APPLICATION NOTE

Modal Testing of a Roll Over Protection Structure

ROPS used in Off-Road Vehicles at AIMIL Noise & Vibration Engineering Services (NVES), *with Kumaraswamy S, Dy. Application Manager.*

Introduction

Roll Over Protection Structure (ROPS) refers to operator compartment structures (usually cabs – Enclosed Roll Over Protection Structure or frames – Roll Over Protection Structure) intended to protect equipment operators from injuries caused by vehicle overturns or rollovers. ROPS are commonly found on off-road vehicles used in construction (Road Compactors, Pavers etc) and agriculture (Tractors etc). The ROPS tested for **modal** behaviour in the present case is for use in a road compactor; which is a compactor type vehicle used to compact soil, gravel, asphalt in the construction of roads and foundations. Road compactor tested here is a vibratory roller machine wherein the drum vibrating at different frequencies during compaction. The objective of the modal test on ROPS is to determine the natural or resonant frequencies. Thus to ensure that **the natural frequencies of the ROPS are not in the frequency range of operation** of the compactor machine which would otherwise result in resonance phenomenon and may eventually cause failure of ROPS.

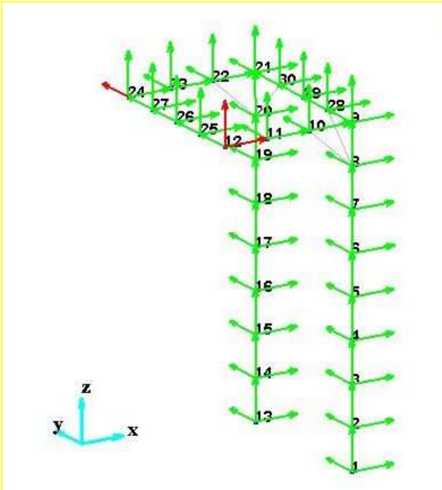
Description

The task involved experimental modal testing on Roll Over Protection Structure of a compactor machine in its assembled condition. Impulse excitation using an impact hammer is used to determine natural frequencies, up to a frequency bandwidth of 60 Hz, damping and mode shapes of the structure.

An **impulse hammer** with built-in force transducer is used to excite the structure and to measure the excitation force. Impulse hammer with a super soft tip and an extender mass is used for exciting the structure. **Two low mass tri-axial IEPE type** (Integrated Electronics Piezo-Electric type – Endevco Make, Model No: 65-100) accelerometers are used to measure the response due to excitation. The force and the response are recorded on **an 8 channel data acquisition system (OROS France, OR36)**. The measured data is analyzed using NVSolutions – **OROS Modal 2 software** suite to determine the modal parameters of the structure.
The procedure adopted is as explained below.

Geometry Creation

A representative geometry of the test structure is created using points linked using lines. The points defined in the geometry are the actual physical locations where structure is excited and input force / acceleration response are measured. For the structure under test, three degrees of freedom (DOFs) for excitation and 30 locations are identified for response measurements in the three directions – **MIMO** (Multi Input – Multi Output). Figure below illustrates the representative geometry created using OROS Modal 2 software suite. The figure also shows the measurement/excitation locations and the direction convention adopted for the modal testing.



Excitation Degree of Freedom - Reference
(3 Locations *represented by Red arrows*)

Measurement Degree of Freedom - Response
(30 Locations *represented by Green arrows*)

Boundary Conditions

This basically involves defining test structure suspension/mounting method during testing. In the present case the objective of the test is to determine the dynamic characteristics under the operating conditions and this is ensured by defining the test boundary conditions to match **as close as possible to the operating boundary conditions** by testing the structure in its assembled condition.

