

PARTIAL ROTOR-TO-STATOR RUB DEMONSTRATION

Robert Grissom
Bently Nevada Corporation
Minden, Nevada 89423

A rotor radial rub typically occurs in seals or at a blade tip or shroud when there is insufficient clearance, high vibration, or the shaft equilibrium position has been displaced to effectively limit the clearance (eccentricity).

There are two extreme cases of radial rubs: full annular rub; when the rotor maintains continuous contact with the seal, etc., and a partial rub; when the contact occurs during a fraction of the precession period (Fig. 1). They both involve similar physical phenomena such as friction and modification of stiffness. In partial rubs with consecutive impacts, a significant average value of radial force is generated. This results in shaft average displacement in the direction opposite the rub location.

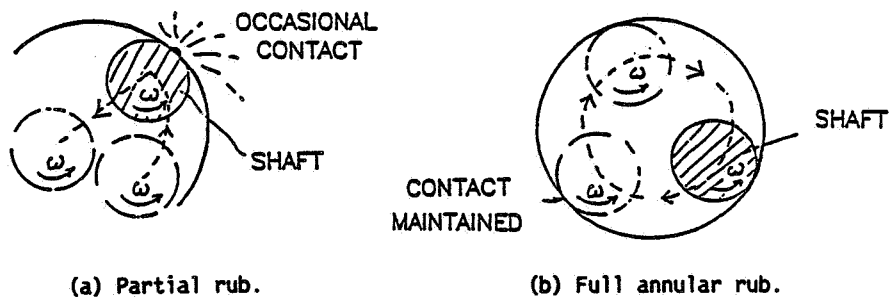


Figure 1. - Two distinct rub regimes.

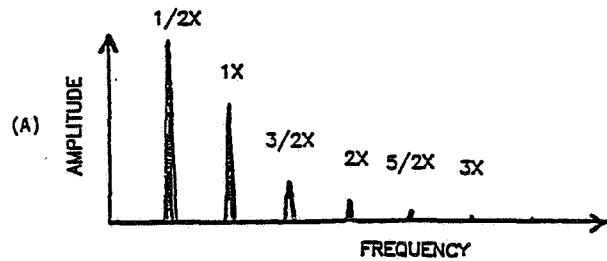
OBJECTIVE

The rotor rig demonstrates the characteristics of a partial lateral rub of varying severity and location. These characteristics include:

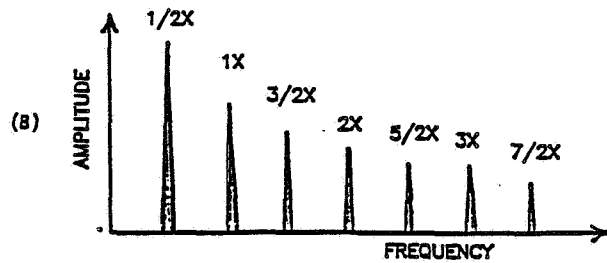
- Subharmonic components as a function of rotative speed/first balance resonance ratio and radial force (Fig. 2)
- Higher harmonic content as a function of severity (Fig. 3)
- Increased average rotor stiffness resulting in increased first balance resonance speed
- Change in overall orbital pattern as a sum of the unbalance response ($1 \times$) and subharmonic response ($1/n \times$) (Fig. 4)

When:	
$\omega < 2\omega_r$	result is 1x
$\omega \geq 2\omega_r$	result is 1x OR 1/2x
$\omega \geq 3\omega_r$	result is 1x OR 1/2x OR 1/3x
$\omega \geq 4\omega_r$	result is 1x OR 1/2x OR 1/3x OR 1/4x
← HIGHER RADIAL FORCE	

Figure 2. - Subharmonic content of rub signal as a function of rotative speed ω and radial force (ω_r is first balance resonance speed.)



(a) Light rub - harmonics attenuate quickly.



(b) Heavy rub - rich frequency spectrum (sharp impacts, friction, and other nonlinearities).

Figure 3. - Harmonic content of rub signals.

