BIO-INSPIRED OPTIMIZATION OF POST-YIELD BEHAVIOR IN LOW-DENSITY MATERIALS

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Low-density filler materials used in sandwich panels and foam core structures are important for efficient support of mechanical loads. These materials contribute to attractive strength and stiffness to weight ratios and are stable when loaded elastically, but even localized post-yield loading can cause significant loss in overall component strength. Many biological systems, and skeletal structures in particular, contain low-density filler materials that suggest mechanisms for improving toughness through evolutionary selection of material microarchitectures. Although adaptation of continuum models of bone tissue in response to elastic loading has been studied [1], the response of discrete models to post-yield loading has not. We have initiated research into evolutionary algorithms applied to beam-truss models of trabecular bone in order to discover material microarchitectures optimized for resistance to post-yield loads.

The models consist of beam finite elements connected initially at uniformly spaced nodal points, forming a two-dimensional truss [2,3]. Nodal positions were randomly varied, producing a number of offspring models. Total plastic strain was chosen as the objective function for model fitness evaluation. A load or displacement was specified in some region of the models, and their post-yield responses were evaluated. The model exhibiting the most favorable response (lowest total plastic strain) was retained, and became the parent of the next generation of variants. Nodal positions were again randomly varied, producing another set of offspring, which were evaluated in the same way. Iteration proceeded until nodal positions stabilized. A small UNIX cluster was used for the calculations, with offspring models running simultaneously on separate processors. And additional processor was used to distribute models and accumulate results.

Some interesting patterns emerged in the structure as the algorithm iterated. The first case that was studied was an applied constant displacement across the top of the frame. In response to this loading, the truss developed a large shear line from top left to bottom right. The majority of the displacement in the frame was transferred into this region, where long beam elements had developed and oriented horizontally. These long beam elements were capable of handling large amounts of bending without yielding. A second loading scheme applied displacement varying linearly from zero to a maximum. In response to this load, the frame developed another region which acted much like the shear line in the uniform displacement case, except this region was localized below the surface and directly under the largest deflection point. While the algorithm produced interesting results, constraints on overall mass and nodal positions need to be added for better comparison among models and more manufacturable patterns.

References

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Keywords: bioinspired, microarchitecture, evolutionary algorithms