

Technical Note RB-12.0501

Dynamic Single-Plane Balancing of an Industrial Heat Exchanger Fan using iRotorBal SP1

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Abstract

This case shows the typical vibration patterns of an imbalance rotor. Global and filtered vibrations values are analyzed together with the vibration spectra and time domain graphs. The 4-runs method was used to balance the rotor in single-plane, using one-channel for data acquisition and the iRotorBal SP1 Application for iPad from Motionics, LLC. Both solutions, analytical and graphical are presented.

1. Vibration Analysis

Global and filtered vibration levels are measured periodically to this machine, using a velocity probe attached to a magnetic base and mounted in the bearing case of the gear transmission, as shown in figure 1.

The measurement point used for vibration data acquisition (TAY) has radial direction, and is located in the bearing case of the fan side in the gear transmission, as shown in figure 2.

A digital Strobe-Lamp was used to detect the rotor speed (590 rpm), for the vibration analysis and balancing procedure.

Figure 3 shows the radial vibration spectra, with an 1X component at 590 rpm (9.84 Hz). The amplitude is very high (15.1 mm/s), indicating a very severe vibration condition. Axial vibration measurements showed very low vibration values at 1X. Figure 4 shows the time-domain vibration graph, with a sinusoidal pattern with periods equal to the rotor speed (1X).

Using 5 cycles of the sinusoid, we can obtain a very exact period value,

$$T_{avg} = \frac{T_5 - T_0}{5} = \frac{0.633s - 0.126s}{5} = 0.1014s \quad (1)$$



Figure 1: Heat Exchanger Fan analyzed

$$f = \frac{1}{T} = \frac{1}{10.14s} = 9.86Hz \quad (2)$$

This high amplitude synchronic component present in the radial vibration spectra, together with the sinusoidal pattern in the time-domain graph, and the low amplitude in the axial measurement, is the key for determining the imbalance problem.

2. Rotor Balancing Procedure

Occasionally it is necessary to balance a rotor where the phase angle is very difficult or impossible to measure. In this case the motor rotor speed is different from the fan speed, and using a phase sensor can cause some errors in the phase measurement. The 4-runs method is practical in this case, because there is no need to measure the phase angle and its precision is acceptable for this type of machine, using just one vibration sensor.

The first part of the procedure is to obtain the trial

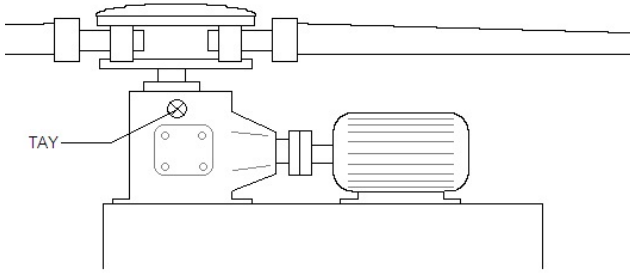


Figure 2: Measurement point location

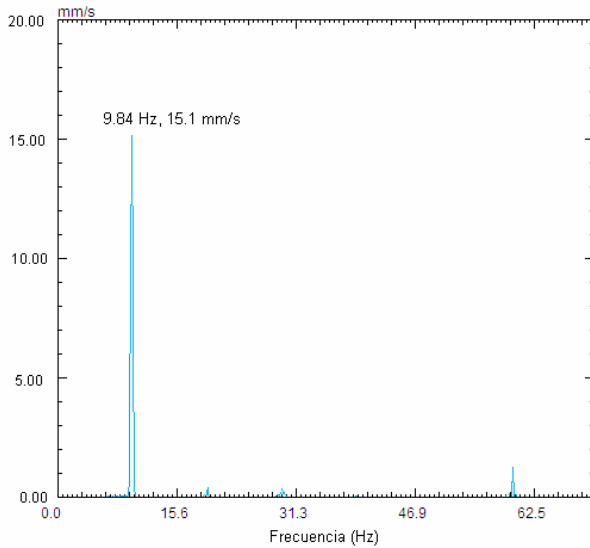


Figure 3: Vibration Spectra in TAY

weight magnitude. From equation (3):

$$5\%Cal_{weightgrs} = \frac{RotorWeight_{Kg}}{R_{cms}} * \left(\frac{2115}{RPM} \right)^2 \quad (3)$$

