MIT researches cause of pain in spacesuit gloves

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Astronaut Joseph R. Tanner, STS-115 mission specialist, waves toward the digital still camera during a space walk. Photo: NASA

All spacesuit gloves stiffen and fill with gas during an astronaut spacewalk, also known as extravehicular activity, or EVA. This pressure production is required to keep astronauts alive in space, and current spacesuits provide one-third of an atmosphere, which is sufficient to ensure astronaut well-being. But the pressurized gloves in a pressurized spacesuit make it very difficult, and often painful, for astronauts to grasp objects during an EVA, which can last up to eight hours each day. Not surprisingly, the most common type of injury reported by astronauts involved in EVA work is hand-related, including a condition known as fingernail delamination, in which the nail completely detaches from the nail bed.

As designers seek to make spacesuits more comfortable, they are exploring the causes of injuries like fingernail delamination. Until recently, researchers suspected that finger length might play a role because astronauts' fingers push against thimble-like structures inside the tips of the gloves. But a recent statistical analysis by researchers and students in the Man Vehicle Laboratory (MVL) of MIT's Department of Aeronautics and Astronautics reveals that the width of an astronaut's hands — not finger length — may be linked to delamination.

As the researchers, including Professor of Aeronautics and Astronautics and Engineering Systems Dava Newman, Roedolph Opperman SM '10 and MVL statistician Alan Natapoff, report in a paper published this month in *Aviation, Space, and Environmental Medicine*, their analysis of more than 200 astronaut injuries indicates a significant correlation between injury and the length of astronauts' metacarpophalangeal (MCP) joint, located where the fingers meet the palm. The paper suggests that spacesuit glove design inherently limits MCP joint mobility, which, in turn, is related to excess pressure on finger pads that reduces blood flow to the fingers and causes tissue damage that can lead to delamination.

Rethinking the joints

According to Newman, the gloves are considered the greatest engineering challenge for spacesuit design. That's because our hands have almost as many degrees of freedom as the rest of our entire body, and maintaining those degrees of freedom to enable fine motor control in a pressurized glove is very difficult. "It's like you're fighting inside a pressurized balloon with very limited ability," said Newman, who has spent the past two decades testing the performance of the Extravehicular Mobility Unit (EMU) spacesuit that NASA astronauts have worn since the 1980s.

Professor of Aeronautics and Astronautics and Engineering Systems Dava Newman Photo: Patrick Gillooly

Introduced in 1998, the current EMU advanced "Phase VI" glove includes an inner pressurized layer and a thick outer layer. When the glove is pressurized, the inner layer becomes stiff, similar to a basketball that is pumped with air. The gloves also contain a rigid palm bar to assist the pressurized glove and hands to bend or flex in order to grip objects and perform tasks.

Although the Phase VI gloves were intended to provide better mobility and more comfort than their predecessor, hand injuries are still a significant problem. Of the 350 EVA training injuries reported between 2002 and 2004, nearly half were hand-related, according to a 2005 study.

Partially sponsored by spacesuit-development company ILC Dover and

NASA, the current study examined a database of 232 crew members' injury records collected by NASA's Johnson Space Center. Newman and her colleagues analyzed hand measurements of the crew members and compared those data to measurements from a noninjured control group. The comparison revealed that crew members whose MCP joint has a circumference of more than 22.8 centimeters (about nine inches) were about four times more likely to suffer delamination than those with an MCP circumference that is less than 22.8 centimeters (20 percent compared to 5 percent). The researchers found no correlation with finger length.

As the locomotive abilities of astronauts become more critical for potential future missions to explore other planets, the researchers encourage NASA to consider elements like the MCP joint as it develops the next-generation spacesuit.

"The study points to a different cause [of delamination] and a different way to deal with it," said Peter Homer, founder of spacesuit-design company Flagsuit LLC, who is working with NASA and commercial companies to develop gloves for the next-generation spacesuit. "We need to look more closely at what is going on with the MCP joint," he said, noting that the sizing and fit of the gloves around the MCP joint should be considered more closely in future designs.

Designing for the future

As part of her ongoing research on EVA performance, Newman is exploring how robotic technology can work in parallel with gas-pressurized suits, including ways to use actuators to help hand muscles fight against pressurized gloves.

She has also spent several years developing technology for the MIT BioSuit, a spacesuit that relies on mechanical counterpressure to enhance astronaut performance. Instead of pressurizing the air inside a bulky spacesuit, the BioSuit applies pressure directly to the skin through tightly wrapped layers of flexible material that function like a “second skin” and enable enhanced mobility and flexibility. Using mechanical counterpressure would get around the hand problem that results from traditional spacesuits, Newman said.

More information:

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