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Fractional Approach to Dynamic Analysis of Coupled Circular Plates with Hereditary Effects

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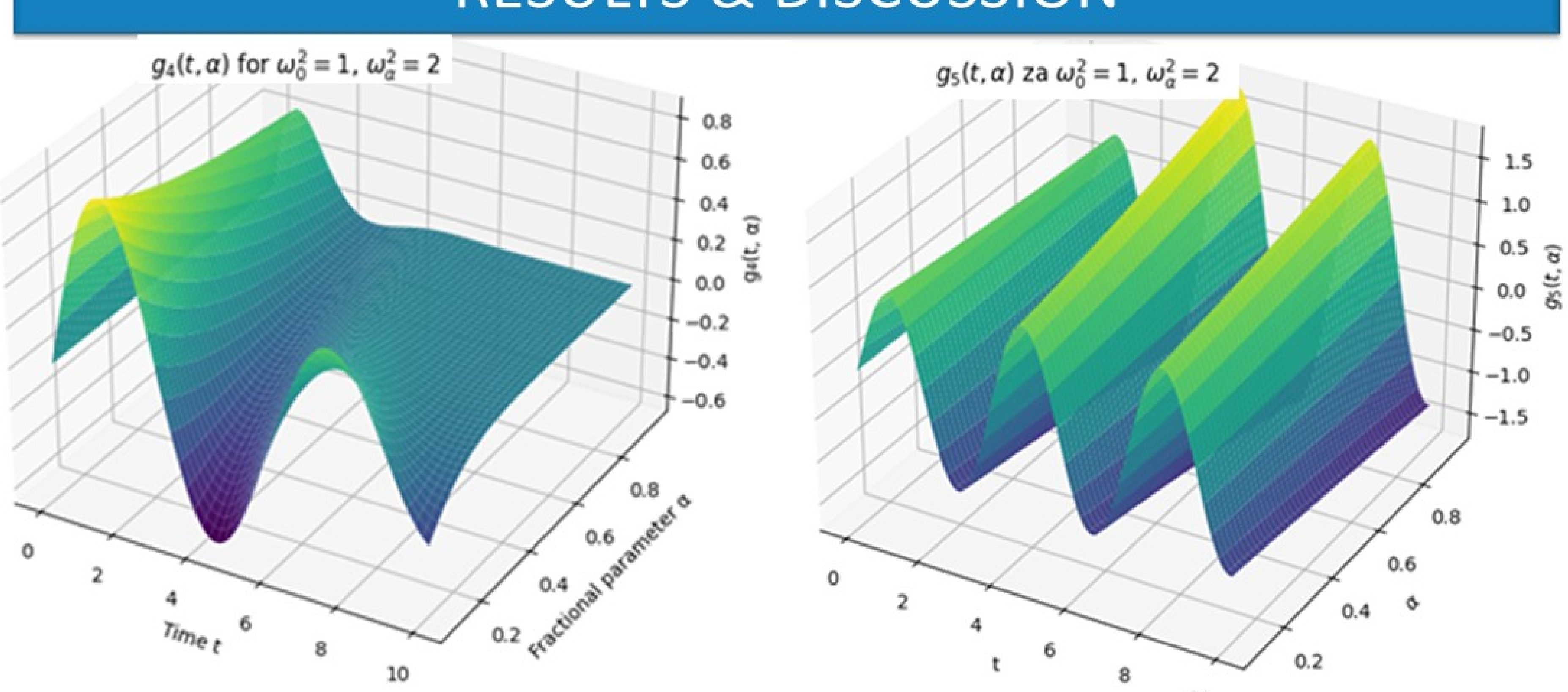
INTRODUCTION & AIM

- Multilayer systems with viscoelastic creep layers appear in aerospace, civil engineering, and microsystems, where time-dependent deformation significantly affects long-term stability.
- Classical integer-order models cannot fully capture hereditary (memory-dependent) behaviour.
- Fractional calculus provides a more accurate framework for modelling viscoelastic damping and creep.

