Lightning Strikes More than Once

The statue of Christ the Redeemer in Rio de Janeiro is plagued by lightning strikes. Multiphysics simulation can help predict where damage is likely to occur, and lightning rods could then be installed to protect this national treasure.

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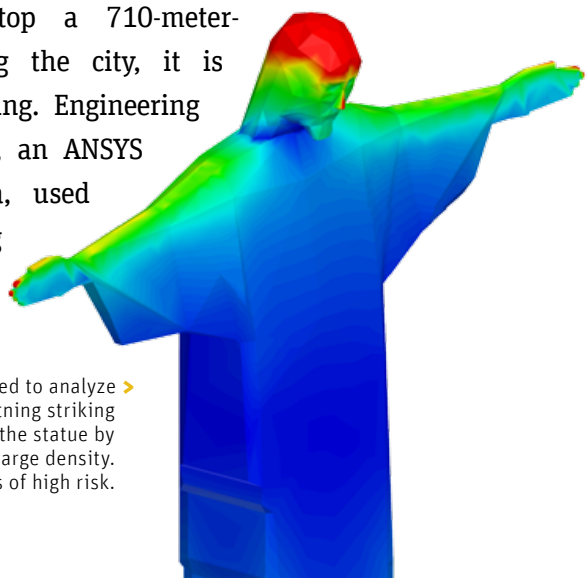
The Christ the Redeemer statue in Rio de Janeiro attracts around two million tourists each year, and is considered one of the seven wonders of the modern world. Construction on the statue began in 1922 and was finished in 1931. It is 30 meters tall, 28 meters wide, and weighs 635 metric tons. Because of its height and placement atop a 710-meter-high mountain overlooking the city, it is frequently struck by lightning. Engineering Simulation and Scientific Software (ESSS), an ANSYS elite channel partner in South America, used ANSYS software to recreate a recent lightning strike in a virtual environment to analyze its effects on the statue.



ANSYS software is used to analyze the chance of lightning striking different parts of the statue by determining accumulated charge density. Red indicates areas of high risk.

WHERE ENGINEERING AND ART MEET

The statue design was the inspiration of French sculptor Paul Landowski. Brazilian engineer Heitor da Silva Costa and French engineer Albert Caquot then used Ladowski’s design to plan construction. The internal structure of the statue is made of reinforced concrete and the outer layer is composed of triangular tiles of soapstone. This collaboration between art and engineering resulted in an enduring and breathtaking monument.

ANSYS Workbench workflow for this multiphysics simulation

DAMAGE FROM LIGHTNING

Soapstone was chosen for its malleable yet resilient nature. But despite its resiliency, lightning strikes have caused significant damage through the years. Lightning rods help to prevent lightning from reaching the statue itself, but even with this safety measure, the statue is struck by lightning on average five times a year. In 2010, damage from a combination of lightning strikes and water damage led Brazil to spend $4 million on a restoration project. In early 2014, the statue was again damaged by lightning strikes to the face and hand. The resulting damage was significant, and workers spent four months repairing the damage and installing additional lightning rods.

SIMULATING THE LIGHTNING STRIKE

Lightning strikes occur when the electrical charge between two objects becomes great enough to ionize the air, which enables an avalanche of current to flow from the higher potential to the lower potential. The prevention and mitigation of strikes are areas of vital interest in engineering lightning protection systems. Lightning rods function by attracting lightning in a controlled

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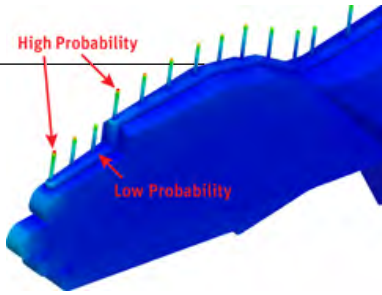

ANSYS software shows the effect of additional lightning rods and their placement. Some rods would have little impact on diverting the charge from a strike.

fashion away from direct interaction with the structure it is protecting. The rods have narrow tips which concentrate the accumulated charge into high densities and make them likely targets for lightning strikes. Lightning rods are connected to thick copper wire, which provides a safe path to the ground, diverting the charge away from the structure.

To determine effects of lightning on Christ the Redeemer, ESSS utilized ANSYS Q3D Extractor and ANSYS Maxwell for electrostatic analysis, and ANSYS HFSS for electromagnetic transient analysis. A key feature of all three products is the automatic adaptive meshing technique, for which the user only needs to specify geometry, material properties and the desired output. The robust meshing capability saves time by eliminating the need to build and refine a finite element mesh. Additionally, a new feature of ANSYS HFSS is the implicit FEM electromagnetic transient solver, which accurately solves electrical problems such as lightning strikes and electrostatic discharge very quickly.

> **"Using *structural thermal analysis* the team determined *deformation damage* to the lightning rods."**

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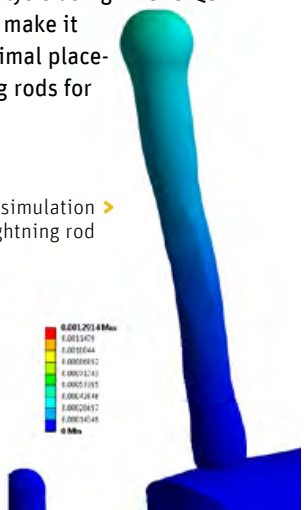
ELECTROSTATIC ANALYSIS

ESSS's simulation showed the areas where lightning is likely to strike, and thus where the rods would be most effective. The statue is at ground potential. When exposed to high electrical potential from the clouds, large electrical charges build up. The accumulated charge density on the structure was analyzed to determine where high charge accumulations, which are most likely to provide a contact point for the ionization streamer leading to the lightning strike, occur. Electrostatic analysis using ANSYS Q3D Extractor and ANSYS Maxwell make it possible to determine the optimal placement and quantity of lightning rods for maximal effect.



Structural deformation simulation of one lightning rod

TRANSIENT ELECTROMAGNETIC FIELD ANALYSIS

Lightning was modeled as a current source with a pulse shape commonly represented as a double exponential in time. The current path for the lightning strike was simulated as contact with the statue rather than the formation of the lightning plasma arc. This allowed engineers to study the effects of the lightning post-arcing. The resulting current distributions along the statue were analyzed using ANSYS HFSS coupled with ANSYS Mechanical through ANSYS Workbench to identify temperature increases from the heating effects of the strike. Using structural thermal analysis, the team determined deformation damage to the lightning rods. ESSS engineers used ANSYS HFSS to calculate the surface loss density on the metallic portions and volume loss density on the dielectric portions. These losses were then used as inputs for the thermal and mechanical fatigue analysis to evaluate the overall structural integrity of the statue.

Engineering simulation is a valuable tool in the design of new structures, and maintenance, repair and deterioration prevention of historic buildings and artwork. Because time and the elements take their toll, the insight gained from simulation can help conserve these wonders in a cost-effective manner so that they can be enjoyed by generations to come. A

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