DYNEXHOBBY

TWO PLANE ROTOR BALANCING

USER ARTICLES

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SAFETY FIRST

High speed rotors contain enough energy to cause damage to people and property. Manufacturer's safety precautions MUST be adhered to during testing and operation of devices.

Safety gear must be worn during testing and operation of devices. High speed rotors can expel high velocity debris during an adverse event.

WARNING!

- ✓ Never stand in front of or alongside a spinning rotor. Stand away at a safe distance.
- ✓ Ensure bystanders are well away from the test article at a safe distance.
- ✓ NEVER run a rotor at full speed when balancing. Mounting cradles are not designed to restrain running devices at operational speeds.
- ✓ Run devices at the slowest possible speeds to avoid injury.
- ✓ Do not leave loose items nearby that can be caught by a spinning rotor.
- ✓ Secure all loose cables to prevent being caught in moving parts.
- ✓ Always stop running devices before working on them.
- ✓ Never place a limb in front of a rotor to stop it or slow it down.
- ✓ Fasten devices in secure mounts when operating at full speed. Follow the manufacturer's instructions for correct device operation.
- ✓ Impulse was **not** designed for full size vehicles or industrial applications.
- ✓ **Always** service engines in accordance with manufacturer's instructions including using authorized service agents for maintaining engines.

Before you begin

Your safety is your own responsibility, including proper use of equipment and safety gear, and determining whether you have adequate skill and experience. Improper use of modeling gear is dangerous, unless used properly and with adequate precautions, including safety gear. Some illustrative photos do not depict safety precautions or equipment, in order to show operating instructions more clearly. These products are not intended for use by children. These products are intended for radio control model applications and should never be used on industrial equipment.

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OVERVIEW

Introduction

This article demonstrates how to apply the DynexHobby Impulse device for balancing rotors in 2 planes. It **does not** demonstrate how to balance engines or devices in general as this requires specific knowledge and experience.

AT THE TIME OF WRITING THIS ARTICLE, THE SOFTWARE IS STILL UNDER DEVELOPMENT AND IS LABELLED AS A "BETA" VERSION. USERS MUST VALIDATE THEIR RESULTS INDEPENDENTLY.

Software

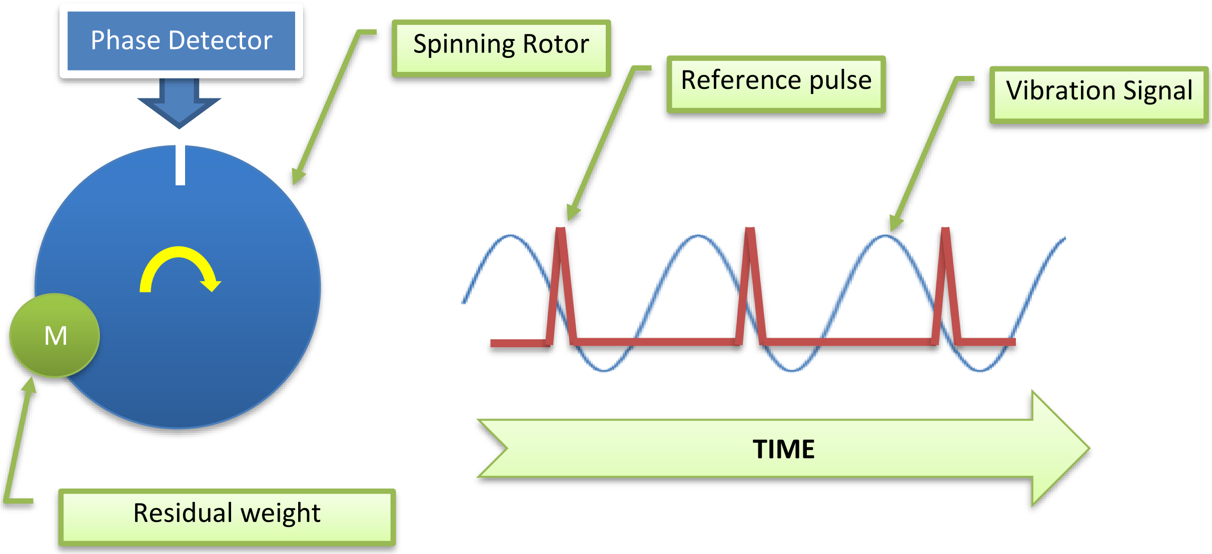
DynexHobby provides analysis tools to determine the balance of rotors. The software for this article is based on the Platinum Software which can be downloaded from www.dynexhobby.com.

Name	Image	Application
Dynex Analysis		Used for all balance methods. This application runs under Microsoft Windows. Note that .NET 4 must be installed for this application to function.

A note about how the software measures vibration for balancing

The following image illustrates how the software measures vibration amplitude and phase. Vibration amplitude is typically measured by channel 1 in the oscilloscope software. An imbalance appears as a **sinusoidal** waveform.

A marker is applied to the rotor such as a white line or a reflective strip. As the marker passes the IR Sensor, a pulse is registered. This pulse refers to a **zero** degree reference position on the rotor. The pulse is typically measured by channel 2 in the software. The time difference between the reference pulse and the sinusoidal waveform is referred to as the **phase shift**. Phase shift usually measured in **degrees** of rotation.


Phase Detector
Spinning Rotor
Reference pulse
Vibration Signal
M
Residual weight
TIME

BASIC THEORY OF BALANCING

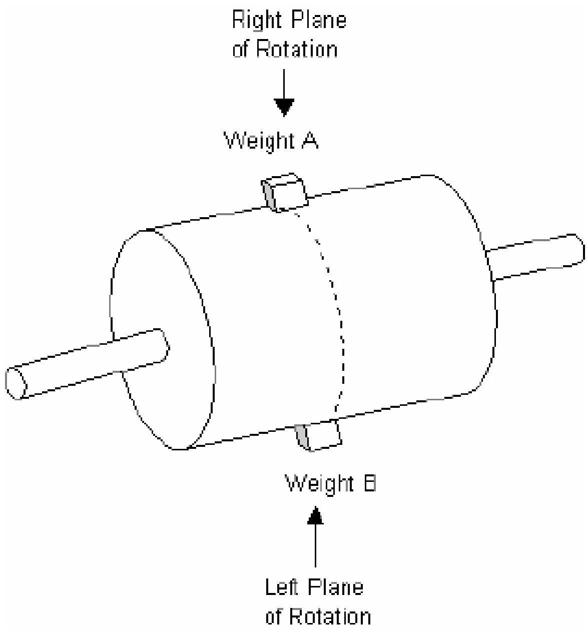
Introduction

Unbalanced rotors have a relatively high force effects on bearings. High levels of unbalance can cause vibration, deformation, power degradation, friction and can degrade service life. In the case of a rotating shaft, the unbalance causes periodical forces to the suspension system which corresponds to the rotational speed. In other words it is synchronous with rotational speed (first order). In order to balance the rotor the correct running speed should be selected in the balancing instrument. The test speed is usually much lower than the operational speed for safety reasons. The correct running speed reduces the disturbance caused by the noise, harmonics, bearings and blade frequencies.

