4D self-shaping mechanisms for achieving double-curved wooden structures

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The hygroscopic nature of wood results in anisotropic dimensional changes in function of ambient climate. Employing smart structural design, we explore how this inherent capacity of wood can be used beneficially for generating large deformations and self-shaping mechanisms. A commonly known set-up for generating structures with single curvature is the bilayer composite lay-up where temperature or moisture responsive materials bend or twist upon changes in ambient climate. The self-shaping of wooden bilayers was previously characterized [1,2] and is suitable for large scale building applications [3]. The next milestone towards complex-shaped timber structures by self-shaping is the generation of double curvature from an initial flat configuration. Change in Gaussian curvature, i.e. the product of two principal curvatures along the two axes of 2D surfaces in 3D space, however, is mathematically impossible. Physically, however, this is possible by using a volume changing material such as wood and by designing adequate structures.

Here, we present different self-shaping mechanisms, which involve a 4D manufacturing approach, to generate double-curved wooden structures starting from an initial flat shape. For each mechanism, the optimal design of the structure is found by parametric studies on numerical models using the Finite Element Method. The material wood is hereby represented by a complex rheological constitutive material model featuring specific deformation mechanisms such as elasto-plasticity, visco-elsaticity, mechano-sorption, and hygro-expansion [4]. The different structure-specific self-shaping mechanisms include the arrangement of bilayer strips to a grid-shell configuration (Fig. 1A), a controlled buckling by anisotropic growth (Fig. 1B), and a structure composed of densified wooden wedges that display set-recovery when wetted (Fig. 1C).

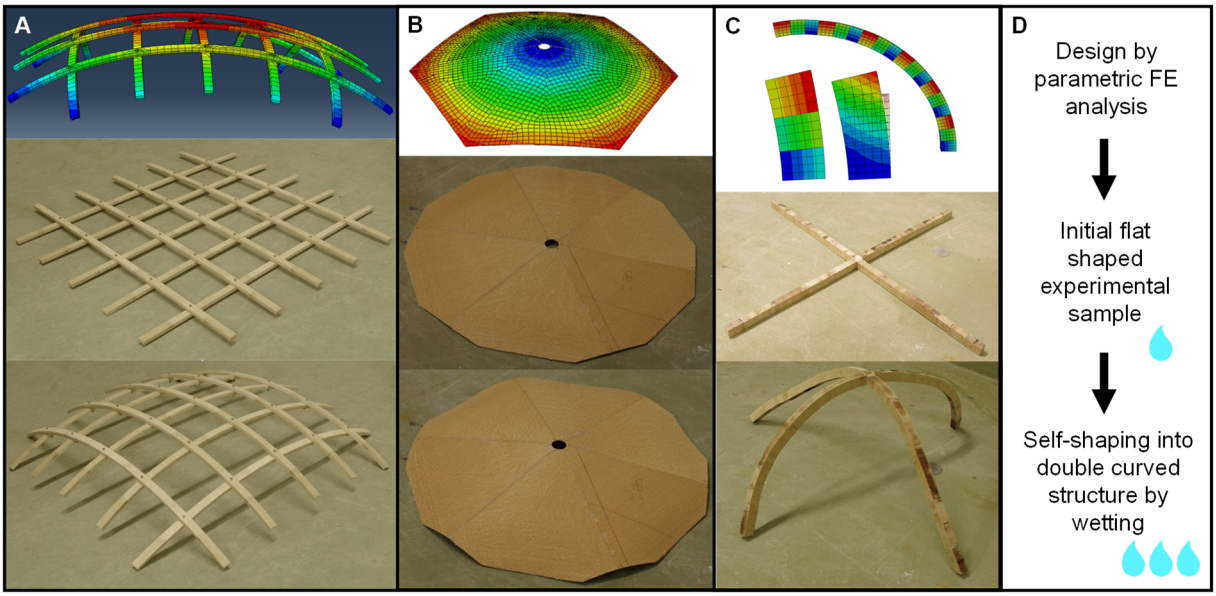

Figure 1: Self-shaping mechanisms for double-curved structures. (A) Bilayer grid-shell. (B) Anisotropic growth buckling. (C) Set-recovery of densified wood wedges. (D) 4D approach.

References

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