14.07

SPACE SUIT TRAUMA COUNTERMEASURE SYSTEM – PRESSURE SENSING CAPABILITY FOR IN-SUIT CHARACTERIZATION

A. Anderson[1], A. Hilbert[1], P. Bertrand[1], D. J. Newman[1],
[1]Massachusetts Institute of Technology

OBJECTIVE

Gas-pressurized space suits are incredibly well engineered tools allowing astronauts to perform critical duties. However, current space suits have an inherent stiffness, causing fatigue, unnecessary energy expenditure, and in some instances injury. These problems are exacerbated with the additional hours astronauts spend training inside the suit, especially underwater in the Neutral Buoyancy Laboratory (NBL). Although the U.S. has studied space suit performance and improved upon system designs, relatively little is known about how the astronaut moves and interacts within the space suit, what factors lead to injury, and how to prevent injury. The objective of this research is to develop an understanding of how the person interacts with the space suit, and to use that information to assess and mitigate injury. We address this issue through several facets.

PRESSURE SENSING SYSTEM

We quantify and evaluate human-space suit interaction with a novel pressure sensing tool, focusing on the arm and shoulders under different loading regimes. The pressure sensing system is integrated into a conformal athletic garment. This garment is worn by the subject and has targets over which hyperelastic, low-pressure sensors are mounted. The Polipo, or octopus in Italian, is the system of 12 sensors that were developed as part of this research effort for low-pressure sensing utilized under soft goods. A significant study on the design and characterization of the sensors was undertaken to optimize them for this application. These sensors are placed over the arm in a way that targets anticipated injury hot spots on the body, and secondarily for uniform body limb coverage. The sensors are detachable from the athletic garment, allowing an independent pressure sensing system. The garment also has a pocket interface over the shoulder to house a Novel pressure sensor, which is used to quantify the high-pressure sensing regime. The high-pressure regime is at the interface between the person's body and the space suit hard upper torso (HUT) interface. Finally, a cover shirt slides easily over the Polipo sensors to prevent catching, ensure proper sensor placement, and to complete the novel body-suit pressure sensor capability.

IN-SUIT HUMAN SUBJECT EVALUATION

An experiment was performed to evaluate human-space suit interaction using the previously described pressure sensing system. Additionally, inertial measurement units (IMUs) were placed both internal and external on the space suit and arm to assess limb biomechanics. Objectives included evaluating the feasibility of pressure sensing as a wearable platform used inside the space suit. Establishing a precedent and methodology initiates our technology development effort to invent an in-suit, wearable pressure sensing capability to quantify human-suit interaction.

Multiple subjects performed the test protocol in the NASA Mark III space suit and the David Clark Corporation Mobility Mock-up suit. Subjects were selected based on availability from a group of personnel who meet the medical requirements for in-suit testing. These individuals have a great deal of experience working inside the space suit and will not have to develop new, potentially confounding movement strategies. The subjects wore the pressure sensing and IMU systems while performing the tests, and pressure profiles and angle histories were recorded. The test protocol consisted of 12 repetitions of 5 motions inside the space suit. The selected movements use the upper body where the sensors are placed. The 5 motions include 3 isolated joint movements (Elbow flexion/extension, Shoulder flexion/extension, and Shoulder abduction/adduction) and 2 functional tasks (Hammering Overhand, Cross Body Reaching). Prior to the experiment, subjects were trained on each movement and allowed to repeat it as many times as they desired for practice. During testing of each movement, the 12 repetitions were further subdivided into 3 groups of 4 repetitions each. This is done to evaluate subject fatigue or potential change of biomechanical strategies over the course of the test period. After each group of movements, qualitative information on subject comfort and noted hot spots was collected. The same information was also collected after training. Each of these test conditions were counterbalanced and randomized for each subject. Unsuited data was also collected after the suited test to form the baseline pressure profile used to mitigate the effects of erroneous readings caused by movement without contact with the suit.

We discuss the results of this experiment and follow-on work. We propose future improvements for the characterization of human biomechanics and injury mechanisms inside the space suit.