Closure to "Discussion of 'A Review of Thickness-Accommodation Techniques in Origami-Inspired Engineering'" (Lang, R. J., Tolman, K. A., Crampton, E. B., Magleby, S. P., and Howell, L. L., 2018, ASME Appl. Mech. Rev., 70(1), p. 010805)

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The authors would like to thank Dr. McAdams for his summary, discussion, and analysis of our paper.

Dr. McAdams highlights in his preliminary discussion the differences between the simplest mathematical models of origami, which are often sufficient to describe paper origami designs, and the more sophisticated design tools required to take into account the properties of materials that arise in the technological applications of origami and origami-inspired design. His discussion provides the opportunity to add a few comments on two important, but distinctly different qualities of an origami design: the quality of *flat-foldability* [1,2], and that of *rigid foldability* [3].

An origami design is *flat-foldable* if it may, in principle, be flattened into a planar form without distortion or addition of creases—even if the actual useful form is never fully flattened. Flat-foldability origami must satisfy some well-known laws, including those enumerated in the Discussion.

An origami design is *rigidly foldable* if it can flex with no distortion or bending of its facets (panels). A given design may be flat-foldable, or rigidly foldable, or both, or neither. Folds made from stiff panels must often be rigidly foldable due to the rigidity of the panel material, but they need not be flat-foldable—though imposing flat-foldability is one possible strategy for achieving rigid foldability [4].

It is worth noting that flat-foldability is not necessary for the construction of origami-inspired thick-folding mechanisms. For that matter, neither is *developability*—the requirement that the form can be unfolded to a flat sheet. There are useful thick-origami forms that are not flat-foldable, such as the corrugations used in cellular-core panels [5,6], and useful nondevelopable folded patterns, such as the so-called "eggbox" pattern [7,8] or discrete Voss surface [9], which, though not developable, is both rigidly foldable *and* flat-foldable.

Whether or not a design is flat-foldable, often, when fabricated from real-world materials, the thickness is non-negligible and must be accounted for explicitly in the kinematic design, and this aspect was the focus of our review.

We appreciated the reviewer's allusion to joint design as sharing properties of a "Wicked Problem"—a term initially unfamiliar to us, but one with a robust following in the design literature. For those readers who (like us) were unfamiliar with the term, a "Wicked Problem," as originally defined by Rittel and Webber [10] and reiterated by Buchanan [11], contains some combination of ten properties (paraphrased here):

(1) No definitive formulation.
(2) No stopping rules.
(3) Solutions are not true or false, only good and bad.
(4) There is no exhaustive list of admissible operations.
(5) There are multiple explanations for the problem.
(6) The specific problem is a symptom of a higher-level problem.
(7) There is no definitive test for formulation and solution.
(8) Solving is a "one-shot" solution, disallowing trial-and-error development.
(9) Each "wicked problem" is unique.
(10) The problem solver is fully responsible for their actions.

A key characteristic of a "wicked problem" that comes out of these properties is this: the act of solving one problem in isolation creates (or highlights) other problems. As McAdams notes, the solution of a kinematic problem at one level of the hierarchy via rolling contacts introduces another at a different level: the need to construct a detailed rolling-contact mechanism. This multilevel dependency is, to some degree, common to all origami-inspired design, including that of thick origami. Addressing the kinematic aspects includes assumptions on the lower-level form of the joints: revolute pin joint, membrane, rolling-contact, or other. Those other levels may not be particularly problematic. The origami-inspired designer can bring a toolkit of techniques to the various levels of design problem, including joint types, materials selections, and the external design constraints that come from desired engineering performance, budgetary considerations, and other economic factors. It is the hallmark of a good designer that they are able to look up and down the design hierarchy and identify those interactions that extend across multiple levels and inject an element of "wickedness" into the design problem. The problem of thickness in origami-inspired design most definitely extends tendrils both up (to the system level) and down (into mechanism and materials) in this hierarchy. It is the authors' hope that our review can provide a useful toolkit and explicit identification of those connections.

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