Axial Flow Inducers

The rotordynamic forces in an unshrouded axial flow pump, or those caused by adding an axial inducer to

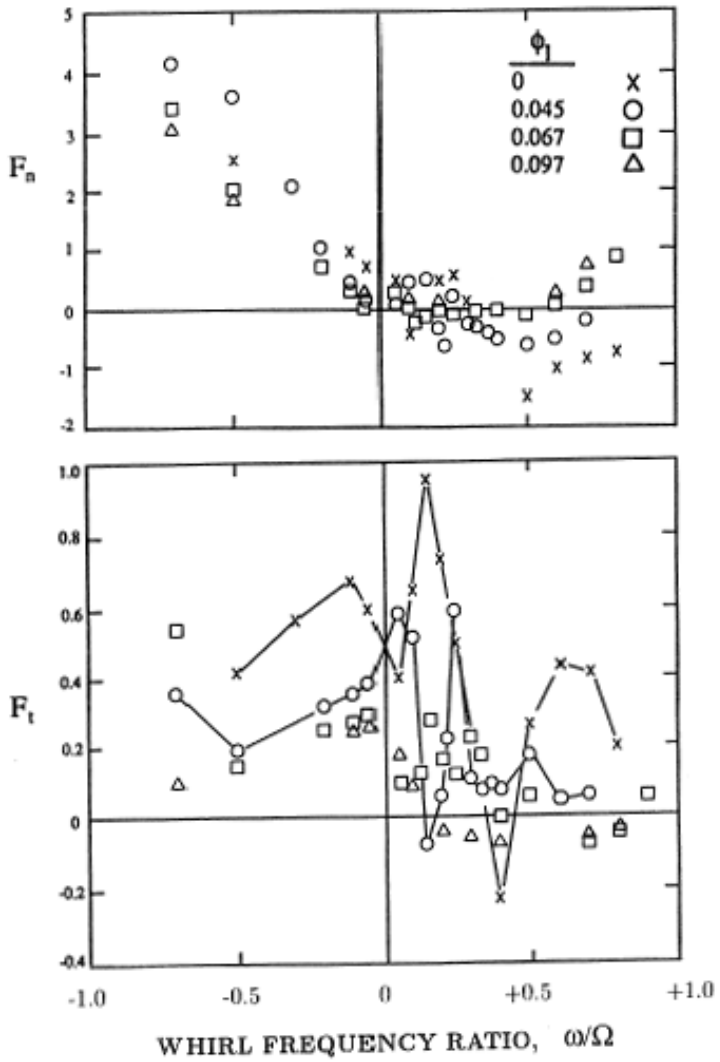

Figure 1: Rotordynamic forces for the helical inducer, Impeller VII, for four different flow coefficients (from Arndt and Franz 1986).

a centrifugal pump, are less well understood. One of the reasons for this is that the phenomena will depend on the dynamic response of the tip clearance flows, an unsteady flow that has not been studied in any detail. The experimental data that does exist (Franz and Arndt 1986, Arndt and Franz 1986, Karyeaclis *et al.* 1989) clearly show that important and qualitatively different effects are manifest by unshrouded axial flow pumps. These effects were not encountered with shrouded centrifugal impellers. They are exemplified by figure 1, which presents data on F_n and F_t for the 9° helical inducer, Impeller VII, tested alone at a series of flow coefficients (Arndt and Franz 1986). At the higher flow coefficients, the variation of F_n and F_t with whirl frequency ratio, ω/Ω, is similar to the centrifugal pump data. However, as the flow coefficient is decreased, somewhat pathological behavior begins to appear in the values of F_t (and to a lesser degree

F_n) at small and positive whirl frequency ratios. This culminates in extremely complicated behavior at shut-off (zero flow) in which F_t changes sign several times for positive whirl frequency ratios, implying several separate regions of destabilizing fluid-induced rotordynamic effect. Note that the maximum values of F_t that were recorded, are large, and could well be responsible for significant vibration in an axial flow pump or inducer. Similar pathological rotordynamic effects were encountered with all the axial inducers tested, including the inducer/impeller combination represented by the high pressure LOX pump in the Space Shuttle Main Engine (Franz and Arndt 1986). However, the details in the variations of F_t with ω/Ω differed from one inducer to another.

Finally, we should note that the current codes for rotordynamic investigations are not well adapted to deal with deviations from the quadratic forms for F_n^* and F_t^* given in equations (Mcb13) and (Mcb14). Consequently, more remains to be done in terms of rotordynamic analysis before the implications of such complex frequency-dependent behavior of F_n^* and F_t^* become clear.