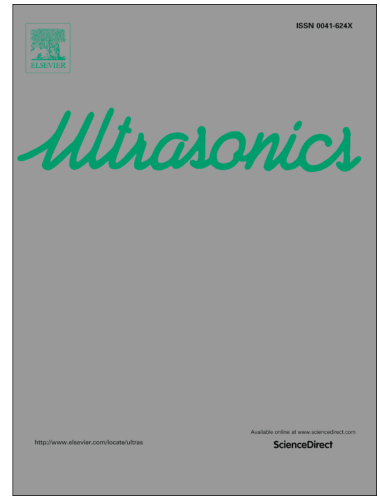

Efficient simulation of elastic guided waves interacting with notches, adhesive joints, delaminations and inclined edges in plate structures

Hauke Gravenkamp

PII: S0041-624X(17)30129-4
DOI: http://dx.doi.org/10.1016/j.ultras.2017.07.019
Reference: ULTRAS 5592

To appear in: *Ultrasonics*

Received Date: 9 February 2017
Revised Date: 4 June 2017
Accepted Date: 30 July 2017

Efficient simulation of elastic guided waves interacting with notches, adhesive joints, delaminations and inclined edges in plate structures

Hauke Gravenkamp*

[a]University of Duisburg-Essen, Universitaetsstrasse 15, 45141 Essen, Germany

Abstract

This paper presents an approach to model transmission and reflection phenomena of elastic guided waves in plates. The formulation is applied to plate structures containing notches, inclined edges, delaminations or (adhesive) joints. For these cases, only the thickness direction of the structure needs to be discretized at several locations, while the direction of propagation is described analytically. Consequently, the number of degrees of freedom is very small. Semi-infinite domains can be modeled, in which case the radiation condition is fulfilled exactly. Traction boundary conditions are introduced on the plate surface without requiring a mesh along the surface. Results are validated against conventional finite element implementations, showing the accuracy of the proposed approach and a reduction of the computational costs by typically 2 to 3 orders of magnitude.

Keywords: guided waves; notches; ultrasound; delaminations; SBFEM

1. Introduction

The mathematical description and simulation of elastic guided waves, particularly in the ultrasonic frequency range, has concerned researchers and engineers for decades (see e.g. [1–6]) and is still an active research field [7–9]. Especially the practical applications of guided waves in the context of non-destructive testing [10–12], structural health monitoring [13, 14] and material characterization [15, 16] have triggered research in this field and created a demand for efficient simulation tools. Even today, with modern computers and very general and easy-to-use finite element implementations at hand, the simulation of guided waves is still considered a challenging and time-consuming task. This is due to the high frequencies and small wavelengths (relative to the dimensions of the structure), requiring fine spatial and temporal discretizations in numerical schemes.

Depending on the application, numerical methods are applied to analyze dispersion properties of guided waves in a given structure or to perform a full dynamic simulation in the time or frequency domain. Often, the structure is long enough to be considered as (semi-)infinite in the numerical model, which is challenging to achieve in mesh-based approaches like finite elements or finite differences [17].

The problem of computing dispersion curves for elastic waveguides of uniform cross-section has been solved for many cases, and highly efficient algorithms are available. Homogeneous or layered plates or cylinders can be modeled using analytical approaches [18] or, e.g. spectral decomposition techniques [19].

*Corresponding author. Tel.: +49-201-183-6949
Email address: hauke.gravenkamp@uni-due.de (Hauke Gravenkamp)