AI-Driven Soft Artificial Muscle for Cardiac Assist Using Hydraulically Amplified Self-Healing Electrostatic Actuators

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Heart failure (HF) is a leading cause of death globally, impacting 60 million people worldwide and leading to 17.9 million deaths. Traditional ventricular assist devices (VADs), a common solution, face challenges such as high rehospitalization rates and complications, including blood clots or internal bleeding, due to their rigid designs. This work presents an AI-driven ventricular assist artificial muscle using hydraulically amplified self-healing electrostatic (HASEL) actuators to address heart failure. I use HASEL actuators, characterized by soft, biocompatible materials and self-healing abilities after dielectric breakdown, to enhance both reliability and performance. These VADs are fabricated using multi-material 3D printing of EcoFlex 00-30 and silicone-based carbon black electrodes to ensure precise and reproducible geometries. With a fast actuation frequency of 2 Hz and no blood contact, the device achieves a strain of 32.9% and a maximum energy output of 5.49 N*mm. The system also employs machine learning (ML) for force prediction and control to address the non-linearities of HASELs. Finite element modeling (FEM) is used to optimize actuator control and behavior as well as collect training data. The ML model achieves a correlation of 91%, demonstrating a high correlation between input and output forces. A flexible pressure sensor is integrated into the actuator for real-time force output monitoring. The actuator is tested on a phantom organ to demonstrate the device's efficacy on a heart model. By combining advanced HASEL actuator design and AI, the system offers a promising new solution to enhance the quality of life for HF patients by addressing the limitations of current VAD technologies.

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