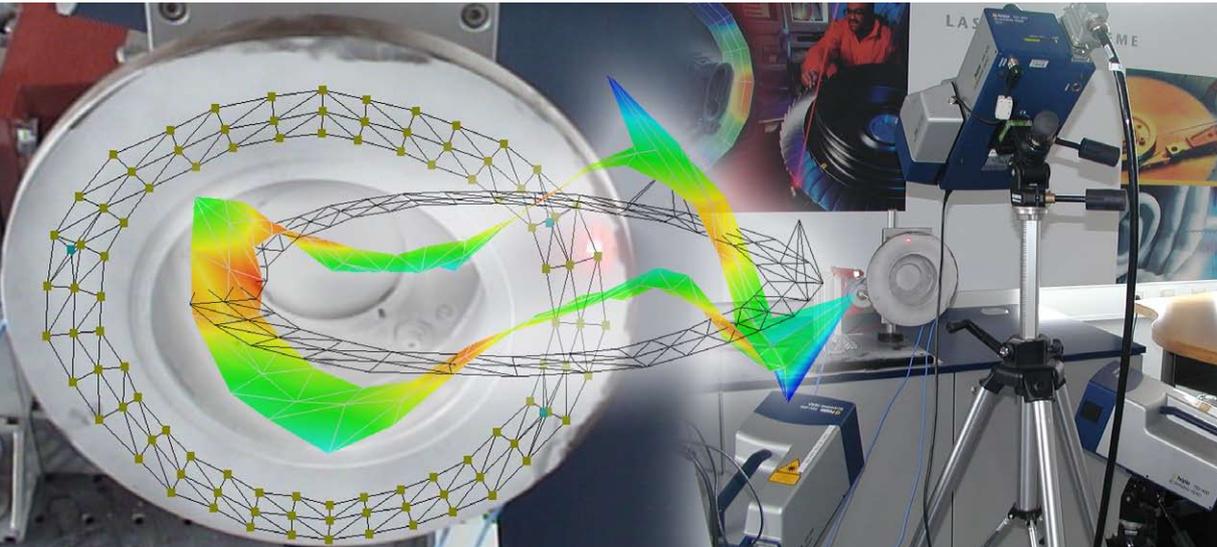


Integrating External Sensors into Scanning Vibrometer Measurements



Field of Application

- A Aerospace
- B Audio & Acoustics
- C Automotive
- D Data Storage
- G General Vibrometry**
- M Microstructures & -systems
- P Production Testing
- S Scientific & Medical
- T Structural Testing
- U Ultrasonics

Vibration measurement data obtained using accelerometers can supplement scanning vibrometer data, for example in cases where a measurement point is not optically accessible. A measurement point of this kind can be inside the measurement object or it may be that for spatial reasons, the scanning vibrometer cannot be suitably positioned to reach certain points. This limitation can be avoided by integrating measurement data from accelerometers into the scanning vibrometer data and evaluating them together. It is possible to integrate external data into both 1-D measurements and also 3-D measurements.

Conditions

Integration as described here requires the 8.5 version of the PSV software, as new functions are required in the signal processor, for example Relindex. The 1-D or 3-D PSV vibration measurement data must be available with the geometry, i.e. the geometry is either imported (for example from an FE model) or it is defined and measured using the PSV software. For this purpose, the software option PSV-S-ImpGeo (data import) or the PSV-A-420 geometry scanning unit is required. With the 1D-PSV, the scanning head must be aligned to be parallel to one axis of the coordinate system.

The accelerometers (1-D or 3-D) need: The coordinates of the measurement points must be known and be available in the same coordinate system as the geometry in the PSV data.

The axes of the recorders must be aligned to be parallel to the axes of the coordinate system. If this is not possible, then the values need to be converted from the local into the global coordinate system, for example using the signal processor. For this purpose, the transformation code between the coordinate systems has to be known.

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Procedure

1. Preparation

The geometry of the object is either defined or imported. The coordinates of the accelerometers are defined in the same geometry. In addition to that, the status of the measurement points is adjusted: the points corresponding to the accelerometers are disabled.

2. Data acquisition

The measurement is carried out as usual with the scanning vibrometer. The geometry point of the recorder is also acquired. The signals of one or two recorders respectively can also be acquired if there are free channels available on the PSV. If not, the measurements with the accelerometers are retrospectively carried out, however with the same settings: the same bandwidth, the same number of FFT lines and the same averaging procedure. For joint evaluation and animation of vibrometer and sensor data, the phase relationship between the measurement points must be available. It can be calculated with the aid of a reference signal measured at the same time.

