

# Vibration Visualization

## Application Note 060



It is difficult to imagine the actual vibration level and distribution from the numerical display or signals, which are basically a mathematical representation of the vibration experienced by the structure under test. Animating the structure's deformation provides users with a clearer representation of the intensity from vibration. A contour scale which graphically displays the magnitude of vibration on the structure using a color plot aids in visualizing the areas a test unit is experiencing the maximum and minimum magnitude of the vibrations.

A 3D geometry model of the structure under test is required to animate the vibration it is experiencing. It is challenging to create a 3D model of intricate geometries because of the complexity involved in measuring the x, y, z coordinates of the test article and to utilize the information to generate a model with lines and surfaces.

The vibration visualization approach proposed by Crystal Instruments not only helps in overcoming the difficulty of producing 3D geometries of any complicated models with a simple procedure but also animates the structure's deformation which makes it possible to visualize the vibration experienced by the testing article during a vibration test. (Figure 1.1)

As illustrated in the diagram above, a series of 2-dimensional photos taken from a smartphone are used to construct a real 3-dimensional model of an object. The object is put under a vibration test, during which the vibration can be visualized in real time using a real 3D model.

The vibration visualization of the 3D model can be performed in real-time while the measurement is ongoing or offline after completing the measurement. The real-time

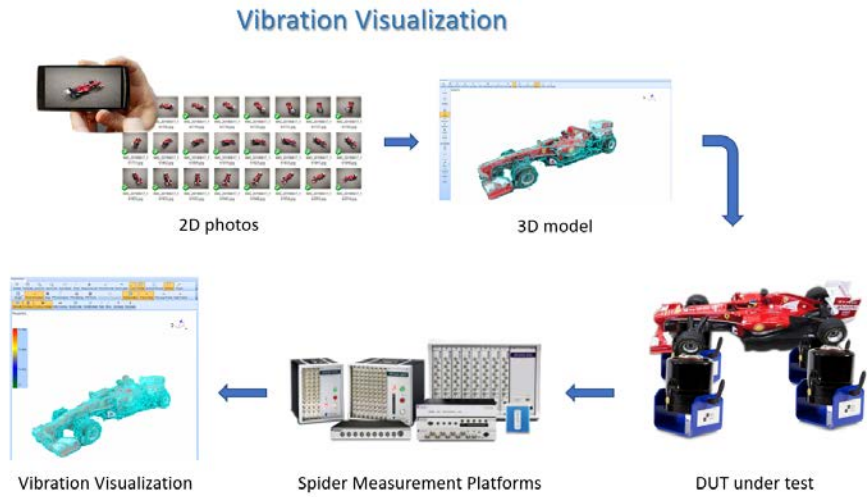


Figure 1.1 An overview of the proposed Vibration Visualization procedure

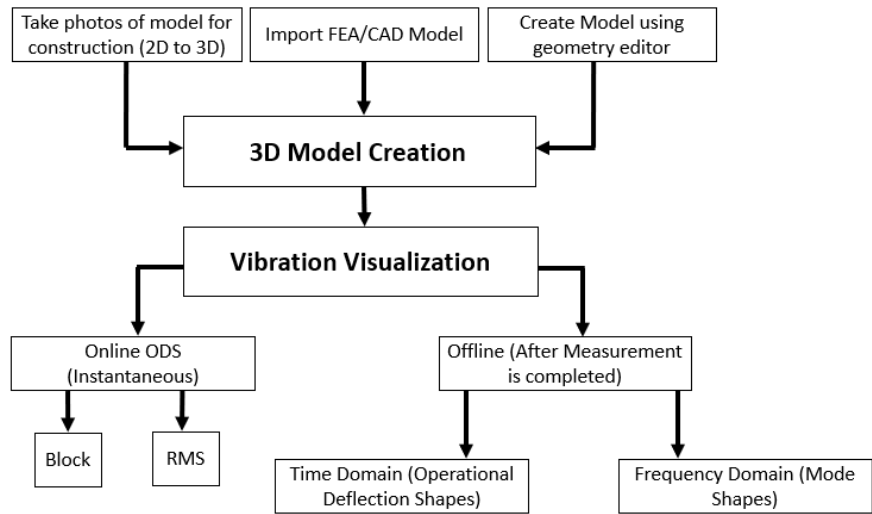


Figure 1.2 A schematic flowchart of the Vibration Visualization process

animation can use point or RMS data of the input channels (sensors) to display the deformation of the test article during the vibration tests. The offline vibration data can be visualized in the time domain as well as the frequency domain. The time domain animation shows the combined effect of all the modes whereas the frequency domain animation uncouples the modes and shows the effect of vibration mode at the respective frequency.

