Dataset Supporting Information

Spatial and Temporal Waveform A and B Loading and Material Data for Lightning Strike Simulations based on Converged FE Meshes

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Notes

The following supporting information provides further guidance on the use and content of this dataset. The loading data is designed to be used with the provided finite element (FE) meshes, Waveform_A_Single_Ply.inp and Waveform_B_Single_Ply.inp, as these have been published and converged [1], [2]. The dataset is also designed for use with ABAQUS. However, adaptation to other FE packages is possible but this may require some user adjustment to the format in which the data is currently presented. Material data for IM600/133 has also been provided to allow the user to attempt to replicate these published works.

Work is planned to update this data set so it is easily applicable to any FE mesh that the user may desire.

Waveform A Loading Data

Waveform A current and pressure loading is applied using equations 1 and 2 depending on the shape of the load, circular or elliptical, respectively. The variables, r, x, a, y and b define the shape of the load and are given in Waveform_A_Loading_Profiles.csv for each load.

$$Field = \left[\left\lfloor \frac{r}{\sqrt{x^2+y^2}} \right\rfloor \Big/ \left(\left\lfloor \frac{r}{\sqrt{x^2+y^2}} \right\rfloor + 1\right)\right] \tag{1}$$

$$Field = \left[\left\lfloor \frac{r}{\sqrt{\frac{x^2}{a^2}+\frac{y^2}{b^2}}} \right\rfloor \Big/ \left(\left\lfloor \frac{r}{\sqrt{\frac{x^2}{a^2}+\frac{y^2}{b^2}}} \right\rfloor + 1\right)\right] \tag{2}$$

Also included in Waveform_A_Loading_Profiles.csv are the amplitudes corresponding to each load. These amplitudes are shown graphically in Figure 1 for current and Figure 2 for pressure.

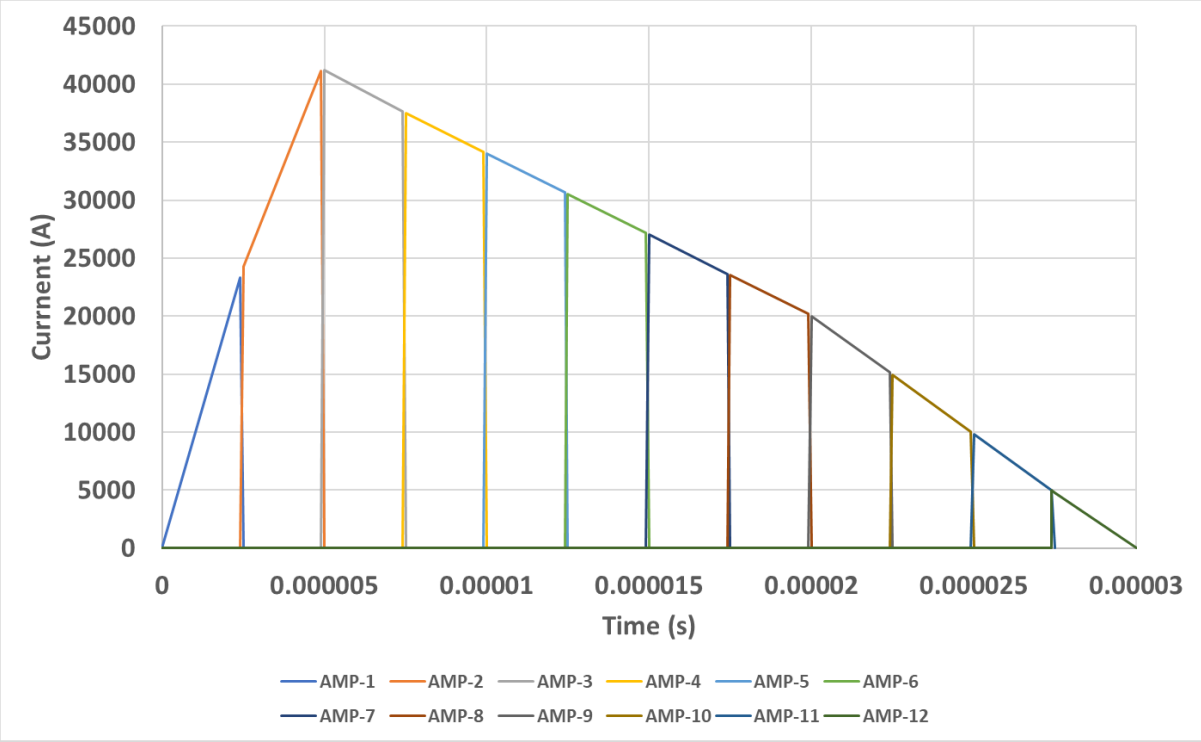

Figure 1 - Waveform A Current Load Amplitudes

Further information on the Waveform A model, loading strategy and the above equations can be found in reference [1].