The unbalance is radial in their line of action and it is a vector quantity. A vector has both magnitude and direction. The direction can be characterized by the phase between the unbalance vector (from the center of the shaft) and a vector to the reference point at the shaft (from the center of the shaft).

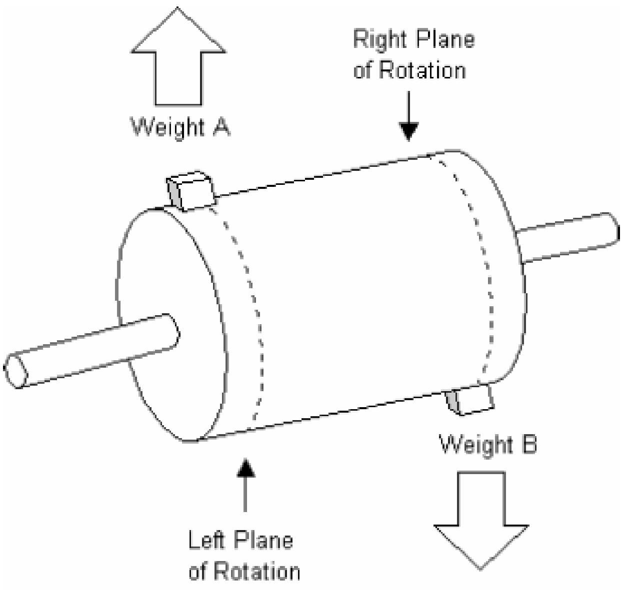
Static Unbalance

The general dynamic unbalance consists of the static **(single plane)** unbalance. This is when the mass center line is **parallel** and not coincidental with the rotational axis. This kind of balance exists in disk shape structures. It can be eliminated by a compensating weight. This method is appropriate for balancing ducted fan units, wheels or any disc shaped rotors.



Coupled Unbalance

The other type of unbalance is when a pair of weights are at two ends of the shaft but on opposite sides to each other (180°). The rotor is in static balance, but the centrifugal forces will produce a moment about the center of mass when the rotor turns. In this case, only a couple unbalance exists. The mass center line **crosses** the shaft axes at the center of gravity.

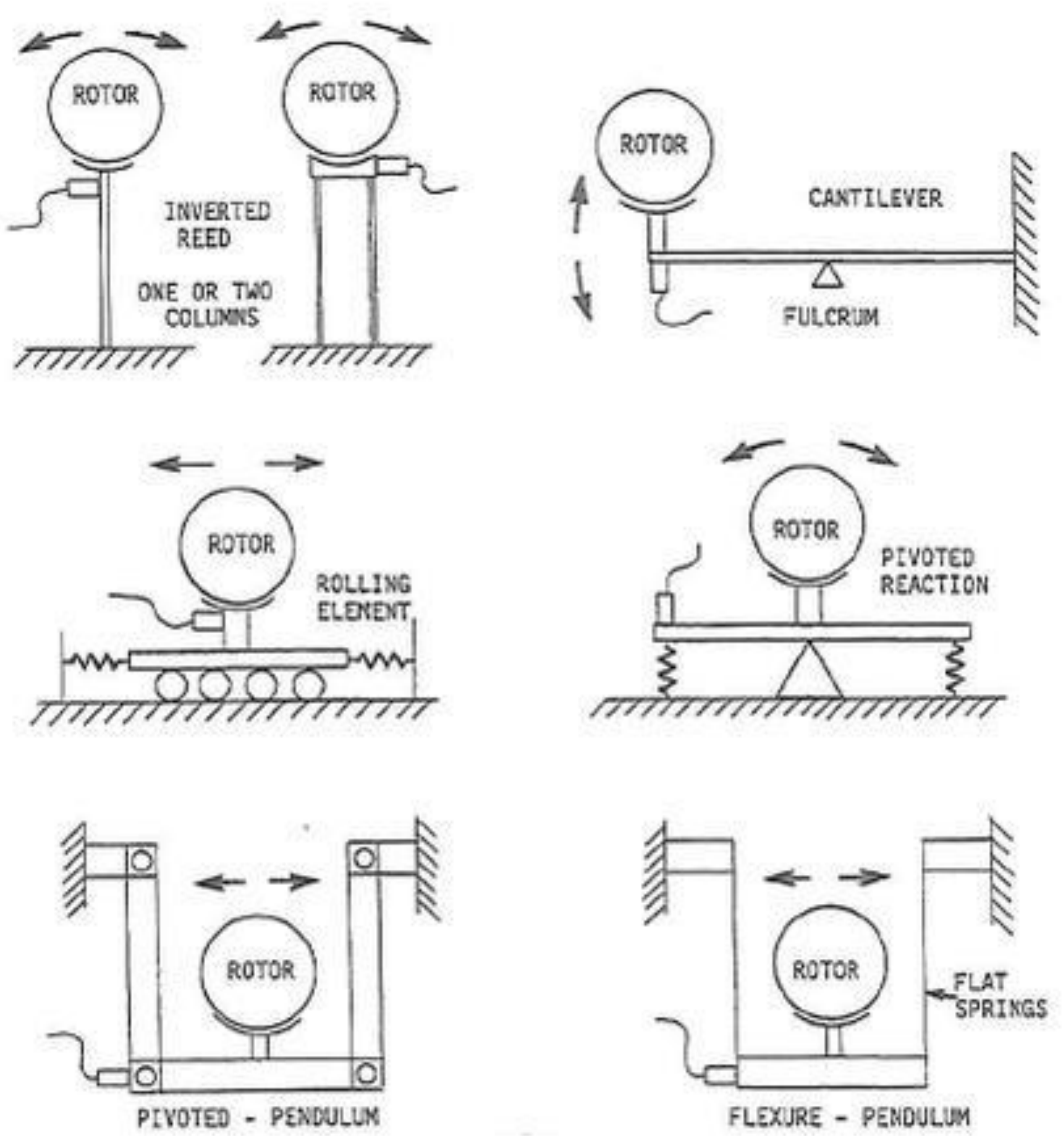


The couple unbalance can be compensated by two weights, which are positioned to counteract the couple unbalance at two planes. The ideal balancing task is to reduce the inhomogeneous mass distribution caused forces by adding or removing weights along the shaft.

