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Abstract

An auxetic tow or fiber bundle that will expand in diameter when extended axially would be very useful. It could be woven into a shape-changing cloth, perhaps used for ballistic protection, or as an easily cleaned filter. To explore this concept, spiral fiber bundle structures under tension were explored. Theory describing the geometry of spiral structures was developed. Several types of finite element models for these spiral structures using laminated plate elements, beam elements and solid elements with contact were then developed and compared at a range of angles. The beam and solid element models provide the best approximation and indicate that a 30°/45° fiber structure is a good angle combination to not only provide significant radial expansion but also show a relatively low stress. Several polymeric specimens were 3D-printed and tested under tension. Testing confirmed that the spiral fiber systems exhibited auxetic behavior. The polymeric specimens exhibited more radial expansion than the finite element predictions. Thus, spiral fiber bundles show promise and will be explored further.

Keywords: auxetic structures, finite element analysis

1. Introduction

Auxetic materials are materials which have a negative Poissons ratio. Because of this extraordinary characteristic, negative Poissons ratio or auxetic composites can provide tailored or enhanced properties, such as stress stiffening, increased vibration damping, better indentation resistance and higher fracture toughness [1]. Thus, auxetic materials can have a wide scope of possible applications, such as tunable filters, blast protection cloth, aeroengine fan blades, arterial prostheses and annuloplasty prosthesis [2–6].

Many auxetic structures have been developed to date. Typical types include re-entrant cellular structures, chiral structures, rotating units and unbalanced

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