- ORBITS --- POWERFUL TOOL

- NUMBER OF $K\phi$ INDICATES 1X, 1/2X, 1/3X... RUB
- EXTERNAL LOOPS IN ORBITS INDICATE REVERSE REBOUNDED MOTION
- UNFILTERED ORBIT SHAPES INDICATE RADIAL POSITION OF RUBBING PLACE



- FILTERED ORBITS: 1X + 1/2X



- COMPLEX ORBIT SHAPE: PARTIAL RUB, SEVERAL LOCATIONS

Figure 4. - Orbital pattern characteristics, including keyphasor (once-per-turn reference signal), of a partial rub.

ROTOR RIG

The rotor rig consists of a rigidly supported long, flexible single disk shaft rotating in Oilite (oil impregnated, sintered bronze) bushings, driven by a variable speed (0-12,000 rpm) electric motor through a flexible coupling. Vertical and horizontal brass screws are used to initiate the rub (Fig. 5).

INSTRUMENTATION

X-Y proximity probes mounted at the disk provide shaft vibration data to an oscilloscope for time base and orbit presentations, and to a Digital Vector Filter (DVF 2) for bandpass filtering, speed, and phase data. An FFT spectrum analyzer is used to generate the frequency domain presentation.

MEASUREMENT PARAMETERS

First balance resonance speed (ω_r) measured with the help of spectrum analyzer (e.g., impulse testing). Time domain, orbital pattern and frequency domain for harmonic content of vibration signal measured at rotative speeds of:

- Less than $2\omega_r$
- At $2\omega_r$
- Between $2\omega_r$ and $3\omega_r$
- Above $3\omega_r$

Direction of precession of orbital components filtered at synchronous ($1\times$) speed and $1/n\times$ frequency evaluated with the help of the oscilloscope.

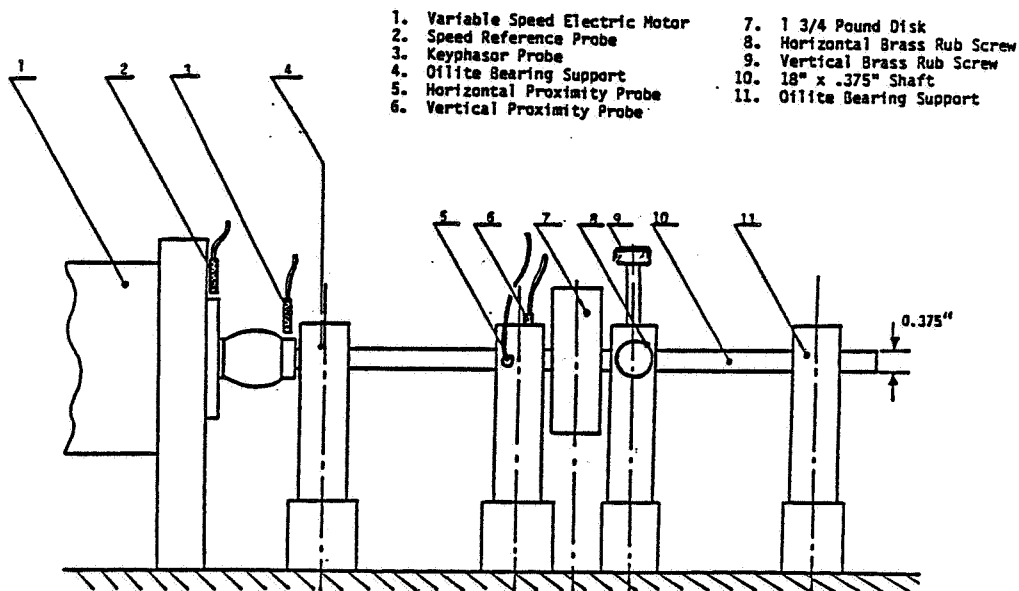


Figure 5. - Rotor rig for partial rub demonstration.

RESULTS

ORIGINAL PAGE IS
OF POOR QUALITY

Results are given in the form of cascade spectra and orbit plots including $1x$ and $1/nx$ orbit components in Figures 6 and 7.

