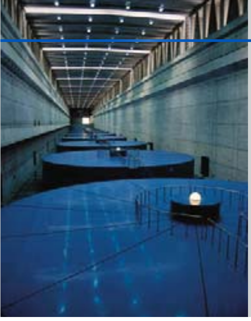

ZOOM MC/TM

VibroSystM

AN004

Techniques to Verify Rotor Stability Using Air Gap Measurements

Knowledge of rotor stability is essential in the process of evaluating machine condition and behavior using VibroSystM product data. The following techniques are used to verify overall dynamic rotor stability by evaluating if shaft displacement, rotor rim distortion, and rotor rim vibration are present. The techniques use different types of measurements and graphs available with the ZOOM software from VibroSystM. They provide a great deal of first level information on a machine or generator condition and behavior.

Before proceeding with the evaluation, it is important to note that a small air gap variation – called Acceptable Air Gap Runout (AAGR)[1] – of 0.13 mm / *5 mils* is tolerated due to normal shaft vibration and/or stator vibration as outlined in our mechanical tolerance guidelines (*Application Note AN001*).

A) Preliminary Verification

The preliminary verification quickly outlines whether a rotor is stable or not. It compares Signature[2] measurements taken at three steady[3] operating conditions: Speed No Load–Excited, Full Load, Full Load–Hot (at least 3 hours generating). If the process is successful, we can assume that the rotor shape is stable and air gap data can be used for correlation. Otherwise, further investigation (sections B, C, D) is needed to define the anomaly.

1. Compare the rotor shapes seen by all sensors for each three operating conditions individually (Figure 1). If all curves can be superimposed in each individual graph, there is stability within each measurement. If not, verify for the possibility of rotational axis displacement and/or rotor rim distortion.

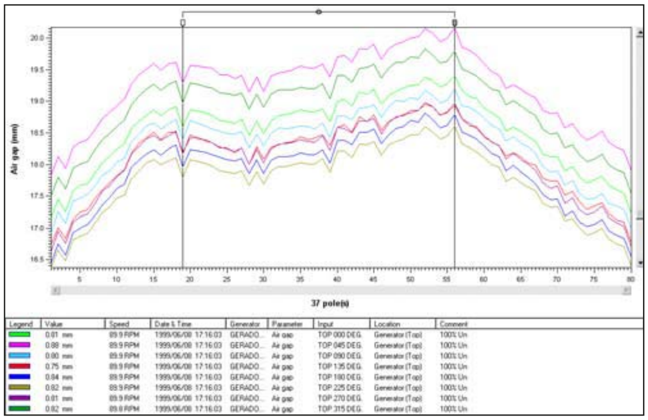

Figure 1: Stability of rotor shape seen by all four sensors at SNL–Excited traced from a Signature measurement.

2. Compare the rotor shapes measured one sensor at a time for the same three operating conditions (Figure 2). If no significant variation is visible in any area of the graphs for every sensor, it indicates rotor stability over its operating range. Otherwise, look for the possibility of rotational axis displacement and/or rotor rim distortion.

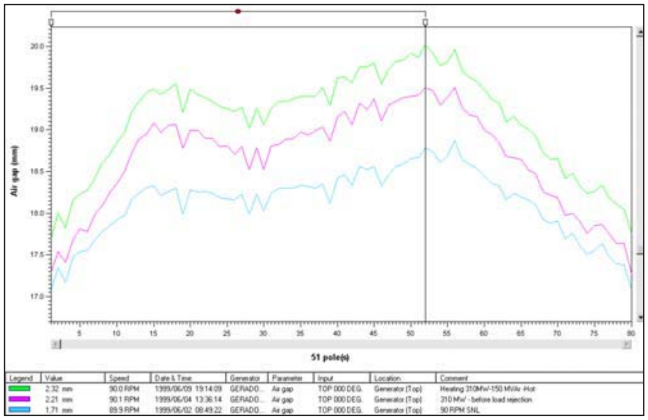

Figure 2: Stability of rotor shape seen by one sensor at four steady operating conditions traced from a Signature measurement.

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B) Detection of Rotor Axis Displacement (Shaft Runout, Magnetic Pull)

Radial displacement of the rotor rotational axis must remain stable over one machine rotation and from one measurement to another. If the axis moves, it affects the readings and it must be considered in analyzing any results. The following describes two methods of evaluating rotor axis stability:

3. Verify air gap stability over multiple rotations for each sensor. Select a Pole[4] measurement of a steady operating condition and display one pole at a time (at spider arm locations if applicable) for all sensors in best view mode (Figure 3). Repeat the process for different poles, always viewing one pole at a time.