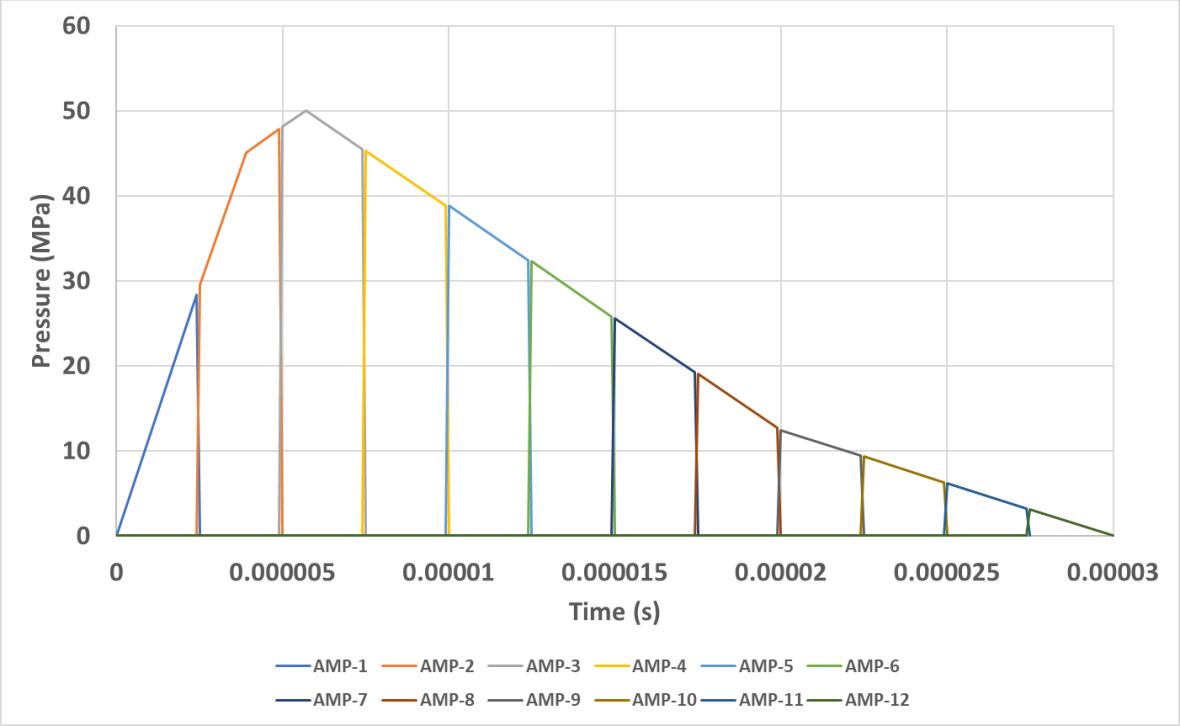

Figure 2 - Waveform A Pressure Load Amplitudes

The resulting temperature profile from the above loading is provided, should the reader wish to apply this in a mechanical analysis such as in refs. [3]–[5]. The temperature vs time profile is provided for every node in the previously mentioned model. This data is available in Waveform_A_Temperature_Profiles_All_Plies.xlsx where each tab provides data for each ply. The data is also provided for individual plies in the files Waveform_A_Ply_"n".csv where "n" represents the ply instance. The data in each file is arranged such that column one is the time in seconds and row one is the node reference. For example, from Waveform_A_Ply_0-1.csv column two, row one, Ply_0-1-1, corresponds to the temperature of Ply_0 (a zero degree ply), assembly instance 1, node 1 etc.

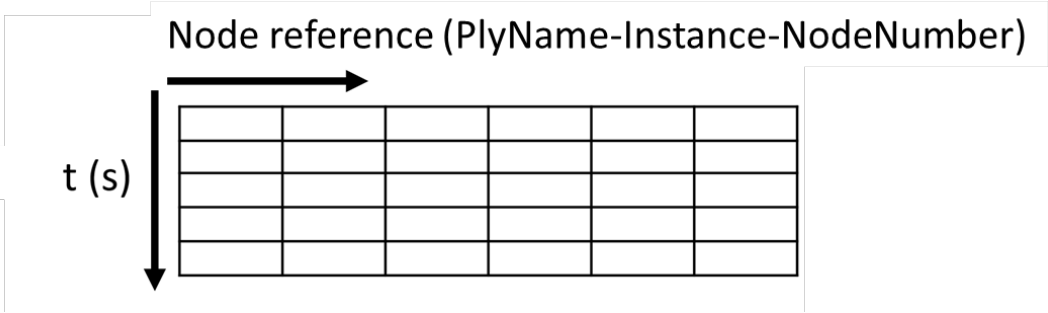

Figure 3 - Waveform A input data file format (csv files beginning with Waveform_A_)

Waveform B Loading Data

Waveform B current, pressure and heat flux loads are provided for both composite and copper specimens (See Ref [6] for relevance of specimen material). These have been extracted from a Waveform B COMSOL model for use in FE damage models. Figure 4 shows the specimen surface, at which the provided data (current, pressure and heat flux) has been extracted.

