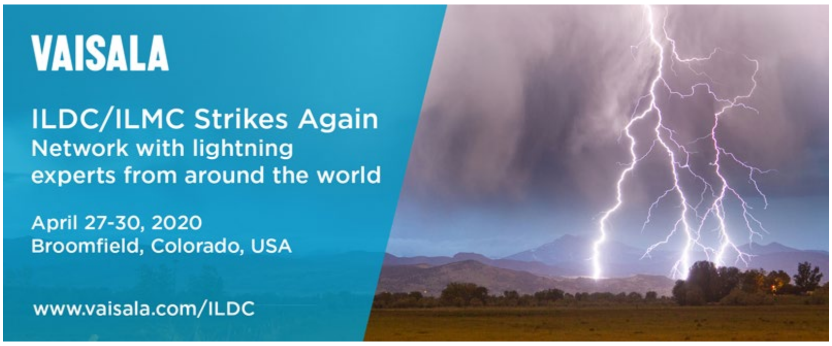

Modeling and Analysis on the Influence of Electrode Configuration in Simulated Lightning Strike Tests

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Abstract

Lightning simulation technology is efficient in investigating the direct lightning strike effects in consideration of the complexity and expense of testing with natural or artificially-triggered lightning. To simulate lightning arcs, the test setup consisted of two electrodes separated by an air gap has been widely used in laboratory to generate electric arcs with high impulse and/or continuing currents. The test materials, such as metal or composite materials, are posited as anode/cathode to study its damage response subjected to the negative/positive lightning current arcs. The behavior and damage of materials after the simulated lightning strike tests provide direct evidence in the certification of lightning protection for composite and metallic materials for many industries, such as aerospace and wind energy. Existing standards for the simulated lightning strike test mainly emphasize on the parameters of different lightning current components, namely the current amplitude, waveforms, duration, and action integral, and recommend a sketchy test setup using an indirect electrode to solve the electrode jet problem. This indirect electrode structure has a ceramic cap installed on head, which absorbs partial (40%~60%) arc energy and restrains shockwave impacts. In addition, the configuration of a simulated lightning strike test is restricted by the simulated lightning generator. The maximum air gap distance between electrodes is dependent on the air breakdown ability of generator. These factors in test configurations (i.e., electrode size, shape, and air gap distance) could significantly affect the distribution of current density, heat flux, and hydrodynamic pressure inflicted to the surface of test material and thereby lead to different damage modes and characteristics. In this study, we will present a two-dimensional numerical model that couples the prediction of electric arc magnetohydrodynamics with the thermal and ablation responses of the test material.

The proposed model will be validated by comparing the predicted damage depth and area of an aluminum sample with the experimental data for a simulated continuing current (lightning C current component) test with an amplitude of 400 A and a duration of 0.5s, and also by comparing the predictions of heat flux and current density in the electric arc plasma channel with the existing experimental data of a tungsten inert gas (TIG) arc in argon environment. Then, this model is employed to study the influence of electrode configurations on electric arc characteristics and the response of the test material.

The plasma temperature, current density, heat flux, and hydrodynamic pressure within the arc will be quantitatively compared, as well as the thermal and ablation responses of aluminum material. The model was implemented using finite element analysis with COMSOL Multiphysics, which concurrently solves the Maxwell's equations, heat energy conservation equation, and Navier-Stokes equation in the electric arc plasma domain and the heat conduction equation in the test material domain. In the arc-material coupling process, temperature distribution and ablation responses of the aluminum anode were concurrently calculated and compared, together with time evolutions of arc characteristics. The changes of plasma temperature, heat flux, current density, and hydrodynamic pressure of arc with different electrode configuration and increasing arc gap distances will be discussed. The influence of air gap distance and cathode shapes (i.e., hemisphere, ellipsoid, and cone) on the damage responses of anode material will be detailed in the full paper.

Topic Areas

Lightning Interactions with Transmission Lines and Wind Farms, Lightning Safety, Protection, and Casualty Occurrence

Submission Format

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