Application Note *VIB-C-01*

The PSV-3D for Car Body Structural Dynamics Testing: a Real-World Test

The suitability of the PSV 400-3D for data acquisition in car body modal testing has been studied in a real-world test on a car body at DaimlerChrysler in Sindelfingen, Germany. The results are very positive. The PSV 400-3D presents a huge potential for time saving as compared to accelerometers. It furthermore shows all the known advantages of laser scanning vibrometers, such as high point densities, non-contact measurements and ease of setup. This article contains the description of the measurements and their results.

Introduction

High-spatial resolution structural dynamics tests on car bodies are usually a time-consuming and cumbersome task if performed with accelerometers. Accelerometers have to be carefully mounted, connected to the data acquisition front-end and their angular orientation has to be determined. Furthermore, for high spatial resolution tests, a very large number of accelerometers has to be employed. This is practically impossible in a single setup as the front end has only a limited number of channels. Therefore, only a subset of all measurement points is taken in an initial run, with dummy masses on the non-used points. In the next run, the accelerometers are moved to the next segment. This process is time consuming and accelerometers are often damaged. Furthermore, cabling, labeling and error checking gets very tedious when using many accelerometers.

A final drawback is the change in mass distribution of the measurement object introduced by the mounted accelerometers and the dummy masses.

Due to its non-contact measurement principle the PSV-3D has the potential to considerably simplify the setup, speed up the test enormously and to enable tests with high spatial resolution without altering the mass or stiffness of the measured object.

Test Site

Data acquisition as needed for a possible subsequent modal analysis has been performed at DaimlerChrysler AG in Sindelfingen, Germany to study the performance and possible limitations of the PSV-3D for this measurement task.

This article outlines the results of this test.

Structural Dynamics Test Setup

A complete car body of a Mercedes E-Class, without engine, drive chain and axes has been used for the test (Figure 1). The car was painted with conventional white car paint. For this kind of surface no additional surface treatment was necessary to obtain the results required for structural dynamics testing. The test object has been excited by one shaker in vertical direction, coupled to the main chassis beam. The car body was mounted on air suspensions for decoupling from the fixture. A lift system was used to conveniently select the best height for the test. This lift system also enables tests on the underbody of the car. Measurement points on the top of the car were assessed by a crane. Tests on the underbody and the top have been extensively performed on another, more recent DaimlerChrysler car model, not reported here for confidentiality reasons.

During this benchmark test, we performed measurements on the entire left and back part of the body (Figure 2). The entire measurement has been divided into 5 sections:

- Front left fender
- Front left door part
- Rear left door part
- Rear left fender
- Back

Figure 1: View of the setup (measurement of a segment on the left rear side)

Figure 2: Measurement grid (total of 472 scan points)

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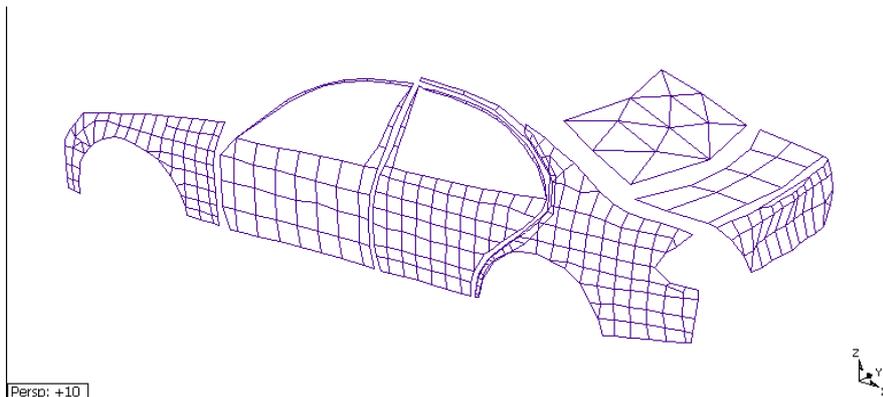
The results of the individual segment-measurements have been combined (stitched) into one global result file. At present (PSV 8.2) a macro has to be used for this purpose, stitching will be incorporated in the next version of PSV Software. During additional testing, it turned out that a division into 3 sections (front part, rear part and back) would have been sufficient.

