Overview

• Orbit Description
• Orbital Construction
• 1X Orbits
• Phase Reference in Orbits
• Compensation
• Frequency Analysis using Orbits
• Precession in Orbits
• Orbit Shapes
• Pedestal orbits
• Field Data Collection
Orbits

• Orbit Plots show the path a rotor takes as it vibrates during operation.
• Orbits are created from the data from two orthogonal (perpendicular) measurements taken simultaneously.
• A phase reference on the rotor is used for filtering an orbit to a specific frequency and identifying frequency content from orbit plots.
• Orbits may be Direct (unfiltered), 1X or nX.
• Like Bode’ or Polar Plots, Orbits may be compensated or un-compensated.
Orbit Construction

*Reproduced from Fundamentals of Rotating Machinery Diagnostics by Donald E. Bently and Charles Hatch
Sample Orbits

Direct Orbit

1x Orbit
The 1X Orbit Due to Imbalance

• Well below the critical speed, the high spot is in phase with the heavy spot and both are on the “outside” of the orbit path.

• Above the first critical speed, the heavy spot is on the “inside” of the orbit path. The high spot, by definition, remains on the “outside”.

Below 1st Critical

Above 1st Critical

Heavy Spot
Orbit Phase Reference

• The location of the rotor when the phase reference trigger fires is indicated by the blank-bright mark on the orbit plot.

  ![Diagram](image)

  Blank-Bright trigger indicating forward precession

• The blank-bright orientation is the standard convention based on the use of the z-axis input for the trigger on an oscilloscope and a negative trigger pulse.
Orbit Vector Compensation

• Compensation allows us to remove any unwanted information from an orbit plot mathematically.
• Filtered 1X orbits can be vector compensated to subtract out the slow roll runout vectors from each probe

1X Orbit  -  1X Slow Roll Vector Orbit  =  1X Compensated Orbit
**Orbit Waveform Compensation**

Waveform compensation can be used to eliminate “glitch” in orbit data caused by surface defects on probe target areas.

A slow-roll waveform is digitally subtracted from vibration waveform data using the trigger as a reference.

The resulting waveform includes actual shaft vibration and any noise in the signal.
Orbit Plots – Loop Rules

• Loop rules can be used to determine vibration frequency when only one timing mark is present.

Vibration Frequency = \[
\frac{\# \text{ of Loops} \pm 1}{\text{Number Rotations}}
\]

No. Rotations = No. Timing Marks

Internal: Add

External: Subtract
Orbit Analysis – Frequency Content

- Multiple timing marks indicate sub-synchronous vibration
- Frequency ratio can be determined by inspection

![Graph showing orbit analysis with loops labeled Loop 1, Loop 2, Loop 3, Loop 4, Loop 5, and 1/4X Vibration.](image)
Orbit Loops

• Loops indicate the presence of non-synchronous vibration
• External loops are caused by dominant forward precession of the non-synchronous components
• Internal loops are caused by dominant reverse precession of the non-synchronous components

1X and 1/2X
Forward Precession

1X and 1/2X
Reverse Precession
**Forward and Reverse Precession**

- Forward precession is the most common vibration observed. The shaft is whirling in the same direction as rotation.
- Reverse precession happens with the shaft is whirling in the opposite direction from rotation. This can happen during rubs or between split critical speeds.
**Precession from Phase Reference**

- The normal “Blank-Bright” convention indicates forward precession
- “Bright-Blank” phase marks indicate reverse precession
- Always check probe orientation and rotation direction!
Orbit Analysis – Non-integer Components

- Shapes of orbits with non-integer multiples or sub-multiple components will be similar to exact integers but will be “skewed”
- The location of the phase reference mark will “rotate” along the orbit path
Orbit Shapes

- The shape of the orbit can be used to evaluate any restrictions to motion that influence machine vibration.

Misalignment

Increasing Severity
Orbit Shapes

- Physical restraints internal to the machine can restrict shaft motion in the bearings. This can be identified using unfiltered orbits.
Pedestal Orbits

- Orbits can be generated from pedestal measurements when accelerometers are installed on a bearing housing.
- Pedestal orbits often contain frequency content associated with housing vibration that may or may not be present if measuring shaft vibration directly.
Field Data Collection

- Avoid pitfalls during data collection:
  - Verify collection parameters are adequate for the application (Fmax, No. of lines, etc.)
  - Verify probe orientation. Does your collector setup match physical location of probes? Are your cables crossed?
  - Check for the correct rotation direction.
  - Is your phase reference a positive or negative trigger?
    - A proximity probe looking at a keyway will produce a negative trigger.
    - A key will produce a positive trigger.
    - Most laser tachometers are selectable.
Field Data

• Many software packages will allow the analyst to view orbits to identify times, speeds, or loads where significant events occur.
Field Data – Operating Deflection Shapes

• 1X orbits can be used to estimate a rotor operating deflection shape when X-Y measurements are available at multiple axial locations.
Closing

• Orbit analysis is another useful tool to keep in your Analyst Toolbox
  • Use both Direct and Filtered (1X) orbits
  • Evaluate affect of vector or waveform compensation on orbit plots
  • Review frequency content apparent in orbits
  • Evaluate the shape of the orbit and what may be influencing this
  • Look for changes in orbit plots caused by time/speed/load changes

• Like any other analysis method, good conclusions can only be made from good data