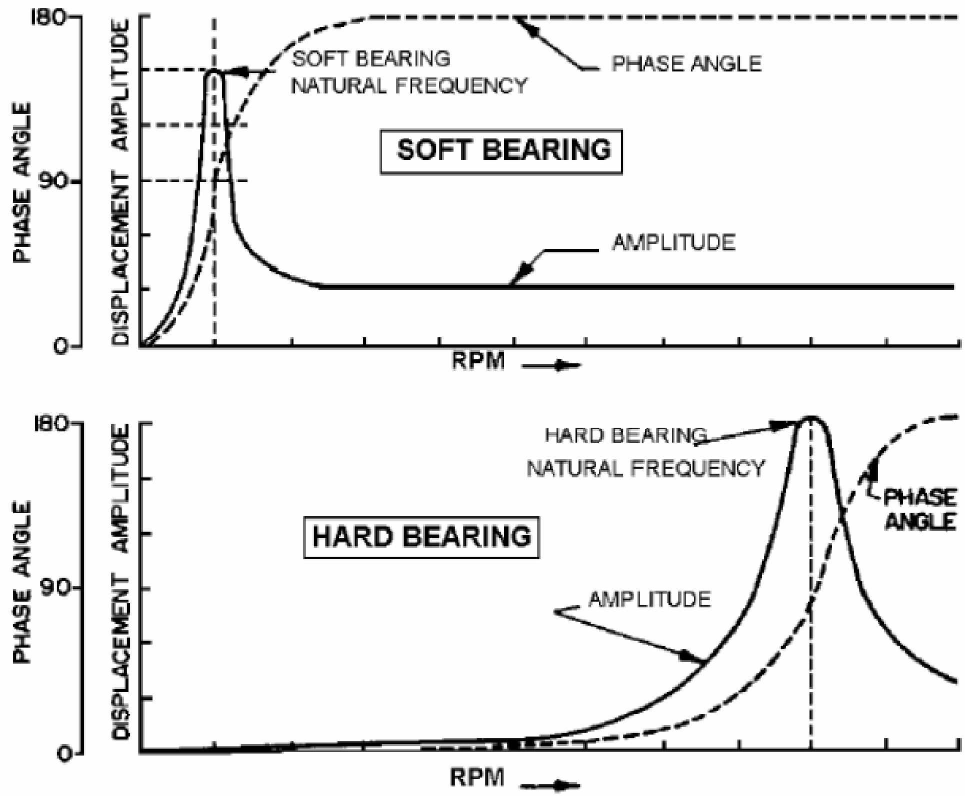
SUSPENSION SYSTEM

The suspension system or the mounting cradle is crucial for single or double plane balancing. The cradle allows the rotor system to oscillate back and forth near its natural state. The oscillation is important for the Impulse to sense vibration and analyze the imbalance. *Note: Mounting cradles are not currently supplied by DynexHobby.*

Some cradle examples are provided below.



Each suspension system has a natural mode of vibration or natural frequency. If tests are conducted at the natural frequency (a specified RPM that cause's natural vibration of the system), then the balancing results will be difficult to achieve. The following diagram illustrates this effect.



To avoid this, the following recommendations should be considered when designing mounting cradles:

- Soft suspension construction to provide a low resonance frequency.
- Run balancing at speeds above the natural frequency for soft bearing mounting systems. This would be in a region where phase angle and amplitude are flat in the charts above.
- Allow the cradle to rock smoothly using frictionless supports. Teflon bearings or magnetic supports are ideal.
- Mechanically isolate the suspension system from the bench. This can be achieved by using a foam rubber mat.

The ideal balance cradle for rotors is a soft bearing pivot-pendulum support as shown Figure 1.

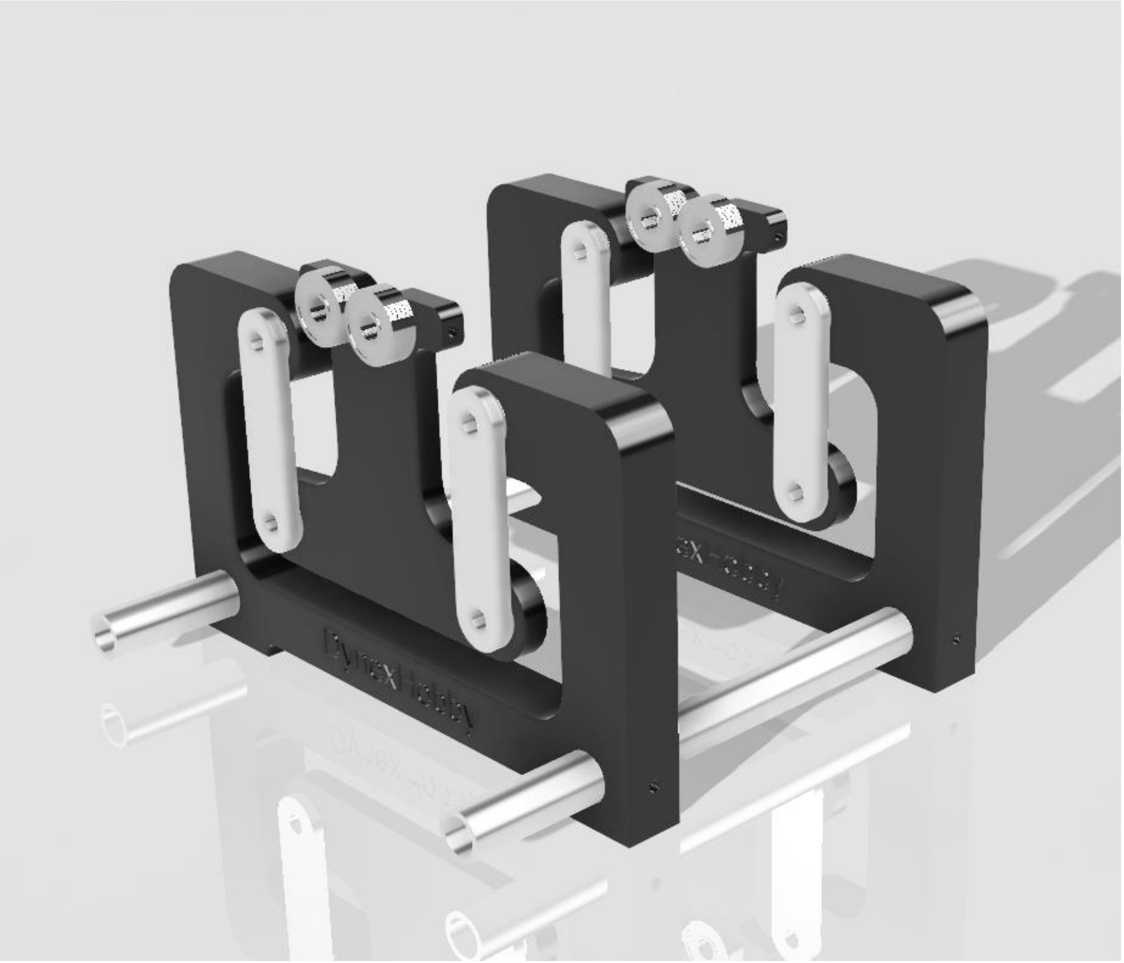


Figure 1 Sample DynexHobby Soft Bearing Balance Cradle

BASIC BALANCING SETUP

Introduction

The rotor or the complete rotor assembly can be mounted to the balance cradle. Refer to Figure 2. Some users have noted that it is easier to balance the rotor first and when a suitable result is obtained, mount the rotor inside the final housing assembly and perform a final balance.

The balance setup includes the Impulse, IR or Laser sensor setup pointing towards a marker on the compressor locknut. A compressor air hose with regulated air pressure is used to spin the rear rotor wheel.

Setup of the laser sensor can be tricky as the laser beam must be position at the correct height and angle for a good signal to be registered. Once a suitable spot is located a solid pulse signal appears on Channel 2 at regular intervals. The signal can be observed in the software. Do not move the IR/Laser sensor once setup.