There are three methods of generating a three-dimensional geometry model of the structure under test. (Figure 1.2)

Crystal Instrument's 3D model reconstruction software uses the advanced technology of 2D to 3D reconstruction to provide a simple solution for the intricacies of creating 3D geometric models from convoluted test structures. This approach not only saves the user a significant amount of time and effort but also provides an accurate model with great simplicity. The user simply takes photos of the test article and feeds it into the software. The uploaded images are matched to extract the features and a 3D model of the structure is constructed after the point and surface reconstruction processes. This method is extremely

easy to use, does not require any manual labor and is much quicker than the other two approaches.

The following steps briefly explains the working principle behind the 2D to 3D reconstruction procedure. (Figure 1.3)

- Capture photos

The user takes 2D photos around the testing object. The photos can be taken using a smartphone or a camera. To obtain an accurate 3D model it is suggested that the user takes photos at about every 15 degrees which corresponds to approximately 24 photos of the test object. Increasing the number of photos will improve the accuracy of the model but might increase processing time.

- 2D to 3D reconstruction in Crystal Instrument's 3D Model Reconstruction software (Figure 1.4)

### 1. Load Images

The 2D photos are imported into the reconstruction software to match the images and extract the features. (Figure 1.5)

### 2. Feature Extraction

Based on the triangulation principle, two corresponding photos are used to determine the depth of the test object. The 15-degree interval helps in obtaining an optimal overlap between consecutive images which further improves the image matching. (Figure 1.6)

The CCD width is determined by the number of pixels in the photo and the focal length of the camera. A higher number of pixels and larger CCD size implies a better resolution of the photo. The image scale basically implies if the photos are rescaled to complete the image matching

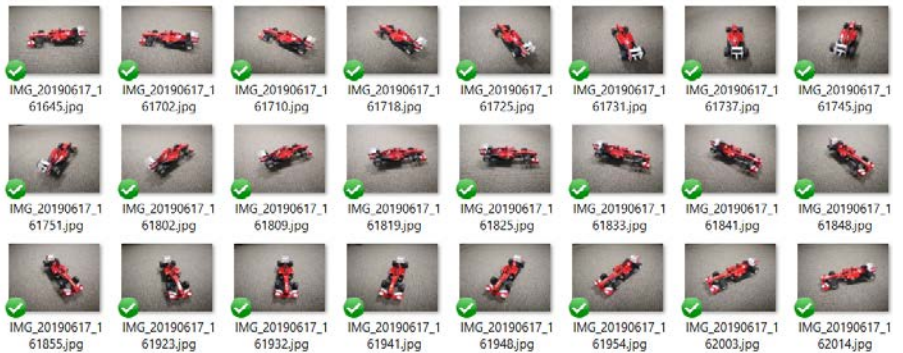


Figure 1.3 Captured Images of the test structure

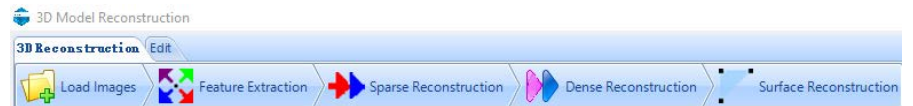


Figure 1.4 A screenshot of the processes involved in 2D to 3D reconstruction procedure

