is crucial to satisfy the API standards. A commercial CFD code was used to evaluate translational and tilt related impedances and stiffness, damping and inertia coefficients due to a whirling impeller or to a shaft at a seal location, including translational and tilt static offsets. Proposed work will include accurate modeling of impeller/diffuser/volute effects, including open face impellers, hole pattern seals, and grooved seals. Finally, work will continue on the development of a TRC CFD solver code to ultimately provide a stand-alone code for TRC member usage. Deliverables will include parameter effect studies, rotordynamic stability, and response software that includes capability for incorporating seal and impeller impedances expressed in a general transfer function form, commercial code modeling tutorials for impellers and seals, and ultimately a stand-alone CFD solver code.

DELIVERABLES

(a) Tutorials on using the ANSYS CFX CFD code for steady state and transient analysis of impeller and seal related impedances and dynamic coefficients.

(b) Parametric studies for rotordynamic coefficient dependence on diffuser/volute design on closed and open impellers, hole pattern and groove geometries on seals.

(c) Stand-alone code with EXCEl GUI and modified version of $XLTRC^2$ that utilizes general impedance curves for rotor stability and imbalance response predictions

(d) Stand-alone FORTRAN code for evaluating the rotordynamic coefficients of smooth, grooved and damper seals and impeller shrouds.

COSTS : 1 PhD Student, 12 months at $2,000/mo. Salary, $197/mo. Insurance, 0.6% Fringe on salary, approx. $9000 Tuition and Fees, CFTurbo License $7200 for volute study ***Total: $45,000***

STATUS OF CURRENT WORK

- A full set of translational and tilt rotordynamic coefficients for a pump impeller were successfully determined and analyzed to explain the influence of coupled motion (cylindrical and conical) on the rotordynamic stability of the shrouded pump impeller problem.
- A general, transfer function curve-fit approach for impedances has been developed to provide a more accurate description of impeller forces than the standard mass/stiffness/damping dynamic coefficient model, for use in stability and response simulations
- Developed systematic approach to study static eccentricity effects on plain annular seals and misaligned centrifugal impellers using the commercial CFD program.
- Developed rotordynamic code for predicting response and stability utilizing general transfer function description of impedances.
- Performed dynamic coefficient analysis for hole pattern seals and leakage study of groove on rotor seals.

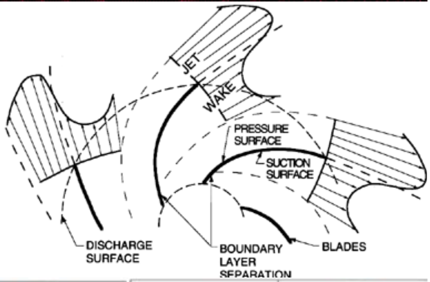
PROPOSED WORK

- Determine rotordynamic coefficients for dynamic perturbation and static eccentricity with transient analysis and mesh deformation for impellers and seals.
- Develop impeller/diffuser/volute interaction model and investigate unsteady volute/diffuser flow effect on the rotordynamic stability of closed and open face centrifugal impellers.
- Develop an alternative formula to the Wachel *kxy* formula in API617 based on CFD model predictions.
- Develop user friendly TRC software to determine translational and rotational mass, damping and stiffness coefficients for a centrifugal impeller utilizing a CFD based approach. This will be accomplished in a gradual manner by first using the generic CFD code CFX and then developing a stand-alone code. The model includes the primary and secondary (leakage) flow paths, inlet region, swirl brakes and outlet region (diffuser).
- Prepare tutorials for TRC reps to model impeller and seal dynamic forces

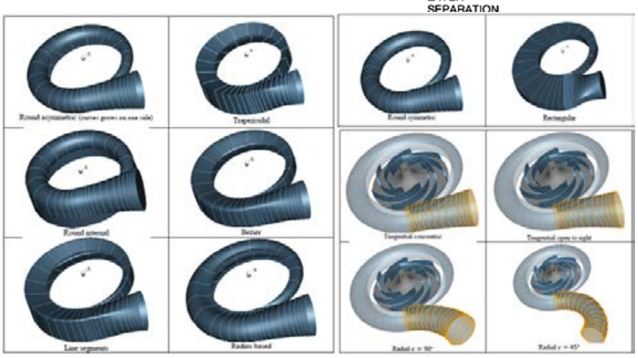
DISCUSSION

(1) Clearance Excitation in Open Face Impellers

Rotordynamic response of a shrouded impeller usually arises from shroud surfaces and seals. An unshrouded whirling impeller is a source of self-excited instability which is sustained by clearance excitation. Conventionally, axial machines were subject of clearance excitation studies. We propose to do such analysis with CFD code CFX for centrifugal machines. In these machines, a larger area is subject to uneven torque distribution. Initial results from CFX modeling are promising. The whirling motion will be modeled in transient solution with mesh deformation.

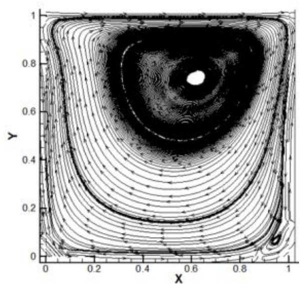


(2) Effect of Impeller/Volute Interaction



The unsteady jet and wake phenomenon is always present in turbomachinery, especially in off flow conditions. The unsteady interaction of jet/wake with cutwater and diffuser vanes along with impeller passing vane frequency causes pressure pulsations that may lead to severe resonance. Multiple volute/diffuser designs will be studied to attain a multi-variable regression rotordynamic analysis and quantify unsteady response of impeller.

(3) Developing Stand-alone CFD Code for Seals and Impellers



CFD simulation of rotordynamic coefficients eliminates most inaccuracies associated with simplified rotordynamic models. A general CFD code requires dimensional and operational inputs. The procedure of CAD modeling, grid generation and solution is done automatically by the code. Effects of surface roughness and inlet pre-swirl ratio will be integrated to the code. Subsequently, a hybrid scheme will be implemented to allow for multi-core/multi-thread parallel computation. The code will be initially developed for seals then will be upgraded for impeller shroud rotordynamic forces.