Optimum structure of micropolar solids under momentum load conditions

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Abstract

In classical elasticity, deformation modes of an infinitesimally small element are represented as stretching and shearing. Furthermore, bending properties of solids are determined by tensile (compressive) properties such as Young's modulus. Since the region near the neutral surface of a bended beam does not contribute to the structural rigidity, the optimum structures of classical elastic solids should be truss frames.

In micropolar elasticity, the additional deformation mode of bending is introduced, and that of the macro-element is expressed by the micro-rotation in the macro-element. Therefore bending and tensile properties of micropolar materials are independent of each other. The theory of micropolar elasticity has been applied to materials with substructure such as bio-materials, concrete, liquid crystals with rigid molecules and so on.

Optimum topologies of isotropic micropolar solids in two-dimension were analyzed in this paper. In the process of mechanical analysis, the weighted residual method and 8-node isoparameteric elements were employed for the finite element analysis. We analyzed problems minimizing the mean compliance of the structure, employing the solid isotropic material with penalization (SIMP) method and the gravity control function for filtering of checkerboard structures.

We survey the optimum structure under momentum loads as mechanical boundary conditions, which can be applied in two ways; one is couple of forces (CF) and the other is the momentum load at a loading point (ML). Though these two conditions of loading are macroscopically equivalent, local stress conditions around loading points are different.

The bending problems of a cantilever loaded on ML-conditions at a free end are simulated as an example. In the case of classical solids, the optimal structure is a two-forked frame whose branches consist of tension and compression members. Varying material constants in such a way as to increase bending rigidity, the optimum structure changes as the following progression: two-forked branches at the fixed side become shorter first, then a three-forked structure appears, and finally the structure becomes a single simple beam. That is, the bended area in the structure increases with the bending rigidity.

In the case of CF-conditions, the wide joint area of the two-forked frame appears around loading points and the structure is rather stable to the change of bending rigidity. At the wide area around load points, forces produce a macroscopic resultant momentum. Therefore the whole optimum structure is insensitive to local conditions around loading points. In high bending rigidity, a single beam structure finally appears on the fixed end.

Though mechanical boundary condition of momentum loads are macroscopically equivalent, the difference of the local distribution of strain energy density around loading points strongly influences the whole optimum structure of micropolar materials.

Keywords: Micropolar elasticity, Optimization, Continuum, Finite Element Method