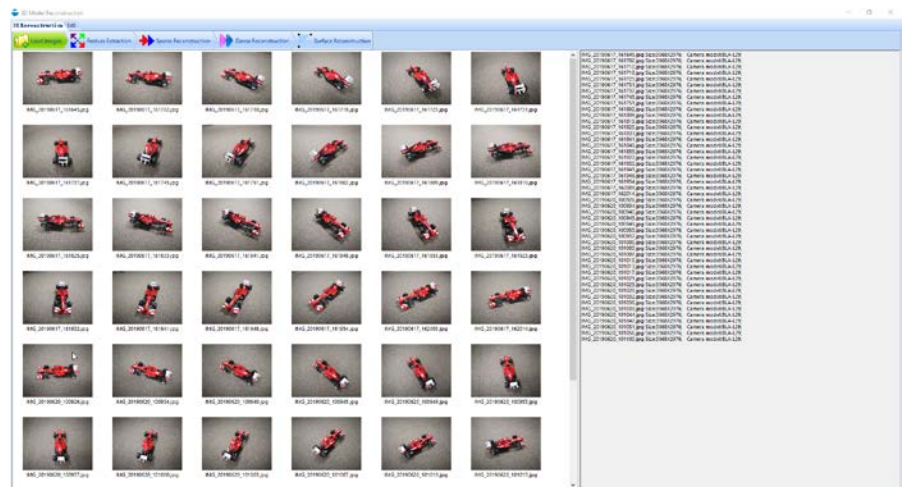


Figure 1.5 Images loaded into the EDM 3D Reconstruction software

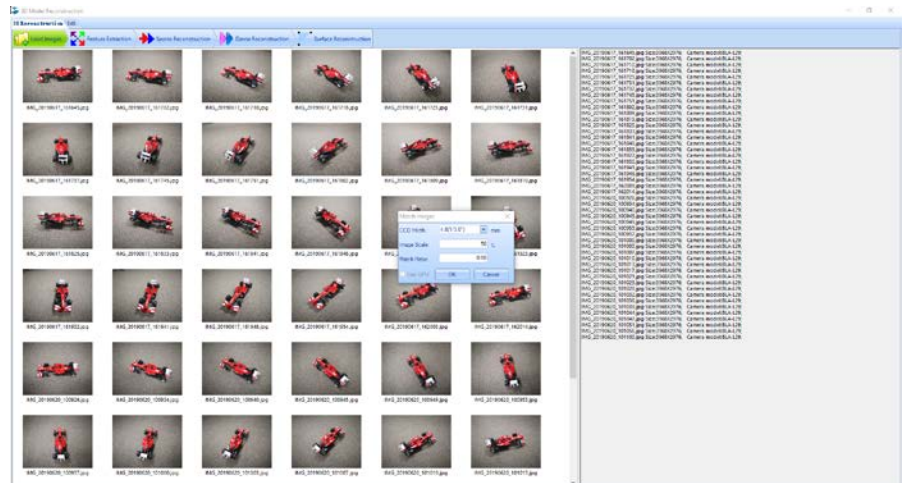


Figure 1.6

process. The default match ratio of 0.6 should be enough to obtain a

good match between the images. This is a suitable balance between good

image matching and the fast feature extraction process. (Figure 1.7)

### 3. Sparse and Dense Reconstruction

Detecting the key features from the images helps in creating a sparse point model of the test structure. This is a fast and rough model creation before the constructed point geometry is fine tuned in the dense point reconstruction procedure. The initial image pairs to begin the sparse point model reconstruction can be automatically chosen by the software. (Figure 1.8)

More information from the feature extraction and sparse point reconstruction is used to generate a dense point 3D model. (Figure 1.9 and Figure 1.10)

### 4. Surface Reconstruction

A complete 3D model is produced in the surface reconstruction stage by automatically joining all the points in the penultimate dense point model. (Figure 1.11)

### 5. Geometry Editor

Once the 3D model is in the Geometry Editor, various features in the software can be used to trim and modify certain sections of the 3D model to improve the aesthetics of the geometric model. One typical operation is to remove the floor for the race car model as seen in the following screenshot. The resulting model can then be exported to a .vrm format and imported into EDM Modal, VCS or DSA software to utilize the vibration visualization application. (Figure 1.12)

The constructed 3D model is used to visualize the vibration of the test structure either in real-time (Online ODS) when the measurement is ongoing, or post-process (time domain and frequency domain) after all the measurement runs are completed. This is discussed in detail in the next section. (Figure 1.13)



