Supporting data for finite-element simulations of ultrasonic guided wave propagation on a plate with a permanently corrugated shape

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1. Introduction

1.1. Context of data

The data refers to finite-element (FE) simulations of ultrasonic guided wave (GW) propagation on a plate with a permanently corrugated shape. The purpose of this study was to test the hypothesis that a short time window of GW propagation under high-amplitude, low-frequency vibration (HA-LFV) can be described by GW propagation in a structure with a permanently corrugated shape.

The numerical data in this dataset is part of the PhD project of Pedro Ochôa. The research conducted for the PhD project of Pedro Ochôa was integrated in the Thermoplastic Affordable Primary Aircraft Structure 2 (TAPAS 2) project, financed by the Netherlands Enterprise Agency of the Ministry of Economic Affairs.

This dataset is made public both to act as supplementary material for the doctoral dissertation of Pedro Ochôa and other publications, and to allow other researchers to use this data in their own work.

1.2. Structure of the dataset

The dataset contains the following file groups:

- Finite-element guided wave signals

1.2.1. Finite-element guided wave signals

The files in this file group are text output files of Abaqus, called Report files, containing the numerical guided wave signals.

- File format: Report (.rpt)
- Naming convention: `Run_n_U2_2ms.rpt`
  - `n` = run number

2. Methodological information

In an effort to test the working hypothesis that a short time window of GW propagation under HA-LFV can be described by GW propagation in a structure with a permanently corrugated shape, the commercial programme Abaqus/Explicit (Dassault Systèmes) was employed to build an FE model of a square aluminium plate with a permanently corrugated shape, with two thin PZT discs for GW actuation and sensing, as represented in Figure 1. Boundary conditions (BC) were applied to the two top vertices of the upper surface by blocking the displacements in all directions.
The dimensions of the plate were 1 m × 1 m × 2 mm, and the PZT discs had a diameter of 20 mm and a thickness of 0.4 mm. The actuator was positioned at $(x, y) = (0.1, 0.1)$ m, while the sensor was at $(x, y) = (0.9, 0.9)$ m. The permanently corrugated shape of the region between the two transducers was defined by a periodic geometry based on the corrugation height, h_c, and the corrugation wavelength, w_c = 760/#Lobes, as illustrated in Figure 1.

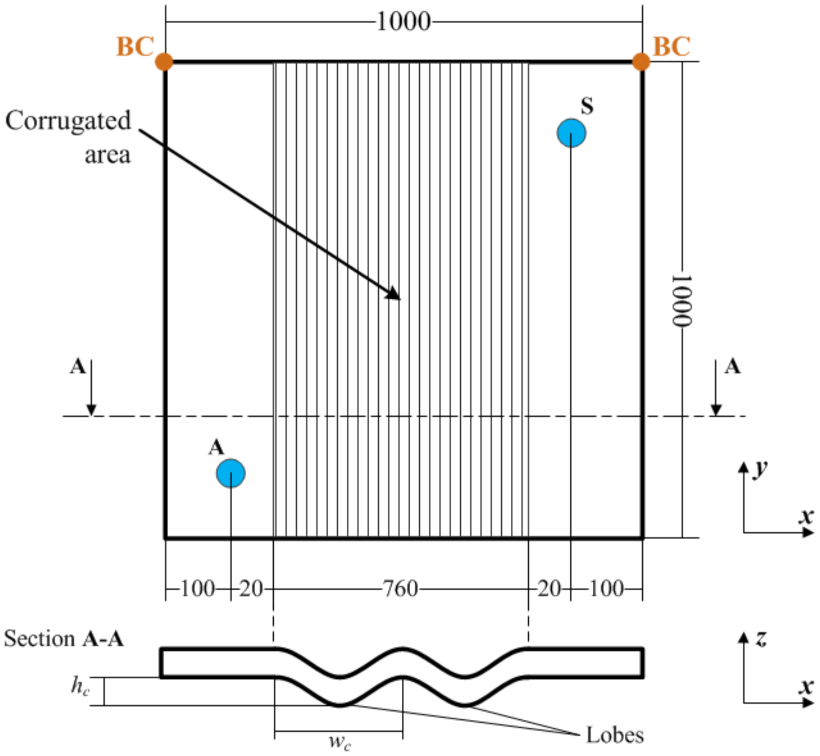

Figure 1. Definition of the geometry of the model of the plate with permanent corrugated shape. The GW actuator and sensor are indicated with "A" and "S", respectively. The $U_x = U_y = U_z = 0$ boundary conditions are applied on the two top vertices of the upper surface indicated by the BC circles. All dimensions are in millimetres.