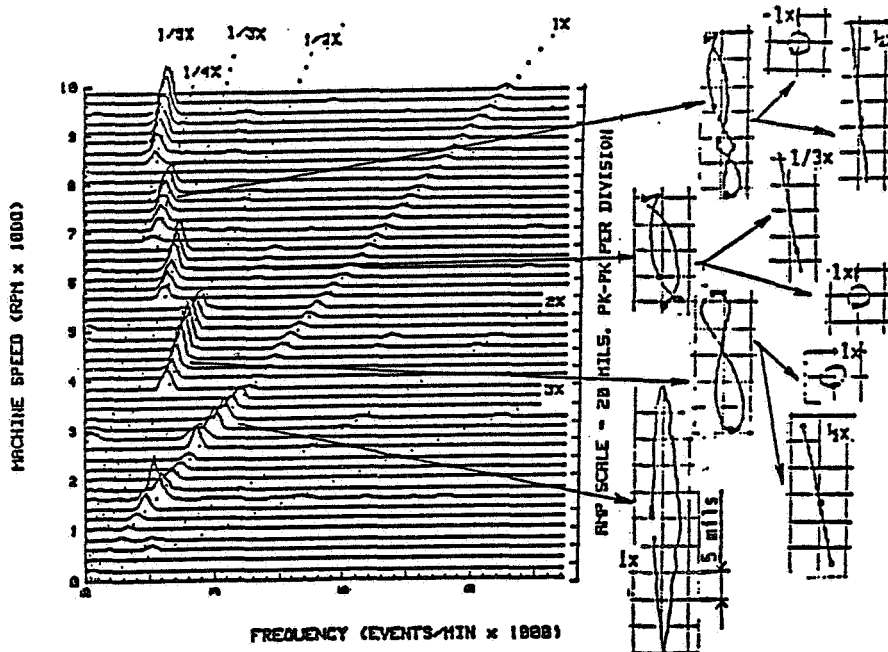


Figure 6. - Cascade spectrum and oscilloscope orbit patterns of light rubs, producing primarily subharmonic frequency components.

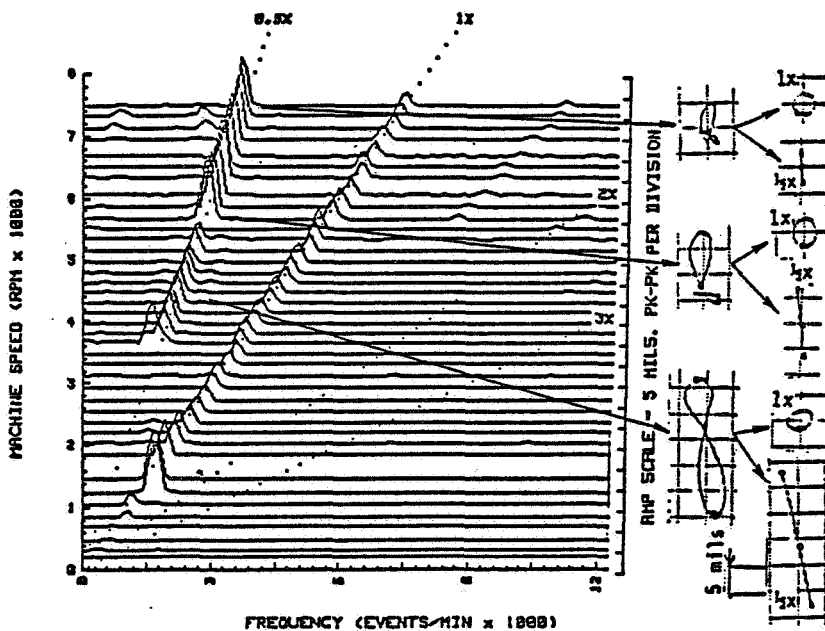


Figure 7. - Cascade spectrum and oscilloscope orbit patterns of rub with higher radial force.