Automotive
Energy & Power Analysis
Field Service
Environmental
Research & Development

Field Balancing

Manual

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1 Introduction and Basics

Rotating machines very often produce a lot of vibration. This vibration can have many reasons like misalignment, loose parts, and also imbalance. Imbalance of a rotating part or rotor produces a force which is transferred over the bearing(s) to the structure.

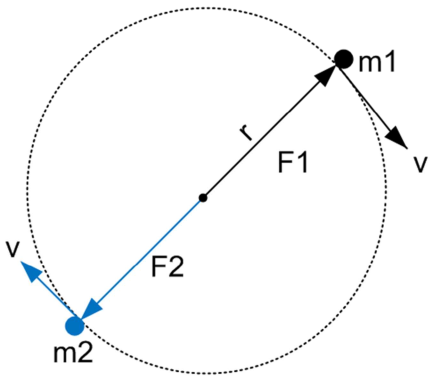
An imbalanced rotor creates a force with the rotor frequency.
So imagine a fan at 3200rpm, the unbalanced fan will create a force with a frequency of 3300rpm/60= 55rps=55Hz.

Rpm……rotations per minute
Rps…….rotations per second

The unbalance could be pictured like this.

Try to connect a part with weight of x kg on a cord, and spin it.
The spinning part will create a force with the spinning frequency.
The force is growing with the spinning frequency².

Now we add a second part on a cord, and spin it in that way that both parts are always 180deg apart from each other with the same length to the centre. Now every part would produce a force, but because the parts are opposite from each other (180deg) and have the same weight and speed the forces will cancel each other out. So no force if left to pull the rotor or the structure. The system is BALANCED. The picture below shows this.



$$Fz = m * \omega^2 * r$$ or

$$Fz = \frac{m * v^2}{r}$$

m…..kg
r……meter
v……*m/s*

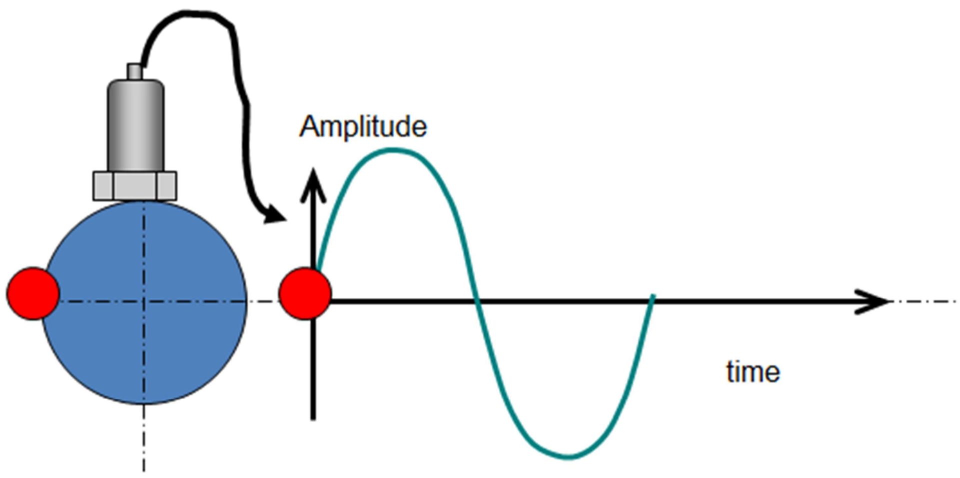
The vibration pattern is a mixture of different excitation frequencies, related to imbalance , eccentricity, bearing faults, and other excitation forces produced.

At Filed balancing the goal is to eliminate the imbalance of a machine to reduce the overall vibration level. At field balancing we do not have any information of the structure and the behaviour of it, so we could only measure the vibration pattern result.

Unless a very big unbalance is causing the main vibration, it is very hard to localize the source of the vibration.

As described above an unbalanced rotor, fan or shaft, creates a force which results in acceleration or velocity, with the rotation speed frequency, so reflecting 1st Order of the vibration.

Info: For further explanations results from Order tacking are required, please refer to Order tracking manual of DEWETRON.



1.1 Balancing

At balancing we would like to measure the unbalanced shaft and add a contra mass on the right position of the rotor, so that the forces cancel each other out.

1.2 Single Plane , Dual Plane procedure

Depending on the rotating part, either single plane balancing or dual plane balancing is used.

- Single plane is used if the shaft is so small or there is no possibility to apply mass on two planes
- Dual plane is used if also torque should be eliminated

Balancing is divided into 3 major steps.

1.2.1 Record the actual status.

First the machine is operated under normal condition. To get out the vibration caused by unbalance we extract the 1^{st} Order and Phase of the vibration signal.

1.2.2 Add trial mass

After that the machine has to be stopped, and a trial mass, which has to be chosen carefully, must be added to the rotor, and the 1^{st} Order and Phase will be recorded again.
So we add an artificial known mass to the rotor which must change the amplitude or phase significantly. If not, the trial mass is too small or should be placed at another position.

1.2.3 Correction mass

Out of the first two steps we know how the trial mass changes the unbalance of the rotor and we are able to calculate the correction mass and the position in relation to trial mass.

1.2.4 Basic calculation of single Plane

Here the basic calculation will be introduced.

At initial run we get   29 mm/s @ 285 deg
with trial mass we get   18 mm/s @ 254 deg at a trial mass of 10 gramms.

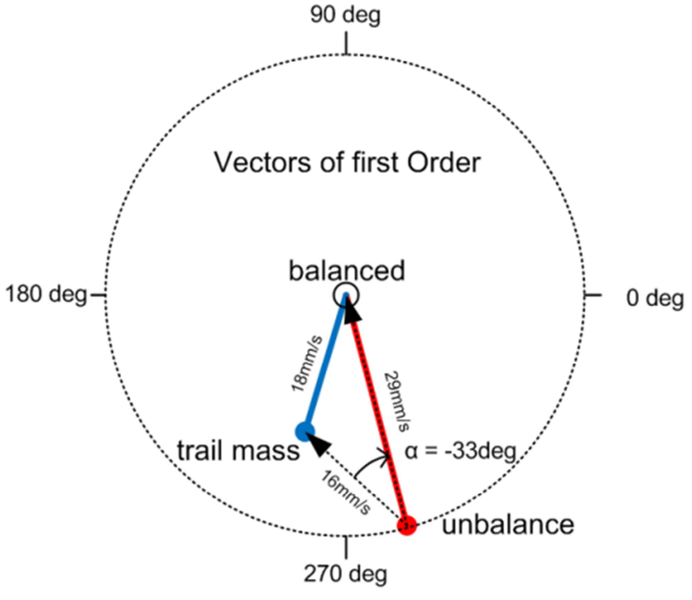
The correction mass is now calculated from the relation of the vector