The signals of the recorders can in principle also be acquired with other software if the same parameters are used as in the PSV software (more on this in the last section of the document). Here, FRF signals (frequency response function) are usually combined.

3. Combination of the measurement values

The measurement data from the scanning vibrometer and all recorders is combined into a common data set (UDDF) and can then be evaluated and animated.

Example: Integration of External Measurement Data Acquired with the PSV Software

1. Preparation

A condition of making the measurement is a valid 2-D and 3-D alignment. In the example shown, a brake disc was measured using the PSV-400-3-D (Figure 1). The excitation was triggered by a shaker (Figure 2).

At the point of excitation, a transducer was affixed. In addition to that, on the back of the brake disc, three accelerometers were glued on.

First of all, the geometry for the scan points is defined in standard and point mode (or is imported). After that, a geometry scan is carried out.

For every sensor, an additional scan point is now defined. If this has not happened yet, then you have to change to point mode under Define Scan Point. In the example shown, three accelerometers were used, one uniaxial and two triaxial ones and they

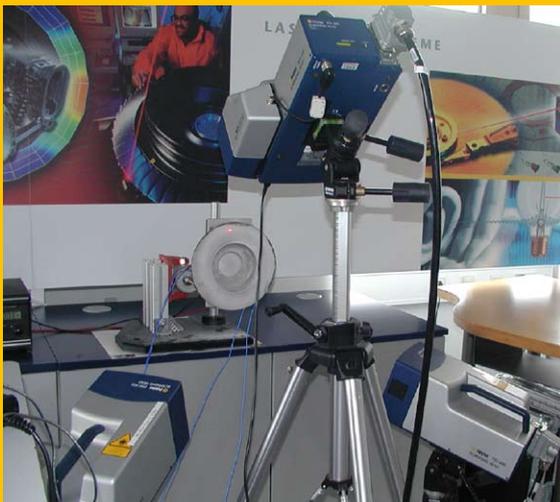


Figure 1: Object and setup of scanning heads.

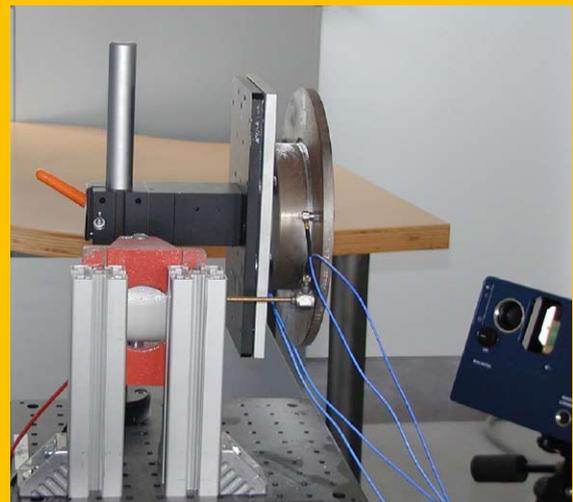


Figure 2: View of the object and the point of excitation.

are affixed to the back of the brake disc. The three additional scan points were initially defined on the front, respectively near the relevant accelerometer. With the aid of the function Connect Points the additional scan points are integrated into the measurement grid (Figure 3). The coordinates of these points are measured with the geometry scan unit.

As the accelerometers are on the back of the disc, the z-coordinates still have to be adjusted, the z-components of the coordinate system used are at a right angle to the surface of the brake disc. The thickness of the disc and half the thickness of the accelerometers are subtracted from the z-value of the coordinates. To do this, the function *Modify 3D Coordinates* is used:

- Select the measurement point and using a right click, select *Modify 3D Coordinates* (Figure 4)
- Enter the x-, y- and z-coordinates in the new window *Modify 3D Coordinates* (Figure 5)

The points are then given the geometry status Modified.