The procedure began attaching a 50grs trial weight at the balancing radius and in one of the 6 blades of the fan denoted with the No. 1 (0°); the vibration amplitude was measured at this point. This procedure was repeated attaching the trial weight to blades No. 3 (120°) and No. 5 (240°) and registering the vibration values. Table 1, shows the data obtained.

Figure 5, shows the polar diagram for the balancing procedure. A Circle was drawn in the origin wit a radius equal to the original vibration amplitude (15.10mm/s). Over this circumference positions 0° , 120° and 240° were selected, drawing circles in each one of them with the respective vibration amplitude radius. This 3 circumferences intersects in one common point (area) which defines the

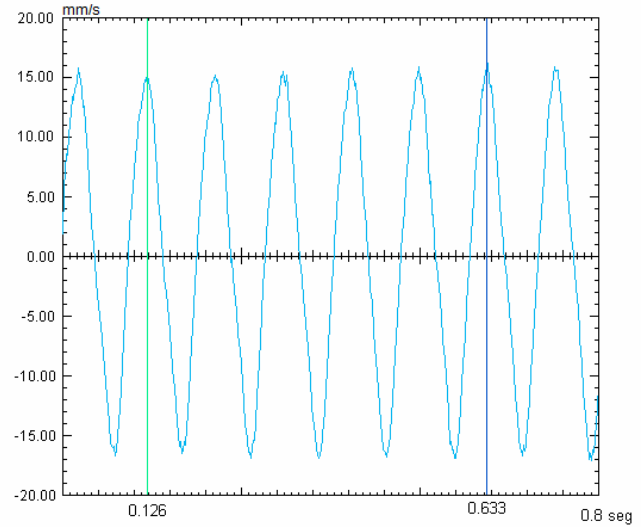


Figure 4: Time-domain graph in TAY

magnitude and direction of the correction weight vector. Using the original vibration and this resultant vector a sensibility factor is calculated to obtain the correction weight magnitude.

Table 1: 4-runs balancing data

Run No.	Vib (mm/s)	$W_{angle} (^\circ)$	Blade No.
1	15.10	-	-
2	18.40	0°	1
3	15.20	120°	3
4	12.40	240°	5

The problem can be solved analytical with equations (4) y (5):

$$W_c = \frac{W_t}{\sqrt{X^2 + Y^2}}, \quad \theta = \arctg\left(\frac{Y}{X}\right) + 180 \quad (4)$$

with,

$$X = \frac{2P_1^2 - P_2^2 - P_3^2}{6O^2} \quad \text{and} \quad Y = \frac{P_2^2 - P_3^2}{3.4641O^2} \quad (5)$$

where,

W_c : Correction Weight

W_t : Trial Weight

θ : Phase Angle

O : Original Vibration Amplitude

P_1, P_2 y P_3 : Vibration Amplitude in each run

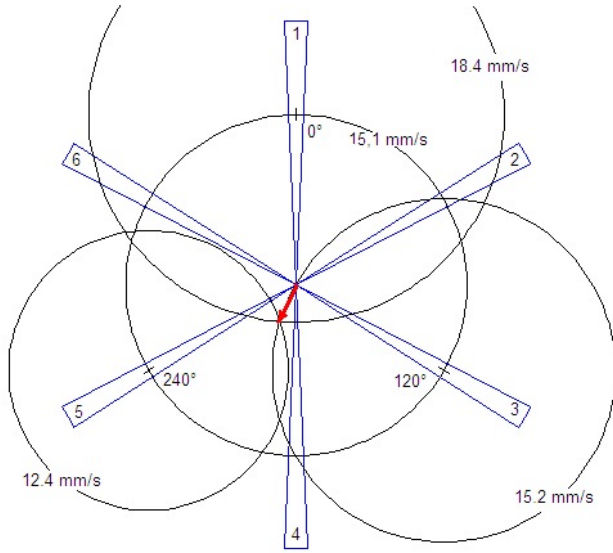


Figure 5: 4-runs polar graph

Solving equations (4) and (5), yields:

