Guided wave and mechanical testing of defective thermoplastic composite ultrasonic welds

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1. Introduction

1.1. Context of data

The data refers to measurements on single-lap joints manufactured by ultrasonic welding (UW) of adherends made of weave carbon fibre fabric reinforced polyphenylene sulphide semipreg material. Three different set of UW process parameters were used to manufacture three different batches of joints. The process parameters were selected such that one of the batches had non-defective welds (reference specimens), and the other two had welds with two types of well-controlled manufacturing defects, as indicated in Table 1. The purpose of the study was to understand how ultrasonic guided waves (GWs) interact with different defective weld interfaces.

Table 1. Test batches and corresponding specimen names.

Specimen group	# Joints	Specimen names
Batch 1	5	uw140318-002 to uw140318-006
Batch 2	5	uw140318-007 to uw140318-011
Batch 3	4	uw150318-001 to uw150318-004

The data in this dataset was collected in the Aerospace Structures and Materials Laboratory of the Delft University of Technology between March and April 2018. It is made public both to act as supplementary data for publications and to allow other researchers to use this data in their own work.

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1.2. Structure of the dataset

The dataset contains the following file groups:

- Guided wave test data
- Guided wave test results
- Mechanical test data
- Mechanical test results

1.2.1. Guided wave test data

This file group contains raw ultrasonic signals from GW tests performed on thermoplastic composite (TpC) ultrasonic welds.

- Naming convention: `D_uwSp_FkHz.mat`
  - `D` = testing date
  - `Sp` = specimen name
  - `F` = GW excitation frequency
- File format: MATLAB formatted data (.mat)

1.2.2. Guided wave test results

This file group contains the results obtained by processing the raw GW test data along with the MATLAB scripts for that purpose.
The script files are:

- `GW_USW_Joints_metrics_2_avg_values.m`
- `GW_USW_Joints_metrics_3_cross_corr.m`
- `InterX.m` (called by the above scripts)
- `specimen_idx.m` (called by the above scripts)

The result files are:

- `GW_test_results_2.mat` where the values of different signal features are stored;
- `GW_cc_metrics.mat` where the coefficient of correlation between signals are stored.

1.2.3. Mechanical test data

This file group contains raw strain-force curve points from static single-lap shear (SLS) tests performed on TpC ultrasonic welds.

- Naming convention: `sls_uwSp.csv`
  - `Sp` = specimen name
- File format: Comma-separated values (.csv)

1.2.4. Mechanical test results

This file group contains the results obtained by processing the raw Mechanical test data.
The file group includes only the file `single_lap_shear_results.csv`.

2. Methodological information

2.1. Guided wave test data

The ultrasonic excitation was produced by an Agilent 33500 B arbitrary waveform generator and transmitted to the specimen by a piezo-ceramic (PZT) transducer. The same type of PZT transducer was used to sense the ultrasonic response which was then acquired by a PicoScope 6402 A digital oscilloscope. The full GW testing setup is shown in Figure 1.
The PZT transducers were discs with 10 mm diameter and 0.4 mm thickness, made of APC 850 material provided by American Piezo Ltd. They were bonded to the composite adherends at the positions indicated in Figure 2.
The excitation signal was a sinusoidal tone-burst with a 10-cycle Hanning window amplitude modulation generated at four frequencies: 204, 349, 486 and 619 kHz.

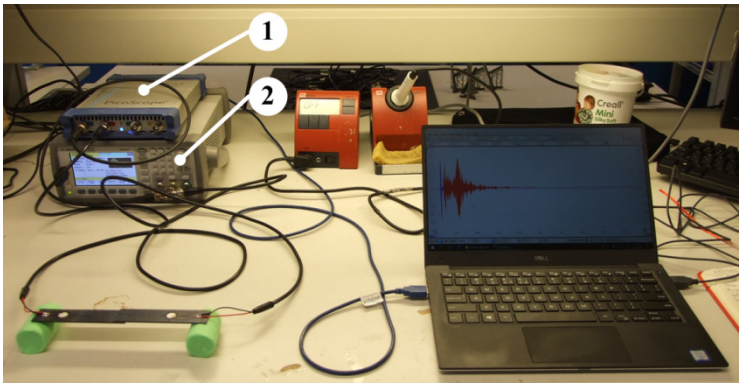

Figure 1. Complete set-up used for ultrasonic guided wave testing: 1) digital oscilloscope; 2) waveform generator.

