A modified third order polynomial approach for reliability analysis with scarce samples

In applications requiring reliability analysis, sometimes only samples of random responses are available. In such instances, the relationship between the random response and its CDF is approximated and used for reliability predictions. In literature, researchers have used a family of normal polynomial models to fit random responses. It has been shown that a third order polynomial with fractile constraints in the space of reliability index works well for most distribution types for low-medium reliability indices. However, the fitted model deviates largely for higher reliability indices.

Current work

This paper looks at fitting a third order polynomial to CDF in the transformed reliability index space. In one of the earlier works, it has been observed by the author that applying logarithm to the reliability index tends to linearize the CDF. Irrespective of this assumption and the feature that CDF is monotonic; one can impose fractile constraints and fit the CDF in the modified space using third order polynomial. Results show that simulated data from normal, lognormal, exponential, burr distribution and classical engineering examples like the biaxially loaded cantilever beam are fitted well by this approach. About 200 samples are sufficient to predict reliability indices (or corresponding inverse measures) of the range of 4-4.5. If not for this method, one would require about 5e5-1e6 samples for the same accuracy. The selected distributions cover different types of possible tails.

Future work

Current work focussed on developing an accurate estimate of the reliability using one set of random responses. In the recent past, researchers have used a variant of Monte Carlo Simulation (MCS) called the separable MC with good success. SMC is suitable when the limit state function is available in a decomposed manner as response and capacity. Sometimes, it is expensive to get the responses compared to capacity. It has been shown that the limit state, if can be decomposed as a product of response per unit load and load vector, then limited amount of response estimates (which are computationally expensive) can be used with large number of load and capacity samples(which are sampled easily) to estimate failure probability. With the proposed approach, one will be able to predict response for a higher reliability index with scarce samples. This predicted value can be used with a large number of load and capacity samples to estimate failure probability at the unobserved levels. This combines the advantage of the modified third order polynomial approach in estimating reliability at unobserved level with the SMC which provides an improved accuracy of the estimate. The proposed method will be demonstrated on true distributions, the cantilever beam problem and a composite laminate problem with Tsai-Wu failure criterion.