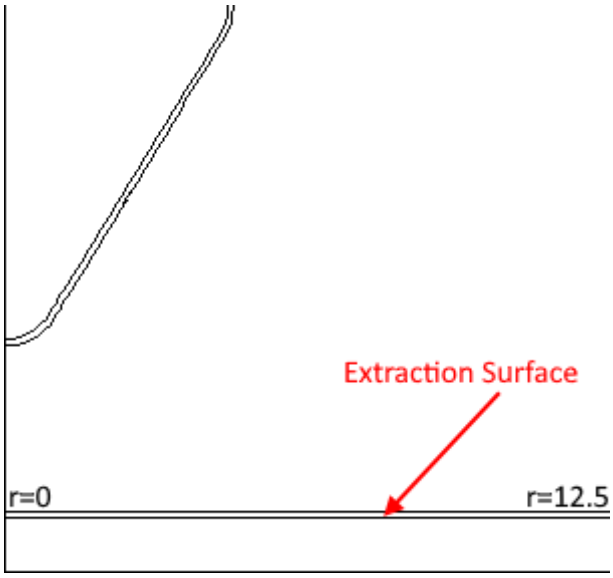

Figure 4 - COMSOL Simulation Output Extraction Surface for Waveform B

In this instance loading was applied to surfaces determined by studying the outputs from COMSOL. Readers are directed to reference [2] for further information on the Waveform B model and loading methodology. The data provided for Waveform B (dataset csv files beginning with Waveform_B_) is in the following form; Column one corresponds to the time while row one corresponds to the radius at which the load is to be applied from the centre of the specimen, Figure 5.

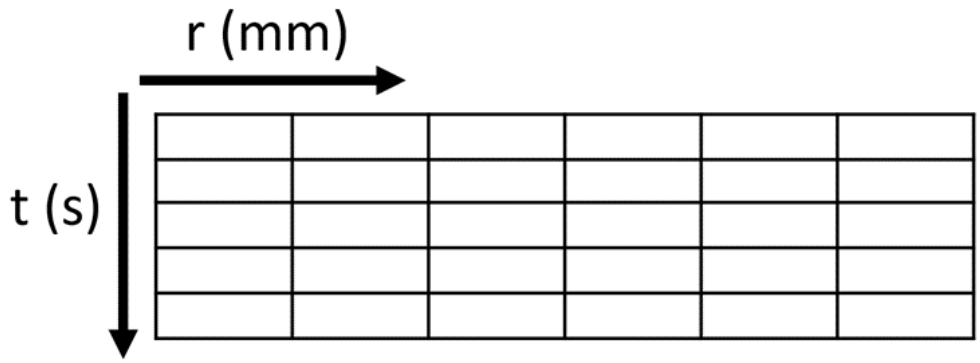

Figure 5 - Waveform B input data file format (csv files beginning with Waveform_B_)

References

[1] P. Foster, G. Abdelal, and A. Murphy, "Understanding how arc attachment behaviour influences the prediction of composite specimen thermal loading during an artificial lightning strike test," *Compos. Struct.*, vol. 192, pp. 671–683, 2018.

[2] S. L. J. Millen, A. Murphy, G. Abdelal, and G. Catalanotti, "Sequential finite element modelling of lightning arc plasma and composite specimen thermal-electric damage," *Comput. Struct.*, vol. 222, pp. 48–62, 2019.

[3] P. Foster, G. Abdelal, and A. Murphy, "Modelling of mechanical failure due to constrained thermal expansion at the lightning arc attachment point in carbon fibre epoxy composite material," *Eng. Fail. Anal.*, vol. 94, pp. 364–378, 2018.

[4] S. L. J. Millen, A. Murphy, G. Catalanotti, and G. Abdelal, "Coupled thermal-mechanical progressive damage model with strain and heating rate effects for lightning strike damage assessment," *Appl. Compos. Mater.*, vol. 26, no. 5, pp. 1437–1459, 2019.

[5] S. L. J. Millen and A. Murphy, "Understanding the influence of test specimen boundary conditions on material failure resulting from artificial lightning strike," *Eng. Fail. Anal.*, vol. 114, 2020.

[6] S. L. J. Millen, A. Murphy, G. Abdelal, and G. Catalanotti, "Specimen Representation on the Prediction of Artificial Test Lightning Plasma, Resulting Specimen Loading and Subsequent Composite Material Damage," *Compos. Struct.*, vol. 231, p. 111545, 2020.