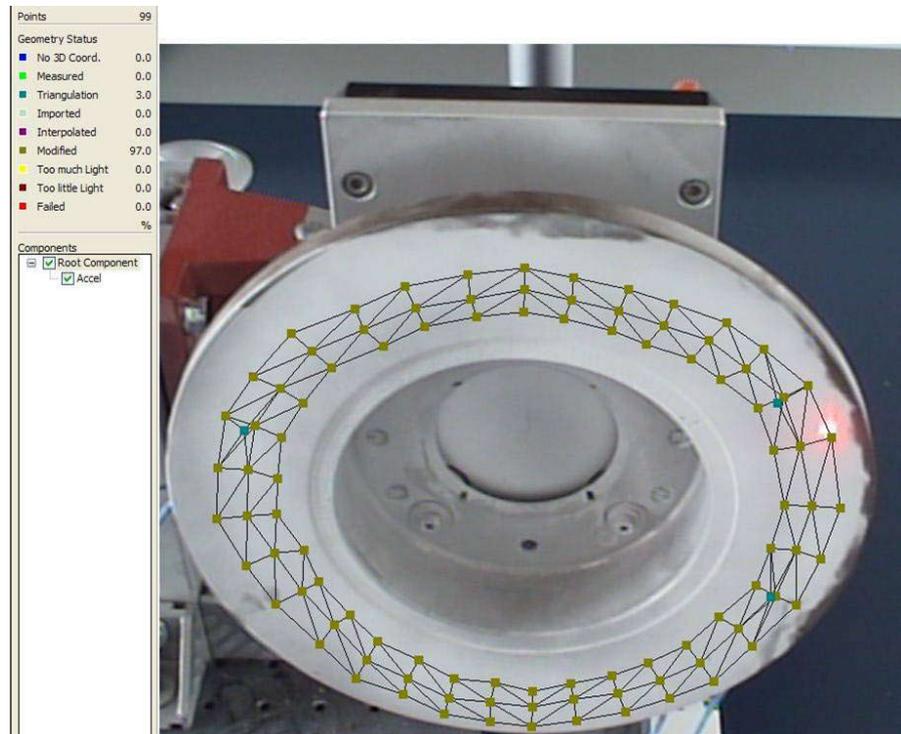


Figure 3: Geometry of the brake disc and dummy measurement points for the three accelerometers (dark green).

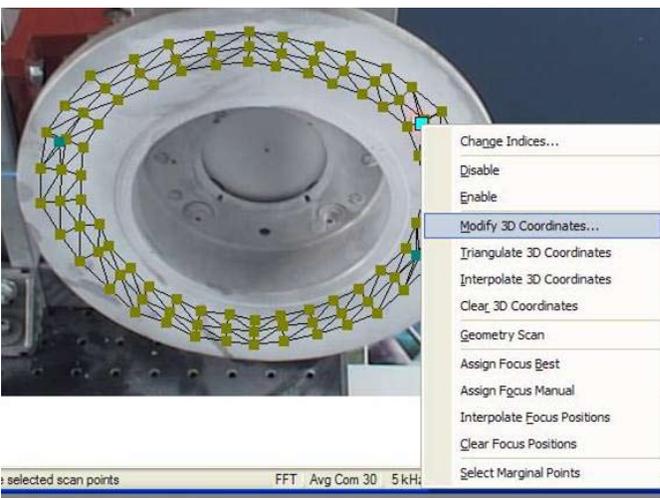


Figure 4: Changing the 3D coordinates of the selected sensor measurement point (Step 1).

