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Two-scale computational homogenization of transversely loaded sheets

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Introduction
Philips has identified display manufacturing as one of its strategic technologies for the future. Accordingly, there is a strong interest in the research and development of novel displays, including variants of flexible displays. It is important for them to have a procedure for designing fail-safe flexible displays, which can be considered as structured multi-layer shells.

Objective
The objective of this project is to numerically predict the behavior of mechanically loaded thin shell-type structures. For this purpose, a multi-level approach will be pursued via computational homogenization.

Results
The deformation of a shell with a periodic substructure is studied using both a full-scale model and the proposed multi-level approach. The shell is clamped at the two ends and in the center a vertical load is applied. The material behavior is modeled as elastoplastic with hardening. The results from the full-scale and the multi-scale analysis are shown in figures 2 and 3 (only the left-hand side is shown). The contour plots present the plastic strain.

Discussion
For periodic shell structure the multi-level approach offers a feasible procedure in case a full-scale analysis would be impossible because of excessive calculation time.

Method
Homogenization scheme
A computational homogenization scheme with shell elements at the macro-level and plane-strain elements at the micro-level is used, figure 1. The macroscopic central layer strain $\epsilon$ and the curvature $\kappa$ are used to define the boundary value problem on a representative volume element (RVE). The generalized stress-strain tangent matrix $D$ is obtained from an RVE analysis at each macroscopic integration point according to:

$$ D = \frac{W}{h} L^T K^* L, \quad L = \exp(\epsilon) \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & \kappa & 1 \end{bmatrix} $$

with $W$ is the RVE width and $h$ the RVE out-of-plane dimension. The reduced stiffness matrix $K^*$ is obtained via condensation of the RVE stiffness.