Aim of the study

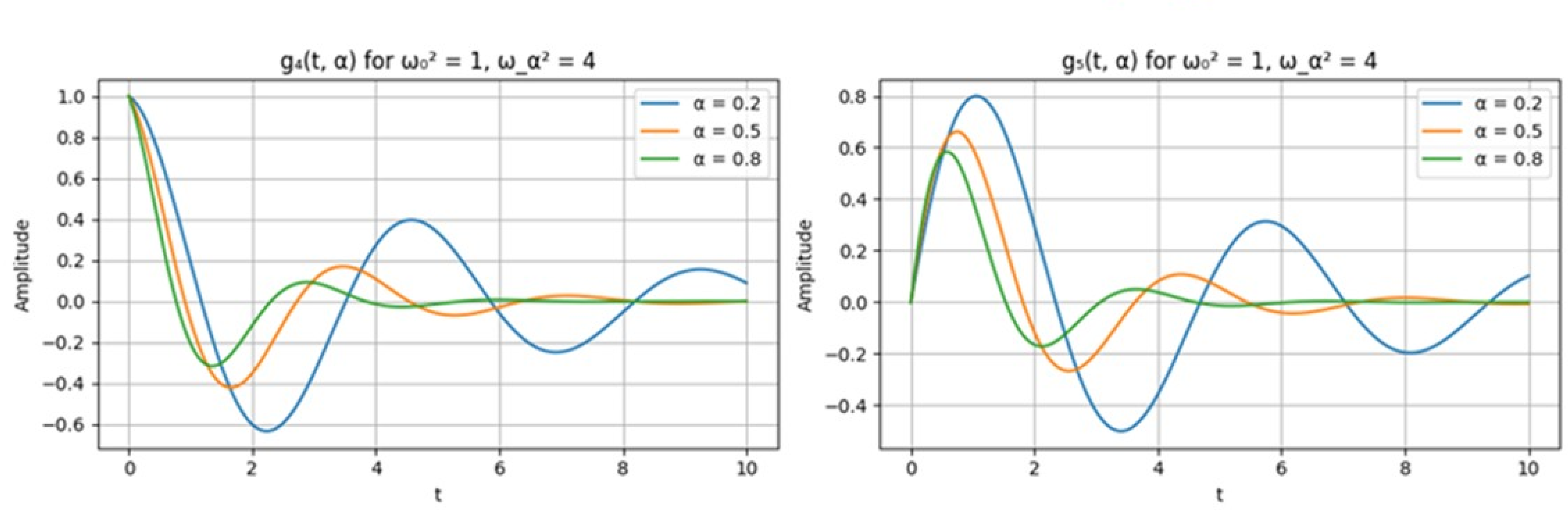
- Develop a general analytical model for vibrations of an M-plate system connected by hereditary viscoelastic interlayers.
- Derive closed-form expressions for natural frequencies, mode shapes, and time-dependent responses.
- Analyse how fractional order (α) and kinetic stiffness influence dynamic behaviour.

RESULTS & DISCUSSION



1. Multi-frequency vibration regimes
- Coupling through hereditary layers produces M distinct natural frequencies per mode family.
- Modal families remain temporally uncoupled, enabling precise identification of resonance conditions.

2. Effect of fractional parameter α
- Low α (≈ 0.2) → weak hereditary damping → sustained oscillations.
- High α (≈ 0.8) → strong memory effects → rapid amplitude decay.
- Fractional order acts as a tuneable damping control.



METHOD

Model

- System: M circular plates coupled by viscoelastic creep layers.
- Governing equations: partial integro-differential equations from hereditary viscoelasticity and D'Alembert's principle.
- Creep layers modelled via fractional derivatives $(0 < \alpha \leq 1)$.

Reduction

- Separation of variables using Bernoulli's method
- Reduction to ordinary integro-differential equations
- Solution via Laplace transforms
- Spectral properties obtained from determinant $\Delta nm(p) = 0$

Key Outputs

Explicit analytical expressions for:

- Natural frequencies
- Eigenfunctions
- Fractional time-response functions including hereditary damping
- Identification of multi-frequency regimes in M-plate systems.

CONCLUSION

- Developed a general analytical fractional-order model for hereditary vibrations in multilayer circular plate systems.
- Demonstrated multi-frequency regimes, temporal modal uncoupling, and tuneable damping via fractional order.
- Showed how fractional damping and coupling stiffness jointly influence oscillation amplitude, decay rate, and energy transfer.
- Framework provides a powerful tool for optimizing multilayer structures under long-term loading.

FUTURE WORK / REFERENCES

- Include non-ideal creep laws and anisotropic interlayers
- Extend to nonlinear oscillations and thermal effects
- Integrate with numerical FEM models for complex geometries
- Apply in design of vibration isolators, microdevices, sandwich structures

- Hedrih K.R., Fractal Fract. 9(3) (2025), 170. https://doi.org/10.3390/fractalfract9030170
- Simonović J., Dynamics of Mechanical Systems of Complex Structure, MSc Thesis (2008)
- Machado J., Kiryakova V., Mainardi F., Recent History of Fractional Calculus (2011) https://doi.org/10.1016/j.cnsns.2010.05.027
- Simonović J., Fractal Fract. 10(1), (2026) 72. https://doi.org/10.3390/fractalfract10010072