In-between the measurements of the individual segments, the scanning heads have been manually moved to their new positions to scan the next segment. In order to be able to stitch the individual measurements together into one global model, a consistent global coordinate system for all measurements is needed. We used the standard coordinate system of DaimlerChrysler, with the origin in the middle of the front axes, x in opposition to the driving direction, y pointing from the middle of the car out to the right (view from drivers perspective) and z vertically upwards.

Overall, 472 Scan-points have been measured, each one with its x, y, z vibration components, hence a total of 1416 degrees of freedom. This is largely sufficient for experimental modal tests on the selected surfaces and for the frequency range of interest (up to 200 Hz).

Settings

Even though the interesting frequency range is only up to 200 Hz, 500 Hz bandwidth has been selected with a frequency resolution of 0.625 Hz (Table 1).

As the resulting surface speeds are very low, the high resolution digital decoder VD-07 in its most sensitive range 1mm/s/V (10 mm/s peak) has been used. This range has by far the best noise performance for this measurement task.

In a pre-study, different excitation signals have been tested. As the behavior of the structure is reasonably linear, pseudo-random excitation has been selected. Pseudo-random and periodic chirp present the advantage that amplitude correction files can be applied in the Polytec software to tune the excitation signal to flatten resonances in the applied force. Furthermore, these signals are better suited to measurements with relatively few averages (about 10, see below). Pseudo-random has finally been preferred to periodic chirp as higher excitation forces could be

applied to the structure without breaking the glue of the force transducer.

In order to keep the measurement time short, 10 averages have been selected for standard measurements during day time, 30 averages for measurements over night. 10 averages result in a measurement time of about 30 min for a segment of 100 points which is convenient for such tests and delivers high-quality data.

Table 1: Settings	
Used decoder and range	VD 07, 1mm/s/V
Frequency range	0 – 500 Hz
Frequency resolution	0.625 Hz (800 FFT lines)
Excitation signal	Pseudo random
Excitation force at 150 Hz	500 mN
No. of averages	10 during day time, 30 during night

Workflow

In order to provide an insight on how a measurement with the PSV-3D is performed, the typical workflow is outlined below.

1. **Physically setup** the heads on their tripods to cover the desired scan area. Several considerations should be made:

   - The maximum ±20° scan angle must not be exceeded for ALL heads

   - Distance must not be too big for good signal to noise ratio. This depends also on the scattering properties of the surface and the vibration level (as a rule of thumb for typical modal tests on white paint surfaces the maximum useful distance is somewhere between 3 and 5 m)

   - Sufficient angular separation of the axes of the scan heads (ideal position is an equilateral triangle). Typically, the orientation of each scan head axis is between 10° and 20° to the surface normal, depending on the scattering properties of the surface

2. **2-D alignment** to establish the connection between position on the video image and scan angles

3. **3-D alignment**

   - Definition of the coordinate system by pointing the sensor head with the distance sensor to 3 known points on the car

   - Alignment of left and right heads using 4-7 points whose coordinates can be measured with the distance sensor

4. **Measurement grid definition** (alternatively import of geometry file in universal file format, then skip point 5)

5. **Geometry scan** to get the 3D coordinates of the measurement points (alternatively manually set the distances)

6. **Focus setting**

7. **A/D settings** of the measurement system (frequency range and resolution, excitation signal, window, number of averages etc.)

8. **Perform measurement** (points are automatically scanned)

9. **Data visualization** in the PSV software to check deflection shapes

10. **Data export** into customer's modal analysis software package

Results

In the following paragraph some of the results obtained during the test at DaimlerChrysler are presented.

Stitching of the individual segments

A pre-version of a software feature which will be available in future versions of PSV is used to combine (stitch) all individual measurement segments into one combined PSV file. Global deflection shapes can easily be visualized in this way. The following figures (Figure 3 – 5) show some of the obtained deflection shapes.

The different segments fit very well together, both in terms of pure geometry as well as in terms of the observed deflection shapes, which often extend over more than one segment. An excellent spatial resolution for the frequencies of interest has been achieved without any disturbance of the vibration characteristics of the structure.