Figure 1.7 A screenshot of the completed Feature Extraction process

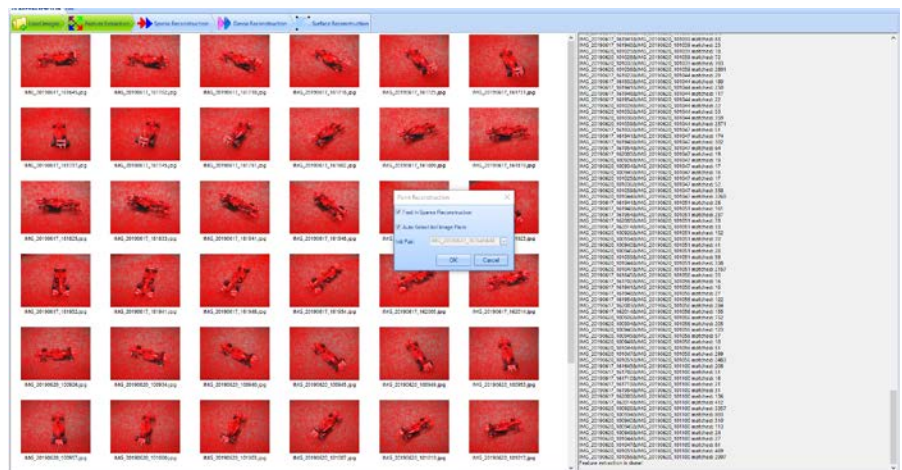


Figure 1.8 Settings for Sparse Reconstruction process

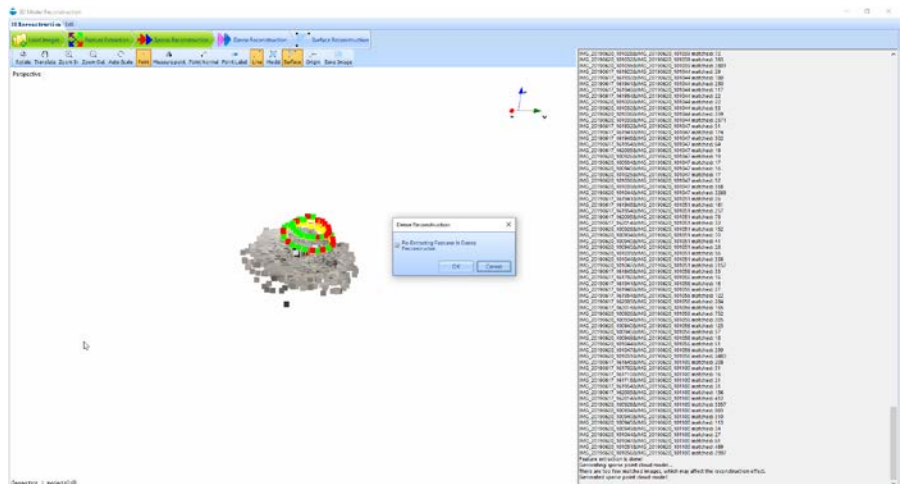


Figure 1.9 Prompt for Dense Reconstruction process

Using the created 3D model, the vibration visualization can be carried out while the vibration test or analysis is ongoing, or after the vibration data

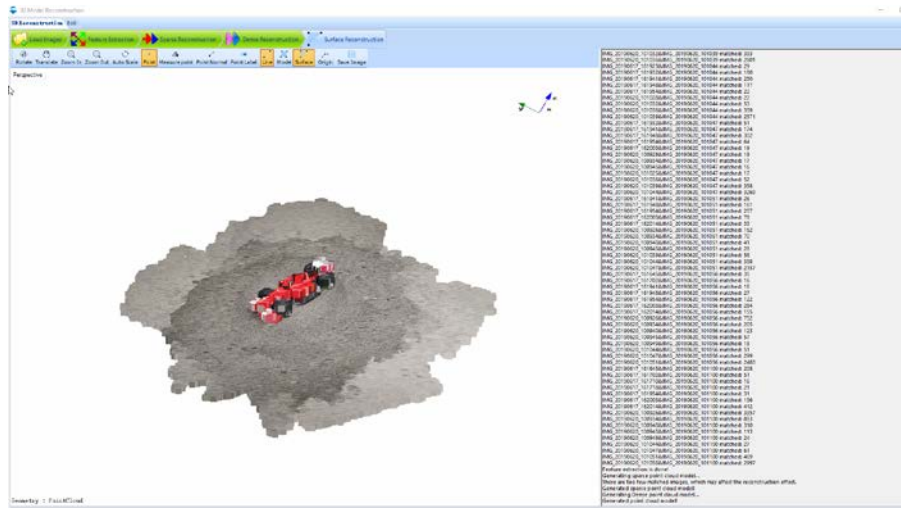
is saved or recorded. After attaching sensors onto the test structure at different measurement points, a vibration test is carried out. The data acquired at these sensor locations

is used to animate the vibration of the 3D model at these measurement points. The measured data set can be used to perform global interpolation and calculate the deformation of the unmeasured points spread across the entire structure. This greatly simplifies the process of measuring data at all the points. Vibration visualization feature collectively provides the animation of the test structure at these points on the constructed 3D model.