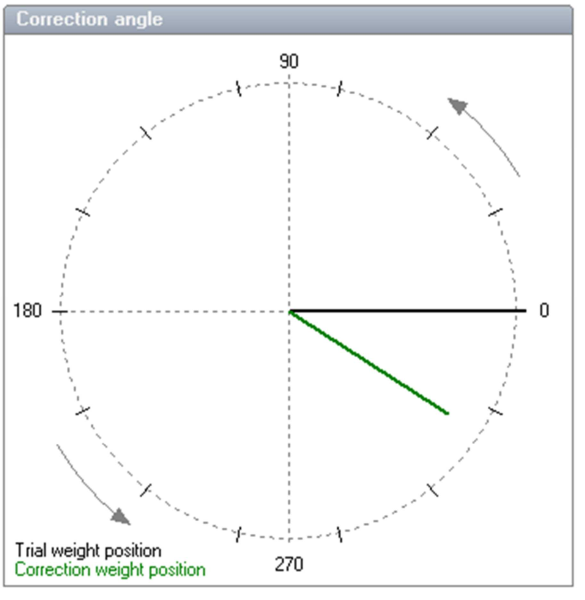
Correction mass[g] $= \frac{unbalanceto\ \ balance}{unbalance\ to\ trail\ mass}\ x\ trail\ mass[g]$

In our case $correction\ mass = \frac{29}{16} * 10g = 18g$

The correction angle α= -33 deg is the angle between the "unbalance to trial mass" and "unbalance to balanced" vector.

The correction angle is started from the trial mass position on the rotor. The angle is counted positive into the running direction of the rotor. The correction angle is -33deg
or 360 – 33 = 327deg.





2 The measurement

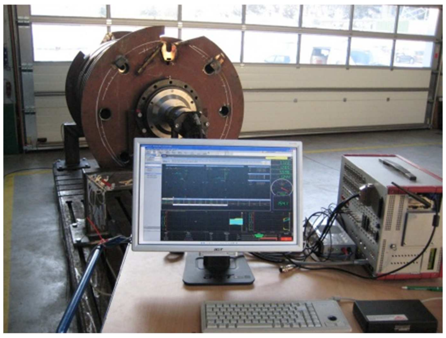
2.1 What do we need

- 1x Acceleration sensor to measure the vibration single plane balancing
- 2x Acceleration sensors to measure the vibration dual plane balancing
- RPM sensor to measure rpm
- Order tracking Module to extract 1st Order and Phase
- Balancing Visual control which guides trough balancing procedure

Order tracking Module needs RPM channel, which also must deliver a pulse per revolution so that phase could be extracted, too.

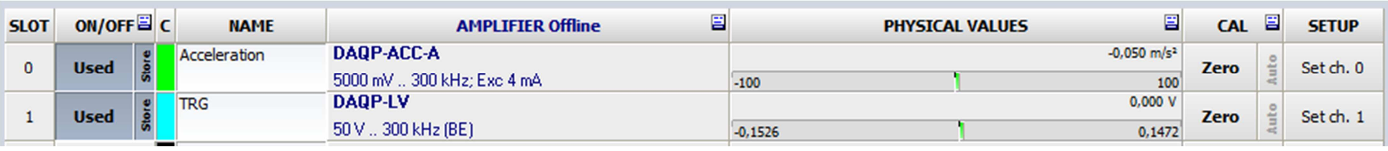
So Tacho Probe with 1 Pulse per revolution, or and Encoder with zero pulse or even CDM Sensor with Trigger Pulse would be suitable for it.

It is recommend to use the Tacho Probe because it is a very easy to setup probe. Only a colour mark, screw head or flute will give 1 pulse/rev which is sufficient for this.
This probe is also used here in this example.

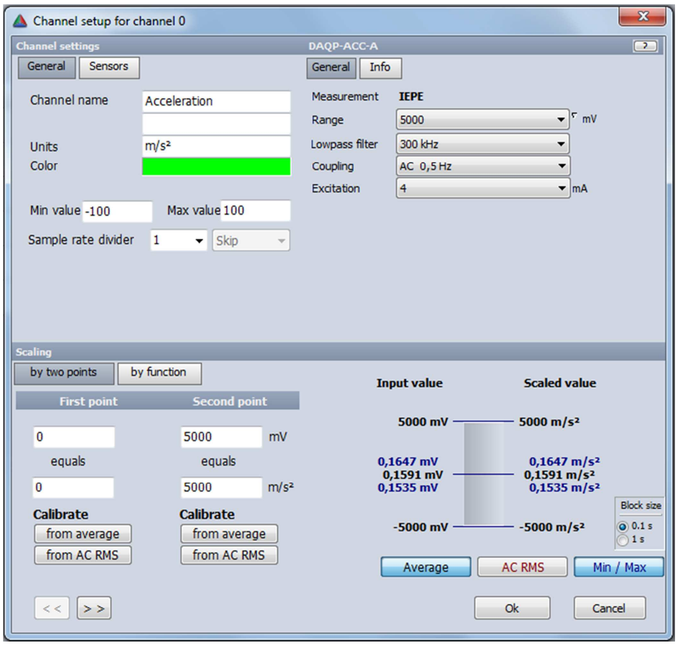


2.2 The analogue Setup

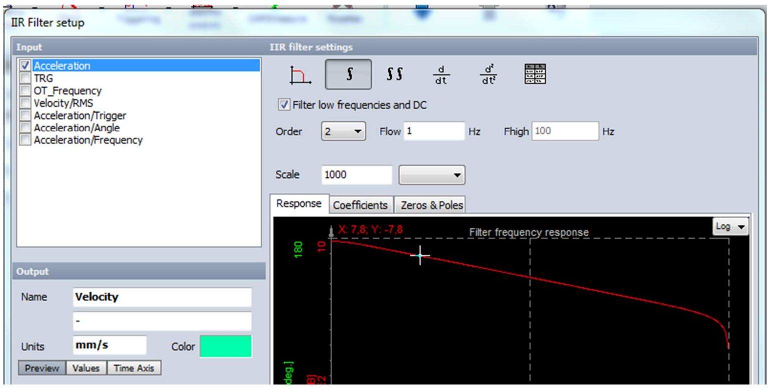
Acceleration sensor and Tacho Probe are connected to the DAQP-ACC-A and DAQP-LV module. For sure also MDAQ-ACC and could be used to connect the sensors.



After that the scaling of the acceleration sensor is done in m/s².



