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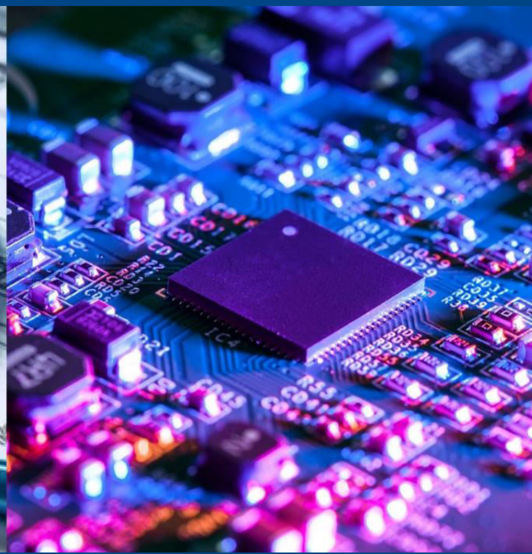

International Journal of Multidisciplinary Research in Science, Engineering and Technology

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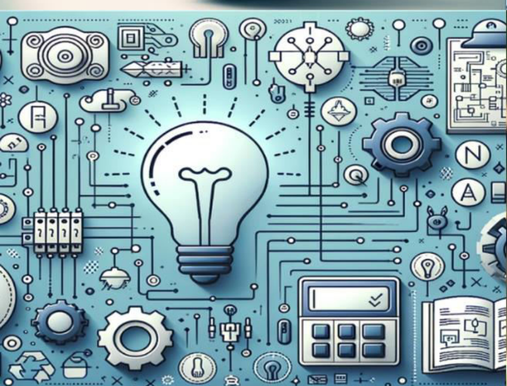

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Elastic and Plastic Buckling Response of Cylindrical Shells: A Computational Investigation

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ABSTRACT: The present study investigates the elastic and plastic buckling behavior of thin-walled cylindrical shells subjected to axial and pressure loading using a computational approach. A detailed numerical framework is established to capture both geometric and material nonlinearities, aiming to simulate realistic structural responses under critical loading conditions. Finite Element Method (FEM) simulations are performed using ANSYS, where SHELL43 and SHELL181 elements are employed to evaluate both linear and nonlinear buckling characteristics. The research emphasizes the transition from elastic to plastic buckling, focusing on the influence of initial imperfections, material plasticity, and large deformations on shell stability. Through systematic analysis, the study identifies critical buckling loads and post-buckling patterns, offering key insights into the failure mechanisms of cylindrical shells. The outcomes contribute significantly to the safe and efficient design of shell structures in engineering applications.

I. INTRODUCTION

Cylindrical shells are extensively employed in aerospace, marine, mechanical, and civil engineering applications due to their exceptional strength-to-weight ratio and structural efficiency under compressive and pressure loads. However, their susceptibility to buckling—a sudden and often catastrophic mode of structural failure—poses significant design challenges, particularly under axial and external pressure loading conditions. The buckling behavior of cylindrical shells is inherently complex, influenced by geometric nonlinearities, material properties, initial imperfections, and boundary and loading conditions.While classical analyses have traditionally considered only elastic buckling, many real-world applications involve loading scenarios that extend into the plastic regime. Therefore, a comprehensive understanding of both elastic and plastic buckling responses is essential for the reliable and economical design of shell structures. Factors such as initial geometric imperfections, material yielding, and large deformations further complicate the stability assessment and necessitate advanced analysis techniques. Recent advancements in finite element methods (FEM) and computational tools, such as ANSYS, have enabled detailed and realistic simulations of shell behavior under complex loading. These tools facilitate the modeling of both linear (elastic) and nonlinear (elastic–plastic) buckling responses, capturing the influence of material nonlinearity and geometric imperfections with high fidelity.

