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Free-form Additive Manufacturing Lab

Abstract

Traditional structural design is a staple of mechanical engineering curricula and typically covered in undergraduate courses of statics and strengths of materials. But new additive manufacturing capabilities allow engineers to design structures free of prismatic constraints. Using 'freeform' design creates a better device.

A traditional senior-year machine design lab was modified to include a transition from prismatic to freeform design through the creation of a simple lever. The lab consists of five parts. First students are presented with an engineering problem of designing a 3-point center-pivot lever using dimension, load and weight parameters (Part I). The lever is designed to address a 'success criteria' equation that includes the aforementioned parameters while abiding the anisotropic material/structure properties of our AM (ABS) material. Next, groups are formed to design an efficient Part I lever (according to the success formula) and be manufactured using AM (Part II). Part II requires the lever to be non-prismatic. In Part III, groups redesign their parts to optimize performance to the success criteria, as well as predicting failure location and mode. Part IV and V occur in our structural modeling course, where students are required to modify existing lever designs. In Part IV, light-weighting is applied through secondary analyses to remove material (e.g. lightening holes). In Part V, free-form shape optimization is implemented. Students are required to apply arcs on both lever segments. Note that freeform design methodology is relatively undefined (i.e. is not covered in traditional mechanics of materials texts) and demanded new curricula be developed.

A metric was developed to assess the success of this outcome. The metric includes progressive assessments of the design process throughout the parts. Results show that students only design with traditional prismatic shapes in Part I. Only half the students combine non-prismatic and efficient cross-sections in Part II. There are minor improvements in Part III regarding success. Continual improvement in success is made in Part IV and V.

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