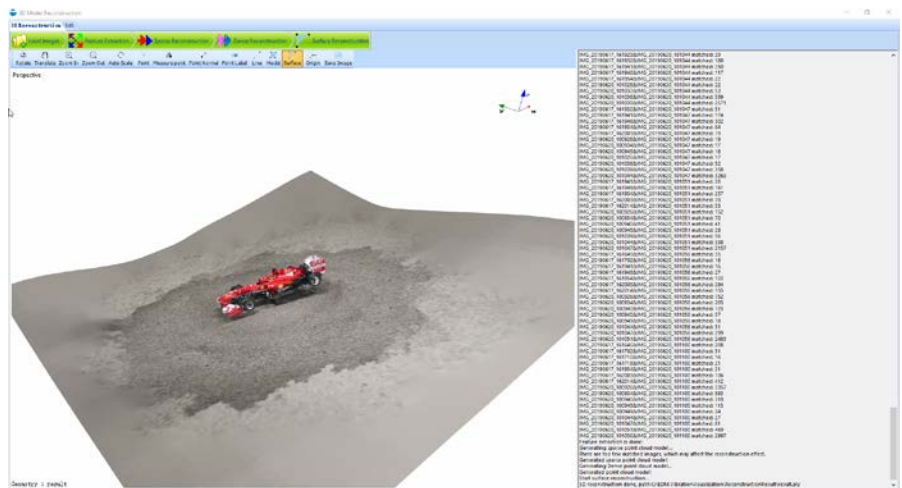
When a 3D model is available, the data from the signals can be used to animate the instantaneous deformation of the structure. Information from this vibration visualization and the contour plot scale can be used to optimize the location of sensors as the user knows which section of the testing article has higher or lower deformation. Similarly, this knowledge can also be used to change the excitation location to obtain an optimal response at the desired locations. This information can also be used to modify the control profile for the test article by reducing the test level in order to prevent any damage to the structure. (Figure 1.14)

*Figure 14 - Vibration visualization of the test structure's operational deflection shape in real time*

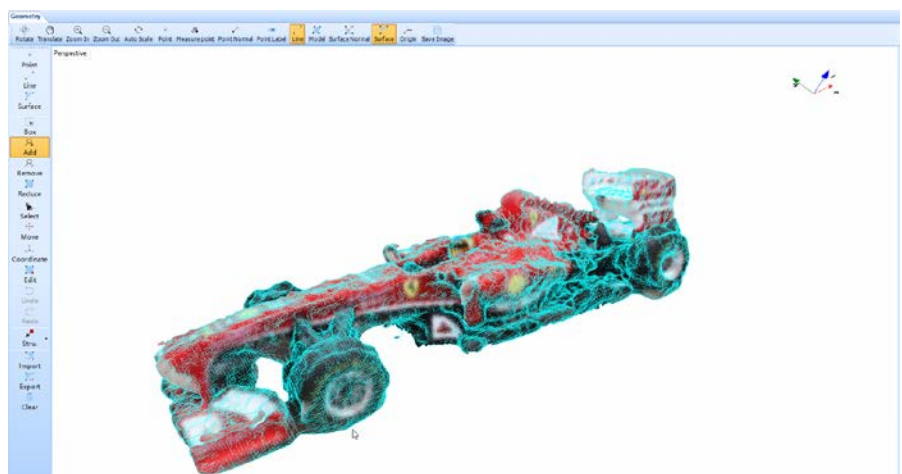
The online vibration visualization feature can use either block or RMS data from the input channels to animate the deformation experienced by the test structure at these sensor locations. The block data is useful for a more instantaneous display of vibration visualization of the structure under test. The animation is updated every 40 milliseconds when the block data of the sensors is used for visualizing the vibration of the test article. While the block option has a faster update, the vibration visualization of the test structure might not be able to reach maximum or minimum deformation.



**Figure 1.10 A screenshot of the dense point constructed model**



**Figure 1.11 A screenshot of the completed surface reconstruction process**



**Figure 1.12 The final 3D model**

The RMS option displays the RMS data of each time block and is more useful to observe which measurement points have maximum or minimum

deformation.

