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Topology Optimization Method Considering Nonlinear Fatigue Damage Accumulation in Time Domain

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ABSTRACT

In engineering practice, most components are subjected to variable-amplitude cyclic loading, resulting in fatigue damage, which is one of the main forms of damage in engineering structures. Nonlinear damage rule is developed based on linear damage rule, which can predict the fatigue life of structures more accurately. Therefore, we present a topology optimization method considering nonlinear fatigue damage accumulation in the time domain. For the time domain, we adopted the rainflow counting method to evaluate the stress level generated by cyclic loading and the Basquin equation to describe the S-N curve. We applied Morrow's plastic work interaction rule to calculate the nonlinear fatigue damage accumulation of structures. Based on this, we develop a topology optimization model considering nonlinear damage, and employ the P-Normal function to address the large-scale constraints and the singularity problem. Meanwhile, the sensitivity equations of the objective function and the fatigue constraint function to the design variables are derived by the adjoint variable method. Finally, the effectiveness of the proposed method is verified by 2D and 3D numerical examples. The results demonstrated that the method can limit maximum fatigue damage while achieving the lightweight design of the structure.

KEYWORDS

Topology optimization; nonlinear damage rule; time domain; rainflow counting method; P-Normal function

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