The spatial resolution could be increased very easily (and has been in the meanwhile, in a subsequent test with about 5000 points on an entire car surface) so that even higher frequency vibration patterns can be spatially resolved in detail. This point is perhaps even more important in acoustics studies than in modal tests as acoustics tests usually extend up to higher frequencies.
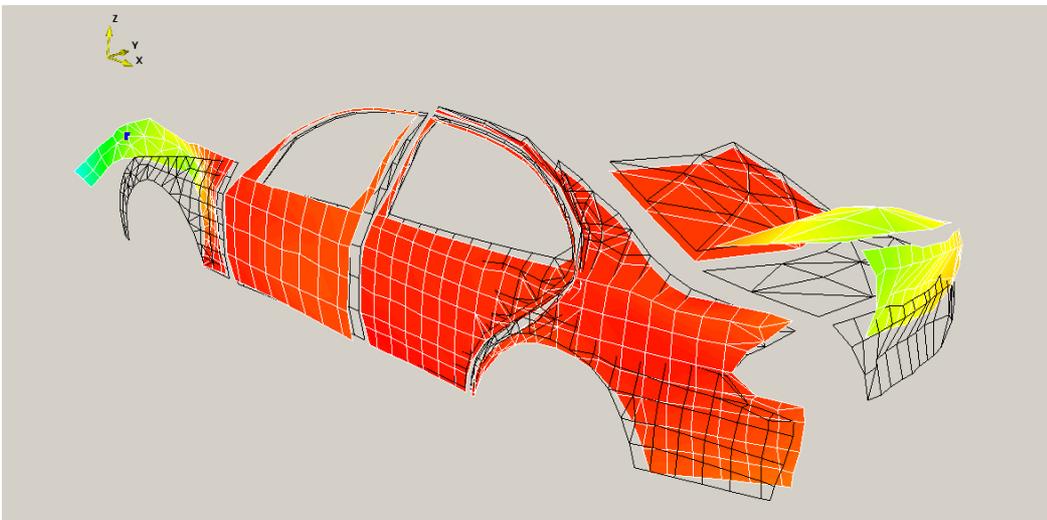

Figure 3: Deflection shape #1. Front fender and trunk opening (frequency value is confidential)
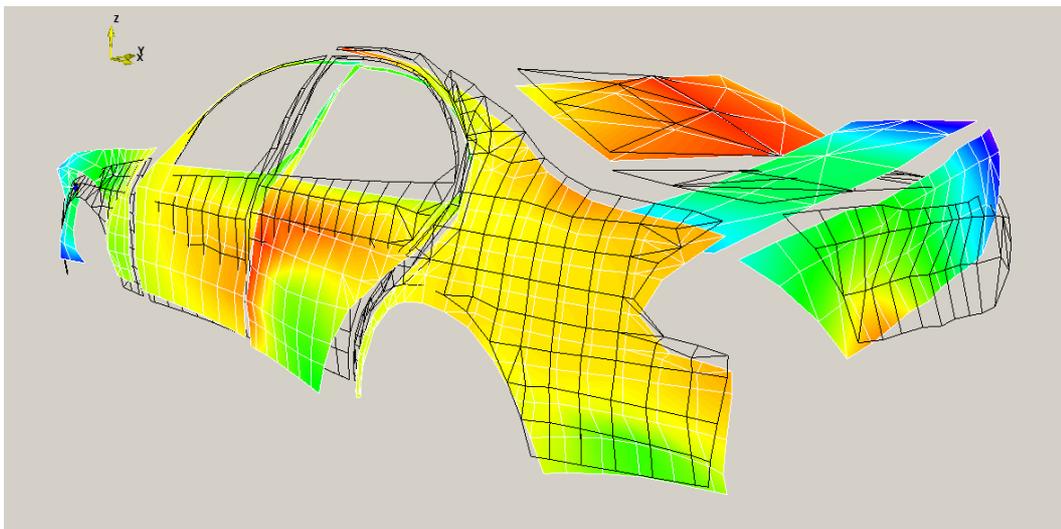
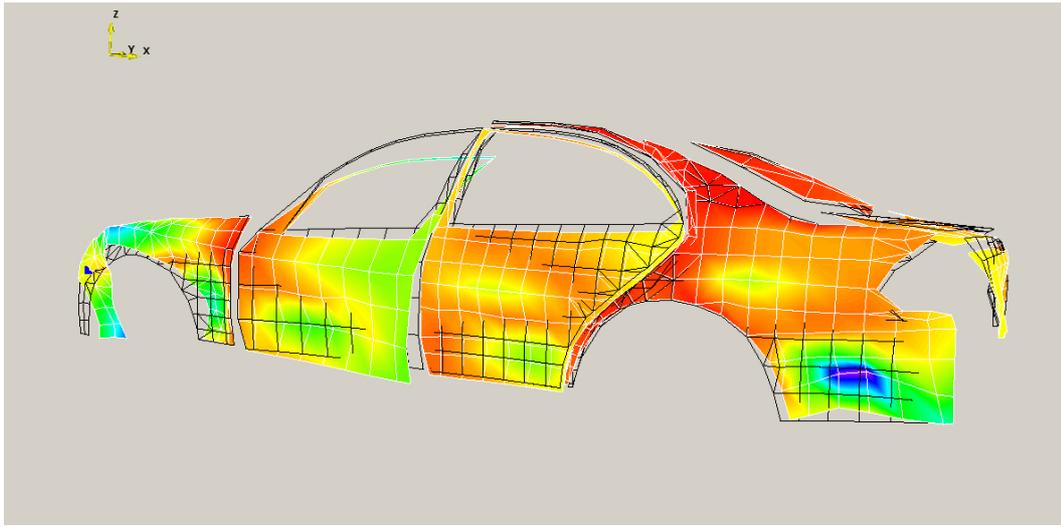**Figure 4: Deflection shape #2. Doors and twist of trunk**