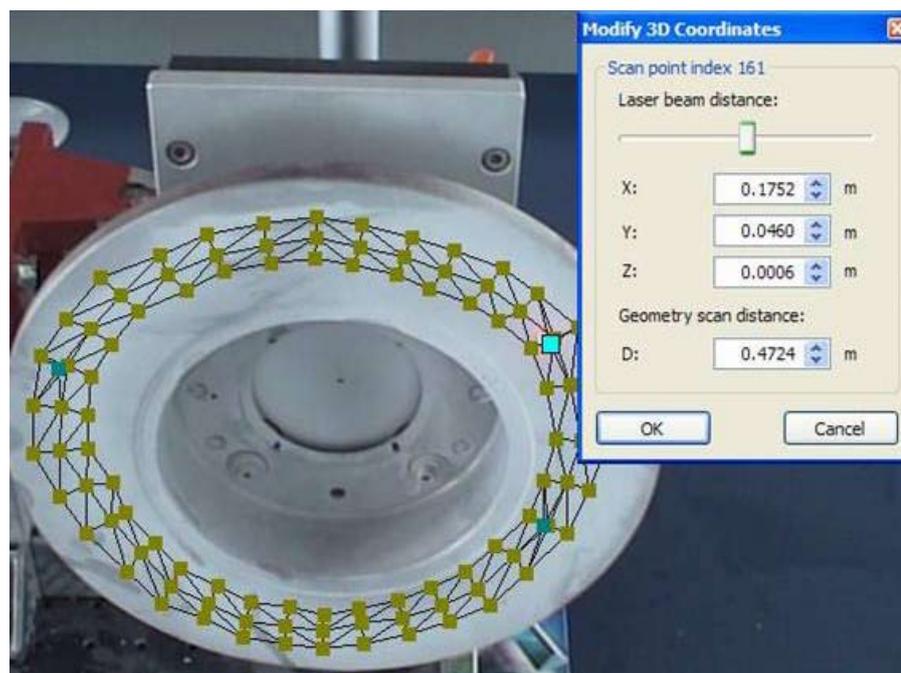


Figure 5: Changing the 3-D coordinates of the selected sensor measurement point (Step 2).

Half the thickness of the accelerometer is taken into consideration because the actual scan point is not on the contact point, but in the center of the accelerometer. Using this method, the results are matched up better.

If required, the indices of the scan points can also be changed. In the example, the uniaxial accelerometer is given the index 163 and the two triaxial sensors are given the indices 161 and 162 (Figure 7). This is done as follows:

- Select the scan point and with the right mouse button, select Change Indices (Figure 6)
- In the new window Change Indices, enter the new indices (Figure 7)

The scan points of the accelerometers have to be disabled before the measurement. This means that in the results file, you have the complete geometry, but for the geometry points of the accelerometers, there is no vibration measurement data available yet.

As shown in Figure 8, it is possible to visualize the 3-D geometry with the accelerometers. The scan points corresponding to the accelerometers are disabled (this status is shown in brown), while the other points measured with the scanning vibrometer are shown in blue.

The accelerometer positions are disabled for the scan. In the signal processor, the corresponding measurement data can be allocated to these points. If the positions of the accelerometers are not available in the vibrometer measurement file, then it is possible to retrospectively generate a separate measurement file with these positions and merge it with the vibrometer measurement file.

2. Data acquisition

First of all, the vibrometer measurement data is captured. If there are still any free reference channels available, the signals from the accelerometer can also be acquired as reference signals. In the case shown, a PSV-400-3D Scanning Vibrometer with 8 channels was available. Three channels (Vib Top, Vib Left & Vib Right) are assigned the three vibrometer signals Top, Left and Right. One channel is assigned the reference signal, in this case the power signal of the excitation (Ref1).

Thus four free channels remain available that are assigned as follows:

- Ref21: Uniaxial accelerometer, Index 163
- Ref22: Triaxial accelerometer, Index 161, x-direction

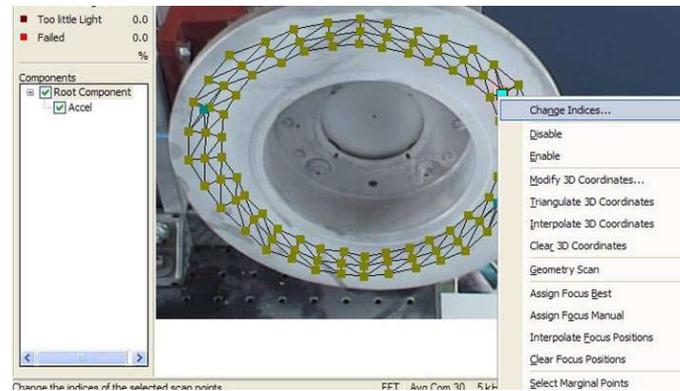


Figure 6: Changing the indices of the selected sensor measurement point (Step 1).

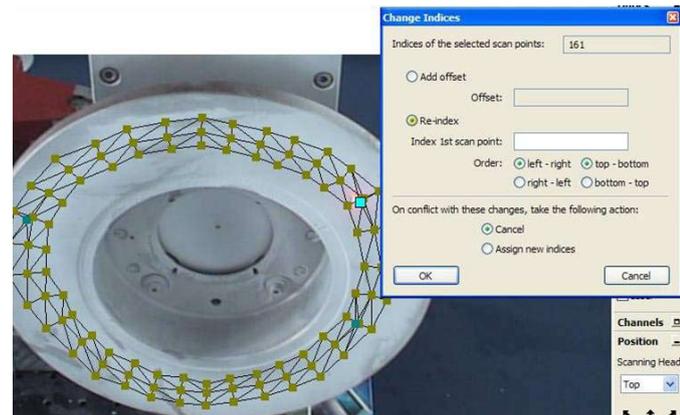


Figure 7: Changing the indices of the selected sensor measurement point (Step 2).

