National Aeronautics and Space Administration

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Buckling Knockdown Factors for Composite Cylinders

The buckling performance of thin-walled cylindrical shells is well known to be sensitive to small geometric and loading imperfections. During design, this sensitivity is typically accounted for by multiplying the predicted buckling load of a geometrically perfect structure by an empirical design factor known as a buckling knockdown factor (KDF). The most widely used source of KDFs for cylindrical launch-vehicle structures is NASA SP-8007. However, general composite shells are outside the original scope of SP-8007, and a universal KDF of 0.65 for all composite shell designs has been used in several recent NASA studies, though the technical justification is unclear. If the NASA SP-8007 is used to calculate KDFs for composite cylinders, the original assumptions and limitations should be understood and care must be taken. Additionally, the universal KDF of 0.65 is thought to be *unconservative for certain designs and is therefore not recommended.*

Background

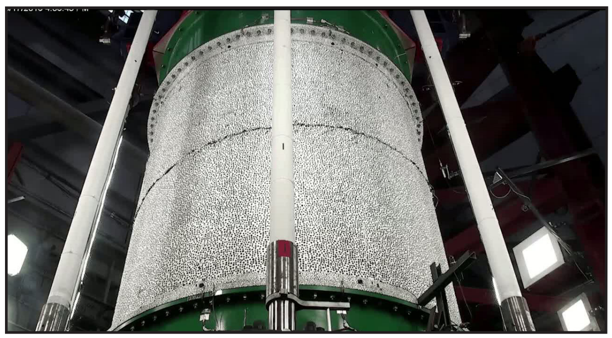
Thin-walled composite shell structures have been used in launch vehicles for many years. Additionally, NASA is increasingly considering composite structures for use in launch vehicles. For many such launch-vehicle shell structures, composite structures are chosen for structural efficiency and reasonable manufacturing considerations. However, it is well known that thin-walled shell structures can be very imperfection sensitive when subjected to destabilizing loads. That is, small geometric or loading imperfections can cause the actual buckling loads of the as-built shells to be significantly lower than the theoretical predictions, which are based on simplified linear bifurcation buckling analyses of geometrically perfect shells. Therefore, it is important to understand the structural response and imperfection sensitivity of such shell structures.

To account for the imperfection sensitivity during design of a thin-walled shell, the theoretical buckling load of the perfect structure is typically multiplied by a buckling KDF to determine a safe design load level. Hence, the guidelines for determining these KDFs can be very important for the design of structurally efficient shells. The most widely used source for KDFs for cylindrical shells is the NASA SP-8007 [1], which has recommendations that were developed based on experimental buckling tests from the 1930s-1960s. However, SP-8007 has not been updated since the late 1960s and few, if any, composite shells were tested in the development. Consequently, the SP-8007 guidelines may not be applicable to shells constructed from modern materials, improved manufacturing processes, and new structural concepts. Several recent NASA studies have used 0.65 as a universal buckling KDF for cylindrical composite shells regardless of the structural concept (sandwich, stiffened shell, etc.) and the design details (thicknesses, stiffener dimensions, layup, etc.).

The NASA Engineering and Safety Center (NESC) is currently assessing the NASA SP-8007 guidelines with the intent of revising these guidelines for selected metallic and composite cylindrical structures. The purpose of this Technical Bulletin is to provide guidance on the KDFs that should be used for composite structures until the new guidelines are developed and published.

Findings and Conclusions

It is unclear from where the universal 0.65 KDF for composite shell structures came, or if it is always conservative. In particular, when applied to anisotropic composite sandwich shells, the SP-8007-recommended KDFs for orthotropic cylinders and isotropic sandwich cylinders can be significantly lower than 0.65. Nonlinear finite-element analysis to date however suggests that these SP-8007 KDFs are conservative for all the sandwich composite cylinders considered. Because the SP-8007 KDFs for many composite shells are less than 0.65, 0.65 should not be used as a universal KDF for composite cylinders unless there is other appropriate rationale.



Sandwich composite test article showing material failure that occurred as a result of global buckling.

If SP-8007 is used to calculate KDFs for composite cylinders, the original assumptions and limitations must be understood and caution should be used if the recommendations are extended outside their original scope. Particular caution should be used when applying SP-8007 recommendations to composite cylinders that do not consist of orthotropic layers aligned with the axial and circumferential directions of the cylinder (cross-ply laminates), those with extreme stiffness tailoring, or those with significant contributions from the extension-shear, extension-bend, or bend-twist terms. Additional consideration must be made for cylindrical shells with low transverse shear stiffness (such as some sandwich shells) because they can have significantly lower predicted buckling loads than similar shells with high transverse shear stiffness. More detailed recommendations will be made by the NESC when the new guidelines are published.

References

1. Anonymous, "Buckling of Thin-Walled Circular Cylinders," NASA SP-8007, 1965, revised 1968.

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