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Seismic fragility with MOCABA

Obtain more realistic fragility curves for seismic risk studies

Getting a grip on seismic outliers with the probabilistic analysis tool MOCABA

Challenge

The classical, log-normal fragility model is **realistic if** the relationship between seismic demand (peak ground acceleration) and the response quantity (stress, deformation) is close to **linear**.

There are several safety-critical components with distinctly **nonlinear** behavior under extreme seismic conditions. A prominent example are fuel assemblies. The limit state is governed by the inelastic deformation of spacer grids, caused by seismic-induced impacts between neighboring fuel assemblies. Other examples are cranes and fuel racks (sliding, impacts).

For such components the lack of realism in the standard fragility model can lead to **misguided efforts** and decisions related to seismic safety, such as unjustified hardware modifications.

Solution

The probabilistic analysis software **MOCABA** is a versatile framework for **multivariate analysis** and has been applied to multiple problems of nuclear safety such as criticality safety analysis and power distribution calculations for nuclear reactors.

MOCABA is directly applicable to fragility analysis. While in the standard fragility model all variables are constrained to follow a log-normal distribution, the MOCABA framework allows one to use **more general distribution models** with a **richer model space**, which can also be applied to multivariate regression problems with strongly nonlinear relationships between input and output parameters. The result is a significantly better fit between the trained model (yellow, red, green curves in the figure) and the test data (blue dots).

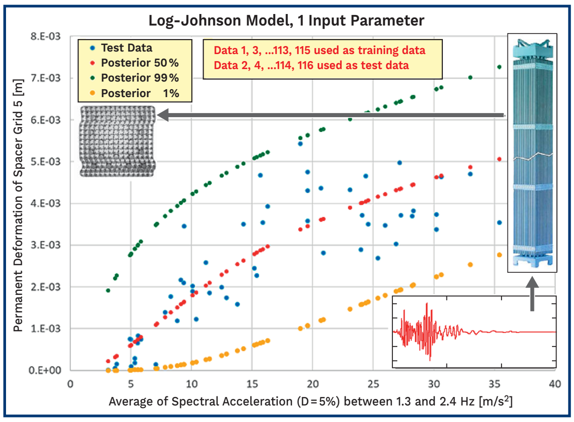
Benchmark studies related to the safety demonstration of fuel assemblies revealed a massive underestimation of the seismic capacity by the standard fragility model, by a factor of two. This shows that a **high-end** fragility analysis with MOCABA can really make a difference.

Note that the direction of the bias is problem-specific. Overestimating of the capacity, i.e. to err on the unsafe side, would be even more troublesome.

Customer benefits

- **More realistic** fragility curves can be obtained than with the standard fragility model (log-normal distribution).
- More realistic estimate of the **risk contribution** from selected components.
- Detection of hidden conservatism (or vulnerabilities!) helps to **avoid costly misallocation** of resources.

Your performance
is **our** everyday **commitment**



Technical information

The domain of application of the MOCABA (MOnte CArlo BAyesian) framework is similar to that of **regression** analysis and – more generally – of **machine learning**. The basis of the analysis is a **dataset** of input and output variables.

- The input variables are the seismic intensity measures (e.g. ground accelerations).
- The output variables are the response quantities governing failure (e.g. permanent spacer grid deformation).

In the benchmark study the model is trained and tested with two datasets of equal size (56 each, see figure above).

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Number of model parameters per variable of the log-Johnson distribution. This means more **flexibility** and a better data fitting compared to the log-normal distribution (2 parameters).

2:1
Ratio between the **realistic** capacity (based on MOCABA) and the capacity **estimated** with the standard fragility model in the benchmark study.

Contact: engineering-studies@framatome.com
www.framatome.com