Analysis of Non-linear Vibrations Using DIC and the Smoothed Harmonics Method

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Abstract. This work focuses on the development of a methodology to extend the down-sampling method to the study of the dynamic behavior of components when non-linear phenomena must be considered. The proposed method is general but in this work it was applied together with a full-field measurement using the Digital Image Correlation. The proposed approach overcomes the cameras low frame rate limitation in case of steady state periodic oscillations by making use of a new sub-sampling technique, named *Smoothed Harmonics Method*. This method allows an accurate reconstruction of the under-sampled signal. The method was applied to a beam with non linear stiffness loaded with harmonic excitation.

Introduction

Non-contact full-field measurement techniques have gained a predominant role since they overcome the main limitations of single point contact techniques: i.e. added mass effect, data transmission for rotating machines and difficulties on describing complex and high-frequency deformed shapes. In this scenario, the development of 3D full-field measurements techniques based on Digital Image Correlation (DIC) are gaining the interest of researchers. The work presented in [1] shows promising results in applying full-field DIC measurements to non-linear phenomena by exploiting high-speed imaging devices. Nevertheless, a high-speed stereo camera system can be unaffordable for most research centres and, moreover, highest frame rates can be achieved only reducing the image resolution, which results in sensitivity loss for small displacements. Many alternative approaches were then developed in literature to overcome this issue by using high-resolution low-speed cameras to measure high-frequency linear vibrations. In particular, [2] extended the applicability of the down-sampling approach to band-limited signals. Nevertheless, the feasibility of this approach in the case of non-linear phenomena was not proven yet. Therefore, the objective of this work is to develop a methodology for using the standard high-resolution, low-speed cameras, to study high-frequency nonlinear phenomena. Accordingly, a new down-sampling method denoted to as *Smoothed Harmonics Method* (SHM) was developed and applied to reconstruct the non-linear response of a beam.

Results and Discussion

SHM can detect the amplitude and phase of a given harmonic contribution of an aliased signal. SHM allows the signal in the time domain to be accurately reconstructed when the frequencies of its main harmonics are known. This method was applied to the analysis of the non-linear response of a beam with a clamped end and an unilateral contact at the other end. Due to the non-linearity of the system both superharmonics and subharmonics components of the excitation frequency are present in the response. This behavior has been explained with a qualitative numerical model and accurately measured with a high resolution high speed laser vibrometer on a reference point of the beam. In particular, the response was found in the range of 10–70 Hz with a frequency of the excitation force of 20 Hz. The sampling frequency of the cameras was set to 9.9 Hz. Figure 1 shows the comparison between the reconstructed signal, DIC+SHM, and the laser signal at the reference point. The comparison shows a good agreement between the high-resolution measured signal and the DIC+SHM results. This result demonstrates the feasibility of the proposed methodology.

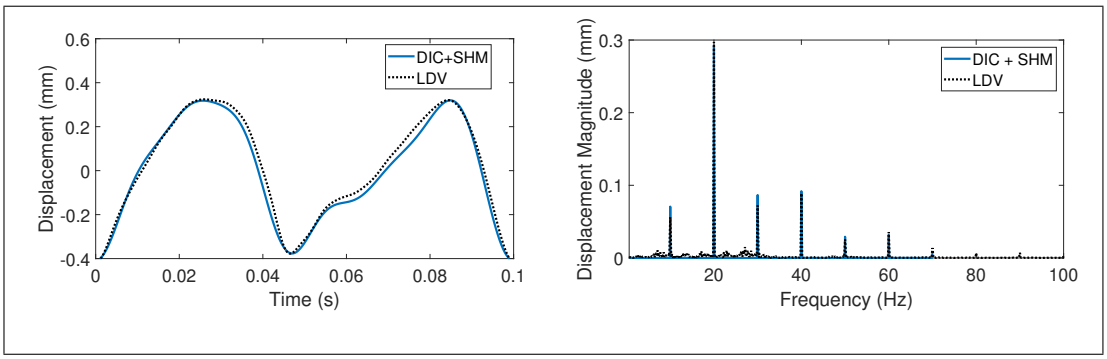

Figure 1: Time and frequency domain comparison between the reconstructed signal, DIC+SHM, and the Laser Doppler Vibrometer (LDV) signal measured at a reference point.

References

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