   A stable machine should trace lines that are somewhat straight for each sensor and pole. If the maximum difference exceeds AAGR tolerance, the variation may be a sign of shaft displacement/vibration or rotor rim looseness/vibration.

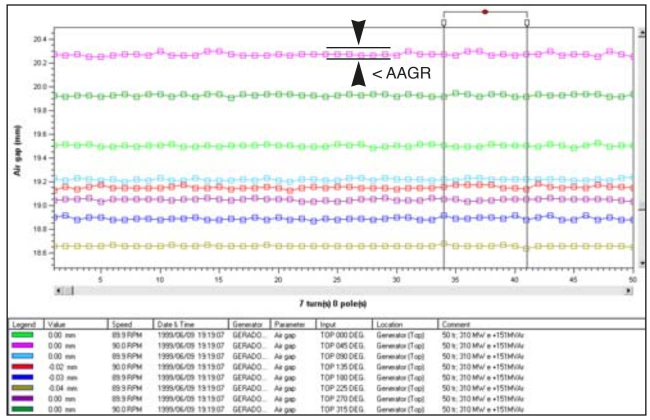

Figure 3: Pole measurement graph of all sensors for one pole from a stable generator at Full Load–Hot over 50 machine rotations.
In this example, note that the average air gap variation is less than 0.05 mm, well within the AAGR.

4. Perform the same verification using a Pole measurement taken during a transient[5] operating condition, i.e. Field Excitation (Figure 4). This should reveal any magnetic pull causing the rotor shaft to move. Theoretically, air gap reduction when the field is applied should be the same for all sensors.

   Position delta markers before and after field excitation. The maximum difference between the highest and lowest delta values (displayed in lower left corner) should not exceed AAGR tolerance. Differences may result from a combination of shaft displacement, rotor rim distortion and stator core movement. To diagnose shaft displacement, pay attention to radially opposed sensors. A small displacement (as in Figure 4) will display a reduction of different amplitude. More commonly, axis displacement will display lines that cross one another or move in opposite directions (Figure 5).

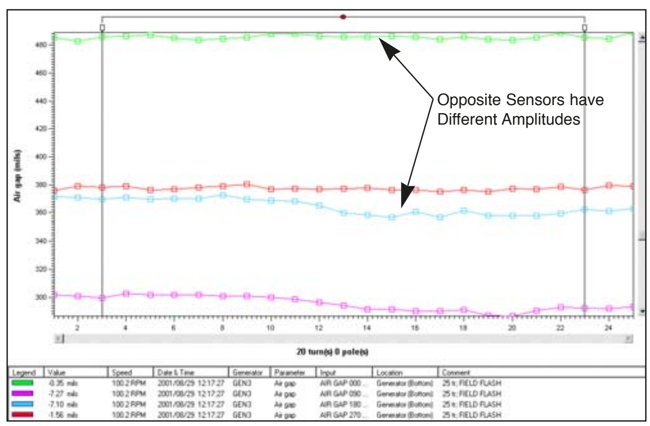

Figure 4: Pole measurement of air gap reduction during Field Excitation showing a small shaft displacement. Displacement usually is towards smallest air gap location.

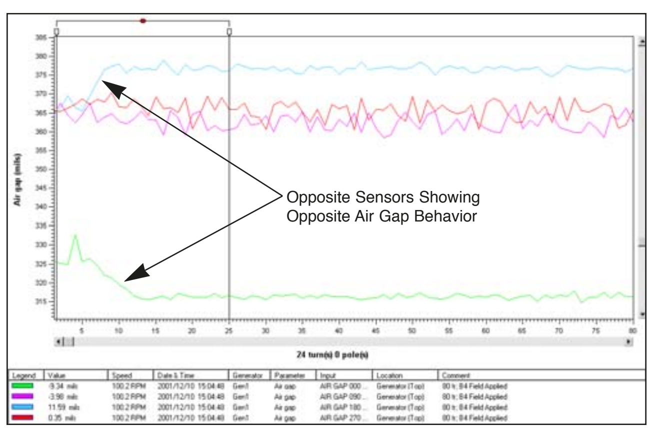

Figure 5: Typical graph of shaft displacement during Field Excitation where opposite sensors show opposite air gap behavior.

