CHAPTER 2.5

STABILITY OF ROTORS IN BEARINGS

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THE NATURE OF ROTOR INSTABILITY PROBLEMS

Introduction

A rotor is said to be unstable when the shaft orbit increases with time, without apparent limit. Instability begins when the rotor speed exceeds a so-called "threshold" speed. Stable operation usually resumes when the speed is again decreased below this threshold speed. Unstable whirl motions can cause mechanical problems such as rubbing between journal and bearing, seal rubbing, and blade/stator rub contacts, and may result in substantial machine damage. Unstable motions can also themselves introduce additional dynamic forces within the bearing which stabilize the whirling at a limiting whirl radius. Such whirl motions are called "bounded" instabilities.

The most common types of unstable rotor conditions are listed in

O. Mahrenholtz (ed.), Dynamics of Rotors
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table 1. Each of these instabilities is listed with the type of rotor-bearing system in which it has most frequently been observed. Typical threshold speed conditions $\omega_{th}$ are also indicated, together with the whirl frequency $\nu$ at which the rotor tends to precess, once the unstable whirl condition has been established.

Unstable whirling is distinguished from unbalance whirling by the following features:

<table>
<thead>
<tr>
<th>Unbalance Whirling</th>
<th>Unstable Whirling</th>
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<tbody>
<tr>
<td>a. Whirl frequency</td>
<td>$\nu = \omega$</td>
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<tr>
<td>b. Threshold speed</td>
<td>none</td>
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</tbody>
</table>

(Where $\omega_c$ is the lowest critical speed of the rotor in its bearings).

The above comparison shows that unstable whirl motions are initiated beyond a certain threshold speed, and occur at a frequency $\nu$, which differs from the rotor speed $\omega$. The unbalance whirl frequency is the same as the rotation speed, i.e., $\nu = \omega$. Unstable whirling is initiated at speeds above a certain threshold speed which is never less than the lowest critical frequency of the system. Unbalance whirling has no threshold speed: it can occur at all rotor speeds, and may become resonant with some lateral mode of the system to cause the so-called "bending critical speeds."

The rotor threshold speed is a major operating parameter of the system. Beyond that speed, the rotor whirl orbit radius may grow rapidly with time in an outward spiral until some stable whirl radius is found (bounded instability) or until some constraining surface, such as bearing or seal face, is struck. Unstable motions which are bounded by the bearing or seal dynamic properties are often acceptable operating