# Supporting data for finite-element simulations of ultrasonic guided wave propagation on a plate subjected to low-frequency vibrations

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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 flat plate subjected to high-amplitude, low-frequency vibration (HA-LFV). The purpose of this study was to investigate the dependency of the LFV-GW interaction on amplitude and on the LFV-GW frequency ratio.

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: `GW_LFV_run_n_Udata.rpt`
    - `n` = run number

## 2. Methodological information

In an effort to investigate the dependency of the GW-LFV interaction on the LFV amplitude and on the LFV-GW frequency ratio, FE programme Abaqus/Explicit was employed to build an FE model of an aluminium plate subjected to HA-LFV, with two thin PZT discs for GW actuation and sensing. The dimensions of the plate were 1 m × 1 mm × 2 mm, and the PZT discs had a diameter of 20 mm and 0.4 mm. The actuator was positioned at ($x$, $y$) = (0.35, 0.35) m, while the sensor was at ($x$, $y$) = (0.65, 0.65) m, as represented in Figure 1.

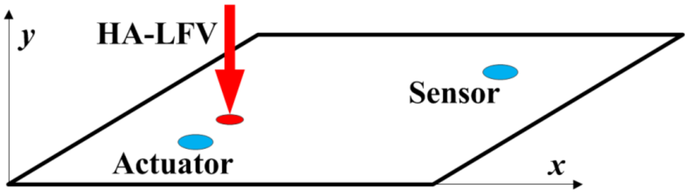


**Figure 1.** Diagram of the FE model for the case of GW propagation under HA-LFV.

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 on the rectangular faces (i.e. pressure) of the actuator patch.
The structured mesh was formed by solid, three-dimensional (3D), 8-node, reduced-integration elements (C3D8R). Twenty elements per wavelength of S0 Lamb mode along the in-plane propagation directions were employed. 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 by 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 2710 kg/m$^3$ and a Poisson's ratio of 0.33. The piezoceramic actuator and sensor material 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 '*' | $\rho$ [kg/m$^3$] | 7600 |
| $c_{12}^E$ [N/m$^2$] | 8.23 | $s_{12}^E$ [m$^2$/N] | -4.67 '*' | $\nu$ [-] | 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 GW excitation was a 10-cycle tone-burst with amplitude modulated by a Hanning window. The HA-LFV was simulated by applying an out-of-plane, sinusoidally time-varying force distributed over a circular area with a diameter of 10 mm, positioned at ($x$, $y$) = (0.35, 0.40) m. The HA-LFV introduction point was located in the left-upper quadrant of the plate. The sensing node was located at the centre of the upper surface of the sensor PZT disc.
A parametric study was conducted by varying the GW excitation frequency, the HA-LFV frequency and amplitude, and the number of LFV cycles before applying the GW excitation. The executed runs are summarised in Table 2.

**Table 2.** Runs of the FE parametric study.

| Run | GW freq [kHz] | LFV freq [Hz] | LFV amp [N] | LFV cycles [-] |
|---|---|---|---|---|
| 1 | 100 | 0 | 0 | 1 |
| 2 | | 250 | 20 | |
| 3 | | | 100 | |
| 4 | | 1000 | 20 | |
| 5 | | | 100 | |
| 6 | 300 | 0 | 0 | 1 |
| 7 | | 250 | 20 | |
| 8 | | | 100 | |
| 9 | | 1000 | 20 | |
| 10 | | | 100 | |
| 11 | 100 | 1000 | 100 | 3 |

## 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 `U3_Sens_pt`, 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