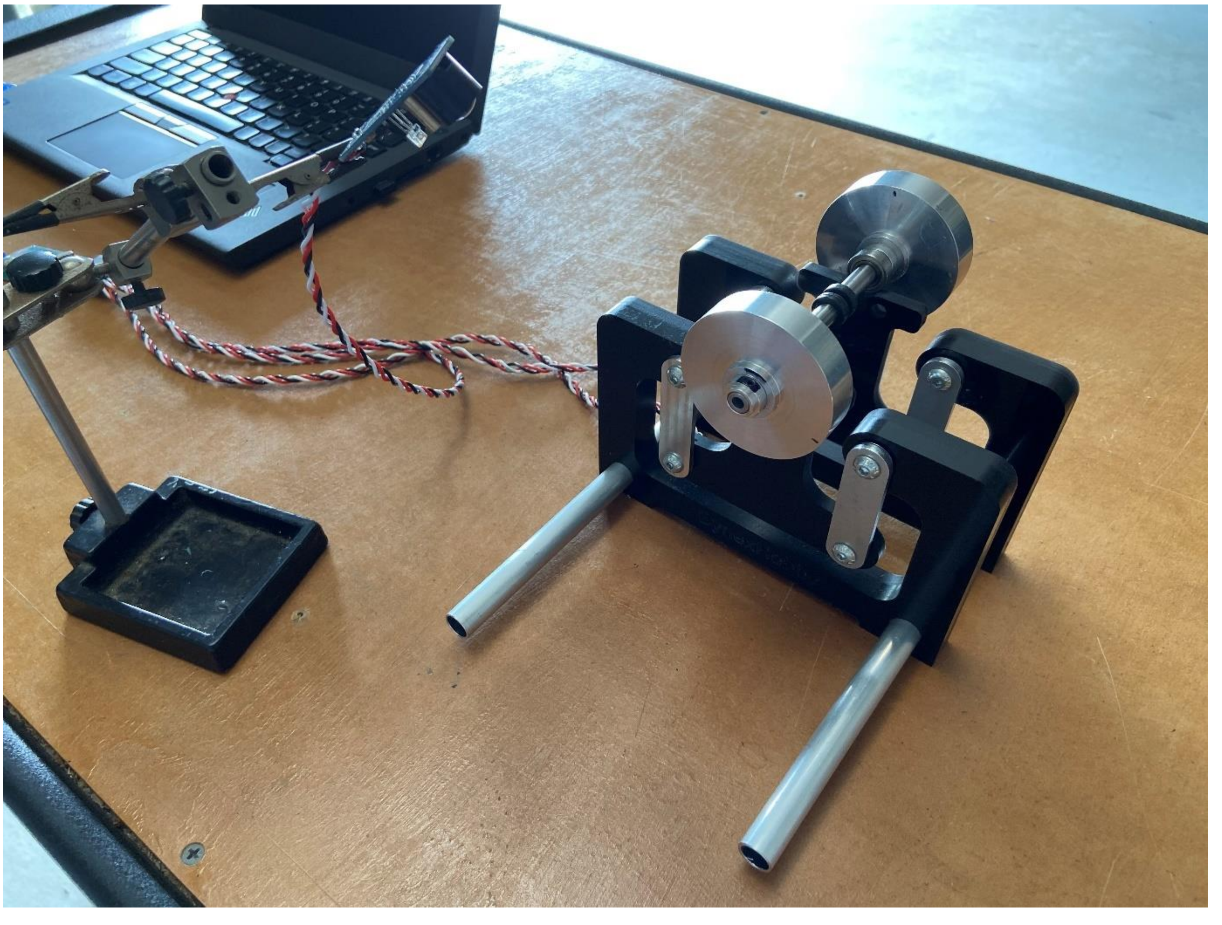


Figure 2 Rotor Balancing Setup

The accelerometer sensors are mounted to the cradle pointing in the same direction as shown in Figure 3. Ensure the Impulse is connected to a PC ready to go.

In general, Plane 1 is designated for the front wheel and Plane 2 is for the rear wheel.

