P30: Experimental and Theoretical Evaluation of Aluminium Deflection due to Lightning Strikes

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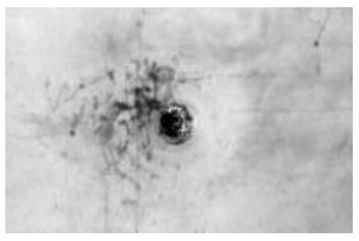
Introduction: This research focuses on the displacement of aluminum plates subjected to the forces generated by a lightning current in order to compare modelling and experimental results directly. The electromechanical forces produced during lightning strikes can cause catastrophic damage such as deflection, matrix crack and delamination. There is a need to understand the performance of existing and new materials under such extreme conditions in order to improve the ability to withstand these forces and minimise damage.

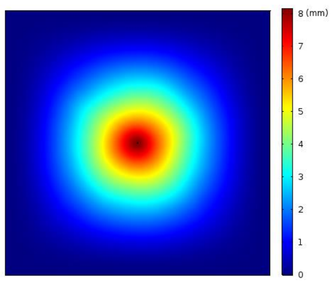


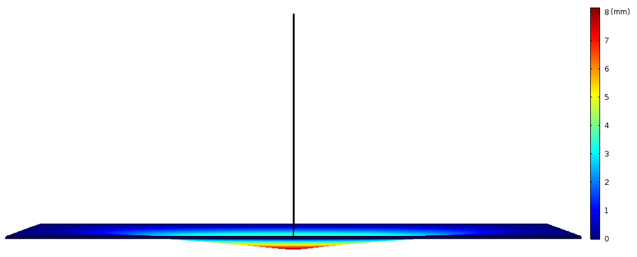
A puncture due to a lightning attachment point on an aluminum skin of an aircraft body [1]

Mechanical Properties of Aluminium

Aluminium (6082)	
Young's Modulus, E	70 GPa
Poisson's Ratio, v	0.34
Density, ρ	2700 kg/m^3
Dimensions	50 x 50 x 0.20 cm

Numerical Model (COMSOL Multiphysics)





Magnetic Fields

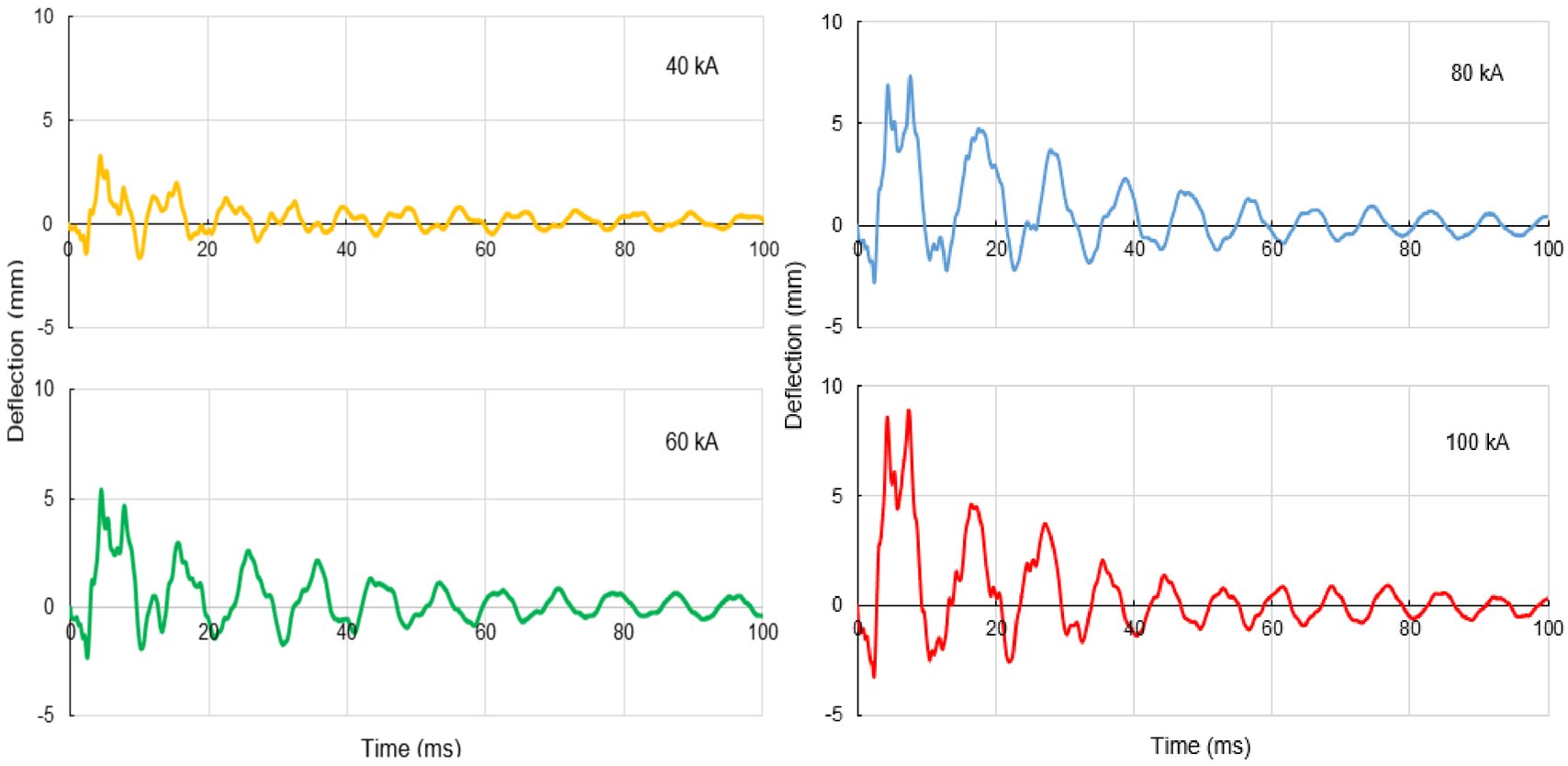
- Electromagnetic force/Lorentz force - Magnetic flux density (B) and Electric current distribution
- $\overrightarrow{F_Z} = \iiint \overrightarrow{J_S}\, dv \times \overrightarrow{B}$

