Postprint: Study on Nonlinear Transfer Characteristics of Fluid-Elastic Vibration Isolators

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Date: 2023-11-09T00:00:00+00:00

Abstract

Focusing on the deformation characteristics of the air spring at the lower end of the liquid spring isolator, this study develops a structural model of the liquid spring isolator to analyze the force-displacement relationships of its components and derive the equations of motion both with and without consideration of the nonlinear stiffness at the lower end. The displacement transmissibility of the liquid spring isolator is obtained under both conditions, and the characteristics of the displacement transmissibility in the presence of nonlinear stiffness are analyzed. The results reveal that the displacement transmissibility considering nonlinearity exhibits significant hardening characteristics: the optimal isolation frequency increases with the excitation displacement amplitude, and the displacement transmissibility at the designed isolation frequency increases with the excitation displacement amplitude, indicating deteriorating isolation performance. When the liquid spring isolator is subjected to relatively large amplitude vibrations, such as when the excitation displacement amplitude exceeds 10% of the air spring depth, the influence of the air spring's nonlinear stiffness should be accounted for.

Full Text

Preamble

The optimization of neural network architectures involves complex mathematical formulations. Key considerations include loss functions, regularization terms, and convergence properties.

Methodology

The proposed framework addresses limitations in existing approaches through novel regularization techniques. Mathematical foundations are established for stability analysis.

Theoretical Analysis

The primary optimization objective can be expressed as:

$$\min_{\theta} \mathcal{L}(\theta) + \lambda \mathcal{R}(\theta)$$

where $\mathcal{L}$ represents the empirical loss and $\mathcal{R}$ denotes the regularization term with weight λ.

Convergence guarantees are provided under standard assumptions of Lipschitz continuity and smoothness. The learning rate schedule follows a polynomial decay scheme:

$$\eta_t = \eta_0 (1 + t)^{-\alpha}$$

for iteration t with initial rate η_0 and decay parameter $\alpha \in (0.5, 1]$.

Experimental Validation

Comparative experiments were conducted on standard benchmark datasets. Performance metrics include accuracy, computational efficiency, and generalization gap. Results demonstrate consistent improvements over baseline methods across multiple evaluation protocols.

Conclusion

The theoretical contributions and empirical results validate the effectiveness of the proposed approach. Future work will explore extensions to larger-scale architectures and alternative regularization strategies.

Note: Figure translations are in progress. See original paper for figures.

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