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C) Detection of Rotor Rim Distortion (Loose Section, Loss of Shrink Fit, Floating Rim)

Distortion of the rotor rim is detected primarily by comparing its shape under different operating conditions. It may be a permanent distortion (rotor rim is not well rounded or does not evolve significantly under operating conditions) or a transient one (rotor rim is loose, changes under dynamic conditions). The following verifications are designed to identify the problem, assuming rotational axis stability was confirmed in section B.

5. Repeat comparison from *Step 1* of section A (all sensors at each three operating conditions individually). If all sensors show the same irregular rotor shape, it is said stable over one machine rotation. However, if the shape is not the same for all sensors on one or more of the graphs, this indicates a cyclic rim movement/looseness. Proceed with the next verification.

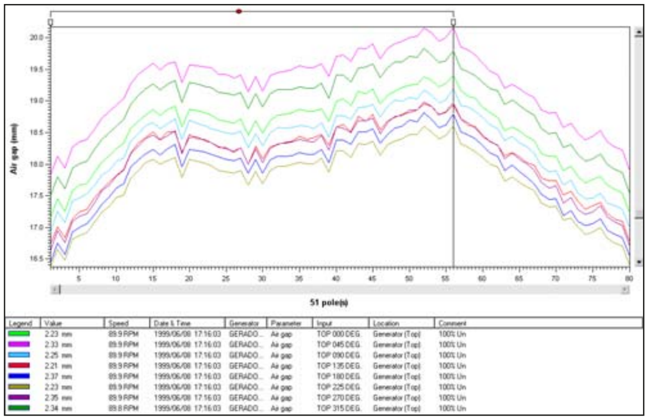

Figure 6: Signature graph showing a stable rotor shape for all sensors with a high circularity value of about 2.25 mm (12% of nominal gap)

6. Repeat comparison from *Step 2* of section A (one sensor at a time showing at least three operating conditions). If the rotor shape is different in a particular area, it is a sign of a loose rim. If the change is visible only on one or a few sensors, it may indicate, for example, a cyclic rim movement due to greater magnetic force in the smaller gap area or gravitational force in the lower section of bulb or horizontal machines (Figures 7 and 8). Otherwise, it may be a sign of other problems, such as stator core movement, which need further investigation.

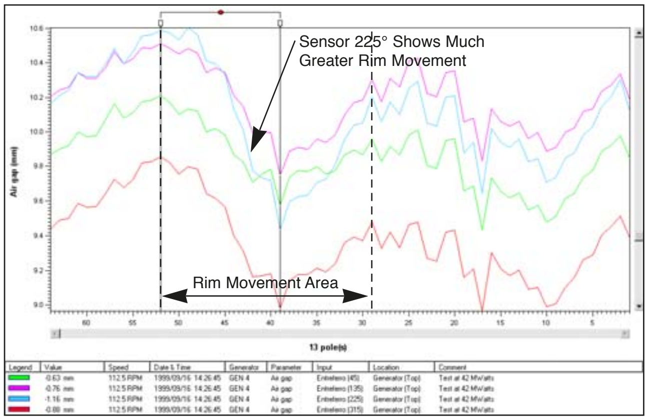

Figure 7: Signature graph showing rim distortion of a bulb unit in the area between the markers. The greatest distortion is facing the bottom sensor (225°, blue line) while the smallest is facing top sensor (45°, green line). Circularity varies by 0.53 mm between top and bottom.

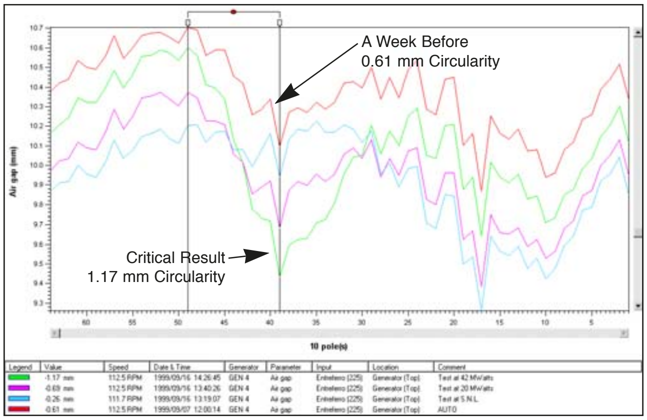

Figure 8: Signature graph showing rim distortion at different loads and compared to the 0.65 mm circularity a week before (red line).