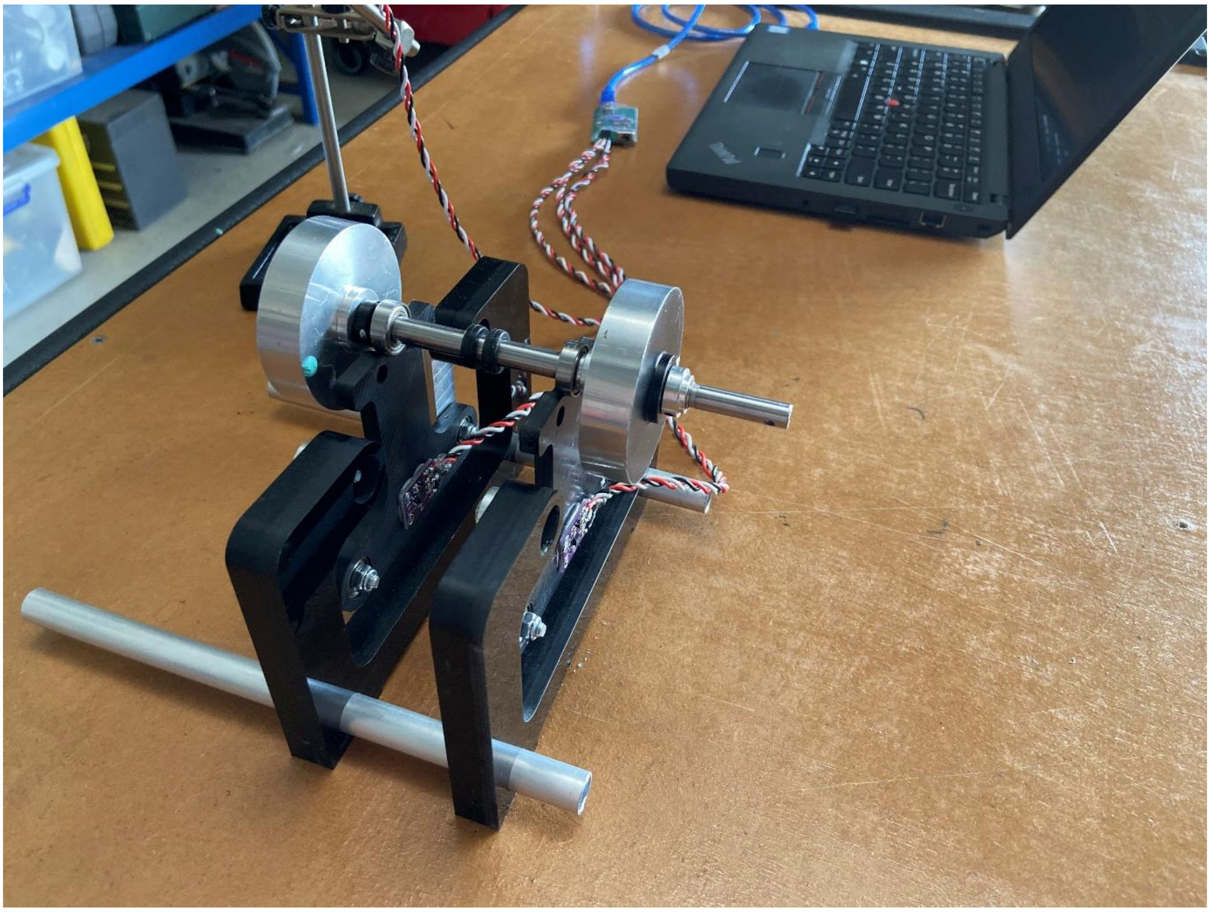


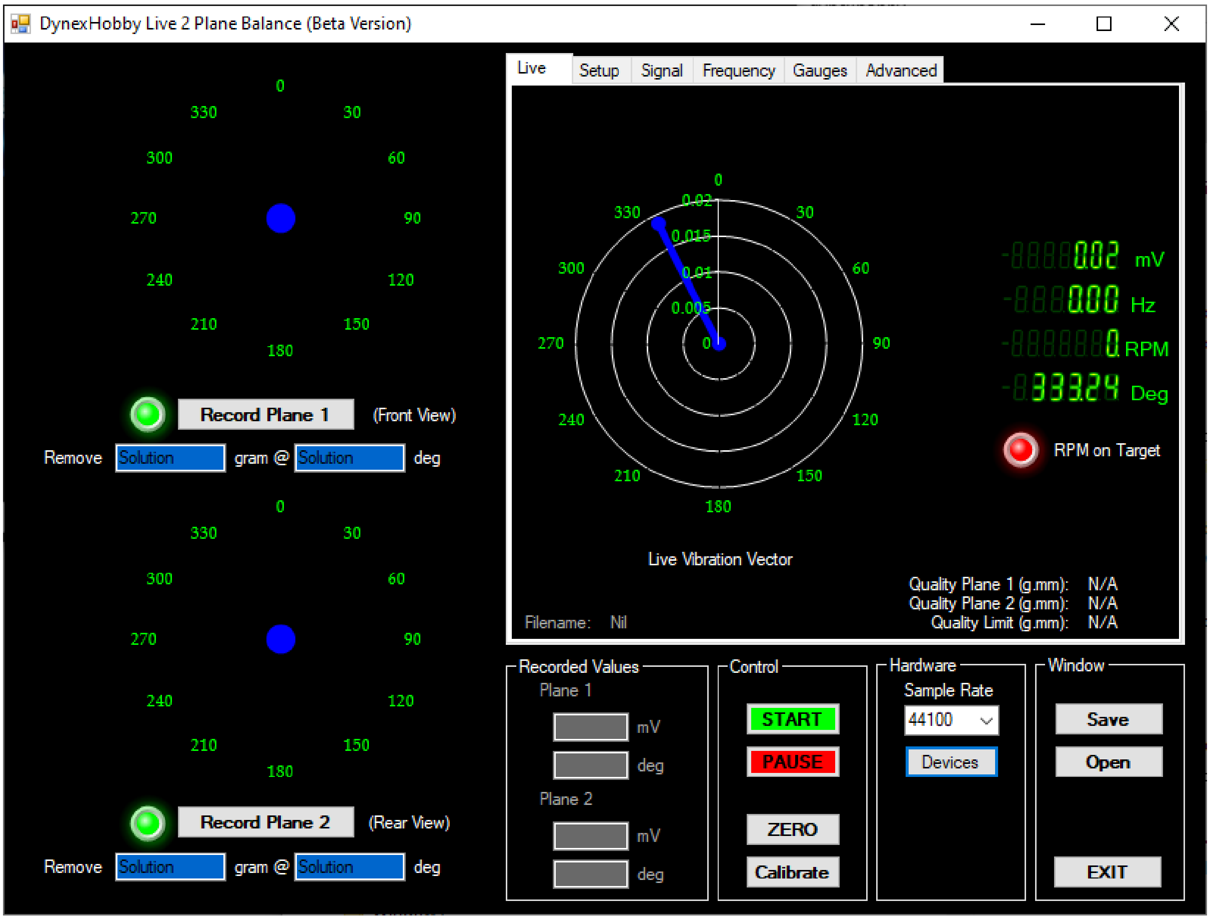
Figure 3 Rotor Balancing Setup

Note: The mechanical setup is crucial for reliable measurement. It is up to the operator to ensure they have sufficient knowledge regarding balancing setup methods. Although Figure 2, illustrates the rotor mounted directly using rotor bearings, results have shown that the play in bearings can affect measurements. It is recommended that a roller bearing type setup be considered similar to Figure 1, using special bearings that only provide point contact directly with the rotor shaft.

SOFTWARE SETUP

Introduction

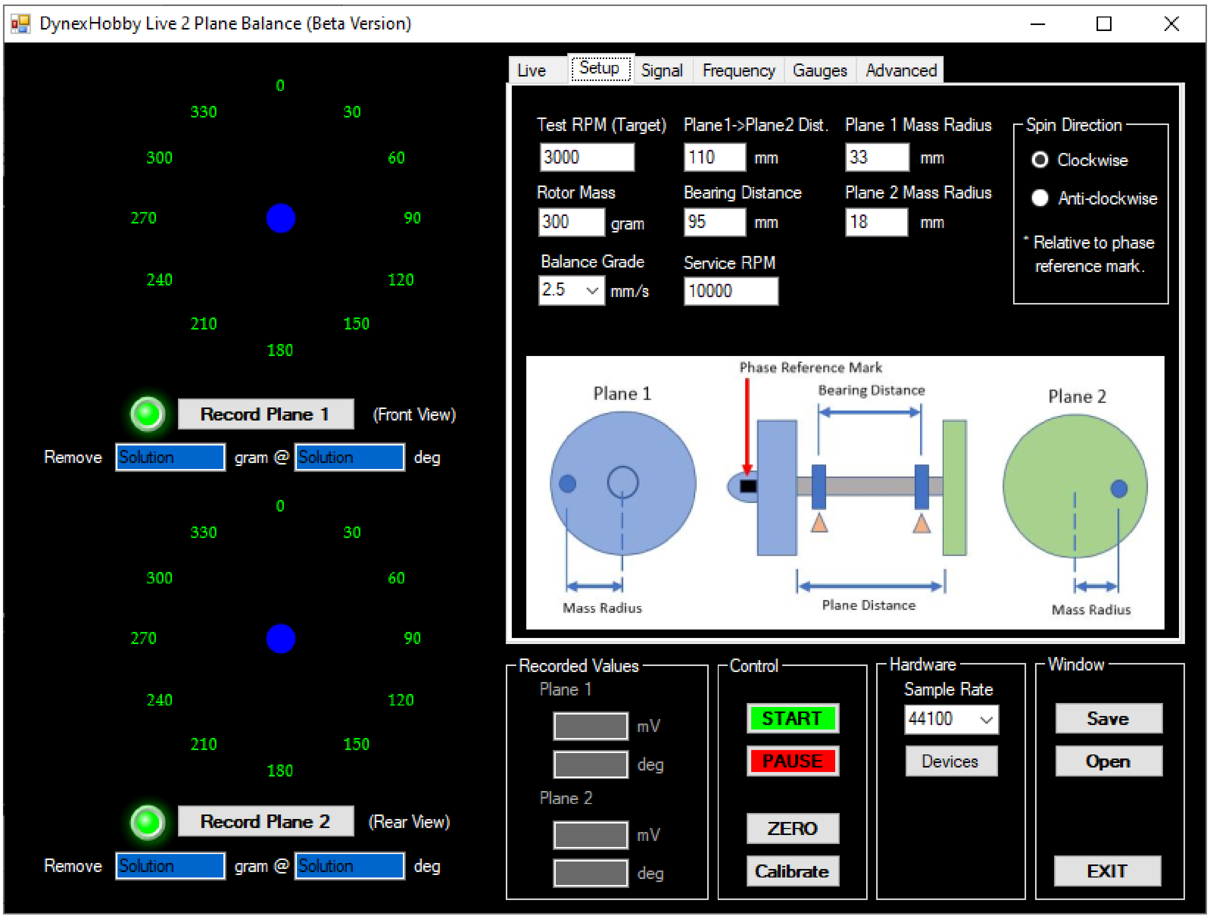
When the rotor balance software is started, the following Window appears.



