STABILITY AND STRENGTH OF MODES IN ROTATING MACHINERY

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Campbell diagram (whirl speed chart) plots the modal frequencies and the probable excitation sources against the rotational speed for a given rotor of interest. It has long been an important tool in the design and operation of rotating machinery for engineers to understand which modes are likely to be excited by the excitation sources of interest, which speed regions are safe for operation, and so on. However, it may lead to erroneous interpretation on the role of modes in the response prediction, unless their relative stability and strength are clearly addressed.

Modal damping (logarithmic decrement) determines the magnification factor, particularly near the corresponding resonant speed. Thus, only the lightly damped modes make significant contributions to the response of rotor near at the corresponding modal frequencies, while the heavily damped modes may be ignored even in the Campbell diagram.

Modes of a rotating shaft can be classified into four groups: forward (*F*), backward (*B*), and their conjugate modes ($\overline{F}$, $\overline{B}$). Forward modes are perhaps the most important, because, unlike the backward modes, they are most likely excited by the most common forward synchoronous excitation source, the mass imbalance of the rotor. Conjugate modes do not exist when the rotor system is isotropic, but they tend to emerge as the system anisotropy or asymmetry is introduced. For a general rotor system, which possesses both anisotropy and asymmetry, there exists an infinite number of modes exist so that the corresponding whirl speed chart is heavily crowded with modes. Some of them are the original forward and backward modes, but the majority of modes are associated with their modulated (with twice the rotational speed and the integer multiples) and conjugate modes, that may not be as serious as the original modes. One of the effective ways to utilize Campbell diagram is to indicate the modal strength depending upon each modal response contribution to the probable excitation sources. In this paper, modes are classified depending upon modal strength into two: strong and weak modes. The strong modes are defined such that they still remain even when the system anisotropy and asymmetry disappear. The weak modes are the modes that start appearing when the system anisotropy and asymmetry are introduced. The order of strength for the weak modes can be identified in consideration of the degree of the system anisotropy and asymmetry.