2.3 Acceleration to velocity calculation



Because vibration levels of rotating machines are almost always referred to by velocity, we have to transform the acceleration input into velocity by using single integration. This is done in the MATH section of DEWESoft, and located in the IIR Filter. So acceleration input is integrated. Because velocity is related to mm/s and acceleration is scaled in m/s², a single integration would give m/s , that's why a scale factor of 1000 is used to get directly mm/s out if the integration.
A high pass filter of second order avoids signal drift because of low frequency integration. It is set to 1-2Hz, if engine speed is > 120rpm.

For more information refer to Math Manual of Dewetron.

2.4 Order tracking Module

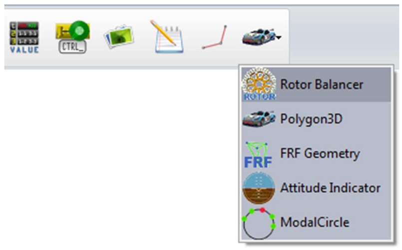
Velocity channel and Tacho channel are applied to the Order tacking module, and 1st Order and Phase will be extracted out of the velocity signal.

For detailed information how the setup the Order tracking module please refer to Order tracking manual of DEWETRON.

2.5 Balancing Procedure

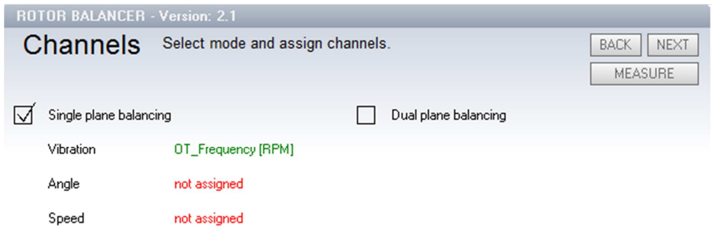
2.5.1 Apply channels to VC

Now that the input channels and the order extraction is prepared, we can now go to measure screen and add the visual control for balancing.

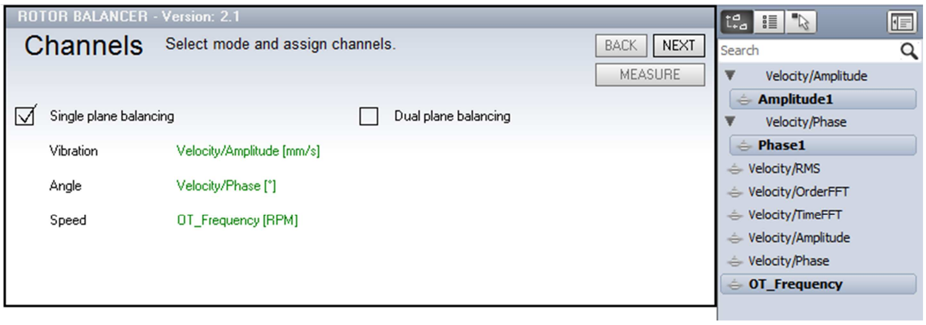


After adding the VC, we have to select first if single plane or dual plane will be used.

At Single plane balancing only one sensor is used, at Dual plane balancing 2 sensors have to be used.

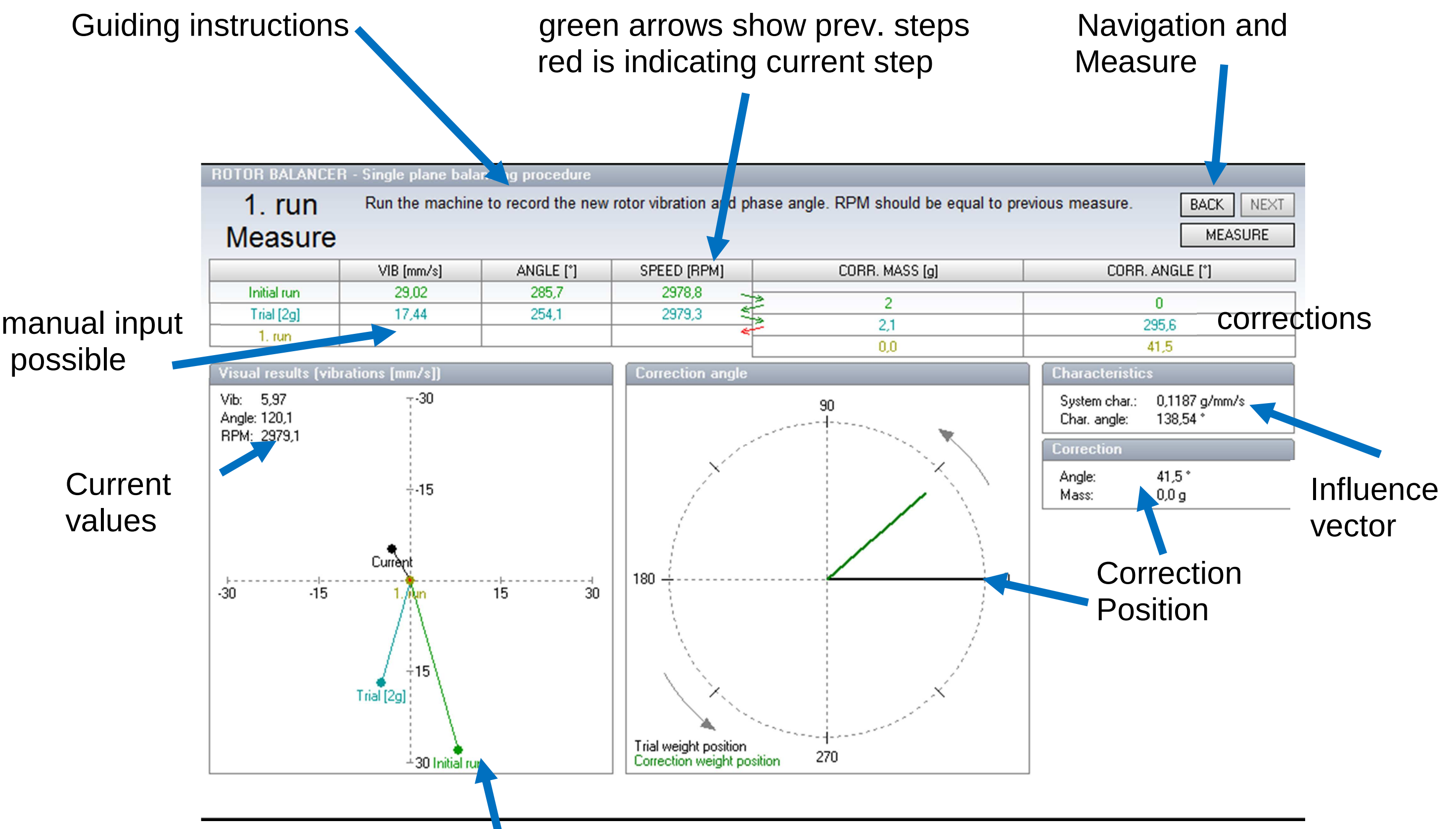


After that Amplitude and Phase channel from Order tracking module has to be applied to the VC.