Once the Window appears, click on the “Devices” button and select the “USB Audio System” and click “OK”. Now when you click on “START” the software will start reading values from Impulse.

Before performing any measurements ensure to click on “ZERO”. This will zero the vibration reading so that the noise floor is removed from measurements.

Now click on the “Rotor Setup” tab located on the top of the window. There are various parameters used to setup the analysis. A sample is shown below.



Test RPM: This is the RPM at which you will perform balancing.

Rotor Mass: This is the mass of the compressor + shaft + rotor. Bearing mass can be included.

Balance Grade: This is how fine you wish to balance. General rotor case is 2.5 mm/s.

Plane 1 ->Plane 2 Dist. : The distance between the compressor and rotor wheels.

Bearing Distance: The distance between the bearings. Use the center of the bearings as the measurement points.

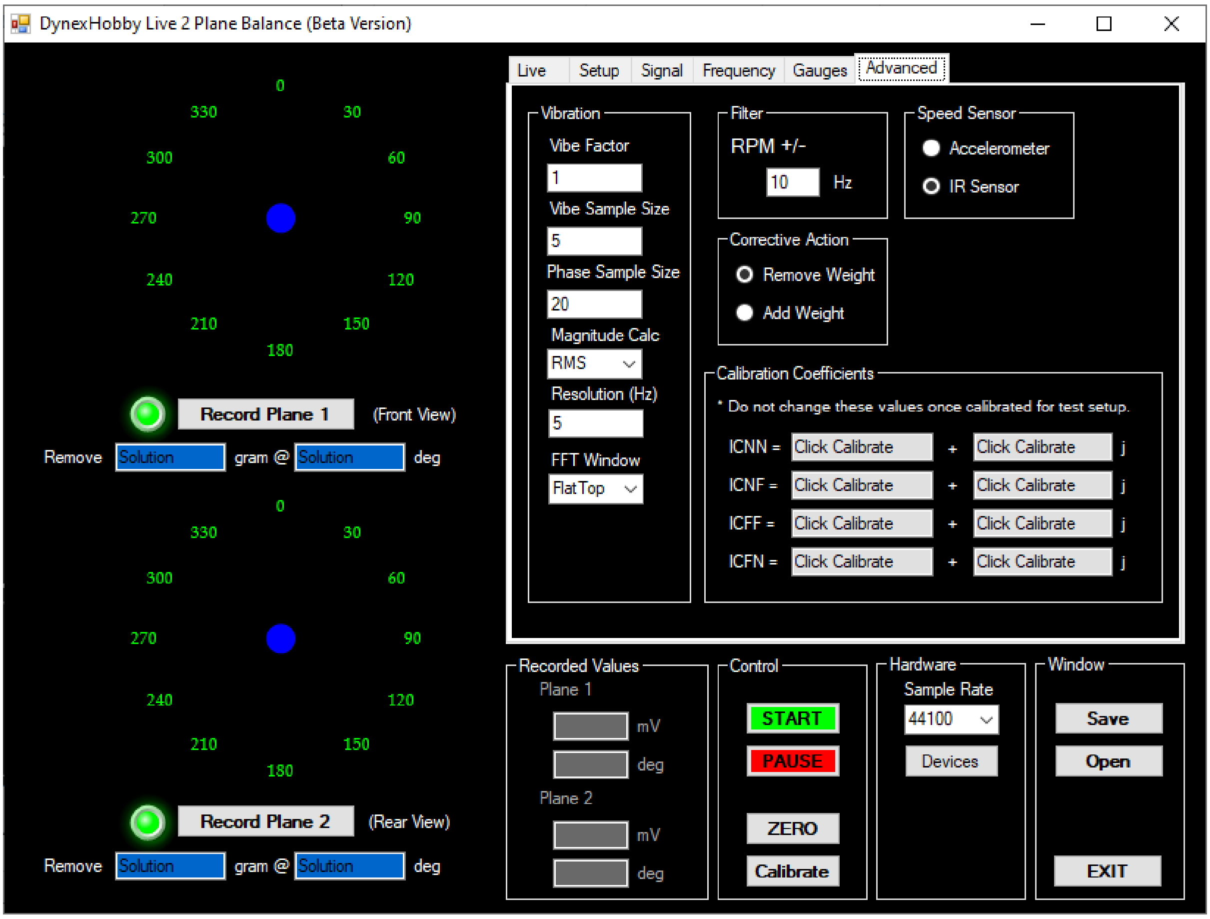
Service RPM: The maximum operational RPM when running at full power.

Plane 1 Mass Radius: The radial distance from the shaft center to where you intend to add/subtract the correction weights. Plane 1 only.

Plane 2 Mass Radius: The radial distance from the shaft center to where you intend to add/subtract the correction weights. Plane 2 only.

Spin Direction: The direction the phase reference mark spins relative to the IR or Laser sensor.

Now click on the “Advanced” tab.



Under this window the standard parameters are generally suitable for balancing. However, it is best to set the “Speed Sensor” option to “IR Sensor” as this provides stable RPM readings.

The “Corrective Action” identifies how you wish to correct for imbalance. That is, you can remove weight or add weight to each plane. When balancing for the first time, it is easier to add weight to understand the process, then when you achieve a good result, remove weight by removing material from the compressor/rotor wheels. Seek advice from a professional on how this is performed.

