Discussion: "Rotordynamic Force Prediction of Centrifugal Compressor Impellers Using Computational Fluid Mechanics" by J. J. Moore, D. L. Ransom, and F. Viana

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The authors are to be commended for an interesting demonstration of computational fluid dynamics (CFD) methods in the analysis of rotordynamic forces for impellers in centrifugal compressors. CFD approaches clearly represent the future for this important calculation. As they state, data are vitally needed to anchor predictions for impeller coefficients for compressors. In fact, better data would also be helpful for pump impellers. The data of Bolleter et al. [4] yield whirl frequency ratios that range upward from 0.75 to 2.2. To the extent that the destabilizing forces arise from fluid rotation, WFR cannot exceed the average circumferential velocity ratio, and more reasonable values would be on the order of 0.5 (as predicted by the authors).

The authors provide an illuminating discussion of the Wachel model and its current variations with comparisons to their CFD approach. They mentioned Gupta's MS thesis [6], but apparently overlooked the more accessible 2006 work by Gupta and Childs [1] who use a bulk-flow model to predict the forces for the front and back compressor shroud faces and compared their predictions to Wachel's formula. Gupta and Childs showed reasonable agreement with measured results for pump impellers from Bolleter et al. and presented calculated results for the forces developed by the shroud faces of an industrial compressor.

In reviewing CFD literature related to calculation of rotordynamic coefficients for impellers, the authors overlooked the first such calculation by Baskharone et al. [2]. In 1994, he used a finite-element CFD model and produced reasonable comparisons to measured results by Bolleter et al. In Ref. [8], Moore showed comparable comparisons for Bolleter's measured pump data using (i) Moore's CFD developments, (ii) Childs' bulk-flow predictions [5], and (iii) predictions of Baskharone et al..

In their Summary and Conclusions section, the authors state, "Based on this result, it can be concluded that the majority of the destabilizing force of a centrifugal impeller arises from the shroud passage, not the impeller-to-diffuser interaction, since the instability can be predicted by the shroud force alone." Are the authors suggesting that this is a new and unexpected outcome? In regard to measured impeller coefficients for (i) radial-flow (no shroud length) and (ii) customary shrouded pump impellers, Childs (Ref. [3], p. 368) states, "These results strongly suggest that the impeller-diffuser (or volute) *flow* interaction forces in impellers are benign since their radial impeller eliminates any projected axial area for the shroud and thereby eliminates any radial shroud force due to pressure perturbations. The absence of both radially destabilizing forces and axially extended shroud surfaces suggests that the shroud forces are mainly responsible for destabilizing force coefficients." This statement clearly identifies the dominant role for shroud forces in developing rotordynamic coefficients and also emphasizes the importance of the authors' L_{shr} in developing impeller forces. The stated basis for the bulk-flow development of Ref. [5] was the observation that shroud forces (with representative clearances in the leakage path) dominate measured force coefficients.

The authors state, "What makes this particular compressor suitable for a case study is that the impeller aerodynamic cross coupling had the dominant effect on the stability of the machine." Presumably, that judgment rests on the impeller's comparatively long L_{shr}. The subject impeller actually resembles a pump impeller, and pump impeller data show increasing cross-coupled stiffness and direct damping forces as L_{shr} increases and the shroud clearance decreases. In Ref. [1], Childs and Gupta predict smaller contributions from the front shroud face than the eye-packing seal, probably because of their impeller's shorter L_{shr} values and a lower aspect ratio $A_r = L_{\mathrm{shr}}/D$, where D is the impeller diameter. The authors use L_{shr} to create a more rational nondimensionalization of their K_{xy} coefficient. Can one extrapolate from these results and the authors' nondimensionalization to the conclusion that low A_r values—that are typical of high-pressure injection compressors—would produce increasingly small shroud destabilizing forces?

The value of a technical publication rests on the ability of other interested parties in repeating calculations or tests to see if they get the same or different results. In this case, the data provided are not adequate to carry out separate calculations. Specifically, the essential geometrical data for the impeller and shroud surfaces are not provided, making direct comparisons impossible. The OEM who supplied the data for calculation considers these data to be proprietary and has declined requests to provide it by both the authors and the discusser. However, a benchmark comparison could be made if the authors used the data of Ref. [1] for a comparison calculation. Can they provide this additional calculation?

References

[1] Gupta, M., and Childs, D., 2006, "Rotordynamic Stability Predictions for Centrifugal Compressors Using a Bulk-Flow Model to Predict Impeller Shroud Force and Moment Coefficients," ASME Paper No. GT2006–90374.

[2] Baskharone, E. A., Daniel, A. S., and Hensel, S. J., 1994, "Rotordynamic Effects of the Shroud-to-Housing Leakage Flow in Centrifugal Pumps," ASME J. Fluids Eng., **116**, pp. 558–563.

[3] D. Childs, 1993, *Turbomachinery Rotordynamics: Phenomena, Modeling, and Analysis*, Wiley, New York.

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