$$X = \frac{2(18.4^2) - 15.2^2 - 12.4^2}{6(15.1^2)} = 0.2137 \quad (6)$$

$$Y = \frac{15.2^2 - 12.4^2}{3.4641(15.1^2)} = 0.0978 \quad (7)$$

$$W_c = \frac{50 \text{ grs}}{\sqrt{0.2137^2 + 0.0978^2}} = 212.75 \text{ grs} \quad (8)$$

$$\theta = \arctg\left(\frac{0.0978}{0.2137}\right) + 180 = 204.6^\circ \quad (9)$$

For this case the correction weight is 212.75 grs @ 204.60°. This vector can be divided between blades 4 and 5, using a trigonometric relation:

$$W_4 = 212.75 \text{ grs} \left[\frac{\cos 204.6^\circ \sin 240^\circ - \sin 204.6^\circ \cos 240^\circ}{\cos 180^\circ \sin 240^\circ - \sin 180^\circ \cos 240^\circ} \right] \quad (10)$$

$$W_5 = 212.75 \text{ grs} \left[\frac{\sin 204.6^\circ \cos 180^\circ - \cos 204.6^\circ \sin 180^\circ}{\cos 180^\circ \sin 240^\circ - \sin 180^\circ \cos 240^\circ} \right] \quad (11)$$

Solving equations (10) and (11) with the angular values shown in figure 6, yields the correction weight for each blade: 142.3 grs. for blade 4 and 102.2 grs. for blade 5 (figure 7). Figure 8 shows the vibration spectra for point TAY after attaching the correction weights determined in

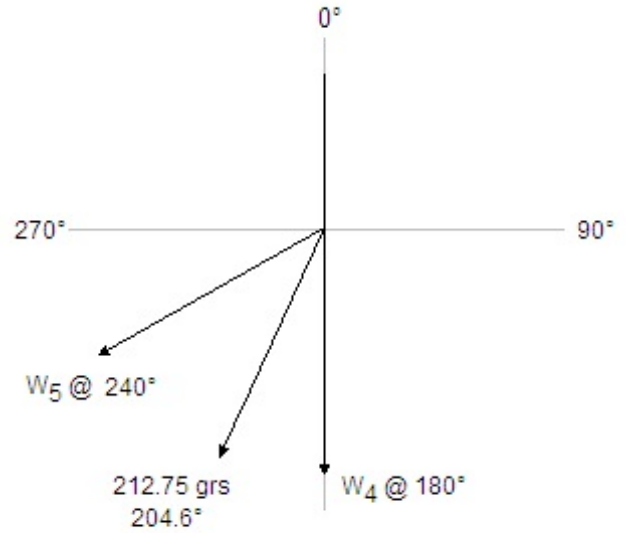


Figure 6: Mass distribution

this balancing procedure.

3. Balancing Procedure using iRotor-Bal SP1

The problem was solved using the iRotorBal SP1 Application for iPad

First the trial weight must be estimated, based on the rotor weight, radius and rpm's, by tapping on the button [Trial Weight] and then [Estimate] a dialog box appears and the data can be entered, as shown in Figure 9. In this case the estimated trial weight is 50 gr.