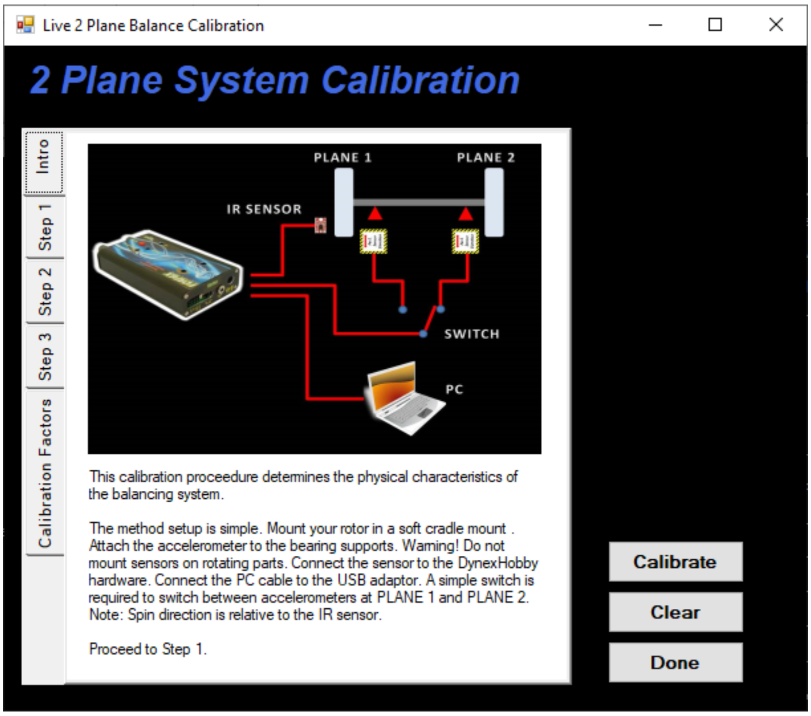
Click back to the “Live” tab ready for the next step.

CALIBRATE THE SYSTEM

Introduction

Once the setup has been established, it is now crucial to calibrate the system. Calibration is a self-learning function where the user teaches Impulse how to measure imbalance at Plane 1 and Plane 2 of the rotor.

Click on the "Calibrate" button to open the calibration window. There are a series of tabs in this window outline the steps required to calibrate the system.



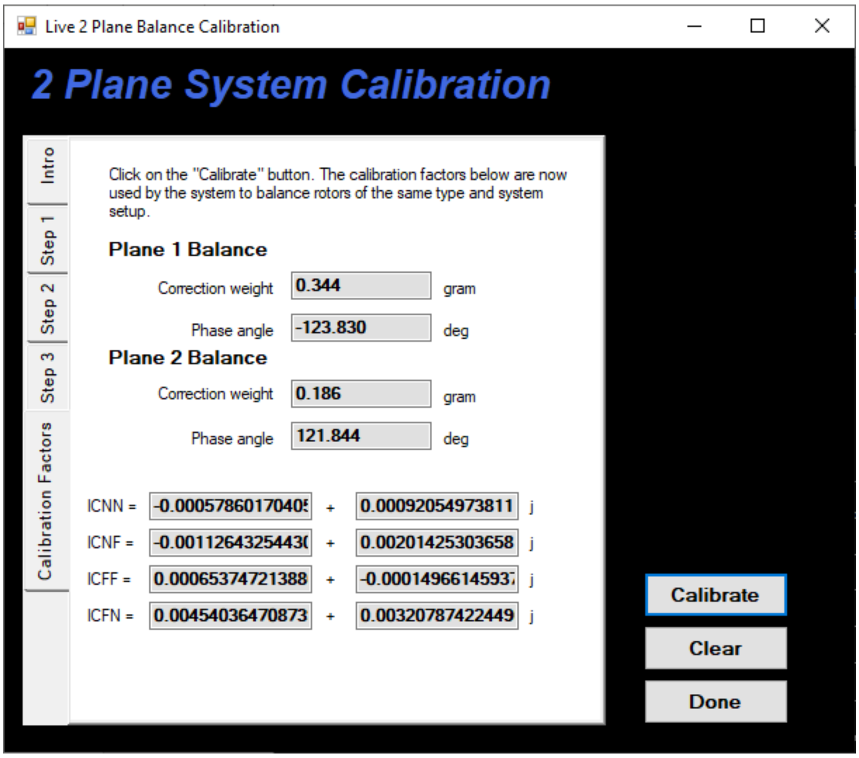
Click on "Step 1". Under this tab you will need to spin the rotor with compressed air in my case at 3000RPM. When this target speed is reached, the green LED indicator will illuminate in the Live view. A red illuminated indicator advises the user that the RPM is out of range.

Once a stable RPM is reached and the readings have stabilized, click on the "Record Plane 1 Data" button. Now on Impulse, switch to "Accel #2" and take the readings again at Plane 2 by clicking on "Record Plane 2 Data" button. Ensure readings have been stabilized before recording any data. When complete, stop spinning the rotor and switch the Impulse back to "Accel #1".

Click on the "Step 2" tab. Now place a piece of Blu Tack on the compressor wheel at the Plane 1 Mass Radius location and in line with the phase reference mark (i.e. where phase angle is zero). Again, spin the rotor at the target speed in my case 3000RPM and take recordings as done in Step 1. When complete, stop spinning the rotor and switch the Impulse back to "Accel #1".

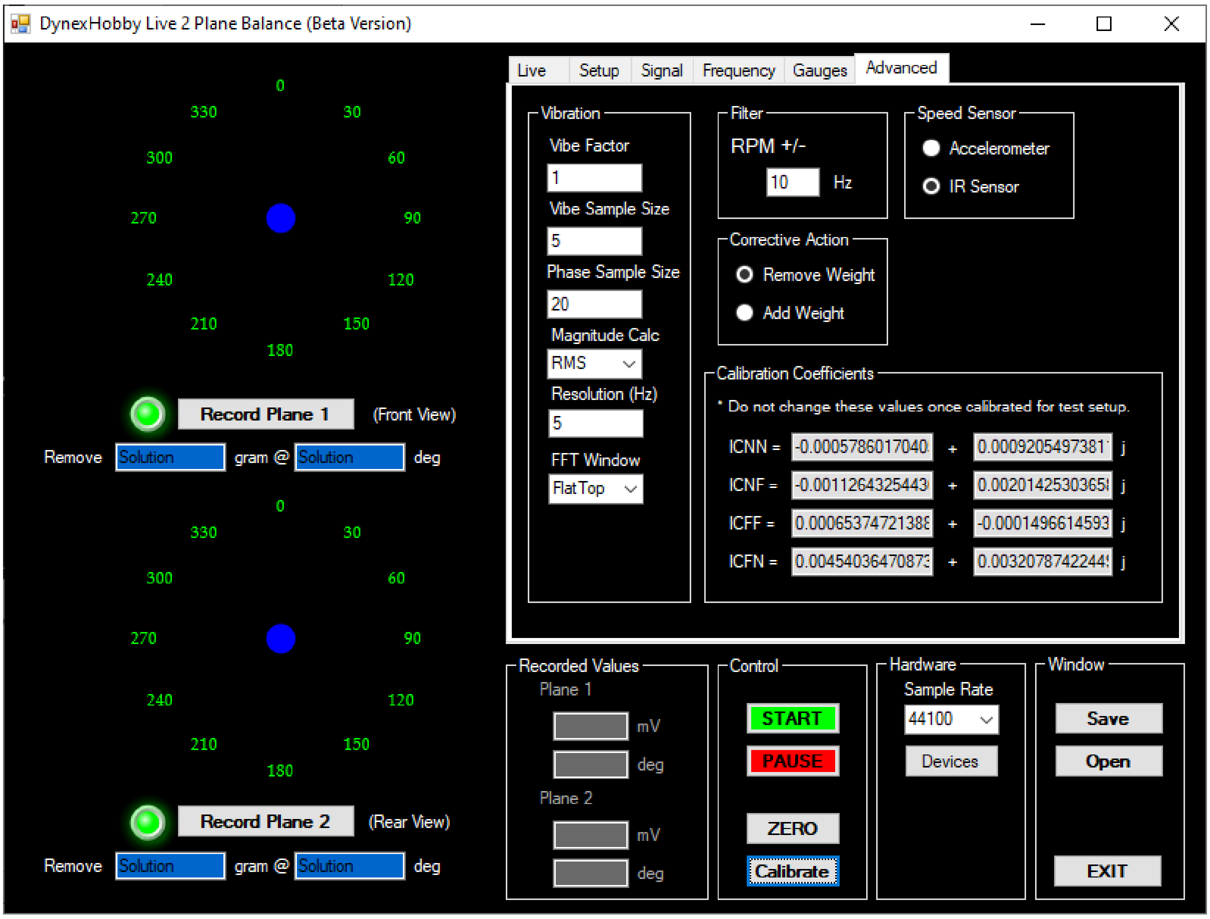
Now click on "Step 3". Remove the Blu Tack on Plane 1 and reapply it to Plane 2 on the rotor wheel at the Plane 2 Mass Radius location and in line with the phase reference mark (i.e. where phase angle is zero). Again, spin the rotor at the target speed in my case 3000RPM and take recordings as done in Step 2. When complete, stop spinning the rotor and switch the Impulse back to "Accel #1". Remove all trial weights.

