重大工程结构环境-荷载耦合试验平台研发

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摘要：目的：为实现不同尺度的重大工程结构在（随机）疲劳荷载与复杂环境耦合作用下的人工加速试验。方法：根据自然暴露实验与加速环境疲劳实验的内在关联，提出时变加速湿热（尤其是低温低湿）、温度-腐蚀等环境仿真方法及实现技术；通过对多套反力架及加载系统的可移动式设计、以及随机载荷实验谱模拟、编制、加载及控制软硬件的设计，实现了对复杂环境下大型结构的多点移动式随机加载技术。结果：突破了低温低湿（5～20℃时≤40%R•H）环境、≤-70℃低温环境、多环境因素的任意组合及其转换的实现技术、变频/带随机载荷加载技术、以及在恶劣的实验环境（浓雾环境、盐雾环境等）中试件疲劳损伤全过程监测、疲劳裂纹萌生、扩展量及表面形貌的高精度测量技术，在国内外首次建立了复杂环境下结构疲劳实验平台及实验技术。

关键字：环境-荷载耦合；时变加速仿真；多点移动式随机加载；整机研发

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Research and development of a coupled environmental and load test platform for major engineering structures

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Abstract: ObjectiveTo realize the artificial acceleration tests of different scale structures under

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(random) fatigue loads and complex environments coupling. Methods According to the internal relationship between natural exposure experiments and accelerated environmental fatigue experiments, the simulation methods and realization techniques of time-varying accelerated hot-wet (especially low temperature and low humidity) and temperature-corrosion environments are proposed; and through the movable design of multiple sets of reaction frames and loading systems, as well as the design of random-loading experimental spectrum simulation, compilation, loading, and controlling software and hardware, the technology of multi-point movable random loading for the large-scaled structures in complex environments have been realized.**Results**A breakthrough has been made in the realization of low-temperature and low-humidity (e.g., ≤40% R•H at 5-20℃) environments, ≤-70℃ low-temperature environments, an arbitrary combination of multi-environmental factors and their conversion, frequency conversion/random loading technology, and monitoring of fatigue damage of the specimens in the whole process in the harsh experimental environments (foggy environment, salt spray environment, etc.). It is the first time at home and abroad to establish a platform for structural fatigue experiments in complex environments, with high-precision measurement of fatigue crack initiation, propagation and surface morphology.

Keywords: Environment-load coupling, time-varying accelerated simulation, multi-point moving random loading, complete machine development

重大工程结构和装备的抗环境疲劳/耐久性能是土木建筑、交通、航空、水利、船舶与海洋等领域的前沿基础性课题，也是这些领域研究的薄弱环节。发展重大工程结构和装备的抗环境疲劳/耐久性技术，必须首先要突破目前困扰所有结构环境疲劳/耐久性实验的瓶颈问题--复杂服役环境与（随机）载荷耦合/共同作用下的结构疲劳实验方法、技术以及实验平台的研制问题。为此，在国家重大科研仪器研制项目的支持下，本研究从复杂环境与疲劳载荷耦合下结构疲劳/耐久性能的表征与实验方法、复杂服役环境（湿热、水/海水/盐雾、冻融等）的实现技术、变频/带随机载荷加载的实现技术、环境疲劳性能在线测试的实现技术、复杂环境与随机载荷耦合下结构疲劳实验系统的研制和集成技术等五方面重要科学和技术问题着手，开展了复杂服役环境与（随机）疲劳载荷耦合/共同作用下的结构疲劳试验平台的整机研发。