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D) Detection of Rotor Rim Vibration

Vibration of the rotor rim is not obvious to detect. It requires two conditions: large air gap variation and low mechanical stiffness of the rim. Large air gap variation results from out-of-round and/or eccentric rotor and stator; rim mechanical stiffness depends on the thickness of the rim and the distance between spider arms. It is detected by comparing sensor readings in minute details to look for subtle variations. The vibration occurs when the field is applied and resembles noise riding over the signal. Change of state is validated by comparing results with field applied against Speed No Load (SNL) not excited.

7. Using Pole or Signature measurements, compare the rotor shape seen by all sensors at SNL and different steady operating conditions, one condition at a time. Pay close attention to the particularities of each curve throughout or over a part of the graph.

   A non-vibrating rim, as in Figure 9, displays similar curves turn after turn under any operating condition. The result of this SNL measurement serves as a dual reference confirming that: the machine is satisfactory in this operating condition and that the monitoring system is okay. Thus, any observed change is a true change of machine state.

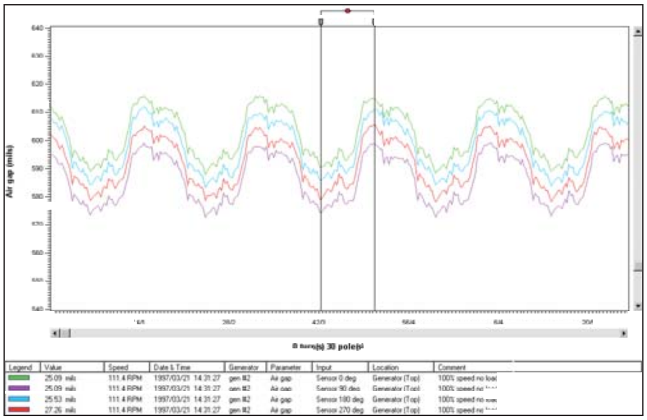

Figure 9: Pole measurement graph of non-vibrating rotor rim over five rotations at SNL. The curves of all four sensors are very similar turn after turn. The air gap variation is 6%.

   Rim vibration is revealed by small variations, similar to noise, from one curve to another and for each pole with respect to its neighboring ones (Figure 10).

   How rotor rim vibration sets apart from shaft vibration, stator core vibration or interference: 1) shaft vibration shows greater differences affecting the amplitude of the overall shape, not the details; 2) stator core vibration most likely affects only one or two sensors at different degrees provided the sensor is at the proper vibrating location on the stator core; and interference cannot affect all sensors simultaneously and uniformly.

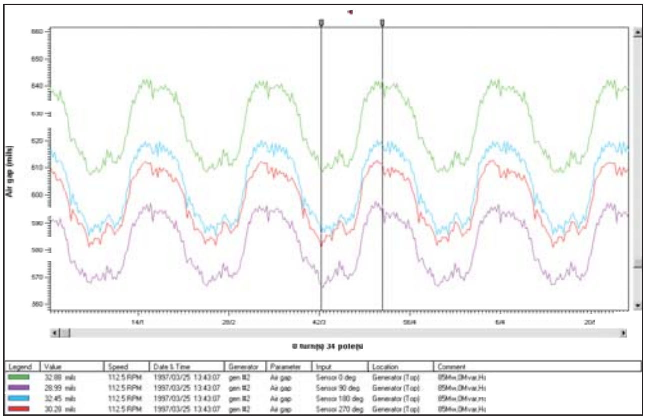

Figure 10: Graph of the same machine displaying rim vibration once under load. Notice the minute noise-like differences over each curve and consecutive rotations. The air gap variation has grown to 11.3% at Full Load-Hot.

1 *Air Gap Runout tolerance: small air gap variation of 0.13 mm / 5 mils accepted and attributed to shaft vibration and stator vibration.*

2 *Signature measurement: minimum air gap reading of each pole over one machine rotation; see Application Note AN002: "ZOOM Measurement & Graph Types".*

3 *Steady operating conditions: speed no load (SNL), SNL–excited, 25% load increments to full load–cold, full load–hot.*

4 *Pole measurement: minimum air gap reading of each pole over multiple machine rotations (10 to 100, user-set), i.e. consecutive Signature measurements; may display all poles or one pole at a time; see Application Note AN002: "ZOOM Measurement & Graph Types".*

5 *Transient operating conditions: start-up, shut-down, field excitation, load rejection, overspeed.*

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