ICCES, 2025, vol.33, no.3

Tech Science Press

DOI: 10.32604/icces.2025.012069

PROCEEDINGS

Intelligent Structural Strength Monitoring Method Using Dynamic Evolving Digital Twin Model

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ABSTRACT

The development of large-scale, high-precision aerospace structures has imposed increasingly stringent requirements on mechanical response monitoring during ground testing. Aiming at the long-standing limitations of mechanical response monitoring for ground tests in terms of accuracy and real-time performance, this study introduces an intelligent structural strength monitoring method using a dynamically evolving digital twin model.

First, a reduced-order modeling method that accounts for actual test deviations is established. By jointly sampling deviation and loading information as variables, a reduced-order model with full-field mechanical responses as output is constructed, enabling rapid updates to reflect the real test conditions. Second, a framework for the dynamic evolution of digital twin models is developed, along with the establishment of the dynamic evolution mechanism and corresponding algorithms. This achieves adaptive updates to the model during the test, leading to the continuous dynamic evolution of structural monitoring results. Finally, based on real sensing data from the test, the digital twin model is driven for online dynamic evolution to achieve high-precision monitoring of structure ground tests. Simultaneously, intelligent interactions between the digital twin model and the real test environment are realized through visualization techniques like mixed reality, breaking the limitations of spatial interaction in traditional tests.

To verify the proposed method, experimental validation was conducted on a typical stiffened shell structure. The results demonstrate that the proposed approach enables the dynamic evolution of the digital twin model based on sensor monitoring data, facilitates model parameter updates, and realizes visual interactions of the monitoring process via hybrid display technologies. These capabilities effectively enhance the accuracy, real-time performance, and interactive levels of equipment structure ground test monitoring.

KEYWORDS

Digital twin; structural monitoring; dynamic evolution

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.