Click on "Calibrate Factors" tab and then click on "Calibrate". You will see a window looking like the one below.



The matrix of numbers shown below are what is called "Influence Coefficients". These values are used by the software to build a mathematical model of your balance setup. They correlate mass and location of imbalance to the speed of your rotor. Click on the "Done" button to continue.

If you click on the "Advanced" tab again, you will see the influence coefficients stored in the main program. Click on the "Save" button to store your balance setup for future reference. You can recall the test setup any time by clicking on the "Open" button. Note, if the test setup is changed in anyway, then a new calibration is required.



A note about calibration. Calibration can be a tricky process to complete. Calibration can be sensitive to the test setup, cradle design, how trial weights are applied and how stable the readings are when recorded. It may take several attempts to achieve a good result, so please be patient with the process.

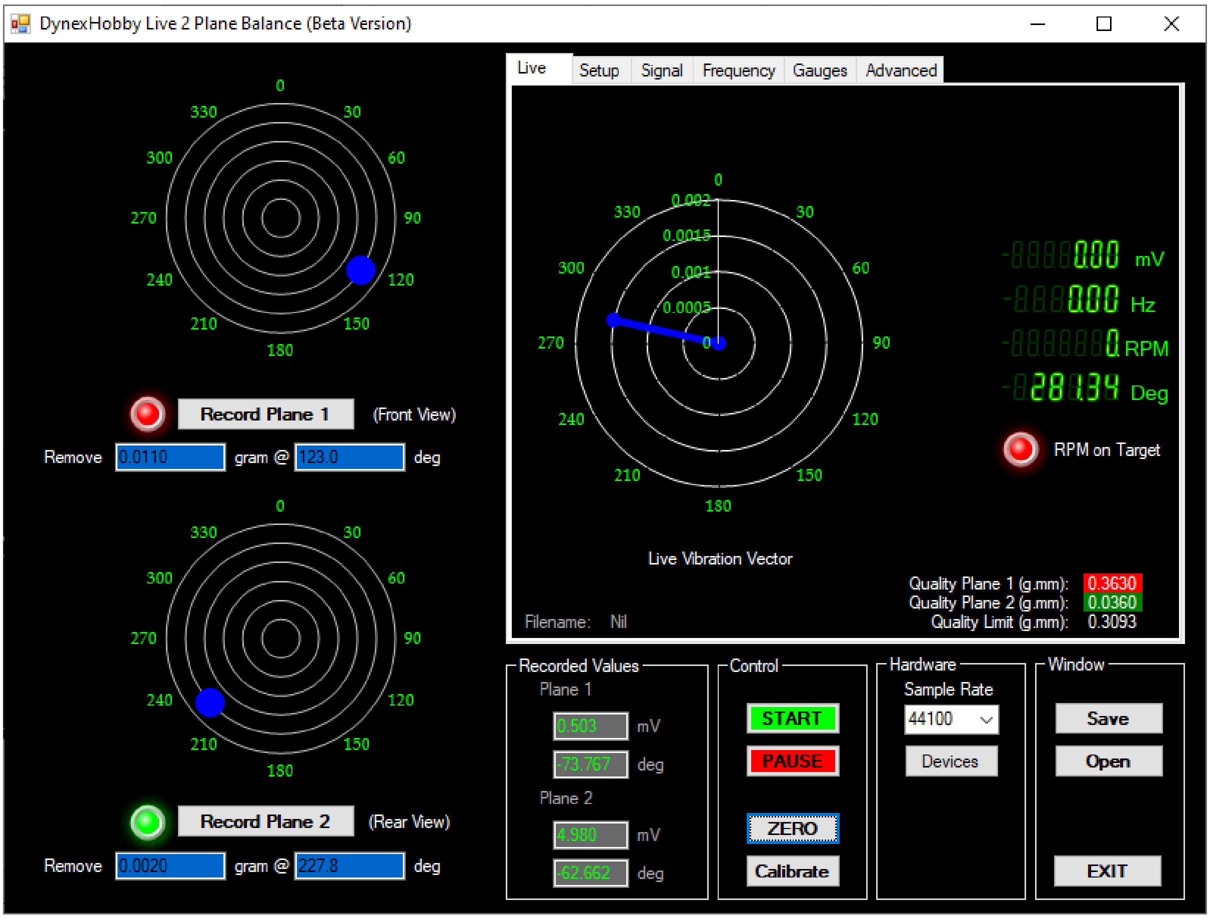
Click back to the “Live” tab to continue balancing.

PERFORM THE BALANCE

Introduction

Once the system has been calibrated, the rotor can now undergo balance measurements. Start spinning the rotor at the target speed in my case 3000RPM. Ensure that Impulse has "Accel #1" selected for Plane 1.

Once the readings have stabilized, click on the "Record Plane 1" button. Now switch the Impulse to "Accel #2" and when the readings have stabilized again, click on the "Record Plane 2" button. When complete, stop spinning the rotor and switch the Impulse back to "Accel #1". The window below is a sample balance run.



In the sample above, the red illuminated indicators shown below the plane wheel images, indicate that the current rotor is outside of an acceptable quality limit. By applying the suggested correction weights, the rotor should be rerun, and readings taken again as described above. When the readings fall within an acceptable limit, the indicators will display a green indication as shown for Plane 2.

The process for balancing requires many attempts and experience and is a difficult task to complete for the novice. Balancing high speed rotors to achieve low residual vibration is challenging and often requires knowledge and understanding of the process. If in doubt seek advice from a professional.

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