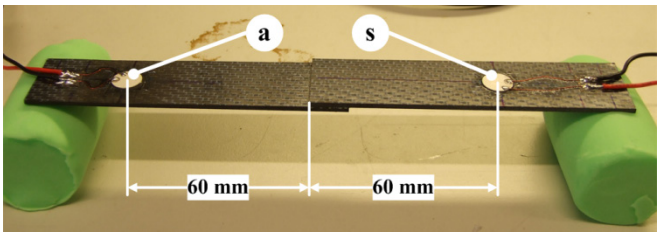

Figure 2. Single-lap joint instrumented with piezo-ceramic transducer discs, one functioning as actuator (a) and the other as sensor (s).

2.2. Guided wave test results

The GW test results in `GW_test_results_2.mat` were generated by running the script `GW_USW_Joints_metrics_2_avg_values.m`.
The GW test results in `GW_cc_metrics.mat` were generated by running the script `GW_USW_Joints_metrics_3_cross_corr.m`.

The version of MATLAB used was 2016b.

2.3. Mechanical test data

The welded joints were mechanically tested according to the ASTM D1002 standard in a Zwick/Roell 250 kN testing machine, in order to extract the single-lap shear strength (SLSS).

2.4. Mechanical test results

The overlap area is calculated is equal to the overlap length times the overlap width. The SLSS corresponds to the stress computed as the maximum force divided by the overlap area.

3. Data specific information

3.1. Guided wave test data

Each data file contains the excitation signal in variable **`A`** and the sensed signal in variable **`B`**. The size of all signals is identified by variable **`RequestedLength`**, which contains the number of useful data points. The sampling interval is given in variable **`Tinterval`**. The reference start instant for the measurements is stored in variable **`Tstart`**.

- Units of measurement
  - Signals: volt (V)
  - Time: second (s)

3.2. Guided wave test results

The file `GW_test_results_2.mat` contains one three-dimension array of double precision values with physical units. The first array dimension corresponds to the number of specimens, the second array dimension corresponds to the number of extracted signal features, and the third array dimension corresponds to the number of GW excitation frequencies tested.

- Units of measurement
  - Dimension 2, column 1 – Maximum FFT magnitude frequency shift: hertz (Hz)
  - Dimension 2, column 2 – Time-domain signal energy: square volt second (V^2.s)
  - Dimension 2, column 3 – Time-of-Flight: second (s)
  - Dimension 2, column 4 – Characteristic frequency shift: hertz (Hz)
  - Dimension 2, column 5 – Power spectral moment of order 1: square volt hertz (V^2.Hz)
  - Dimension 2, column 6 – Frequency bandwidth: hertz (Hz)

The file `GW_cc_metrics.mat` contains two three-dimensional arrays of double precision values with no units (correlation coefficients). The first array dimension corresponds to the number of comparisons between reference and non-reference specimens, the second array dimension corresponds to the number of computed correlation coefficients, and the third array dimension corresponds to the number of GW excitation frequencies tested.

3.3. Mechanical test data

Each file contains the recorded test curve points in which a strain value is always followed by a force value (i.e. `<strain value>,<force value>`).

- Units of measurement
    - Strain: percentage (%)
    - Force: newton (N)

3.4. Mechanical test results

The file contains the information organized in the following order:
Specimen name, Maximum force, Overlap length, Overlap width, Overlap area, SLS stress

- Units of measurement
    - Maximum force: newton (N)
    - Overlap length: millimetre (mm)
    - Overlap width: millimetre (mm)
    - Overlap area: square millimetre (mm^2)
    - SLS stress: mega pascal (MPa)

4. Sharing and Access information