Building a Safer Power Plant

One major concern for power plant designers is a disruptive event that may interrupt energy generation.

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It is impossible to protect structures from all man-made and natural hazards. However, assessing the possible damage caused by a defined hazard enables stakeholders to make informed decisions about the kinds and number of design changes needed. As part of licensing procedures in place throughout most of the world, utilities such as power producers are required to carefully analyze and understand the damage and subsequent effects of these hazards to their power plants and how to effectively protect these structures. Using modern simulation tools from ANSYS, Eletronuclear S.A. worked with ANSYS channel partner ESSS to efficiently simulate potential damage caused by a hypothetical external explosion to a Brazilian nuclear power plant (NPP).

Eletronuclear S.A. was created in 1997 to construct and operate Brazil's ANGRA 1, ANGRA 2 and ANGRA 3 nuclear power plants. ANGRA 1 and 2 plants are operational; when completed, ANGRA 3 will have the capacity to generate 1,350 Megawatts of power, making a major contribution to Brazil's power grid. The hazard studied for this case was a postulated explosive detonation at the highway close to the plant. For the scenario, engineers determined the maximum overpressure caused by the explosion.

An explosion produces sudden changes in pressure, which in turn generate a high-pressure wave, referred to as a blast wave. Engineers used ANSYS Autodyn software to model the initiation of the blast wave from a specific amount of explosive. The blast wave propagation and resultant pressure loading on the power plant's

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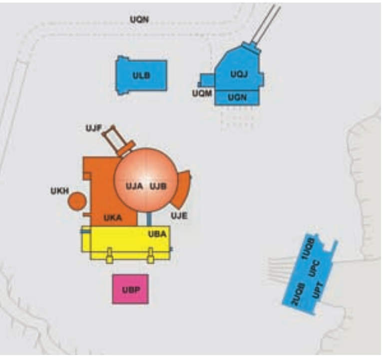
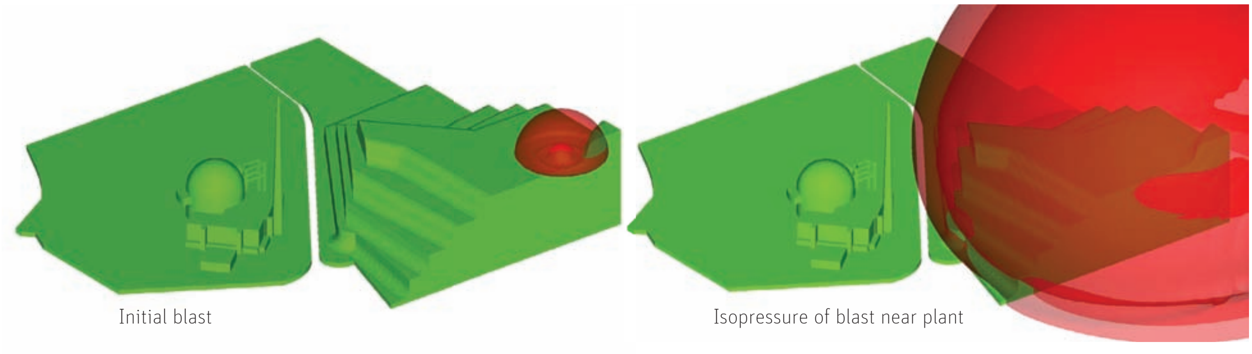
ANGRA nuclear power plant

Satellite view of Brazil's ANGRA plant site



ANGRA 3 site plan



Initial blast

Isopressure of blast near plant

buildings are influenced by the reflection of waves on the terrain and the distance from the source to the plant. Using Autodyn, engineers from Eletronuclear S.A. predicted the severity of pressure waves that the explosion would cause.

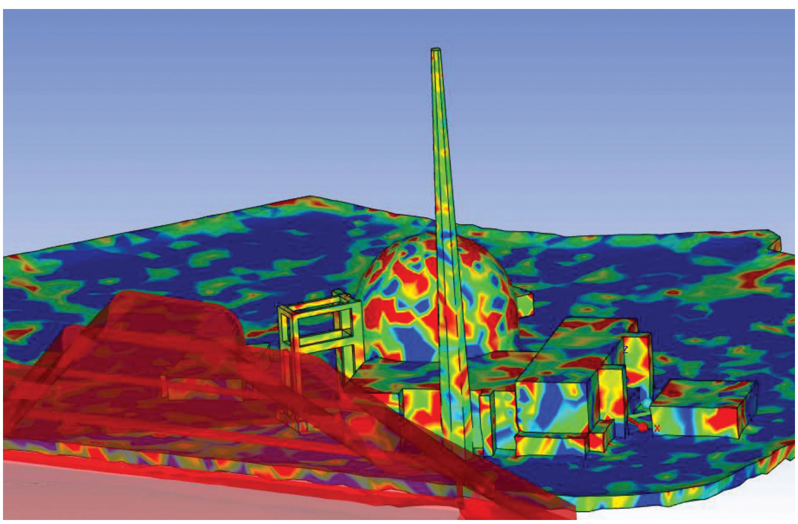
Autodyn is used to simulate short-duration shock and impact events. It is a finite element program, based on first principles, that uses explicit time integration to solve the conservation equations of mass momentum and energy. Usually this technology is used to gain insight into key physical phenomena for problems that involve large deformations, material failure and fluid–structure interaction. Separate solvers built into Autodyn utilize the most effective solution method, based on the response, of rigid or deformable solids and fluids. Additional tools enable portions of the problem to be solved in one or two dimensions to speed up the calculation [1,2,3].

When running a simulation, the geometric model that represents the real problem is discretized into meshed elements, also called zones. Meshing is a critical part of the problem setup as the element size controls the accuracy of the results as well as computing efficiency. Small elements yield higher accuracy but longer running times; the analyst must balance these two opposing demands to obtain accurate results within a reasonable time frame.

The initial stage of the explosion was simulated in Autodyn with the multi-material fluid (Euler) solver. With this tool, different types of materials — in this case, explosive (basically solid), air and gas byproducts of explosives — are all modeled in the same region. Once all the explosives were detonated, the Euler FCT solver came into play. This method simulates the response of ideal gases with second-order accuracy very quickly. (Two seconds of problem time were run.) The geometry of the problem allowed engineers to simulate the initial portion in two dimensions, then map the results into full three-dimensional problem space. This method provided an additional reduction in computing time.

Because running problems in 3-D requires the greatest amount of computational time, the team used a separate series of simulations to determine the largest element size (approximately 3 meters) that would still predict the correct overpressures when compared to analytical results. To further speed up calculations, engineers used rigid materials for the terrain and power plant buildings. Even with these optimizations, the problem size was very large — approximately 3.5 million elements — and the problem time was quite long for explicit-type solutions. The calculation took approximately 12 hours to run on a Dell Latitude™ E6410 laptop.

The results showed that the ANGRA 3 plant could survive the explosion without damage. The Eletronuclear S.A. team gained insight into how to mitigate damage from larger explosions; it also obtained required clearances for plant licensing and construction without the need to perform expensive experiments. The flexibility of the ANSYS Autodyn program enabled Eletronuclear S.A. to complete the project on time and to contribute to the plant's safety. The plant is scheduled to begin operations in 2015. ■



Pressure loading on the ANGRA 3 plant

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