

Energy Absorption Performance Study on Auxetic Metamaterial Based on Miura Origami

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Abstract

The energy absorption material is widely used in many applications and also investigated deeply in mechanical and material fields. Auxetic metamaterial is one popular kind to used designing the absorption device for its light weight and unusual properties, especially the negative Poisson's ratio. Different from other usual structure, the material with negative Poisson's ratio can behave greatly deformation under load which means it can probably reserve higher elastic energy.

Recently, many origami patterns are used in engineering for their deployable performance. Through properly designing, the structure with origami patterns shows negative Poisson's ratio. It is obviously to use these kinds of structure in energy absorption. Such like Miura pattern, as shown in Figure 1, it can be folded or deployed rigidly in one direction of the plane and meanwhile in the other direction the unit will shrink or extend.

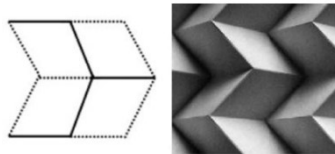


Figure 1 Classic Miura Pattern^[1]

Most of the previous research concentrated on the absorption effect of the auxetic metamaterial of different origami pattern. By experimental tests or FE analysis, researchers can obtain the relationship between mechanical behaviors such like negative Poisson's ration and geometry features of the origami patterns. There is less theoretical analysis about the energy absorption behaviors of the specific auxetic metamaterial structures.

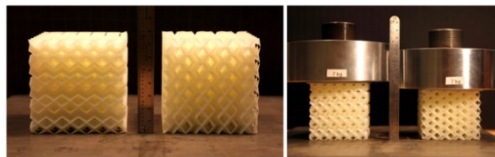
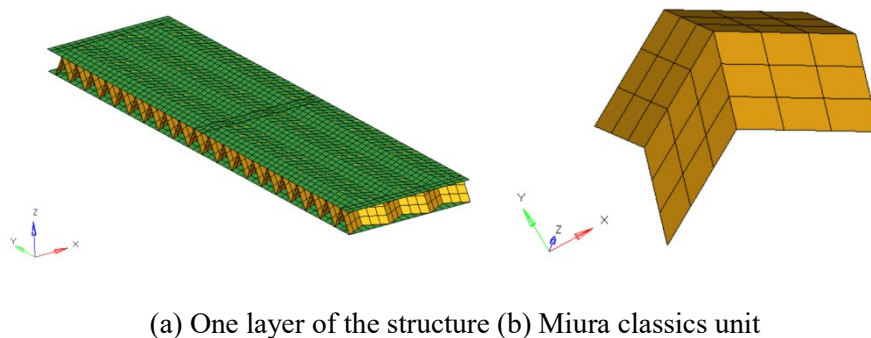


Figure 2 Auxetic metamaterial structure based on miura patterns^[2]

This paper focuses on the auxetic metamaterial structure assembled by miura

pattern units as shown in Figure 2. At first, the mechanical behavior of the structure based on classic miura pattern is studied under static pressure load and dynamic pressure load. The specific force distributed path has been investigated. The base buckling-induced mechanism in two different load cases is analyzed. Second, based on the analytical results, a parameter α used to express the efficiency of force distribution is proposed. This parameter is associated with the unit geometry parameters, number of the layers and material properties of the auxetic metamaterial structure. Also, α is connected with the specific pressure load and the buckling path of miura patterns under the pressure.

Then, by changing the geometry parameters of the miura patterns, several cellular structures are obtained. Each α is calculated. The corresponding FE models are made by ABAQUS with the same external dimensions. Two load cases are applied and analyzed. Comparing the load-displacement curves which are used to express the energy absorption performance of each model, it can be seen that the energy absorption behavior is connected closely with α . When the structure can reserve higher energy, α is relevant higher. This result illustrates that α can be used to evaluate the energy absorption behavior of the auxetic metamaterial structure made by miura patterns. One layer FE model is shown in Figure 3.



(a) One layer of the structure (b) Miura classic unit

Figure 3 FE model

This paper concluded by proposing the new α method for designing auxetic metamaterial structure based on miura pattern for absorbing energy. Furthermore, the structure based on other novel miura patterns are also investigated, and the general calculation method of α is given.

Reference

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