Nonlinear Mechanical Behavior of Sigmoid Functionally Graded Aluminum-Zirconia Composite Beams Under Thermal Loading Postprint

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Abstract

This study investigates the post-buckling and bending behaviors of symmetric and asymmetric sigmoid functionally graded material (S-FGM) beams under thermal loading. Through computational results, the differences in mechanical behavior between the two types of S-FGM beams and between S-FGM beams and conventional functionally graded material beams are analyzed. The composition distribution of the beam material along the thickness direction is assumed to follow a sigmoid law, while the temperature variation through the beam thickness is described by a one-dimensional heat conduction equation that also satisfies the sigmoid law. First, the equilibrium equations and boundary conditions for functionally graded beams are derived using the energy principle. Then, the shooting method is employed to numerically solve the equilibrium paths of S-FGM beams under different boundary conditions. Based on the numerical results, the influences of boundary conditions, composition distribution patterns, and external loads on the mechanical behavior of S-FGM beams are investigated. The results show that: under thermal loading, both symmetric and asymmetric clamped-clamped S-FGM beams undergo bifurcation buckling, whereas clamped-pinned S-FGM beams exhibit thermal bending (except for symmetric beams under uniform thermal loading); the gradient index and the temperature rise ratio between the top and bottom surfaces have significant effects on the bending, buckling, and post-buckling behaviors of S-FGM beams, and the influences of the gradient index and temperature rise ratio on the buckling and post-buckling behaviors of the two types of clamped S-FGM beams are distinctly different.

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Methodology

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Data Collection

Experimental Setup

Analysis Framework

The proposed framework integrates multiple computational approaches for analyzing complex systems. Mathematical formulations provide the foundation for modeling relationships between system components.

Evaluation Metrics

Performance evaluation employs standard measures to assess model accuracy and generalization capabilities.

Discussion

The results demonstrate significant improvements in predictive performance compared to baseline methods. The mathematical framework successfully captures underlying patterns in the data.

Conclusion

This work presents a novel approach combining theoretical analysis with practical implementation. Future research will extend these methods to broader application domains.