The trial weight and the correction weight radius are the same, in this case there is no need to use the [Define Weight Radius] option. The next step is to start the machine and tap on the [Original Vibration Amplitude] button. Then acquire the vibration by tapping on the [DAQ] button, a dialog screen appears showing the vibration spectrum (Figure 10), once the 1X peak is identified in the spectrum the amplitude can be acquired by tapping on the [Get Original Vibration Amplitude] button. The value will be transferred to the original amplitude field box, as shown in the Figure 11.

The process can be repeated by adding the trial weights

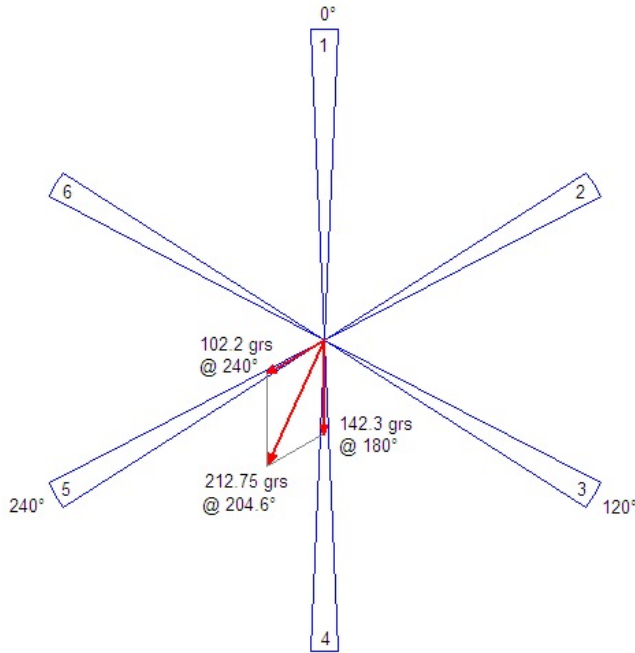


Figure 7: Resultant Correction Weights

in each blade (0, 120 and 240) and getting the 1X amplitude in the same way. After all the data is gathered, the [Correction Weight] button must be pressed and the application will calculate the result correction weight, as shown in Figure 12. In the polar graph the magnitude and angular location of the trial and correction weights can be compared.

To divide the resulting correction weight into to blades the [Weight Angular Distribution] option must be selected from the main menu. Figure 13 shows the screen with the data and results.

4. Results

After attaching the correction weights determined in the balancing procedure (142.3grs @ blade#4 and 102.2grs @ blade#5), vibration levels drop to acceptable values for this type of machine.

Figure 8 shows the vibration spectra for point TAY after balancing, using the same amplitude scale of the original vibration spectra (figure 3), for comparing vibration levels before and after balancing. 1X component dropped from 15.1mm/s to 1.8mm/s.

