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ELECTROMYOGRAPHY-DRIVEN EXTRAMUSCULAR-ASSISTED SPACESUIT GLOVE OPTIMIZATION AND INTEGRATION

Abstract

Human space missions, including transit time spent in microgravity as well as planetary surface operations, are inherently high-risk endeavors, and the extravehicular activity (EVA) component of such missions is no exception. In order to mitigate risk and maximize productivity on EVA, proper spacesuit technologies are necessary, with the goal of reducing physical and physiologic demands while facilitating successful task completion. In particular, optimizing the spacesuit glove and associated hardware for fine motor control to enable a broad array of manual tasks, such as picking up rock samples and driving lunar vehicles, is key to ensuring mission success. This research focuses on proposed modifications to spacesuit glove design, optimized specifically for enhanced injury mitigation and fatigue prevention for extravehicular operations. The design tested and improved upon here focuses on two novel aspects of critical importance: a fingernail injury mitigation system, and a flexure assist mechanism for hand and forearm muscle fatigue prevention. Our prior work demonstrated the viability of a next-generation spacesuit glove design with the ability to mitigate nail delamination by implementing a lightweight fingertip cap and phalangeal frame. In parallel, we also demonstrated the effectiveness of our system in reducing forearm fatigue while preserving agility and dexterity, using actuated artificial tendons that serve to reduce grip loading. Our earlier work revealed a need for improvement in the integration of the artificial tendon actuation mechanism with biological muscle contraction signals from the operator. This work addresses that need by implementing electromyographic (EMG) sensors and feedback control systems found in prosthetic hand devices. Utilizing these EMG sensors and innovative electromechanical drive systems, we refined and tested a smooth fatigue mitigation system. This adapted glove design follows the human hand flexor pulley design and incorporates a set of phalangeal caps and frames actuated by an electromechanical mechanism through a series of tendons guided along the palmar surface of the hand. The data presented shows our progress, highlighting a redesigned and refined prototype with streamlined integration between the glove, fingertip caps, sleeve, and actuators. Building on our previous human subject testing, we have expanded our test group size, with a broader array of anthropometric variations and skin types among subjects. We have also introduced a vast spectrum of tests, including dexterity and fatigue mitigation testing as well as evaluation of the integrated system in a pressurized environment.