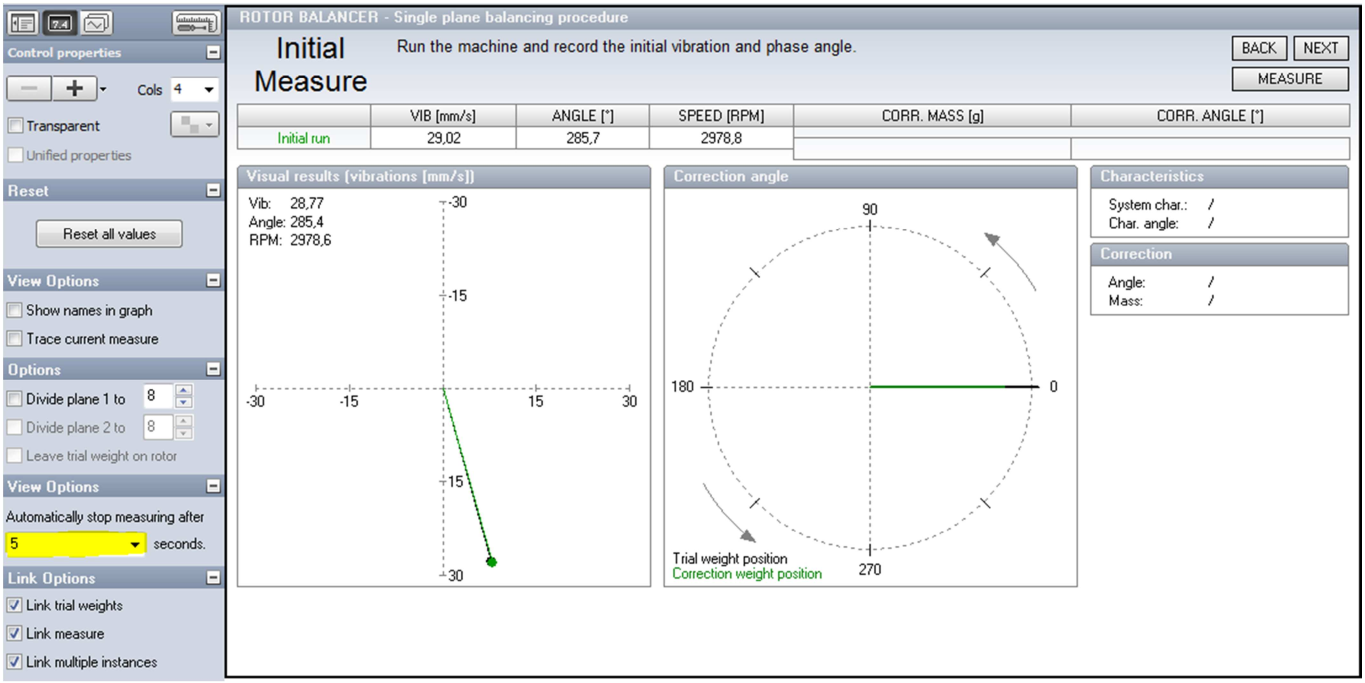
- proceed with NEXT

2.5.2 The Main Balancing Window



Polar Plot and vectors of different runs

2.5.3 Initial run



Now the initial vibration is recorded. It reflects the actual unbalance of the system. So machine is started and amplitude and phase is recorded and added to list. In our case we get 29mm/s @ 285deg. To record the MEASURE button has to be pressed, and it will average the actual amplitude and phase automatically, the result will be added to list.

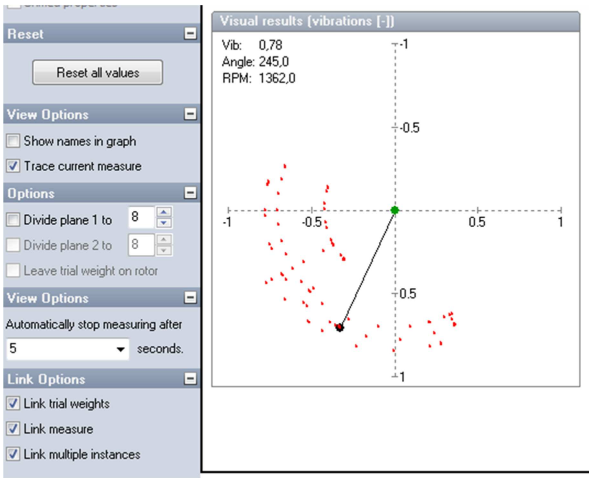
The average time is set under “Automatically stop measuring after xxx seconds

2.5.3.1 Amplitude and Phase not stable

INFO: The amplitude and Phase must be stable to get a reliable result.

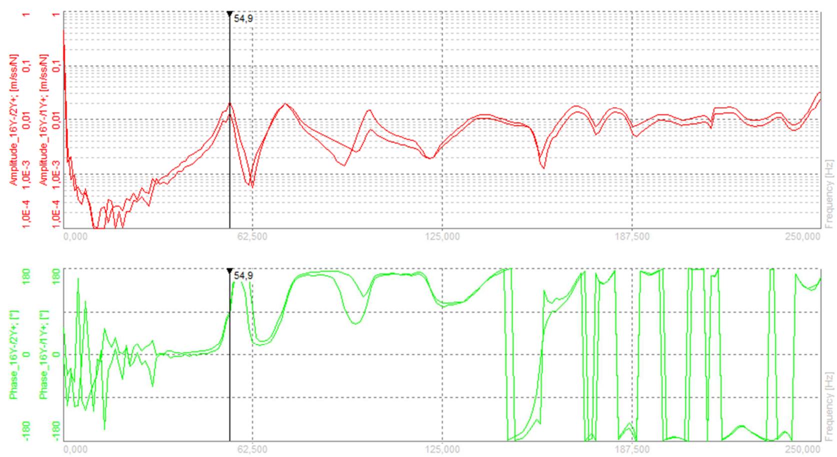
To track the vector the Option:
 “Trace current measure” can be checked.

If amplitude and phase is jumping, moving this could have several reasons.



