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# Enhancing Torsional Stiffness of Continuum Robots Using 3-D Topology Optimized Flexure Joints

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**Abstract- Flexure-joint-based continuum robots are used in a variety of engineering applications, such as minimally invasive surgery and space exploration. However, some highly flexible joints, such as the leaf-spring joint, have a low torsional stiffness, which greatly limits the payload capacity of the constructed continuum robots in their curved configuration. On the other hand, some high-torsional-stiffness joints, such as the cartwheel joint, also suffer from the issue of stress concentration. To cope with these problems, we propose a 3-D-topology-optimization-based method in this article to achieve multi-axis design of flexure joints. Using a multi-objective algorithm, the torsional stiffness and rotational flexibility of different axes of the joint structure are taken into account in the optimization process. In addition, artificial spring elements are introduced in the design problem to realize a balanced stress distribution. To evaluate the feasibility of the proposed method, experiments are also performed to test the bending performance and torsional stiffness of the constructed continuum robot. Results have demonstrated that, the continuum robot equipped with the optimized flexure joints can successfully achieve high torsional stiffness while maintaining its bending flexibility.**