Solid Mechanics

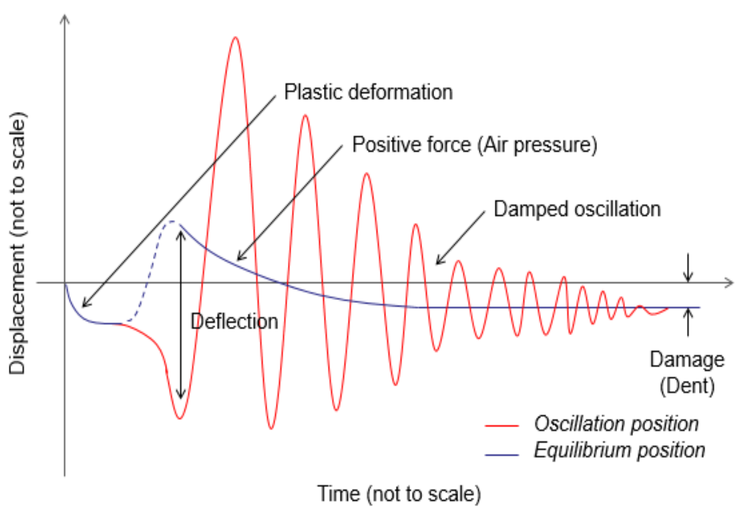
- Electromagnetic force, F_Z
- Displacement/Deflection