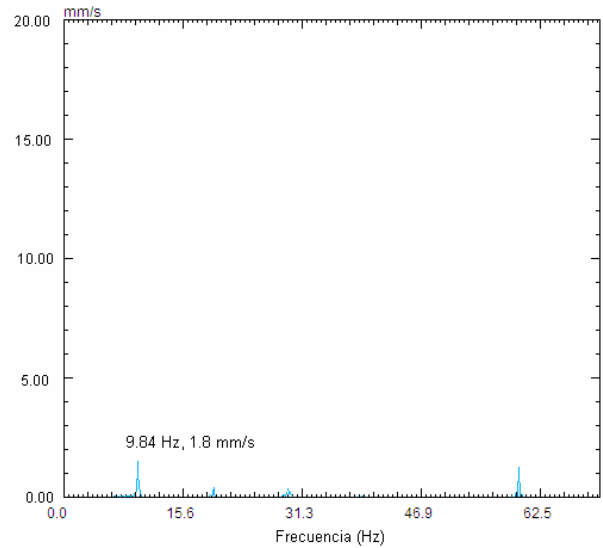


Figure 8: Vibration spectra in TAY after balancing

References

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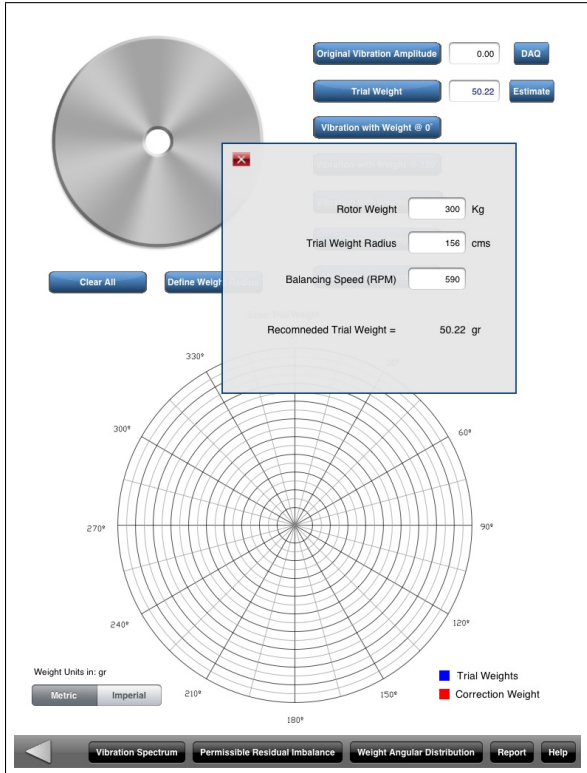


