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Distributed collaborative probabilistic design of multi-failure structure with fluid-structure interaction using fuzzy neural network of regression

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ABSTRACT

To improve the computing efficiency and precision of probabilistic design for multi-failure structure, a distributed collaborative probabilistic design method-based fuzzy neural network of regression (FR) (called as DCFRM) is proposed with the integration of distributed collaborative response surface method and fuzzy neural network regression model. The mathematical model of DCFRM is established and the probabilistic design idea with DCFRM is introduced. The probabilistic analysis of turbine blisk involving multi-failure modes (deformation failure, stress failure and strain failure) was investigated by considering fluid–structure interaction with the proposed method. The distribution characteristics, reliability degree, and sensitivity degree of each failure mode and overall failure mode on turbine blisk are obtained, which provides a useful reference for improving the performance and reliability of aeroengine. Through the comparison of methods shows that the DCFRM reshapes the probability of probabilistic analysis for multi-failure structure and improves the computing efficiency while keeping acceptable computational precision. Moreover, the proposed method offers a useful insight for reliability-based design optimization of multi-failure structure and thereby also enriches the theory and method of mechanical reliability design.

1. Introduction

For multi-failure structure like the turbine blisk of an aeroengine, the reliability, security and performance of mechanical system are seriously influenced by a variety of failure modes on structure responses such as deformation failure, stress failure, strain failure and so forth [1–3]. It is important to accurately estimate the multi-failure traits of the complex structure. However, the coupling effect among multi-physics loads (such as fluid load, heat load and centrifugal load) and multiple structural responses (such as deformation, stress and strain) cause the high nonlinearity and complexity of structure limit state function, which leads to the difficulty of design analysis of multi-failure structure [4,5]. Therefore, efficient analysis methods are expected to reasonably design multi-failure structure. Although much progress of experimental and numerical investigations has been implemented for multi-failure structure via deterministic analysis methods [6–8]. These works are not always concerned the uncertainty of various factors impacting the performance of multi-failure structure. Probabilistic

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