Results

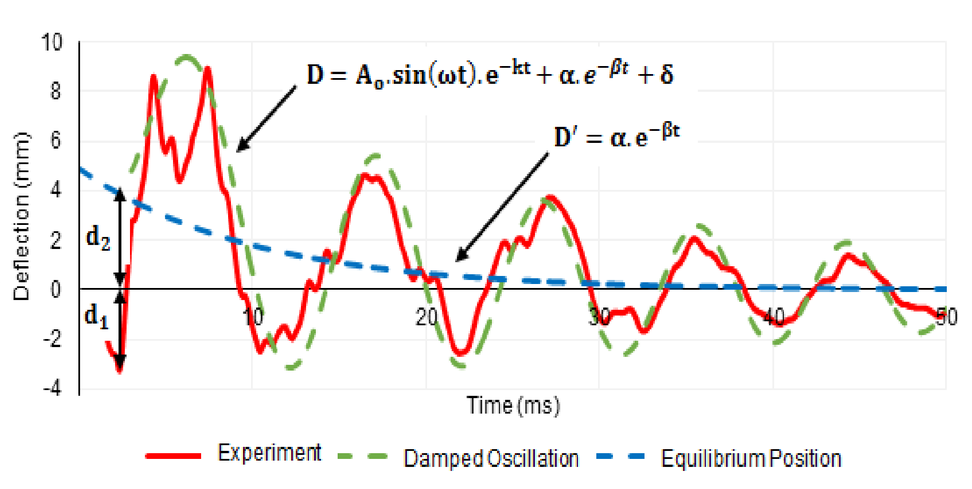
Experimental Results



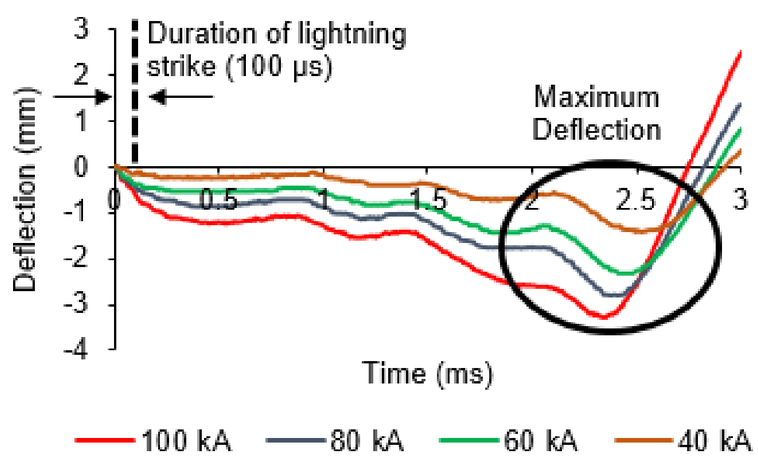
The dynamic deflection of aluminium plates injected with currents of 40, 60, 80 and 100 kA



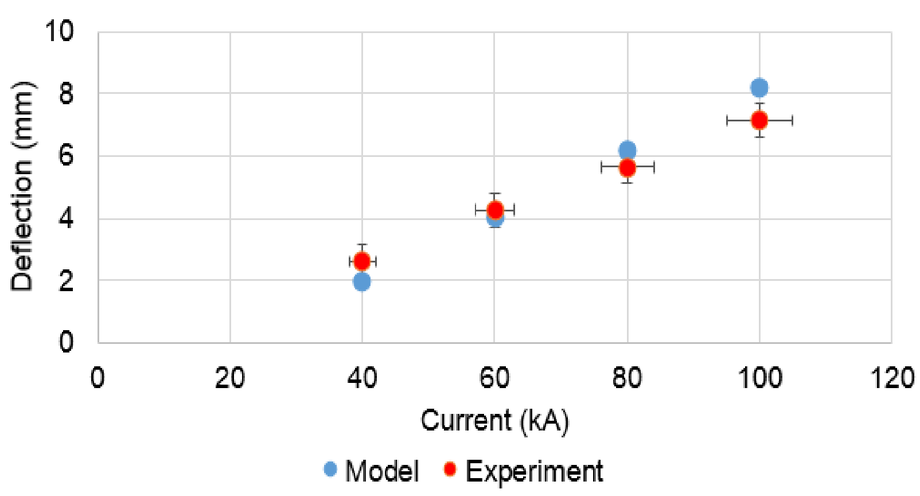
Displacement mechanism for aluminium



Mathematical fits to the 100 kA displacement data revealing the equilibrium position

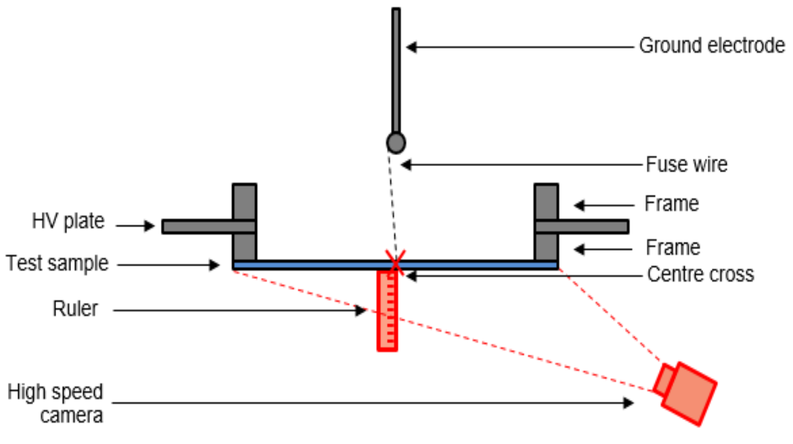


Comparison of dynamic deflection up to the first 3ms following a lightning strike, indicating the maximum deflection and duration of the lightning strike



Comparison of static model and dynamic experimental measurements of maximum displacement

Experimental Setup



Conclusion

- The numerical model only considered the electromagnetic force in a static condition.
- A number of additional factors were observed in the dynamic experimental results such as damped oscillation, constructive and destructive interference, elastic/plastic deformation and an air pressure effect.
- The maximum deflection occurred before the plate swings into a light damping mode.
- The results showed very good agreement and were mostly within the measurement and calculation error margins of the experiment.

Future Work

- Progress onto the study of more complex materials, such as aerospace grade carbon composites.

[1] E. Rupke: 'Aircraft Skins: A Brief Introduction in Lightning Direct Effects Handbook', Agate, pp.53, March 2002