Moments and Lines of Action

Some data on the steady bending moments, M_{ox} and M_{oy}, and on the rotordynamic moments

$$M_n = B_{xx} = B_{yy} \quad ; \quad M_t = B_{yx} = -B_{xy} \tag{Mcn75}$$

have been presented by Franz *et al.* (1990) and Miskovish and Brennen (1992). This data allows evaluation of the axial location of the lines of action of the corresponding radial and rotordynamic forces. Apart from its intrinsic value, knowledge of the line of action of these forces provides clues as to the origin of the forces.

Typical sets of data taken from Miskovish and Brennen (1992) are presented in figures 1 and 2. These were obtained for the Impeller X/Volute A combination operating at a speed of 1000 *rpm*. For convenience, the axial location of the origin of the reference coordinate system has been placed at the center of the impeller discharge. Since the lines of action of the forces are not too far from this location, the moments presented here are small, and, for this reason, the data for the moments is somewhat scattered.

Steady forces and moments are presented for many whirl frequency ratios in figure 1. These forces and moments should, of course, be independent of the whirl frequency ratio, and so the deviation of the data points from the mean for a given flow coefficient represents a measure of the scatter in the data. Despite this scatter, the moment data in figure 1 does suggest that a nonzero steady moment is present, and that it changes with flow coefficient. The typical location for the line of action of F_o, which this data implies, may be best illustrated by an example. At $\phi = 0.06$, the steady vector force F_o has a magnitude of 0.067 ($F_{ox} \approx 0.03, F_{oy} \approx 0.06$) and an angle $\theta_F = 63^\circ$ from the x-axis. The corresponding moment vector has a magnitude of 0.02 and an angle $\theta_M \sim 180^\circ$ from the x-axis. Consequently, the line of action of F_o is an axial distance *upstream* of the origin equal to $0.02 \sin(180 - 63)/0.067 = 0.27$. In other words, the line of action is about a quarter of a discharge radius upstream of the center of the discharge. This is consistent with the previous observation (section (Mcj)) that the pressures acting on the exterior of the shroud also contribute to the steady radial forces; this contribution displaces the line of action upstream of the center of the discharge.

The data of figure 2 could be similarly used to evaluate the lines of action of the rotordynamic forces whose components are F_n and F_t. However, the moments M_n and M_t are small over most of the range of whirl ratios, and lead to lines of action that are less than 0.1 of a radius upstream of the center of the discharge in most cases. This is consistent with other experiments on this same impeller/volute/casing combination that suggest that the shroud force contribution to the rotordynamic matrices is smaller than the impeller discharge contribution in this particular case.