- Vibration signal is very small an buried under noise
  ➔ Find another position on structure where signal is higher
- RPM signal (trigger signal) is not stable
  ➔ Check tacho signal and readjust trigger level

- Balancing is done close or on structural resonance frequency. In other words the first order is close to or on a structural resonance. At a resonance frequency the phase is always changing for 180deg. If first order falls on such a resonance, a small frequency change (rpm change) is enough that phase is changing tremendously. In this case we could hardly measure the vibration caused by the unbalance. Below there is an example out of Modal analysis where a resonance is seen at 54.9Hz = 54,9Hz*60= 3294rpm. Now imagine the speed of the engine would deviate about +-60rpm / 60 = +-1Hz, we would get a phase change of almost 180deg. Because almost no machine could run at a constant speed, it is impossible to get a stable initial run vector.

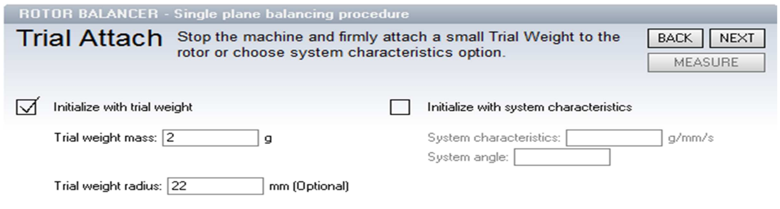


➔ Change engine speed.

2.5.4 Trial weight run

After the initial run we have to stop the machine and attach a trial weight.

The attached trial weight and the optional radius must be entered into the visual control.



Info: Be careful when attaching the trial mass, too high a mass could cause very high vibration, and cause serious harm to engine. Try with small mass and increase if necessary.

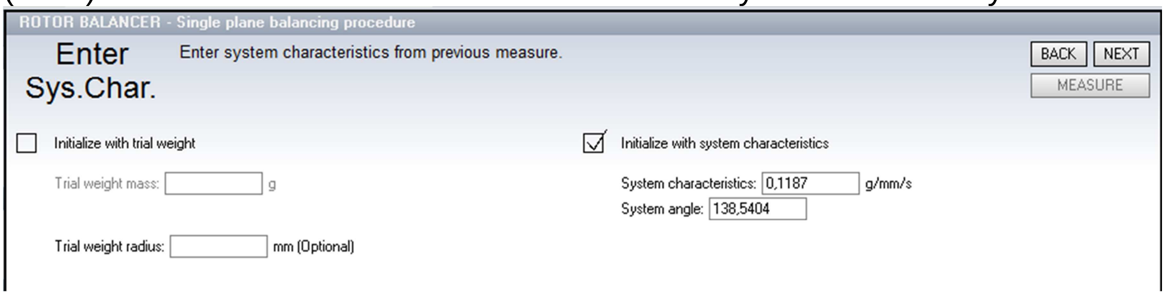
2.5.5 Initialize with system characteristics

If a Balancing was already done on a particular shaft, and the system characteristic is known, a trial weight run is not necessary another time; the system characteristics parameters can be entered manually instead to get the correction mass calculated immediately.
This could be used if a shaft is balanced multiple times in a certain interval.

The system characteristic describes the relation between mass and vibration.

If a previous setup was stored, and loaded again, the system characteristic was stored in the balancing visual control, too. Now it could be entered manually or RESET all values could be pressed.

After that is done the procedure will start on Apply channel to VC (2.5.1). After the Initial run (2.5.2) instead of trial mass the VC will automatically remember the system characteristics.



Info: To rebalance a system with the use of system characteristic the following requirements have to be met:

- Rotor was previously balanced with trial mass
- Rotor characteristics were not changed
- Position of the first trial mass must be known
- Reflection badge (RPM trigger signal) position must stay at the same position
- Optoprobe and vibration sensors must maintain the same angle to each other
- Balancing speed (rpm)

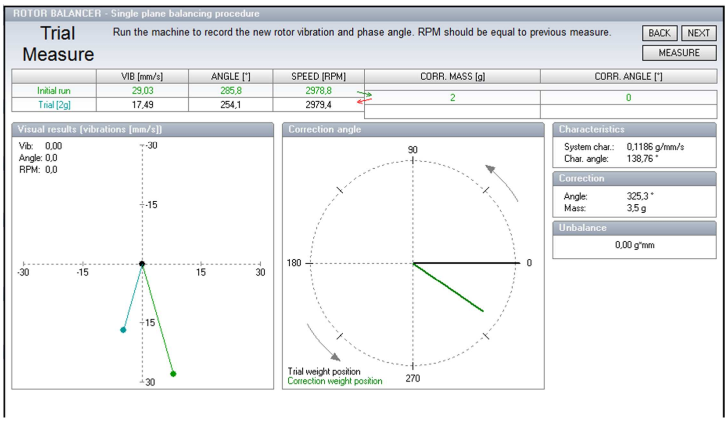
If one of the above requirements is not met, a trial weight run hast to be done again.

2.5.5.1.1 Optional Trial weight radius

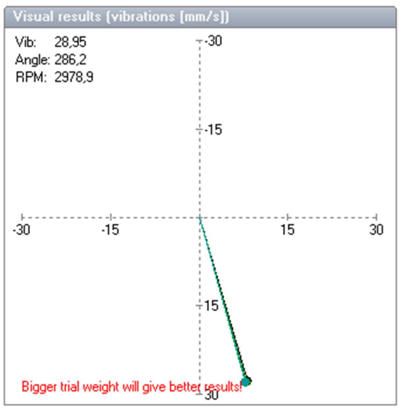
This should be entered, if correction mass could not be placed on the same diameter as trial mass.
So later there will be a possibility to change correction mass diameter.

Now the machine has to be started again and Trial mass vector will be recorded.

In this case the amplitude or the phase should change considerably. In case the change is too small, it is even indicated in the VC.
So trial mass has to be increased or another position has to be found.



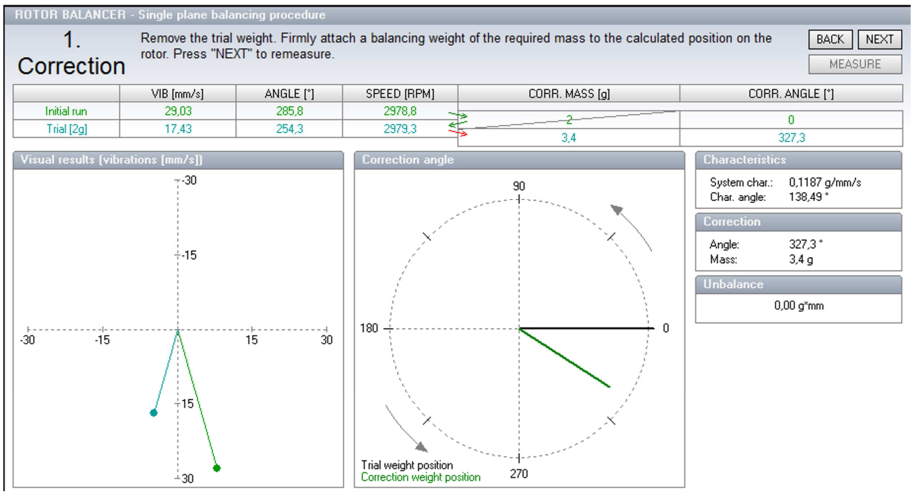
The second picture shows how it looks like if the trial mass is too small. The first harmonic did not change when trial mass was attached.