Figure 5: Deflection shape #3. Front door, front and rear fender

Measurement time

The required time for the entire test was 6 to 7 hours. It is composed out of the time for the initial setup and the setup and measurement time for each segment (Table 2).

Table 2: Measurement Time	
Initial setup	1 h
Setup for each segment	30 – 40 min
Measurement of each segment	30 min

The measurement time for each segment depends on the used parameters, which were

- 100 Measurement points, defined on the video image
- 10 averages, frequency resolution: 0.6 Hz

A pre-requisite is that for each segment three points with known coordinates are marked on the structure. If such marked points are not available, one additional hour is required for their definition with the help of the geometry scan unit.

The total time depends of course on the selected measurement segment. If the surface is well accessible, has 'easy' geometric shape and good backscattering properties, the total setup time will be shorter than for hidden, complicatedly shaped surfaces with bad backscattering properties. The estimation above is valid for a typical measurement segment on the side, rear or back of a car body.

The time saving as compared to accelerometers is considerable. It gets even more important as soon as the number of simultaneously measurable accelerometers is exceeded, as in this case accelerometers and dummy masses would have to be displaced during the measurement process.

For higher density grids, the time saving increases, as for the PSV-3D only measurement time increases, the setup time remains nearly constant.

Advantages for FEM – Test Correlation

FEM calculations can take advantage from the high quality measurement data delivered from the PSV-3D: no accelerometer and dummy masses have to be taken into account in the modeling process. The validation of the FE-model is drastically enhanced by the high spatial resolution of the measurement data. This is especially important if simulations at higher frequencies have to be performed in the structural FE-model.

Furthermore, the PSV 3D system is offering the possibility to import the FEM-geometry-model of the surface (in universal file format). This allows for a measurement at all surface nodes of the FE-model. With this the step of the geometrical correlation between the nodes in the test and FE-model is obsolete.

Summary

The PSV-3D proves to be very well suited for data acquisition for structural dynamics tests on car bodies. The main advantages as compared to conventional accelerometers are

- Significant decrease of test time

- Higher point density allows more precise results

- Measurement exactly at coordinates of FE-model possible by geometry import

- No alteration of structure (no change of mass or stiffness) and therefore easier and better FEM-correlation

- Ease of setup (no cabling or labeling)

- No error checking of cabling

For more information please contact your local Polytec sales engineer or visit our website www.polytec.com

Technical specifications are subject to change without notice. LM_AN_VIB-C-01_2005_01_PDF_E

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