- Ref23: Triaxial accelerometer, Index 161, -y-direction
- Ref24: Triaxial accelerometer, Index 161, +z-direction

The second triaxial recorder had to be acquired separately in a second measurement.

The channel configuration is shown in Figure 9. In the column Index you can enter the index of the scan points that are assigned to the accelerometers. For the separately measured recorders (in this case only one) not all scan points have to be measured again. There are two options:

1. The measurement values of the accelerometer(s) are saved as individual point data (*.pvd-file). To be able to improve allocation of the data, the index of the recorder can be entered in the Acquisition Settings as shown in Figure 9 for the scanning measurement.
2. The measurement values of the accelerometer(s)

are saved as scanning data (*.svd-file), whereby only the corresponding points are active and all other points are disabled.

Both options have advantages and disadvantages:

Method	Advantages	Disadvantages
1	Status of the scan points does not have to be changed	In the signal processor (see below) the index number of the scan points has to be changed
2	No index change in the signal processor necessary	Status of scan points (disable/enable) needs to be changed before the measurement

In the example shown, the second option was selected. The channel assignment remains unchanged for the channels Ref1, Vib Top, Vib Left, Vib Right and Ref 21.

The following assignment applies for the other three channels:

- Ref22: Triaxial accelerometer, Index 162, x-direction
- Ref23: Triaxial accelerometer, Index 162, -y-direction
- Ref24: Triaxial accelerometer, Index 162, +z-direction

In the geometry, the scan point with the index 162 was enabled and all other points were disabled.

It may be necessary to repeat this step until all recorders have been acquired. Then the measurement values of the vibrometers and the accelerometers can be combined. This is done in evaluation mode with the aid of the signal processor (SigPro).

3. Combination of files

In the example shown, the velocity signals are being observed. The table in Figure 10 shows an example calculation in the signal processor.

First of all, measurement signals have to be transferred to the signal processor. For this purpose, the spectra of all scan points (vibrometer data) were copied into cell C2 and the data of the 1D accelerometer (z-direction) into cell C6. The data of the triaxial recorders was copied into cells C10 to C12 and C16 to C18, each respectively in x-, y- and z-direction. The accelerometers were aligned so that they acquired the y-direction which means that the data for the y-coordinates has to be multiplied by -1 to make the phase correct.

For every recorder, three 1-D data sets were combined to make up one 3-D data set. This is done using the function *Make3D* by selecting the cells with the appropriate data sets, for example: C13 = *Make3D* (C10, C11, C12).

The spatial directions are assigned to the data sets as follows:

1st Data set: x-direction

2nd Data set: y-direction

3rd Data set: z-direction

For the 1-D accelerometer, the missing signals (x- and y-direction) are supplemented by 0 and have correspondingly been left empty in the instruction *Make3D*. The combination of 1-D to 3-D data sets takes place in the cells C7, C13 and C19. In the case of measurements with the 1D-PSV, this step with the function *Make3D* is not necessary.

The data from the third accelerometer with the index 162 was acquired separately and already has the right index (see above: advantages of 2nd method). The signals of both the other recorders were acquired during the vibrometer scan; i.e. for each scan point, the signals are available.

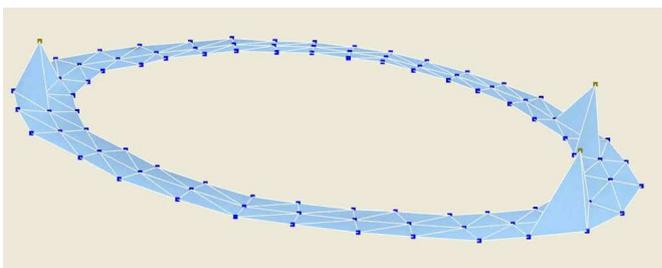


Figure 8: View of the 3-D geometry and the scan point status before the measurement.

