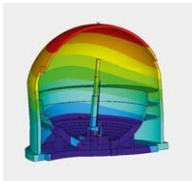


# ADVANCED SIMULATIONS FOR THE NUCLEAR POWER INDUSTRY

Dynardo provides an extensive expertise for the simulation and verification of special load cases like airplane impact or earthquake damage using ANSYS, multiPlas, LS-DYNA and optiSLang.



## Task

In order to conduct linear or non-linear Finite Element (FE) studies of earthquake and airplane loading, Dynardo uses spectral analyses or time integration techniques including

the comparison of acceleration response spectra with ANSYS and LS-DYNA. Using optiSLang, a sensitivity analysis is generated and combined with parametric optimizations for parameter identification and calibration. Finally, optiSLang verifies and proves the safety requirements by robustness evaluations and reliability analyses.

### An airplane impact loading analysis includes:

- Limit load analysis (RIERA load model or dynamic impact analysis)
- Shear and bending failure of concrete
- Bending evolution
- Punch-through behavior

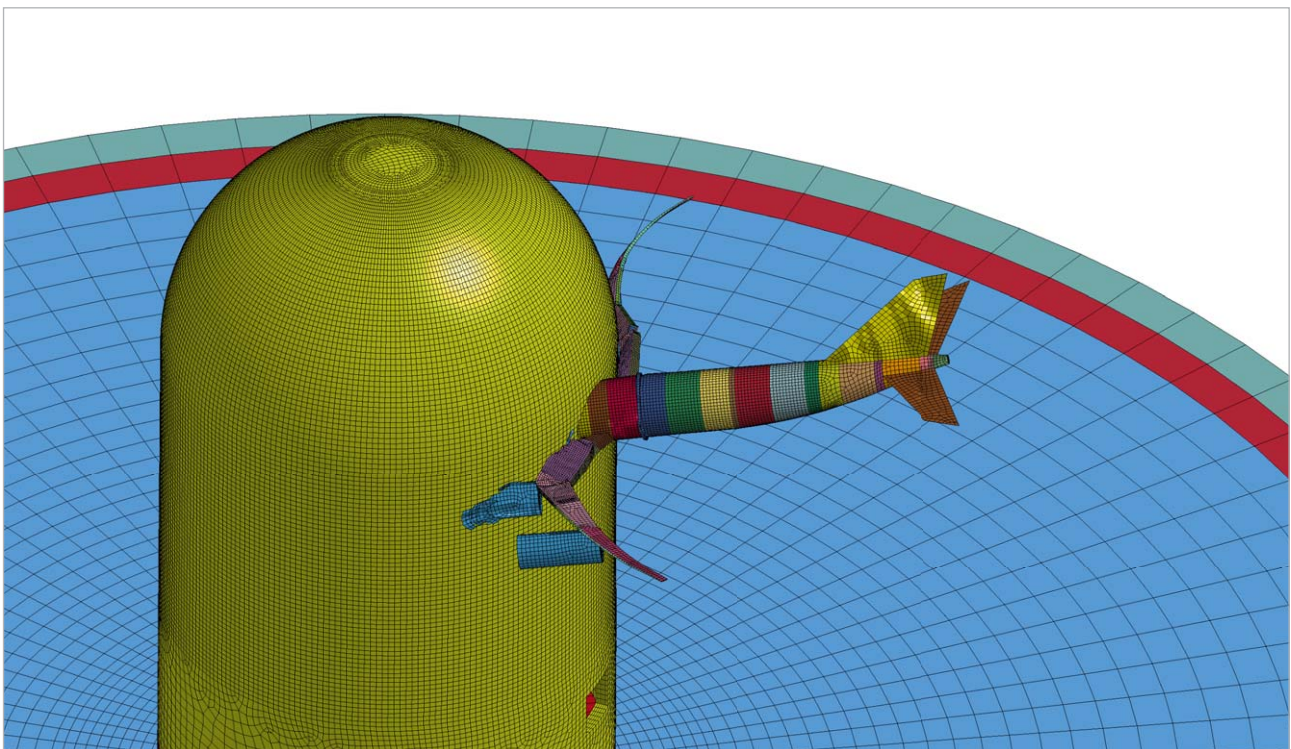
## Modeling

For the simulation, a 3D impact FE-Model (reactor building and underground) is generated with ANSYS. All important positions of the reactor building are included in a transient analysis with LS-DYNA for determining and plotting the acceleration time signals. With a special numerical procedure, then the response spectra is calculated.

