INFLUENCE OF WALL CONSTRUCTION ON THE LOAD-CARRYING BEHAVIOR OF LIGHTWEIGHT STRUCTURES

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From the point-of-view of safety, long-term reliability, and economy, it is advisable to employ structures which are both weight-efficient and insensitive to disturbances. However, a major conclusion to be drawn from the extensive work on the buckling and postbuckling behavior of thin-walled structures over the past decades appears to be that optimization invariably leads to an increased sensitivity of the load-carrying capacity to initial deviations from the ideal geometry. Indeed, this imperfection-sensitivity tends to be most severe for weight-optimized shell structures with particularly high strength-to-weight ratios, so that specimens of such shells normally fail at loads which are merely a fraction of their theoretical buckling values.

So far the only way of dealing constructively with this "unhappy coexistence of efficient shell design and the curse of imperfection-sensitivity" (B. Budiansky) seems to be to reduce the imperfection levels by improving the quality of the manufacturing process, and to prevent the occurrence of additional disturbances throughout the structure's entire service life (which obviously requires a suitably controlled operating environment).

On the other hand, the results of extensive numerical studies recently performed at Dortmund as well as a limited number of experimental results suggest that the load-carrying capacity of certain structural configurations may indeed be improved significantly without a corresponding increase – or even with a decrease – in imperfection-sensitivity, so that comparatively large increases in the practical design loads may be achieved without sacrificing the desired weight-efficiency. In this context, the presentation will focus on the buckling behavior of certain prototypical shells of revolution – e.g. cylindrical shells and spherical caps – which are coated with a comparatively thin layer of a highly compliant material.

An interesting alternative way of achieving marked improvements in the strength-to-weight ratio of lightweight structures is to employ nonsmooth wall constructions and/or to tailor their behavior such that it becomes auxetic. Materials of this kind are characterized by negative values of Poisson's ratio, and the results of systematic analyses indicate that auxeticity may have a remarkably positive effect on the overall load-carrying behavior of thin-walled structures. In particular, for certain configuraations significant gains in weight-efficiency may be achieved by macroscopically auxetic structures consisting of conventional nonauxetic materials. In this context, results for the load-carrying behavior of nonsmooth flat and hollow structures with and without macroscopic auxetic properties will be presented which generally show a significant improvement in load-carrying capacity with only a moderate – or almost no – increase in total weight.

References

H. Obrecht, B. Rosenthal, P. Fuchs, S. Lange, C. Marusczyk, "Buckling, postbuckling and imperfection-sensitivity: Old questions and some new answers", Comput. Mech., 2005 (in press), and the references given there.

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