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CMUT membrane model based on theory of stratified plates

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To optimize and characterize capacitive micromachined transducers, static and dynamic mechanical behavior of the membrane have to be considered and modeled.
Most of cMUT models are based on the classical plate equation. The flexural rigidity is homogenized for multi-layer structure taking into account properties of each material. Homogenization relations are available provided the flexural plate equation can be separated from the in-plane deformation equation, so-called the membrane-like behavior equation. Practically, for membrane partially covered with electrode, at the metallized/non-metallized discontinuity, these equations cannot be solved separately and homogenization procedure is no more available. Moreover, initial membrane deflection introduces supplementary coupling between in-plane and flexural displacements requiring modification of homogenization relations.
A complete analytical formulation of the plate equation is developed in this paper. A finite difference meshing has been used to numerically solve the new set of plate equations. First, a cMUT with simple geometry is modeled for validation and comparison with Finite Element simulation (COMSOL Multiphysics software). Then, the validity domain of the "simple" flexural plate equation is discussed. Finally, an example of membrane optimization is given, where a multi-layer structure is proposed to reduce influence of static pre-stresses in the membrane on collapse voltage and resonance frequency.