Info: During the whole balancing procedure the speed of the machine must be the same. Why? Remember the force created from the unbalanced shaft is transferred over the structure and causes vibration. This transfer is described via the transfer curve also mentioned above at the resonance description. As mentioned, at resonance the phase is changing suddenly for 180 deg. But also before and after, the phase is changing a little bit. So if we would run the engine at a different speed the vector of the first order would change, but only because of the transfer characteristic and not because of trial mass attached. So trial mass measurement at a different speed would include phase error because of different speed, so balancing procedure would not work.

2.5.6 Add correction mass

After trial weight run is finished, the VC will indicate where the correction mass should be added. In this case 3,5g should be placed at 327deg. The VC is also indicating the angular direction. On the rotor this is the running direction.

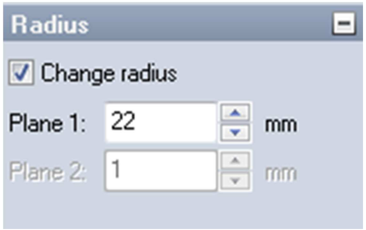


Starting point is always the position of the trial mass. So that's why this has to be remembered.

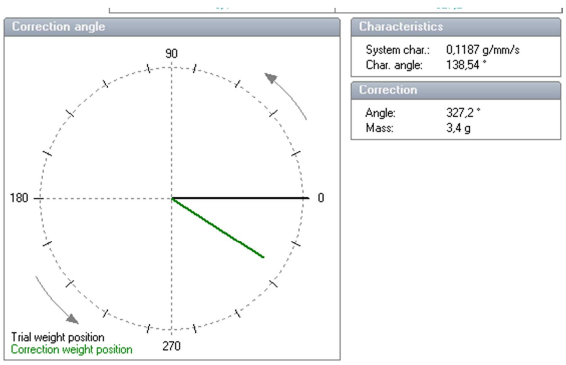
So counting from trial mass position move the indicated angle in running direction and add indicated correction mass. Remember that the diameter of correction mass must normally be equal to trial mass.

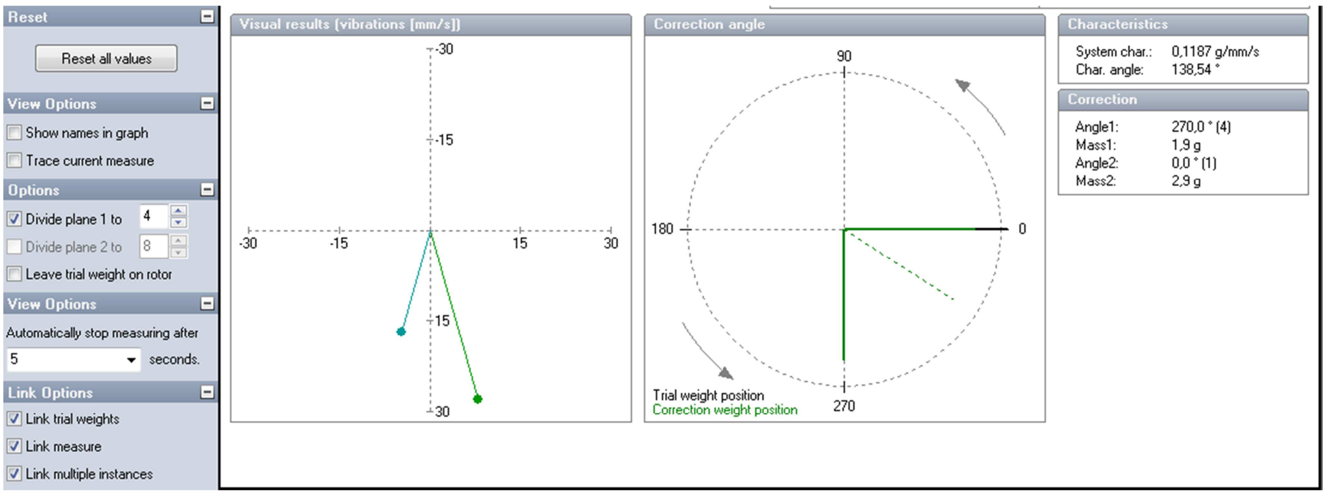
If it is not possible to add correction mass on the defined angle or radius, caused by mechanical limitations, the following could be done.

- If Trial weight radius was entered at the trial weight run 2.5.3 the VC will allow to change the correction mass radius.
  The correction mass radius could be changed in the properties of the VC. So if the radius is changed, also the correction mass weight will change according to new radius.



- Split weight, function is used if correction mass could not be applied on defined position, even if radius would be changed.
  Or if predefined positions (holes) are available on the shaft.