All the regions were defined as deformable three-dimensional volumes. The actuator/sensor adhesive layer was assumed to be infinitesimally thin, and the connection between the plate region and the actuator/sensor patch region was ensured by a tie constraint. The ultrasonic excitation was introduced by applying distributed perpendicular forces (i.e. pressure) on the circular and cylindrical faces of the actuator patch.

The structured mesh was formed by solid, three-dimensional (3D), 8-node, linear, reduced-integration elements (C3D8R). For correct spatial representation of the GW propagation, twenty elements per wavelength of S0 Lamb wave mode were defined along the in-plane propagation directions. Eight elements were defined along the thickness of the plate and one element along the thickness of the PZT patches.

To ensure that the time-step was always shorter than the time required for the fastest wave component to propagate to an adjacent element, i.e. to always ensure convergence of the numerical solution, the simulation time-step was automatically defined in Abaqus by checking the stability condition element by element.

The aluminium material was modelled as isotropic homogeneous, with a Young's modulus of 70 GPa, a density of 2700 kg/m^3 and a Poisson's ratio of 0.33. The material for the PZT actuator and sensor was modelled as orthotropic homogeneous material, with elastic properties equal to those of American Piezo, Ltd. APC 850 material, as listed in Table 1.

Table 1. Properties of the APC 850 piezoelectric ceramic material. The compliances (indicated with '*') were obtained by inversion of the elastic stiffness matrix.

Property	Value (× 10^{10})	Property	Value (× 10^{-12})	Property	Value
c_{11}^{E} [N/m^2]	13.14	s_{11}^{E} [m^2/N]	15.70 '*'	ρ [kg/m^3]	7600
c_{12}^{E} [N/m^2]	8.23	s_{12}^{E} [m^2/N]	-4.67 '*'	ν [-]	0.35
c_{13}^{E} [N/m^2]	8.68	e_{31} [N/Vm]	6.91		
c_{33}^{E} [N/m^2]	12.25	e_{33} [N/Vm]	16.41		
c_{44}^{E} [N/m^2]	1.92	e_{15} [N/Vm]	13.65		

The ultrasonic excitation was introduced by applying distributed perpendicular forces (i.e. pressure) on the faces of the actuator disc. The value of those stresses was computed based on the piezoelectric constitutive equations for an excitation tone-burst maximum amplitude of 16 V. The GW excitation was a 5-cycle tone-burst with amplitude modulated by a Hanning window. The ultrasonic GW response was taken from the out-of-plane displacement of the centre node of the top surface of the sensor disc.
A parametric study was conducted by varying the GW excitation frequency, the number of corrugation lobes and the corrugation height. The executed runs are summarised in Table 2, and the numerical signals are available in.

Table 2. Runs of the FE parametric study.

<table>
<tr><th>Run</th><th>GW freq [kHz]</th><th># Lobes]</th><th>w_c [mm]</th><th>h_c [mm]</th></tr>
<tr><td>1</td><td rowspan="5">100</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>2</td><td rowspan="2">2</td><td rowspan="2">380</td><td>15</td></tr>
<tr><td>3</td><td>30</td></tr>
<tr><td>4</td><td rowspan="2">5</td><td rowspan="2">152</td><td>15</td></tr>
<tr><td>5</td><td>30</td></tr>
<tr><td>6</td><td rowspan="5">300</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>7</td><td rowspan="2">2</td><td rowspan="2">380</td><td>15</td></tr>
<tr><td>8</td><td>30</td></tr>
<tr><td>9</td><td rowspan="2">5</td><td rowspan="2">152</td><td>15</td></tr>
<tr><td>10</td><td>30</td></tr>
</table>

3. Data specific information

3.1. Finite-element guided wave signals

The file contains two columns. The first, identified by **X**, has the time instants for which the numerical GW response was calculated. The second, identified by the same name as the file, has the out-of-plane displacement values that form the GW response at the selected sensing node.

Measurement units

- Time: second (s)
- Displacement: metre (m)

4. Sharing and Access information