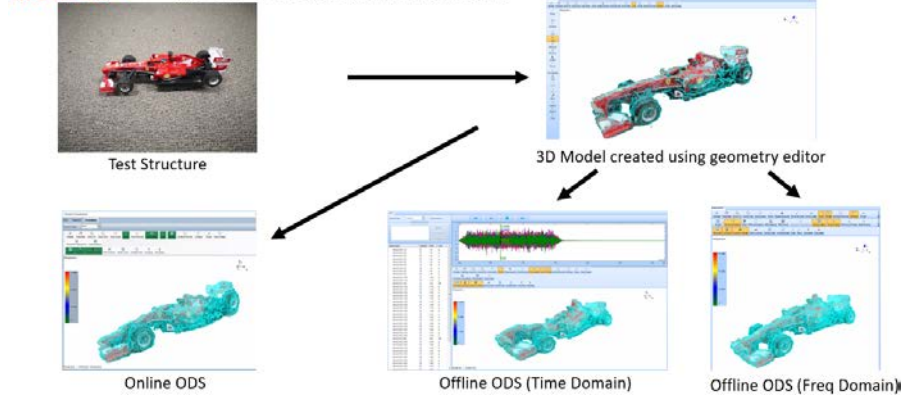
Vibration visualization is not only useful in real time (Online

ODS) where a user can see the instantaneous deformation of the structure but is also helpful after the completion of measurements. The measured data can be analyzed and visualized to observe the test structure's vibration in both the time and frequency domain.

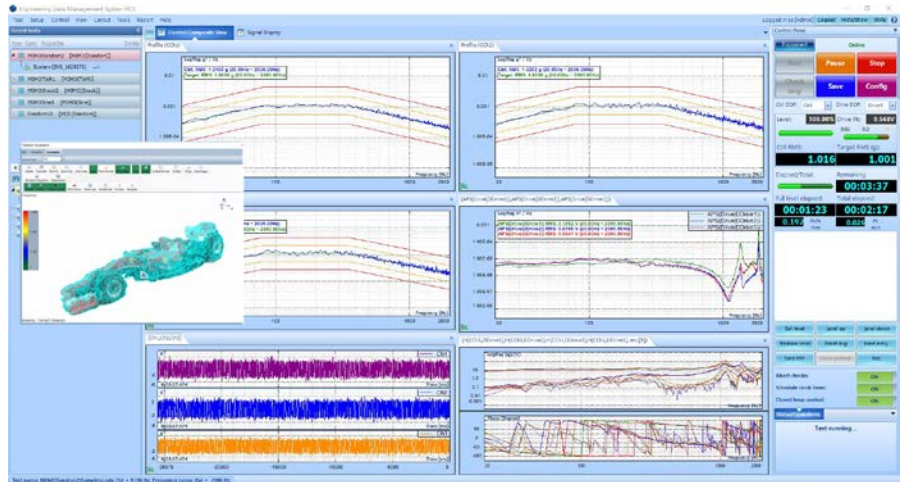
The offline time domain data replays the vibration measured at each time instant during the test. This is more useful to monitor the entire structure's response through the complete excitation event. The three-dimensional geometric model requires a huge number of points for accuracy, but it makes it difficult for the user to have such huge number of measurement points. The global interpolation feature in our software saves the user a significant amount of time and effort. The user sets up the test, establishes a connection and collects data for a reasonable number of measurement points and uses this information to interpolate and calculate the deformation of the unmeasured points spread across the entire structure. The information from the current test can be used to optimize future tests by experimenting around with the configuration settings, test setup etc. (Figure 1.15)

Vibration visualization of offline frequency domain data shows the mode shapes of the test structure at the associated natural frequencies. The animation of these mode shapes further guides users to a better understanding of the dynamic response of the test structure to the input excitation. This information can be used to improve the mechanical characteristics of the test object. The damping of the test structure can be adjusted accordingly to reduce the dominance of certain modes. (Figure 1.16)

