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Wrinkles in Square Membranes

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This paper considers a thin, uniform, elastic, isotropic square membrane loaded at the corners by two pairs of equal and opposite forces (a simple model for a solar sail). Two wrinkling regimes are identified. The first regime occurs for symmetric and moderately asymmetric loading; it is characterised by small, radial corner wrinkles. The second regime occurs for strongly asymmetric loading and is characterised by a single, large diagonal wrinkle, plus small radial corner wrinkles. A simple analytical method for predicting wrinkle wavelengths and out-of-plane wrinkle displacements, and also in-plane corner displacements of the membrane, is presented. The analytical predictions are validated against experimental measurements and detailed finite element simulation results. The accuracy achieved by the analytical model is typically better than 20% on wavelengths and 40% on amplitudes. On the other hand, finite element simulation using thin shell elements is shown to be able to replicate physical experimentation with an accuracy better than 10%.

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