Gain a deeper insight

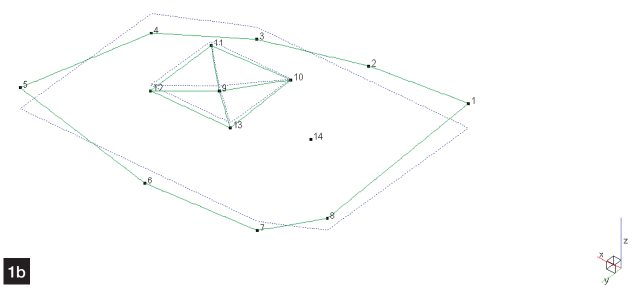
How to gain additional information in vibration testing, such as operational deflection shapes from sine analysis

Vibration testing to international and laboratory standards is important for product verification and approval. Testing has traditionally required an electrodynamic shaker to perform random, sine or shock excitation. Tests are typically used to confirm compliance with a given standard, yet additional information such as operational deflection shapes of the system under test are often neglected, despite being easily identifiable from the measurements at hand. This additional information enables engineers to further identify the source of vibration-induced failures, optimize test fixtures, and compare with real-world deflection shapes using FEA. This can be valuable feedback, helping companies improve products and optimize development processes.

To extract operational deflection shapes, first a comprehensive and representative set of phase-referenced spectra is key. Preferably, measurement positions that are evenly distributed over the test specimen should be selected to achieve an accurate spatial resolution for the operational deflection shapes.

For most applications in the automotive industry, this is already the case, as the vibration level of the specimen is monitored at many locations during a test. Thus, measurement at all relevant positions may be acquired during a single test run. This, however, requires a high number of measurement channels and sensors, which may introduce a mass-loading effect in the case of a light test specimen. In those cases, repeated test runs with a low sensor count are preferable, but require manual relocation of individual sensors between test runs.

1a



1b

FIGURES 1A and B: Electrodynamic shaker with test specimen and sensors (top); undeformed geometry and operational deflection shape extracted from sweep test at 186Hz (bottom)

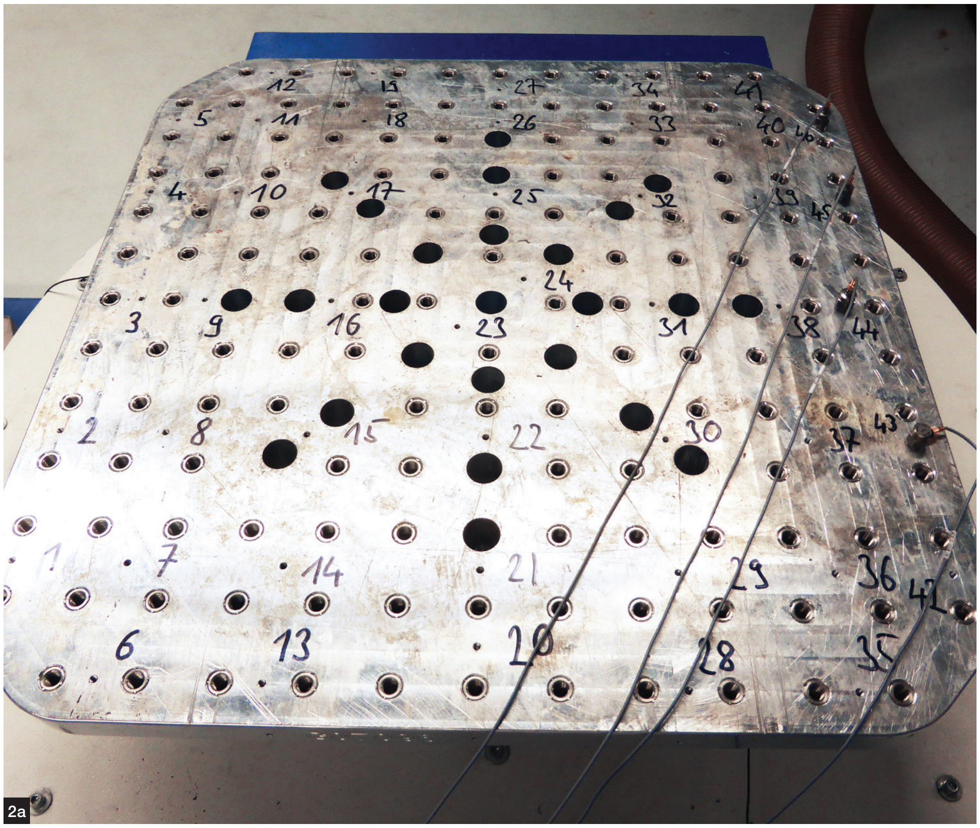
For each test run, the vibration controller generates a spectrum for each measurement point, which is phase-referenced to the control channel. Finally, the results are loaded into modal analysis software. In the software, a geometry is created and each measurement is mapped to a single geometry node. The operational deflection shapes for individual frequencies may now be reviewed and analyzed.