Figure 9: iRotorBalance App: Trial Weight Calculation

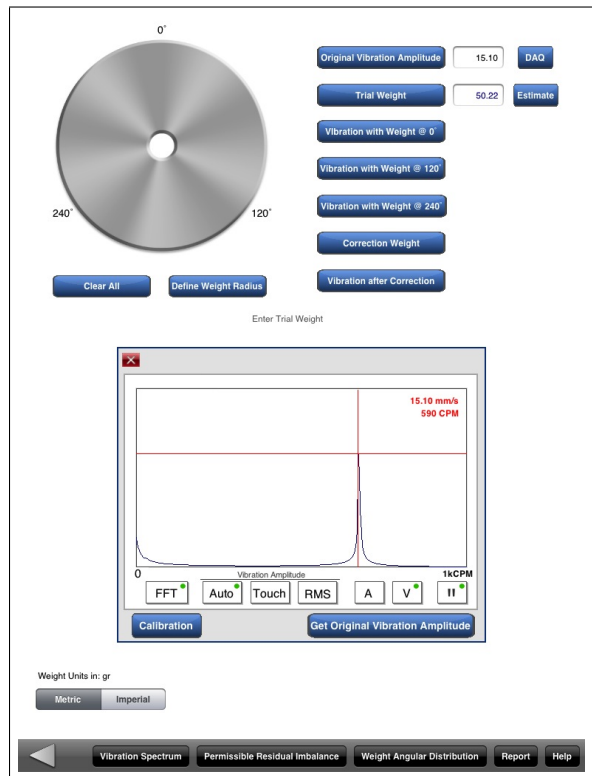


Figure 11: iRotorBalance App: Original Vibration 1X Amplitude

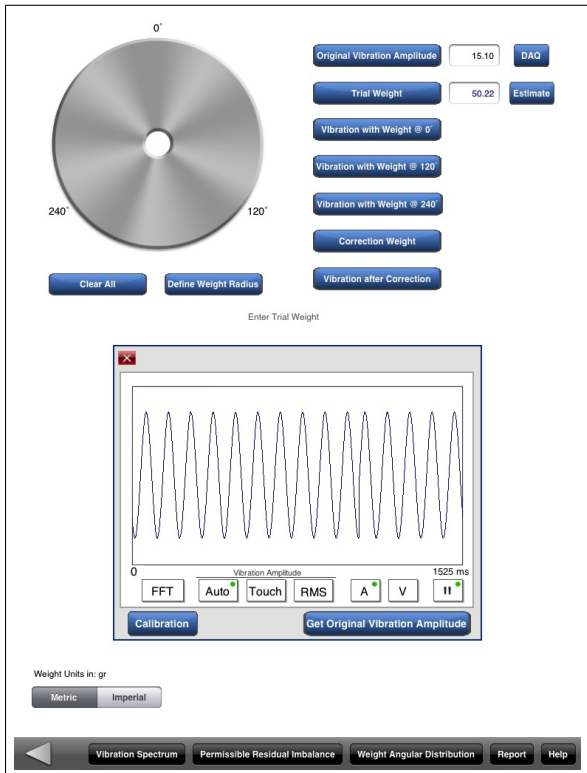


Figure 10: iRotorBalance App: Vibration Waveform

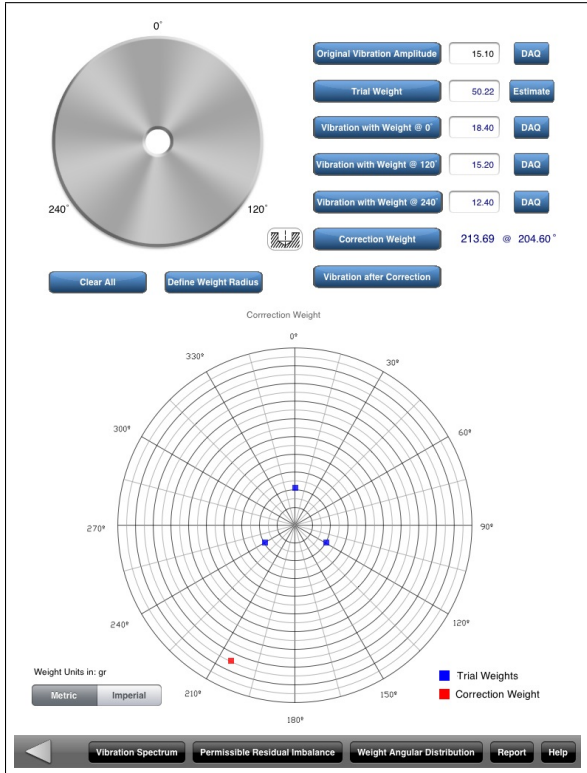


Figure 12: iRotorBalance App: Correction Weight Results

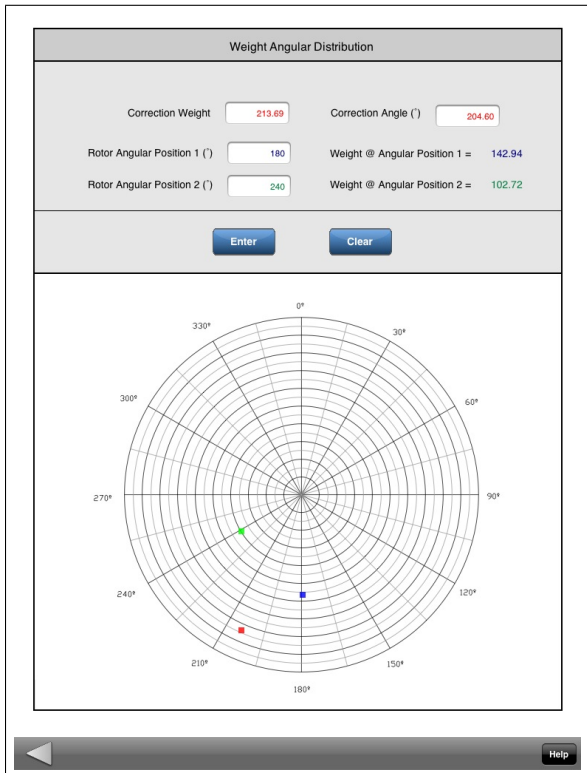


Figure 13: iRotorBalance App: Angular Mass Split