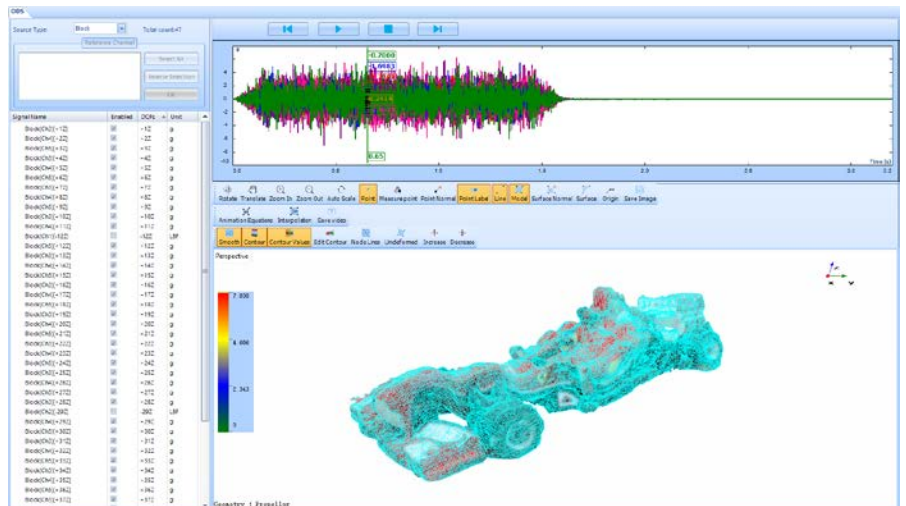
**Method 1 – 2D to 3D Reconstruction**



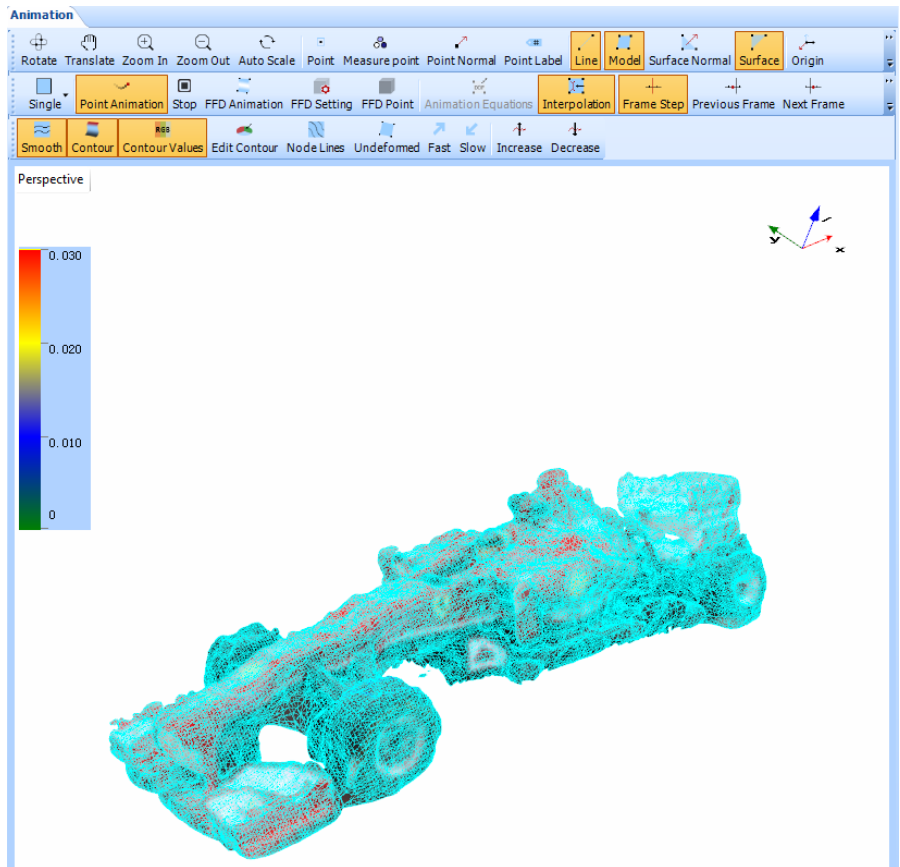
**Figure 1.13** A general overview of the testing process for a reconstructed 3D model



**Figure 1.14** Vibration visualization of the test structure's operational deflection shape in real time



**Figure 1.15** Vibration visualization of the test structure's operational deflection shape in the time domain after completion of a modal test



**Figure 1.16** *Vibration visualization of the test structure's mode shape after completion of a modal test*

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