International Journal of Mechanical Sciences 53 (2011) 1084–1102

Contents lists available at SciVerse ScienceDirect

International Journal of Mechanical Sciences

journal homepage: www.elsevier.com/locate/ijmecsci

A reverse receptance approach for analysis of vibration of grooved plates

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ARTICLE INFO

Article history:
Received 24 February 2011
Received in revised form
20 August 2011
Accepted 6 September 2011
Available online 12 September 2011

Keywords:
Vibration
Plate
Groove
Reverse receptance approach

ABSTRACT

A reverse receptance approach is proposed to solve eigenvalues of a plate with two orthogonally connected through grooves, two parallel through grooves and two parallel internal grooves. The procedure is a modification of the well-known receptance method commonly used to study vibrations of combined structures. In the present paper, vibrations of rectangular plates with grooves in different sizes and boundary conditions are studied analytically to illustrate the approach. A through groove is simulated by a simply supported beam, while an internal groove is simulated by a free–free beam. The accuracy is evaluated by comparing the percent differences between the natural frequencies solved using the reverse receptance method and the standard finite element method.

It is verified that the reverse receptance method with both force and moment connections at the interface of each plate–groove pair and with sufficient interaction points is adequate and accurate for solving vibration characteristics of a plate with either through or internal grooves. Parametric study reveals that the percent differences are directly proportional to the length, the width and the depth of the grooves on the plate. It is found that, for good accuracy, the groove width should not exceed 3.6% of the plate width, while the groove depth should not exceed half of the plate thickness. This report demonstrates the potential of reverse receptance concept in the engineering practice of machine design, as a simple numerical or analytical approach to study dynamics of structures with complex geometries.

1. Introduction

In development of machine component, it is often necessary to go through an iterative process to define a suitable component geometry that satisfies both the physical need and the performance requirement. This process can be tedious and costly. Thus, finding an expedient way to simplify the process is of great interest to design engineers.

One of the major tasks in this process is to determine the sizes and locations of grooves, slots and holes to make the components functional and compatible. Engineers need to accurately assess the component performance changes due to these structural deductions and make decisions accordingly. For example, the oscillatory and acoustical properties being altered by a proposed deduction can be critical to the component response and to the overall machine performance. A simple approach to assess the effects is to perform complete finite element analysis of the component and perhaps the connecting parts for each proposed deduction. Clearly, such a process can become very cost ineffective and time-consuming. Current practice usually resolves this problem in two ways: the first is to ignore the grooves and cutouts, based on the thought that their effects are not significantly large and can be covered by the safety margins. For some components, this seems acceptable. However, for components whose behaviors are sensitive to the boundary conditions and geometry, the effects of deductions cannot be ignored. One example is the vibratory characteristics of a plate or shell structural component. The natural frequencies and associated mode shapes may change due to the existence of grooves, slots and holes. In these cases, the second way, a sub-structuring deduction procedure may be introduced to modify the stiffness, or the element mesh, around where the grooves, slots and holes are located. For the rest of the structure, finite element mesh model remains unchanged.

It is the objective of the present paper to introduce a rational approach for the sub-structuring deduction. The basic concept proposed in the paper is a reverse receptance. This concept, in essence, is a modification of an approximation technique in vibration known as the receptance method. It has been widely used in industry to assess the frequencies and mode shapes of combined structures based on the

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doi:10.1016/j.ijmecsci.2011.09.003