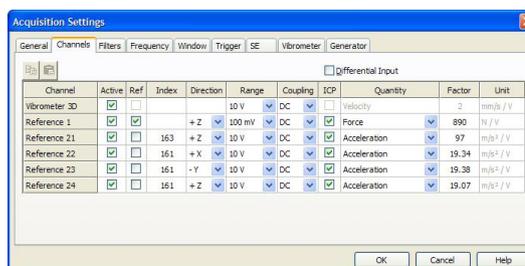


Figure 9: Acquisition Settings - configuration of channels.

Here the signals were copied from point 123; thus the index still has to be adjusted. This is done using the function *ReIndex* which the original index and the new index have to be entered into.

The entry $=ReIndex(C7, 123, 163)$ in cell C8 for example, has the effect that the data sets with the index 123 that are in cell C7 are now given the index 163.

The values have to be copied from an individual spectrum (in our case the spectrum of point 123); it is not possible to copy the average spectrum because it does not contain any phase information.

Now the data sets only have to be combined with *PointUnion* which is done in cell C21. The result of this is a data set with the points up to 159 (vibrometer measurement) as well as 161, 162 and 163 (accelerometers). For every point, the spectra are available with all the information, amplitudes, phases, real and imaginary part in x-, y- and z-direction. In cell C22, the description of the combined data set is changed. Cell C22 now has to be copied using a right mouse-click and has to be inserted into the original file using Paste. A user defined channel (Usr Channel) which contains the user defined signal

FFT/Velocity is generated automatically.

The data from the user defined signal can be animated as usual, whereby the frequency is selected using the cursor. Figure 11 shows an example of a deflection shape of the combined measurement. The average spectrum is not included in the file. If required, it can be calculated using the signal processor. In cell C23, the average spectrum is calculated using the function *StatMean*. Using Copy/Paste, this signal can also be integrated into the original file. The user defined signal FFT/Velocity now contains the average spectrum across all measurement points as well as single spectra.

There is the possibility of forming several user defined signals. If additional signals become necessary, for example acceleration or FRF, then the steps with the signal processor have to be carried out again as described above. All user defined signals can also be exported as UFF signals and be read into ME'scope or LMS software. This export can also be done directly from the signal processor.

	A	B	C
1	Sensor type	Calculation	Signal type: velocity
2			=CopyVibData("D:\Bremse_B61_1107_2.svd","FFT","Vib 3D","Velocity",1, 1)
3			
4	1D accelerometer	original data index 163; +X	
5		original data index 163; +Y	
6		original data index 163; +Z	=Point(CopyVibData("D:\Bremse_B61_1107_2.svd","FFT","Ref21","Velocity",1, 0),{123})
7		convert uniax to triax	=Make3D(, , C6)
8		set index to 163	=ReIndex(C7,123,163)
9			
10	3D accelerometer	original data index 161; +X	=Point(CopyVibData("D:\Bremse_B61_1107_2.svd","FFT","Ref22","Velocity",1, 0),{123})
11		original data index 161; +Y	=-1*Point(CopyVibData("D:\Bremse_B61_1107_2.svd","FFT","Ref23","Velocity",1, 0),{123})
12		original data index 161; +Z	=Point(CopyVibData("D:\Bremse_B61_1107_2.svd","FFT","Ref24","Velocity",1, 0),{123})
13		convert uniax to triax	=Make3D(C10, C11, C12)
14		set index to 161	=ReIndex(C13,123,161)
15			
16	3D accelerometer	original data index 162; +X	=CopyVibData("D:\B67_1207.svd","FFT","Ref22","Velocity",1, 0)
17		original data index 162; +Y	=-1*CopyVibData("D:\B67_1207.svd","FFT","Ref23","Velocity",1, 0)
18		original data index 162; +Z	=CopyVibData("D:\B67_1207.svd","FFT","Ref24","Velocity",1, 0)
19		convert uniax to triax	=Make3D(C16, C17, C18)
20			
21	All signals	combines data sets	=PointUnion(C2, C8, C14, C19 , , , , ,)
22		description of combined data sets	=Scale(C21, , , , , , , , "FFT / velocity")
23			=statmean(c22)
24			

Figure 10: Calculation in the signal processor.

