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Parameters identification by a single point free response measurement

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ABSTRACT

When a thin rectangular plate is restrained on the two long edges and free on the remaining edges, the equivalent stiffness of the restraining joints can be identified by the order of the natural frequencies obtained using the free response of the plate at a single location. This work presents a method to identify the equivalent stiffness of the restraining joints, being represented as simply supporting the plate but elastically restraining it in rotation. An integral transform is used to map the autospectrum of the free response from the frequency domain to the stiffness domain in order to identify the equivalent torsional stiffness of the restrained edges of the plate and also the order of natural frequencies. The kernel of the integral transform is built interpolating data from a finite element model of the plate. The method introduced in this paper can also be applied to plates or shells with different shapes and boundary conditions.

1. Introduction

Experimental Modal Analysis (EMA) aims to identify the modal parameters of a structure by measuring the frequency response function at several points on the structure. Using the classic quadrature picking technique, it is possible to extract information about natural frequencies, damping and mode shapes [1,2]. In order to perform a modal analysis it is necessary to excite the structure with a measurable force which, depending on the situation, can be a random noise, an impulse, chirp or other time based function. In order to reconstruct the correct shape it is necessary to measure the response at several points; the higher the number of modes to be identified, the more points need to be measured. When the excitation is not known or is not measurable, Operational Modal Analysis (*OMA*) allows the estimation of modal properties by only measuring the response of the structure. This technique has been successfully used in civil, mechanical and aerospace engineering applications with both random excitation and harmonic forces [3–6]. Apart from frequency based methods, time-domain methods have been extensively investigated to estimate the modal parameters of structures. Among the most known methods are the complex exponential method [7], the poly reference time domain method [8], the Ibrahim Time Domain Method (ITD) [9–11] and the Eigenvalue Realisation Algorithm (ERA) [12]. All the aforementioned methods need measurements at several points on the structure. In 1980, Zaghlool [13] proposed a method called Single Station Time Domain Technique (SSTD) for the modal identification based on a single point measurement of the free response. A shaker was used to excite the structure using a random input signal containing the range of frequencies required, but there was no need to measure the driving force. The number of modes considered in the system had to be

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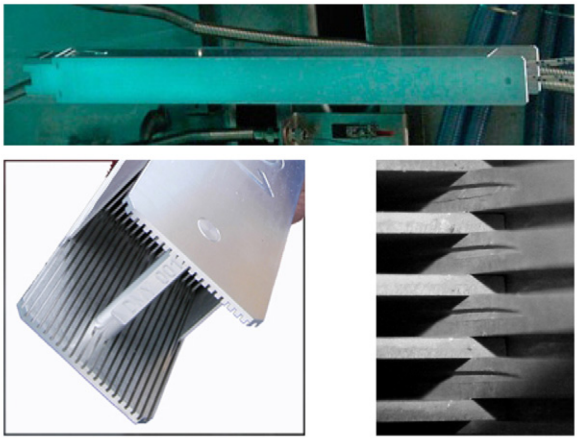

Fig. 1. Picture of a fuel assembly with particular of the swaged plates.

fixed and the measurements had to be repeated with the same level of excitation at several points to reconstruct the mode shapes. This method, however, cannot be used to solve the problem addressed in the present work.

In this work the problem of identification of the modal order of a structure with uncertainties on the boundary conditions and using only a single point measurement of the free response is addressed. The method can be applied to structures with a limited absorption, uncertainties on the boundary conditions and limitations on the possibilities to excite them with a measurable force. In this work the method is applied to plate type nuclear fuel assemblies, but other applications in both civil, mechanical and aerospace engineering are possible and can be inspired from the results of this work.

The need to perform a parameters identification using a single point measurement was driven by the necessity of identifying the order of natural frequencies and the value of the equivalent stiffness of the restrained edges of the rectangular plates contained in a plate type nuclear fuel assembly. A fuel assembly consists of a long box-like structure with several internal parallel plates containing the nuclear material. The side walls of the box are commonly fixed to the inlet nozzle using screws, forming a rigid base structure. The internal plates are inserted into slots machined into the side walls and restrained by means of the plastic deformation of the ridge between slots using a swaging tool. A fuel assembly and swaging detail of the internal plates are shown in Fig. 1. The plates can be considered as laterally fixed but elastically restrained in rotation with unknown torsional spring stiffness [14].

The visible part of the internal plates is very limited, so only the displacement at the end (trailing edge) of the plates can be measured. The stiffness of the side connection is not known and depends on the manufacturing process. Furthermore the natural frequencies of the plates are practically decoupled from the containing structure so it is neither possible to excite them by an impact hammer nor to excite them efficiently directly using an impact hammer or a shaker due to the lack of space. In theory the equivalent stiffness of the attachment of the plate can be found using a standard finite element model updating method. The correlation between the modal properties predicted by a finite element model and those estimated through a modal test on the actual system, is improved by minimising the error between some modelled parameters and those obtained from a modal test in a least squares sense [15–17]. Nevertheless finite element updating requires the knowledge of experimental natural frequencies and mode shapes.

The requirement about the knowledge of mode shapes is not important if it is known which frequency belongs to which mode. Unfortunately this is not the case for the fuel assembly plates, due to the following reasons.

- The manufacturing process can result in a joint stiffness varying between the extreme cases of a simple support (free rotation) and a perfect clamp (rotation restrained).
- The fundamental natural frequencies can shift from around 500 up to 1100 Hz respectively, in these extreme cases.
- The modal density, especially at low frequency is very high due to the large aspect ratio of the plates.
- It is practically impossible to excite the plates with a desired frequency band and to identify relationships between the peaks of the free response frequency spectrum and the mode to which it belongs, since the boundary condition is not determined.

In this work, a method is presented to identify the boundary conditions and the natural frequencies without knowing *a priori* either the joint stiffness or the order of the modes excited.

2. Model of the plate

Previous researchers studying the static and dynamic instability of the plates due to the interaction with a coolant flow, assumed simply supported boundary conditions or fully clamped edges for the plates in the fuel assemblies [18,19] .