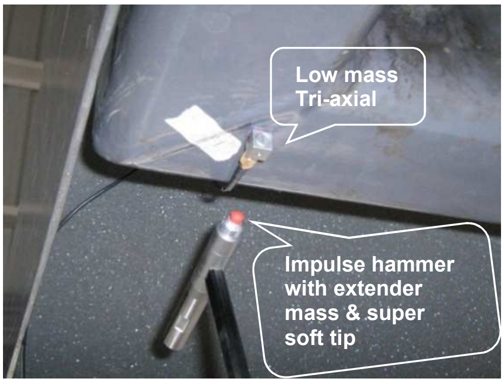
Excitation technique

Multi Input Multi Output (MIMO) and Roving Response technique is employed here. The structure is excited at three DOFs (Multi Input) sequentially one after the others and the acceleration response is measured in all the locations (30 locations – Multi Output) in three orthogonal directions (Horizontal, Vertical & Axial). The excitation location is selected by ensuring that the excitation or force input reaches all through the structure to be able **to excite all likely modes of the structure**. This is done by scanning or surveying the response at different locations for the excitation at different locations on the structure. An Impulse hammer with extender mass fitted with a super soft tip is used to excite the structure. Force transducer built in measures the excitation force. The super soft tip and the extender mass configuration for excitation is selected as the frequency range of interest for modal testing is relatively lower (10 - 60 Hz).

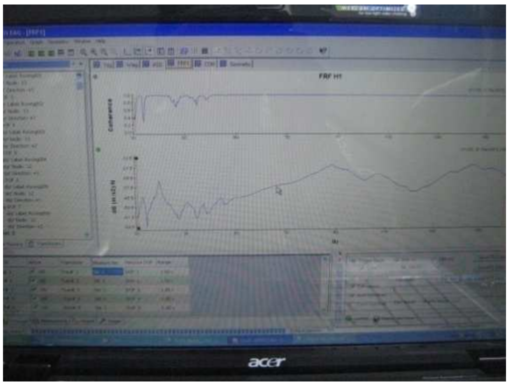
Test configuration

Before proceeding with the testing, the test conditions (like suitability of excitation point, selection of hammer tip etc) are validated for ensuring the correct data for modal analysis. This is done by monitoring and measuring the **Force spectrum, Driving Point FRF, Coherence to confirm and be assured of the reciprocity, linearity, selection of excitation locations and the selection of hammer tip.** These pre-test checks are essential to measure correct data from the testing and to process reliable results from the analysis

OROS System: OR36



Force & acceleration Sensor



OROS Modal 2 Software

Force Spectrum

The force input made using an impulse hammer should excite the structure at all the frequencies within the frequency range of interest. In the present case, the interest is the lower frequencies from 10 to 60 Hz, thus Impulse hammer with extender mass & super soft tip is used to excite the structure. During the measurements it was ensured that the force spectrum is linear for all the frequencies up to 100 Hz; assuring force excitation at all the frequencies within the frequency range of interest for testing.

