Theoretical and experimental modal analysis of circular cross-section shaft

Yahya Muhammed Ameen[*1] **and Jaafar Khalaf Ali**[2]

[1,2]Dept. of Mechanical Engineering, College of Engineering, University of Basrah, Basrah, Iraq
* yahyaameen@yahoo.com

Abstract. Experimental Modal Analysis (EMA) is very helpful in engineering design and manufacturing of machine components. In this paper, modal parameters which are natural frequencies, mode shapes and damping ratios are extracted for free-free boundary conditions circular shaft, using EMA, then two disks are added to this shaft as second case study. EMA has been verified as effective and accurate tool, despite of increasing geometrical complexity and nonlinear behaviour of the structure. The two well-known excitation techniques (i.e. impact hammer and shaker) are used for this purpose. For validation, natural frequencies and mode shapes are determined analytically and numerically by Finite Element Modelling (FEM) ANSYS 15 workbench software, and then compared with results obtained experimentally. Noticeable remarks about these approaches are listed. Coherence plots are compared between impact and shaker tests. Digital Signal Processing (DSP) settings like windows type and sample (record) time are compared. The recommended DSP settings mentioned in this work can be used as a general guidance for researchers and people who are working in modal analysis.
Keywords: experimental modal analysis, frequency response function, modal parameters, coherence, processing windows.

1. Introduction

In order to understand vibrational behaviour and avoid (or control) vibrational problems, researchers and engineers often resort to effective and reliable tool called Experimental Modal Analysis (EMA). The basic idea of EMA is exciting the structure under test mechanically via impact hammer (impulse force) or shaker (periodic and/or random forces), then the dynamic response (acceleration, velocity or displacement) due to this excitation measured simultaneously. After data transformation of the two signals from time domain to frequency domain, analysing these signals leads to evaluation of Frequency Response Function (FRF), a cornerstone of modal analysis. The most important results are modal parameters (so called dynamic characteristics), which are natural frequencies, modal damping and mode shapes (characteristic displacement patterns).

Beginning from 1940’s (e.g. Kennedy and Pancu [1]), EMA used increasingly and had become considerable approach to evaluate modal parameters of static and dynamic structures in mechanical and civil engineering design and in health monitoring. EMA related strongly with Digital Signal Processing (DSP) techniques. Generation of FRF’s requires adequate (or correct) DSP settings (Richard C. and James [2], Peter Avitabile [3]).

Modal parameters of rotating structures are functions of rotational speed. This complexity together with the nature of moving parts, make it difficult to apply EMA on rotating structures. Special instruments and knowledge are required to get accurate results. However, there is no significant