AUXETIC BEHAVIOR OF FIBER NETWORKS: PAPER AND NONWOVEN FABRICS

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Auxetic materials/structures have been subjects of scientific curiosity due to their counterintuitive response to deformation; specifically, they exhibit a negative Poisson's ratio. While some natural materials are auxetic, scientists and engineers have sought to produce this property in synthetic materials/structures with a goal of improving properties such as damping and producing composites with mechanically interlocking interfaces. The objective of this research was to more fully understand the out-of-plane auxetic response of engineered fiber structures, specifically paper [1] and nonwoven fabrics [2, 3].

Several paper samples and handsheets were tested to quantify their auxetic response and understand how processing and structure affected their auxeticity. The results showed that paper structures possessed a wide distribution of Poisson's ratio values, both positive and negative. The difference in the values of Poisson's ratio suggested a strong correlation with the fiber-network structure and the processing conditions employed during papermaking.

The nonwoven fabrics studied were needle-punched nonwoven fabrics. These fabrics contained pillars of entangled fibers that were oriented roughly parallel to the thickness direction, and they were not auxetic in their as-produced state. To produce an auxetic response, a post-processing heat compression step was explored to orient more of the fibers in the plane and produce additional fiber junction points. Large, negative values for Poisson's ratio were observed for the fabrics after heat compression. Of the available processing parameters, temperature was found to affect the auxetic response most strongly, by increasing the compression set of the fabric and, as a result, the auxetic response.

Overall, these results showed some commonality between the two systems studied in that fiber network structure and fiber junctions worked together to produce an out-of-plane auxetic response. Additionally, these structural attributes may provide general design guidelines for producing these auxetic fiber structures from other materials, leading to their use in composites.

References

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