### Modeling of the airplane

Dynardo develops an airplane model for different types. The following global characteristics are considered:

- Distribution of mass (structure, payload and gasoline)
- Pull-off strength of engines
- Stiffness and strength of structures
- Buckling loads of: Wings, wing box and other fuselage sections



FE-Model (reactor building and underground) for a simulation of plain impacts

## Modeling of the power plant buildings and containments

The modeling of the building structure includes all important load bearing structural parts. Furthermore, several detailed models are generated, such as:

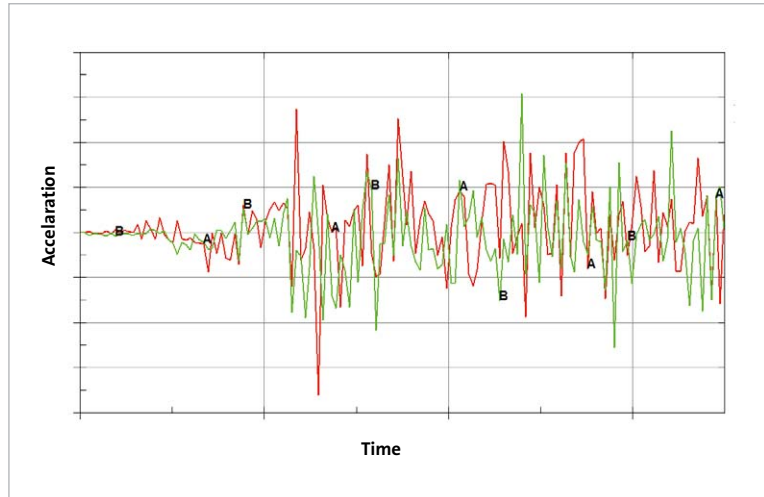
- Volume models with brick meshing, shell parts and beam structures
- Detailed modelings of reinforcement into impact zone
- Models of the power plant including 100.000 to 1.000.000 elements and nodes

## Simulation & Analysis

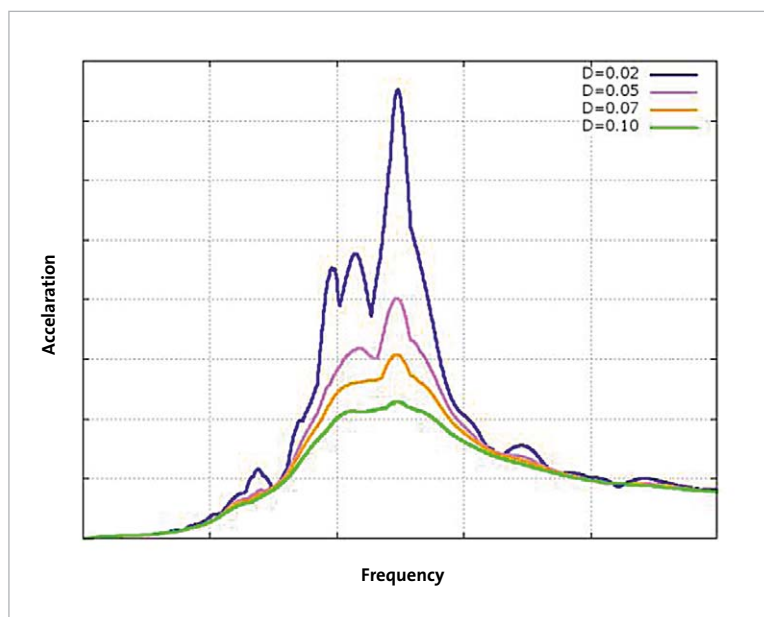
The modeling also considers non-linear material behavior as well as contact or strain rate dependency. A transient analysis for different load cases is conducted to compare the airplane impact (elastic and plastic) vs. the aftermath of an earthquake (elastic). The verification of test and analysis results is secured by a sensitivity analysis and the computation of the acceleration response spectra.

For earthquake analysis of nuclear power plants the following additional evaluations can be done:

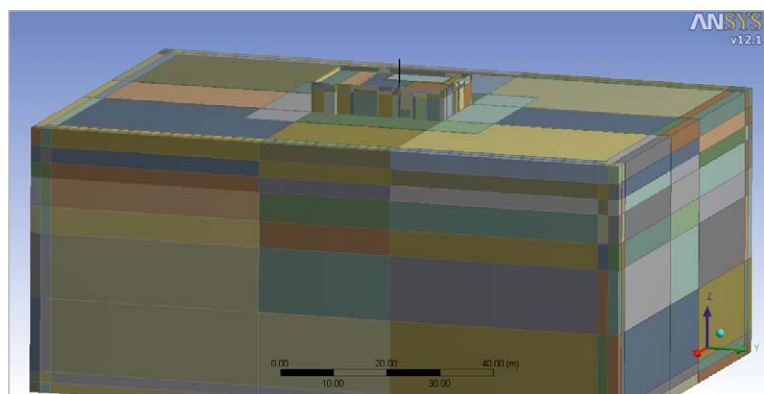
- Simulation and proof for earthquake loads
- Response spektra method and transient dynamic analysis, including the soil-structure interaction
- Sensitivity analysis and system identification, verification of damping assumptions
- Consideration of different subsoil layers and pile foundation
- Non reflection boundaries for prevention of wave reflection



Acceleration-time-signals plot



Determination of acceleration response spectra



Consideration of different subsoil layers and pile foundation for earthquake analysis