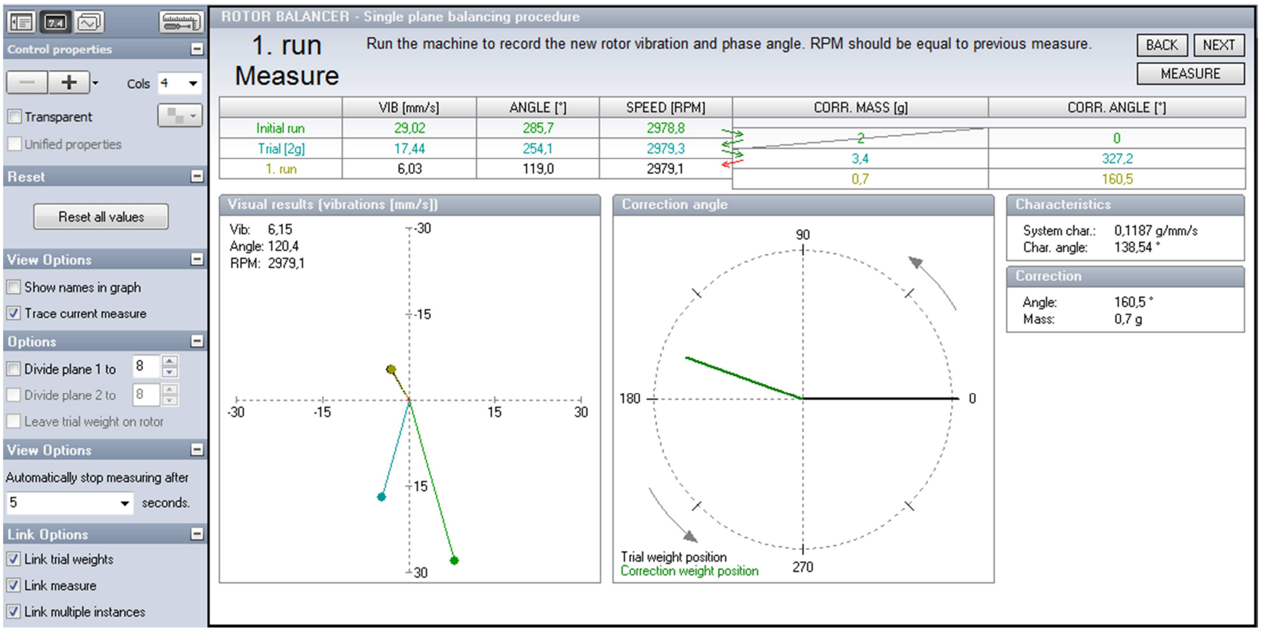


The upper example will show how this is working. The correction mass should be entered at 327deg. But we only have 4 available positions on the shaft, so we enable the Divide plane option and set it to 4. Now the VC will split the weight into 2 parts at position 0 and 270deg.

INFO: In case the splitting is done because prepared positions are used to apply the correction mass, the trial mass must be placed on one of the prepared positions. The reason for this is VC starts dividing the plane at 0deg = trial mass position.

2.5.7 Check balancing result

After pressing NEXT Button we check the new vibration pattern which should have improved a lot.



We could see that the 1st run will give us 6mm/s so we achieved almost 5 time better result. After recording the VC will give a new correction mass position, to improve.

2.5.8 Additional settings in Balancing Module

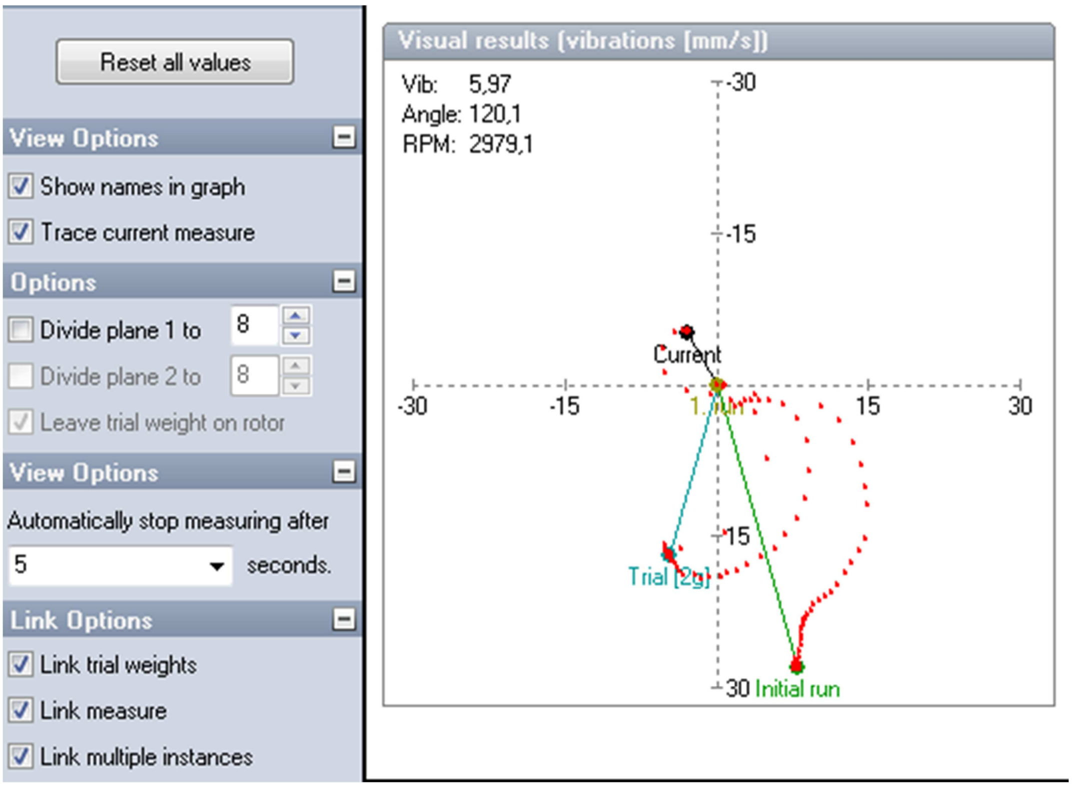
2.5.8.1 Leave trial weight on Rotor

After adding the trial weight, and before adding the correction weight, there is a possibility to check that trial weight stays on rotor. This is sometimes helpfully because sometimes it could be a big effort to remove trial weight. So if it does not disturb it could stay on the rotor. But LEAVE TRIAL WEIGHT ON ROTOR has to be check that this is taken in account at the correction mass.

2.5.8.2 Show names in graph

2.5.8.3 Show current trace

If these options are checked, the names of the different test runs are also labelled in the polar diagram, and the trace (red dots) are tracked.



2.5.8.4 Link Options Multiple VCs

Sometimes it could happen that amplitude and phase is not stable, and also vibration pattern is very small. So a different position of the sensor has to be found.

To save time, 2 or more VC could be added at the same time. Every VC will get a different acceleration signal which comes from different places on the structure.
The whole procedure is the same, and that way we do not have to operate each of the Balancing VC separately, we could link the VC, so only one will be operated and the others will follow, and only provide different results.

The link Options will provide the right solution for this. So if LINK MULTIPLE INSTANCES is selected, Measure and Trial weight could be linked to operate the simultaneously.

2.5.8.4.1 Which Result

If we use now multiple instances the question is which VC or which result should be chosen for the correction.

- ➔ The one where amplitude and phase is stable
- ➔ The one where the influence vector is smallest.

Influence vector describes the relation between vibration pattern change on specific mass change.
1g/mm/s tells us that 1g will change the vibration level of first order for 1mm/s
If influence vector is 0,5g/mm/s we only have 0,5g to get the same vibration change.