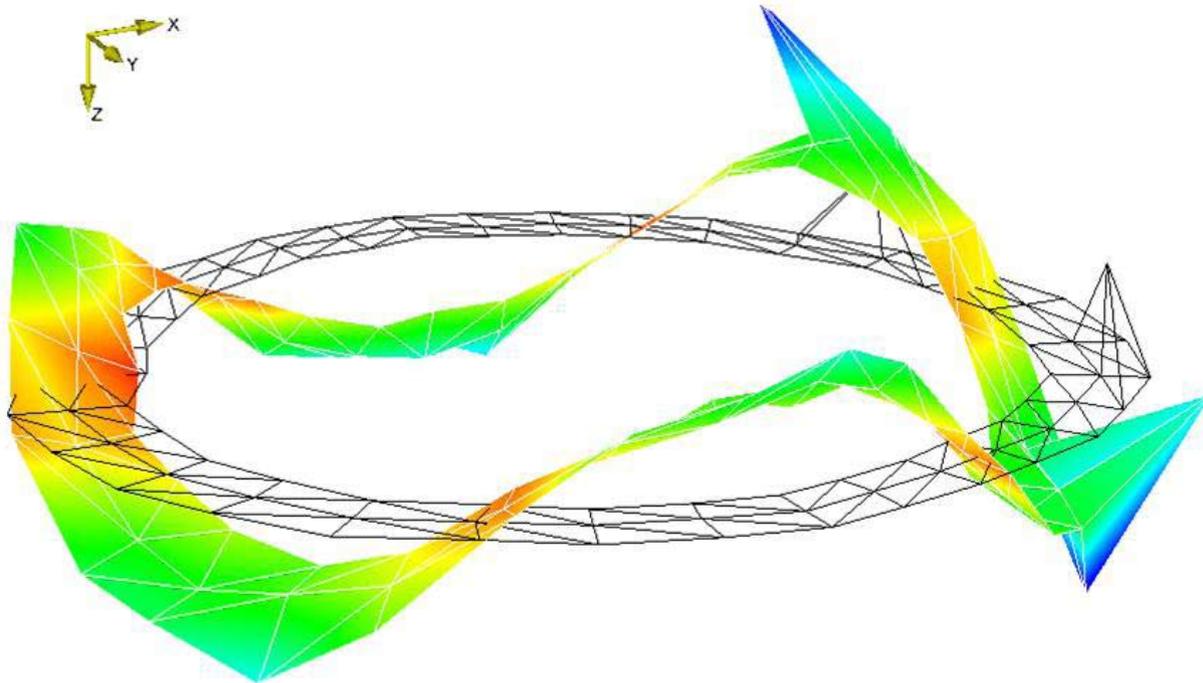


Figure 11: Combined measurement: Deflection shape, 1935 kHz.

Parameters for Integrating External Data not Acquired with the PSV Software

It is also possible to combine the data from recorders which has been acquired with external software (such as LMS) with the scan data. It is important that the external program and the PSV software are working with the same frequency resolution and the same bandwidth. As of version 8.5, the PSV software has additional bandwidths available to simplify a combination of this kind. In addition to that, it is necessary to work with the same reference in both programs which is why FRF functions are usually combined.

3. Combination of files

In the LMS software, the bandwidth is defined as half the sample frequency. A sample frequency of 10 kHz thus corresponds to a bandwidth of 5 kHz. If you select 1024 lines here, this results in a frequency resolution of $5000/1024 = 4.882$ Hz.

In the PSV software, the parameters have to be selected so that the same frequency resolution is attained.

The bandwidth is defined here as the sample frequency divided by 2.56. A sample frequency of 20 kHz thus results in a bandwidth of 7.8125 kHz. With 1600 lines, you get a frequency resolution of $7812.5/1600 = 4.8828$ Hz.

This therefore attains the same frequency resolution as with LMS. To get the same bandwidth as well, the setting Frequency from/to also has to be used in the A/D window. With a bandwidth of 0 to 5 kHz, you get the same bandwidth as with the LMS software.

Now the vibration measurement data can be acquired with the PSV and the accelerometers. To combine the file, first of the all the data from the accelerometers has to be imported into the *.svd file. This is done via File > Import; the external data must be available as a Universal File. The signals are imported as user defined signals into the PSV file; for this purpose, a new channel „Usr“ is automatically created.

Subsequently, the user defined signals can be copied into the signal processor. The combination with the vibrometer data is carried out as described above.

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For more information on the Scanning Vibrometer and the Software please contact your local Polytec sales/application engineer or visit our website on www.polytec.com/psv400.