

High Speed 3D Digital Image Correlation for experimental modal analysis during base motion excitation

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Introduction

Recent research has proved that 3D Digital Image Correlation using High Speed cameras (HS 3D-DIC) is an interesting technique for experimental modal analysis since it provides full-field non-invasive modal characterisations. Previous work using HS 3D-DIC for modal analysis has been focused on mode shapes determination during fixed-sine excitation [1] and the identification of modal parameters in full-field Frequency Response Functions (FRFs) during random excitation tests [2]. In this study, full modal characterisation was performed using transmissibility functions during base motion excitation tests, dealing with Transmissibility Functions instead of FRFs. A reference Material (RM) [3] consisting in a stepped cantilever bar for optical sets calibration has been studied. Finally, a modal identification has been performed using the circle-fit method on modified Transmissibility Functions [4].

Finite Element Method (FEM) has been employed for validation purposes. Modal Assurance Criterion (MAC) was considered in order to provide a quantitative indicator for mode shapes comparison.

Experimental procedure

The adopted experimental setup is shown in Fig. 1. Measurements were performed using two high speed cameras (model FastCam SA4 by Photron). A white noise random excitation was applied using an electrodynamic shaker. In addition, an accelerometer was employed to measure the excitation in the clamping system to determine the transmissibility functions. A DAQ system (NI USB-6251 DAQ) was also employed to register the accelerometer signal and to synchronise it with high speed cameras.

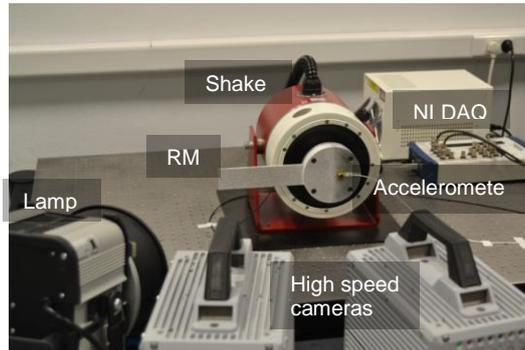


Fig. 1: Experimental set up for modal analysis

DIC processing allowed to obtain displacement fields. Processing those fields together with the accelerometer, full-field Transmissibility Functions were obtained. Previous to circle-fit analysis, Transmissibility functions had to be transformed into equivalent FRFs by means of the Eq. 1.

$$H(i\omega) = \frac{T(i\omega)}{(\omega / \omega_n)^2} \quad (1)$$

Results

From the analysis of full-field transmissibility functions, two resonance peaks were detected. In Fig. 2, transmissibility function from a point of the tip shows the two peaks corresponding to bending modes. The vicinity of each peak was analysed using the circle-fit method for modal parameters identification. The first natural frequency was found at 135.38 Hz and the structural damping ratio for this mode was 1.69%. For the second mode, the natural frequency was 767.78 Hz and the damping ratio 1.45%. FEM analysis determined the first two bending modes at 131 Hz and 818 Hz.

Full-field experimental mode shapes are presented in Fig. 3 with a normalised scale. Both modes illustrates typical bending modes where maximum displacement takes place at the released tip. The first mode shows one zero-displacement node at the clamping. The second mode shows an additional zero-displacement node, located at 120 mm.

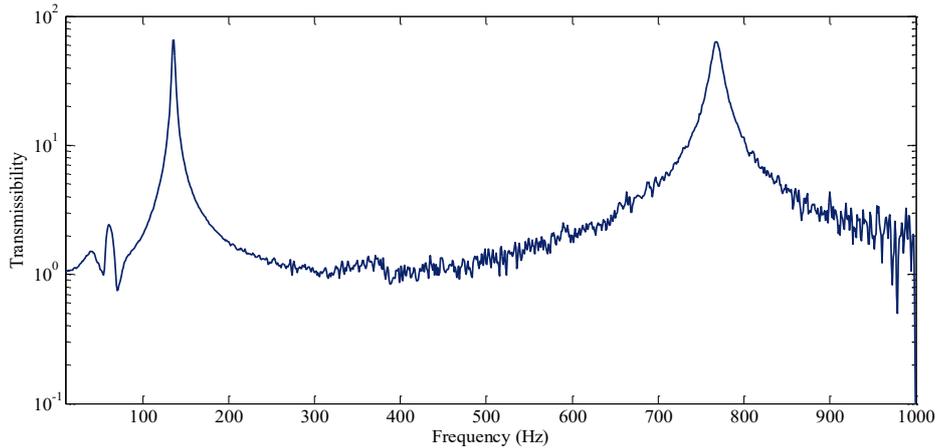


Fig. 2: Transmissibility function at the tip of the beam

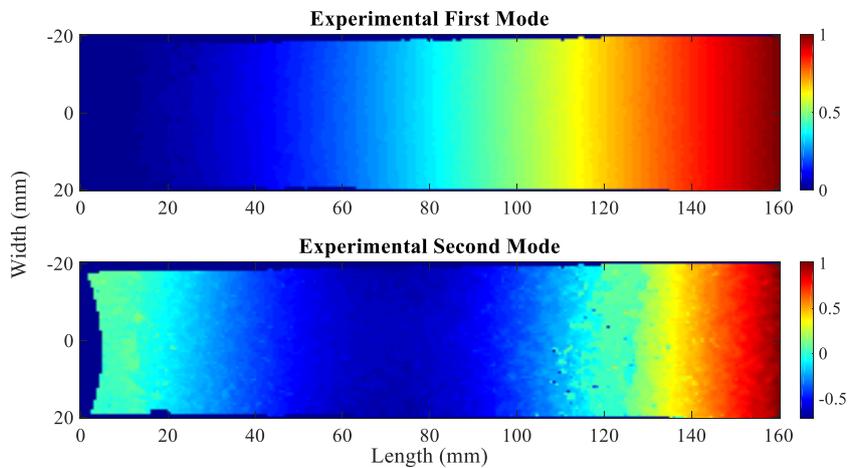


Fig. 3: Experimental mode shapes of the first two bending modes using DIC

The correlation between experimental and FEM mode shapes was analysed using MAC. For the first mode, a correlation factor of 1.0000 was obtained while for the second mode the correlation factor was 0.9836. Thus, both results are consistent according to numerical models.

Conclusion

Full-field modal characterisation has been performed using HS 3D-DIC for base motion excitation configurations. As a result, the real behaviour of the beam was registered. Moreover, the full-field beam view provides a better characterisation of mode shapes. For the analysis, only a random excitation test to obtain transmissibility function was required. The circle-fit method was able to identify natural frequency and determine their corresponding structural damping ratios and mode shapes. Experimental results agreed with those obtained from FEM calculations. In particular, the MAC indicator was employed to compare mode shapes showing values close to unity, what involves good correlation between both methods.

References

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