Driving Point FRF

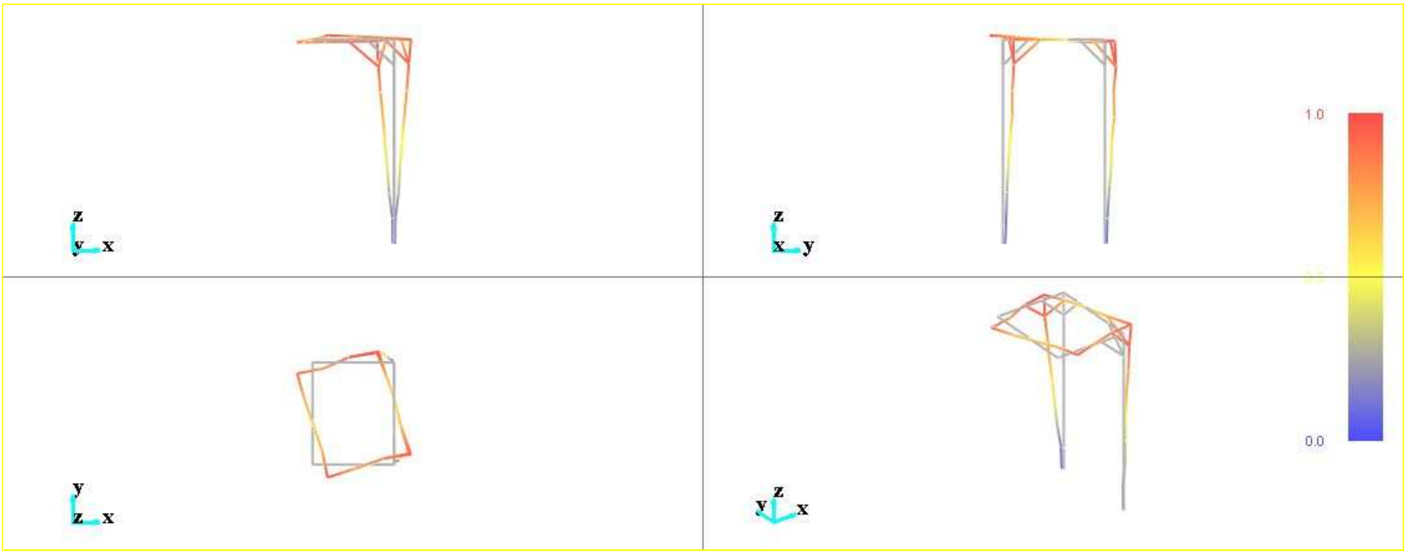
A driving point FRF is an FRF between an input and an output signal at the same degree of freedom. For modal analysis, this is most commonly the FRF obtained when the exciter and the accelerometer are positioned at the same DOF (node and direction).