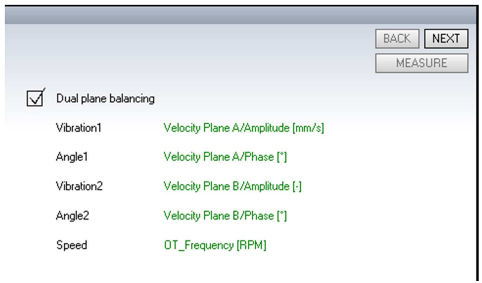
So we should carry on balancing where a small trial mass will give us a high vibration signal.
So unbalance is clearly seen on structure and not damped. So we should carry on where influence vector is 0,5g/mm/s!

2.5.9 Difference Dual Plane Balancing

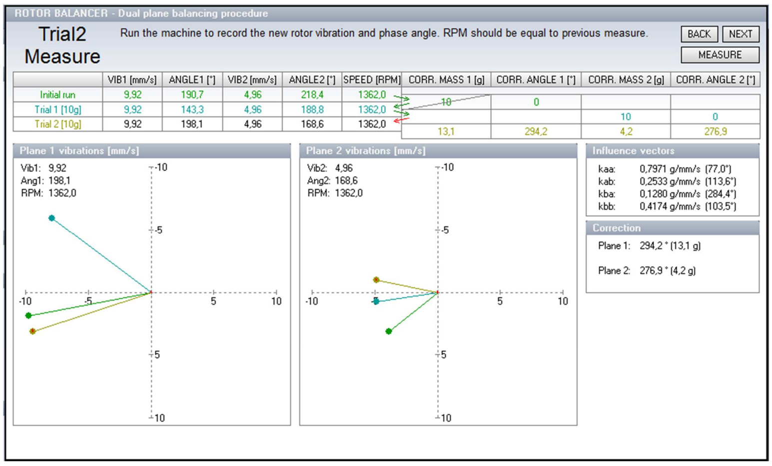
The procedure is the same as used at single plane Balancing.

At dual plane Balancing two sensor have to be used, applied to Order tracking, and also applied to the Balancing visual Control.

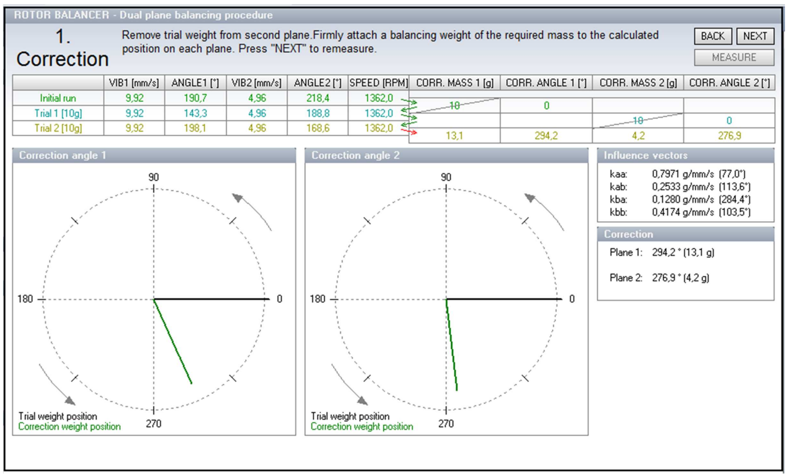
- So at point 2.5.1 five channels are applied to the balancing module like shown in the example on the left.



- Trial weight run has to be done for both planes individually



- And for sure correction mass is also added on every plane.



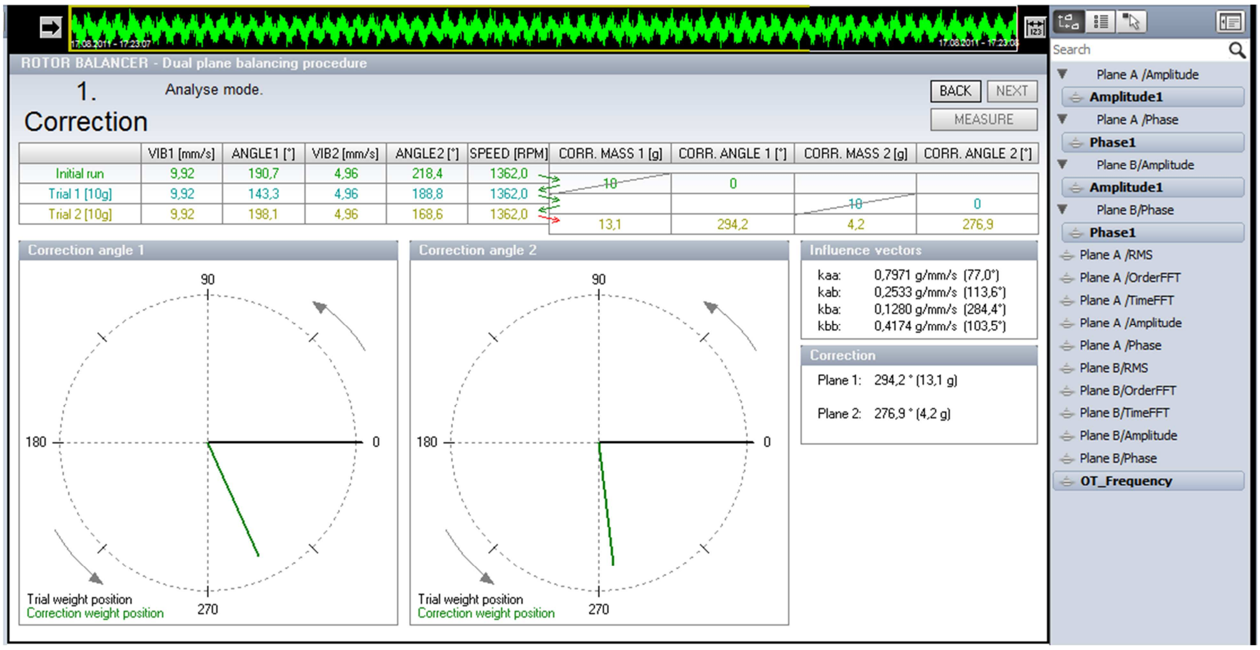
2.6 Storing the Result.

At the whole balancing procedure only amplitude and phase of first order is needed. This results are extracted out of Order tracking module and applied into the data fields of the visual controls at the right moment. At the end we get a list view in the VC of the balancing which is the result.

This will be stored in the setup. So at the end of the balancing it is enough to store the setup, and next time the setup is loaded, we will get the result. In case a known shaft is balanced again this would even help us to initialize with the system characteristic (2.5.5).

In case also a data file should exist, it is enough to store at the end of the balancing procedure A few seconds into a data file. If this file is loaded again the result is also shown in the data file.

INFO: BALANCING is only working in MEASURE MODE !!!



Result stored in data file.