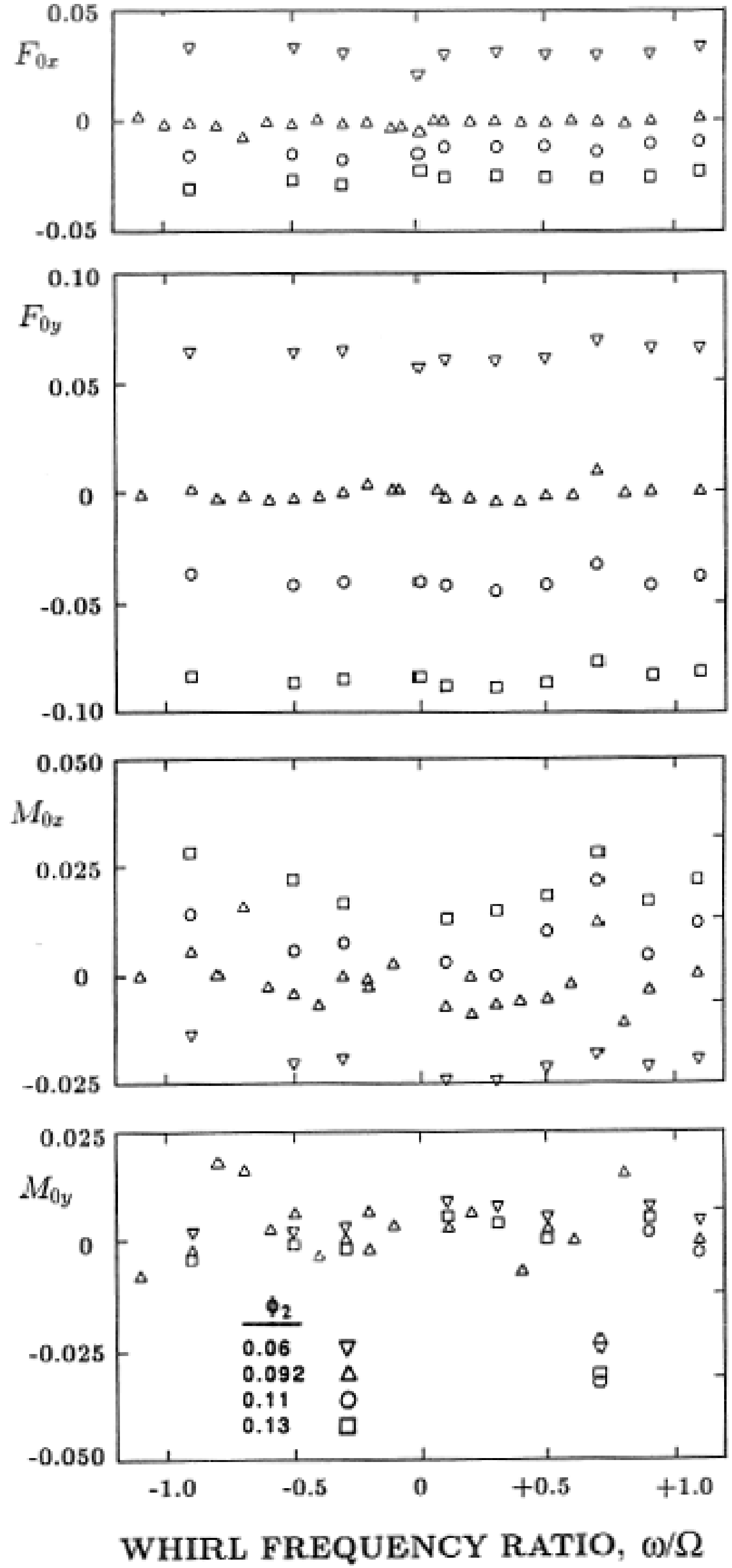

Figure 1: Steady radial forces, F_{ox} and F_{oy}, and moments, M_{ox} and M_{oy}, for Impeller X/Volute A at a speed of 1000 *rpm* and various flow coefficients as indicated (from Miskovish and Brennen 1992).

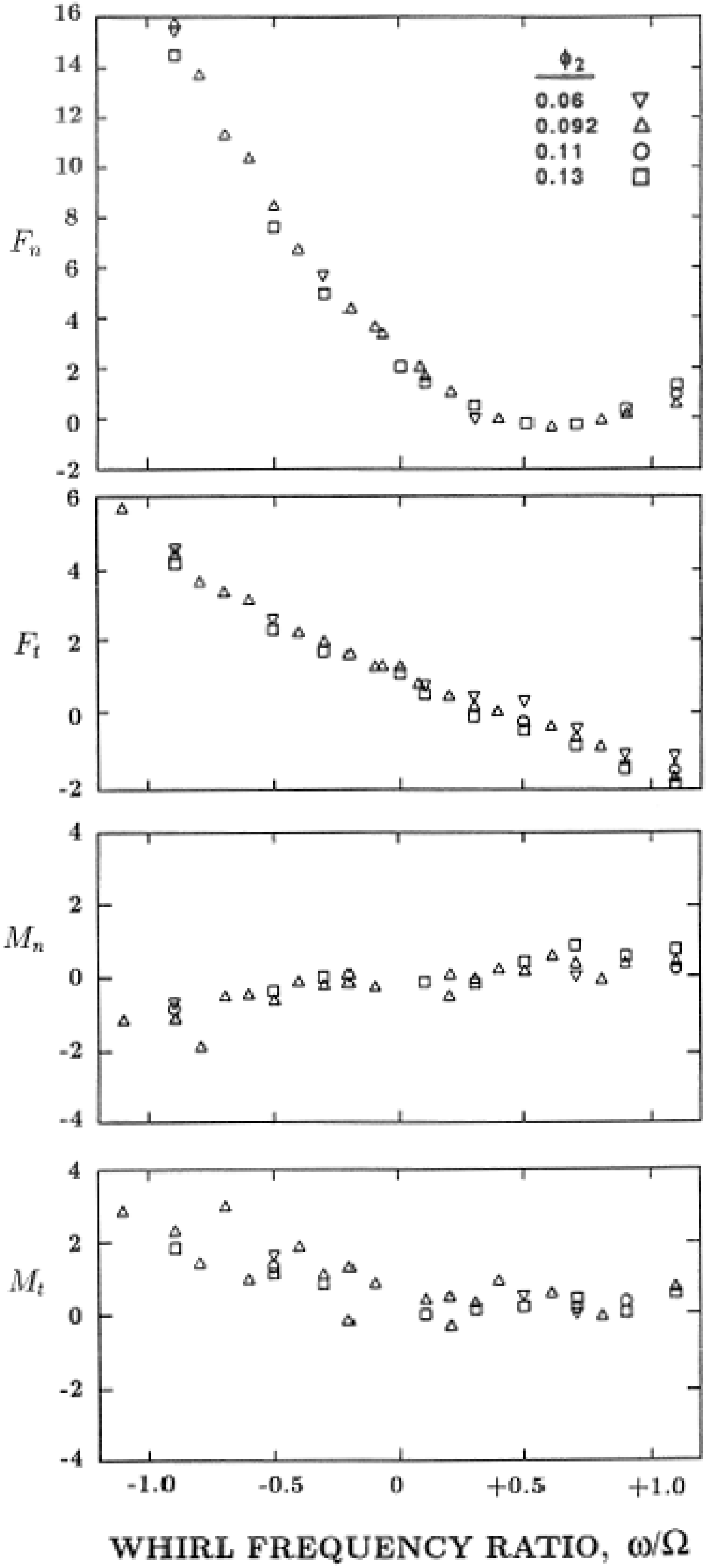

Figure 2: Normal and tangential rotordynamic forces, F_n and F_t, and moments, M_n and M_t, for Impeller X/Volute A at 1000 *rpm* and various flow coefficients as indicated (from Miskovish and Brennen 1992).