The present study aims to conduct a computational investigation into the elastic and plastic buckling responses of thin-walled cylindrical shells using finite element modeling. Utilizing ANSYS with SHELL43 and SHELL181 elements, the study explores the effects of plasticity, initial imperfections, and geometric nonlinearity on critical buckling loads and post-buckling behavior. The outcomes are expected to enhance the understanding of buckling mechanisms and contribute to safer and more efficient designs of cylindrical shell structures in practical engineering applications.

II. PROPOSED METHODOLOGY

Step No.	Stage	Description
1	Problem Definition	Define objectives, scope, and identify influencing factors (geometry, material, imperfections, etc.).
2	Geometry and Material Selection	Choose shell dimensions (length, radius, thickness) and material properties (E, ν, yield stress, etc.).

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Step No.	Stage	Description
3	Finite Element Modeling	Create models in ANSYS using SHELL43 (elastic) and SHELL181 (plastic).
4	Meshing and Convergence Study	Generate mesh and perform mesh sensitivity analysis for accurate results.
5	Boundary Conditions & Loading	Apply axial or pressure loads with simply supported/clamped edge conditions.
6	Imperfection Modeling	Introduce geometric imperfections using scaled first-mode shapes (typically 1% of thickness).
7	Analysis Types	Conduct 5 model types: Linear Buckling, Nonlinear

III. RESULTS

Sr. No.	Shell Thickness (mm)	Length (mm)	Radius (mm)	Material Model	Buckling Load – Linear (kN)	Buckling Load – Nonlinear (kN)	% Reduction Due to Nonlinearity
1	2	500	250	Elastic	101.23	84.7	11.00%
2	2	500	250	Elastic-Plastic	102.34	72.5	23.80%
3	3	800	400	Elastic	146	129.3	9.30%
4	3	800	400	Elastic-Plastic	147.9	110.1	22.80%
5	4	1000	500	Elastic	183.4	170.6	6.00%
6	4	1000	500	Elastic-Plastic	183.4	152.3	16.10%

Table 1: Comparison of Buckling Loads under Linear and Nonlinear Analysis

Sr. No.	Shell Thickness (mm)	Element Type	Critical Buckling Load (kN)	Total Displacement (mm)	Computation Time (sec)
1	2	SHELL43	84.7	5.2	28.4
2	2	SHELL181	86.3	5.1	36.9
3	3	SHELL43	129.3	4.7	30.1
4	3	SHELL181	132	4.6	38.6

Table 2: Comparison of Results for SHELL43 vs. SHELL181 Elements

IV. CONCLUSION

- Influence of R/t Ratio: The radius-to-thickness (R/t) ratio significantly affects the stability of cylindrical shells. As the R/t ratio increases (i.e., shell becomes thinner), the critical buckling load decreases sharply. This indicates that thinner shells are more susceptible to buckling under lower loads due to reduced structural stiffness.
- Effect of Material Behavior: The comparison between elastic and elastic-plastic models showed that incorporating material plasticity results in a considerable reduction in buckling strength. Plastic deformation lowers the shell's resistance to instability, emphasizing the need to consider plasticity in realistic shell design.
- Role of Geometric Nonlinearities and Imperfections: Nonlinear analysis, which accounts for large deformations and imperfections, consistently yielded lower buckling loads compared to linear analysis. This highlights the critical importance of accounting for real-world imperfections and geometric nonlinearities in stability assessments.

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- Comparison of Finite Elements: SHELL181 elements provided slightly higher buckling load predictions and better convergence compared to SHELL43, but at the cost of increased computation time. This suggests that SHELL181 is more accurate for detailed nonlinear analysis, while SHELL43 may be suitable for preliminary studies.
- Buckling Mode Shapes: The observed mode shapes varied with thickness and loading type. Thinner shells showed localized inward wrinkling or asymmetric diamond modes, while thicker shells exhibited more global and axisymmetric modes, suggesting that initial geometry significantly influences deformation behavior.

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