Effect of Characterization Test Matrix on Design Errors: Repetition or Exploration?

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Abstract

For structural design, it is critical to identify failure modes and appropriately characterize them as early during the design stage as possible. A key to predicting structural failure is the construction of design allowable charts for each failure mode, e.g., failure load map with respect to geometry and load conditions. Due to the complexity of failure mechanisms and lack of knowledge, analytical prediction models are not reliable enough. Therefore, failure-criterion characterization tends to rely on tests.

We typically conduct a matrix of characterization tests to cover the expected design space. To achieve the accuracy of failure load mapping, we may want to repeat several tests for the same configuration to eliminate the effect of noise in test observation due to variability in material properties and test conditions. On the other hand, exploring within the design space with many different configurations is more likely to spot yet-unidentified failure modes. For a given number of tests, there arises a resource allocation problem: repetition or exploration?

This paper investigates an effective strategy of experimental characterization of structural failure criteria. We examine the problem using interpolation techniques, known as surrogate models, to approximate the failure load of a structural element as a function of problem parameters. Polynomial response surface (PRS), support vector regression (SVR) and Gaussian process regression (GPR) that are known to be capable of smoothing equivalent to a noise filter are used. We compare repetition and exploration for two structural elements, such as a support bracket and a composite laminate plate.

The study shows that repetition of tests is not necessarily needed to improve the accuracy of failure load surface approximation. A denser matrix is more important to reduce the error in approximation as well as to locate yet-unidentified failure modes. This conclusion is stronger when the failure load surface is complicated, where modeling error tends to be more influential than noise. Furthermore, it is found that fitting the surrogate models with all repeated data leads to better accuracy than using only the mean values of repeated data.

Keywords: Test, surrogate models, Failure modes, resource allocation