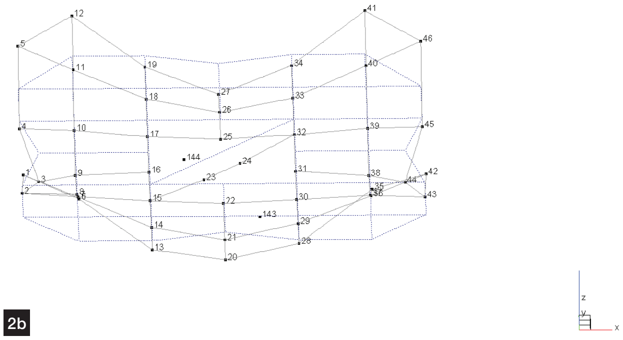
The analysis of a PCB, depicted in Figure 1, has been carried out using m+p international's software solutions, m+p VibControl and the m+p Analyzer. The circuit board is attached to a shaker, which is also being used by the controller to control the vibration level, with the reference sensor placed at position 14. The tear drop accelerometer measures the response vibration level and is relocated between the test runs to measurement positions 1 to 13. A sweep test with a sweep rate of 1 oct/min in the frequency range of 100-500Hz at 0.5*g* p-p amplitude was chosen at the reference sensor.

The analysis showed three frequencies with high response amplitudes – 186Hz, 284Hz and 408Hz. Figure 1b depicts the undeformed geometry (blue) and operational deflection shape at 186Hz (green). High amplitudes were observed at the four corners of the PCB, where points 1 and 5 are moving in and out of phase to points 4 and 8. This type of analysis may give an insight into where high stress levels in the board occur and which circuit paths are most prone to failure. It also helps engineers in planning follow-up tests, such as choosing appropriate sine dwell test frequencies.

The following example illustrates the results of a test campaign at a customer site, where operational deflection shapes of a head expander were acquired. Figure 2 shows the head expander without any additional test specimen (top) and the geometry for deflection shape analysis (bottom). At 1,954Hz the four corners of the head expander are moving in phase, showing a plate-like vibration. This result, together with additional lower-frequency operational deflection shapes, verified the preliminary finite element calculation. It also confirmed the correct placement of the reference sensor in a gap between the head expander and the armature, as placing it directly on the head expander may result in over- or under-testing.

Using the data acquired from a sweep test, it is possible to create a model of a test specimen or fixture and easily visualize the operational deflection shapes encountered during a vibration test. These results provide engineers with additional insight into the vibration characteristics, help improve test methods, and enable the source of vibration-induced failure to be identified. Data acquisition and operational deflection shape calculation are an integral part of the m+p VibControl and m+p Analyzer. Data types are compatible and geometry generation and measurement mapping can easily be conducted. ❮





FIGURES 2A AND B: Head expander with sensors and measuring grid (top); undeformed and deformed operational deflection shape extracted at 1,954Hz (bottom)