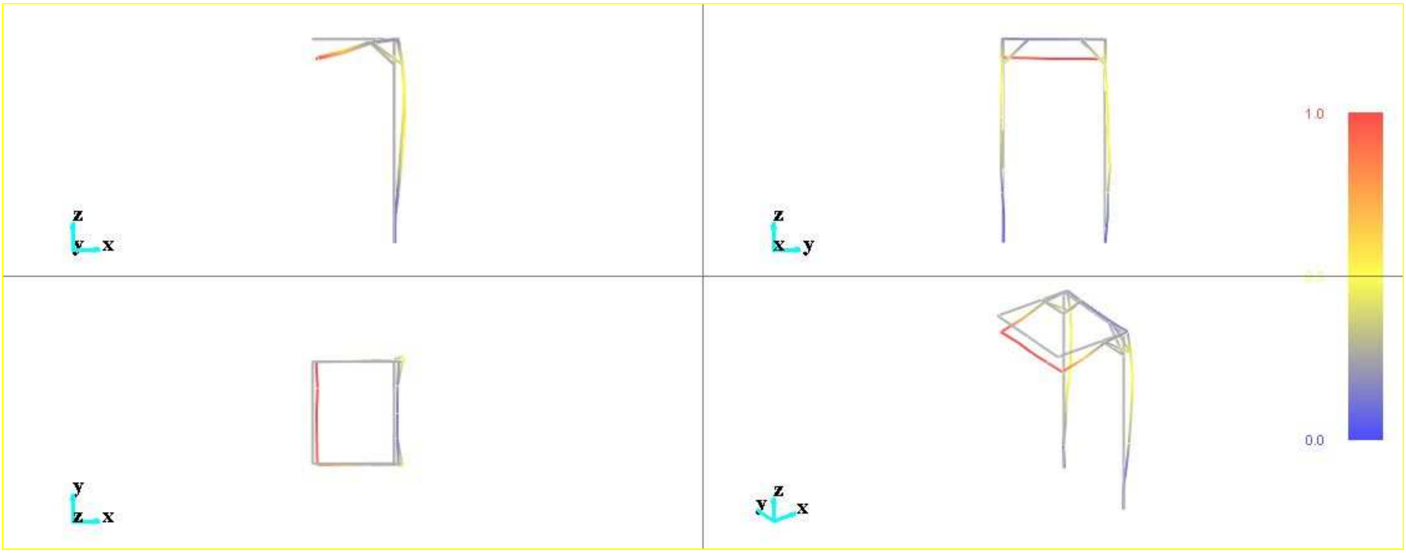
Coherence

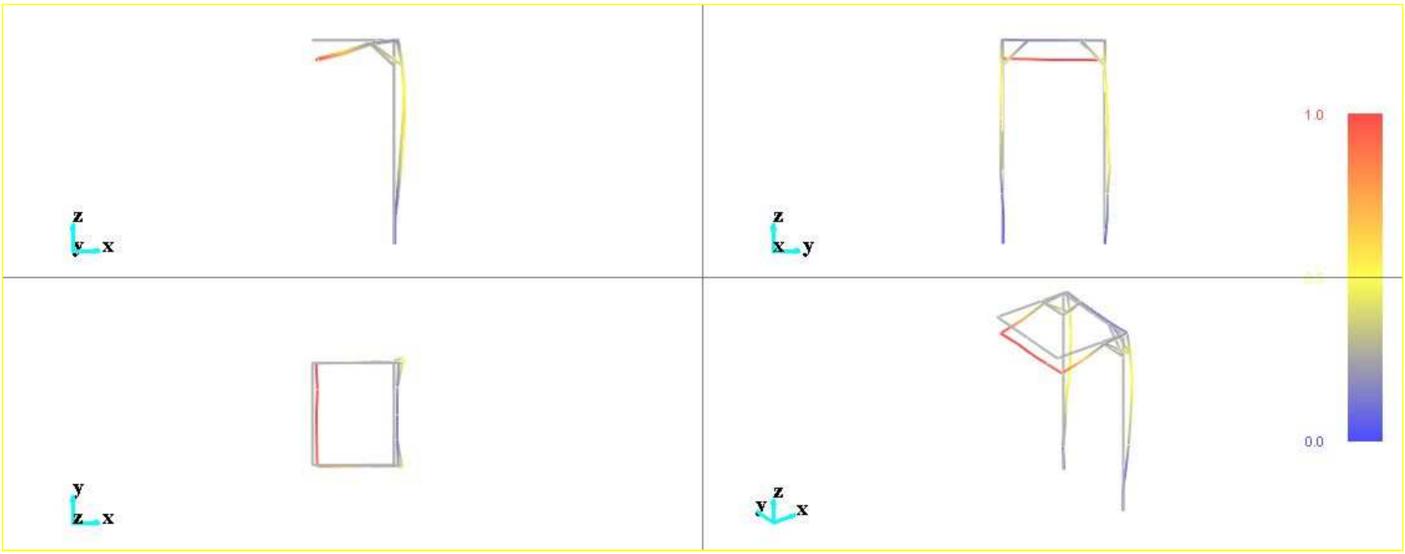
Coherence is the depiction of how much of output response is caused by the input force; a Coherence of 1 or 100 % is the best relationship between input and output and implies the measured response is purely because of the input excitation. The Coherence Function also provides a means of assessing the degree of linearity between the input and output signals. Practically coherence values of around 85 to 90 % (0.85 to 0.90) at resonance frequencies are acceptable.

After measuring FRFs at all 30 locations on the structure, the FRF data are analyzed for determining the modal behaviour of ROPS. ***EMA-BroBand, EMA-NarBand*** **and** ***EMA-SelBand MIMO*** **algorithms** in OROS Modal 2 software are used to compute natural frequencies of the structure. Further, damping ratio at each of the computed natural frequencies and mode shapes illustrating the structural deformation at each of the natural frequencies is determined. The Measurements & Analysis are validated for its correctness by computing **MAC** (Modal Assurance Criterion), **Synthesized and Stabilized FRF plot.**

Typical mode shapes of ROPS determined using OROS Modal 2 are given below.







Conclusion

OROS Analyzer with OROS Modal 2 offers a complete package for Modal Testing (both shaker based and impulse hammer based testing) starting **from geometry creation to data acquisition to data analysis** (using various algorithms depending on the type of testing). The solution is easy to use and help to **perform a quick and reliable modal testing**. Using OROS system and Modal solution; the test case explained above was done in **just ONE day**. The results of experimental modal testing were appeared to be in good correlation with modal analysis performed using Finite Element Analysis (FEA).

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