High-power artificial muscle for consumer robots

As part of the Impulsing Paradigm Change through disruptive Technologies Programme (known as ImPACT), and its 'Tough Robotics Challenge' – an initiative of the Japanese Cabinet Office Council for Science, Technology and Innovation – a research team including Professor Koichi Suzumori from the Tokyo Institute of Technology and Dr Ryo Sakurai from Bridgestone Corporation has succeeded in developing a hydraulically driven, high-power, artificial muscle that is expected to become part of the smallest, lightest and most powerful consumer robots yet created.

The purpose of the ImPACT Tough Robotics Challenge is to create the various 'tough technologies' that are essential for robots used for disaster prevention, emergency response and recovery, rescue and humanitarian support.

Robots that operate in disaster areas need to be lightweight, powerful, capable of controlling large forces precisely, have sufficient shock resistance and other mechanical 'toughness'. These are different from robots used under specific controlled conditions indoors and in factories. Methods using electric motors and reduction gears have limitations so hydraulic actuators are essential.

This research has developed a new McKibben type artificial muscle that can be driven by hydraulic pressure of 5.0 MPa, which can generate significantly more power than conventional methods while remaining lightweight.

In addition, the solution minimises sliding friction, which becomes an issue when trying to achieve high precision control, and it has strong resistance to shock. It is expected that this component will allow for great progress to be made towards the practical application of robots in extreme environments.

The ImPACT programme's artificial muscle, developed using rubber tube, is extremely powerful but lightweight and is strongly resistant to impact and vibration, allowing for the most compact, tough and energy-efficient robots ever created, which are all keys for robot use at extreme disaster sites.

ImPACT's Tough Robotics Challenge targets the development of robots for rescuing people after disasters such as the Great East Japan Earthquake Disaster and the Han-Shin Awaji Earthquake Disaster. With existing robots, a number of problems tend to arise. For example, it has been reported that they cannot operate at disaster sites, that there have been total breakdowns and that they do not meet the working conditions. These problems must be overcome in order to achieve the programme goals.

To create tough robots with excellent mobility and power, the researchers are carrying out research and development of hydraulic actuators such as motors and cylinders, which are key components. Most current robots are driven by electric motors based on technology commonly used for consumer products; however, there are problems related to their structure.

First, the strength-to-weight ratio, calculated by dividing the generated force by the weight of the actuator, is low – electric actuators are low powered and heavy. Second, the robots have low resistance to outside impact and vibration – they break easily – and third, it is difficult to achieve large power output while also moving gently, which these situations often require.

To address these problems, the Tokyo Institute of Technology and Bridgestone have focused on the development of human-like muscles, which are capable of expending large amounts of power whilst also being capable of the flexible movement required to do the work required. Since 2014, the researchers have been striving for output greater than that possible by human muscles, while simultaneously trying to reproduce their flexibility.

These artificial muscles consist of rubber tubes and high-tensile fibres, and are actuated by hydraulic pressure. The use of rubber tubes and high-tensile fibres make it possible to achieve smooth movement, and the use of hydraulic pressure makes it possible to achieve a high strength-to-weight ratio, high shock and vibration resistance, and appropriately gentle movement.

This research opens up new possibilities for creating robots that have greater 'toughness' than current robots; are highly resistant to external shock and vibration; able to perform high intensity jobs; and handle delicate jobs requiring precise power control.

Overview of research achievements

The high-power artificial muscle that was successfully developed is a McKibben type artificial muscle. As seen in Figure 1, it consists of a rubber tube surrounded by a woven sleeve. Conventional McKibben type artificial muscles operate at an air pressure of 0.3 to 0.6 MPa, but the artificial muscle developed by the researchers can be used in hydraulic pressure drives and is operable at a pressure of 5.0 MPa, which is much higher than conventional McKibben type artificial muscles. It is, therefore, possible to generate a significantly higher amount of power with the muscle developed in this research.

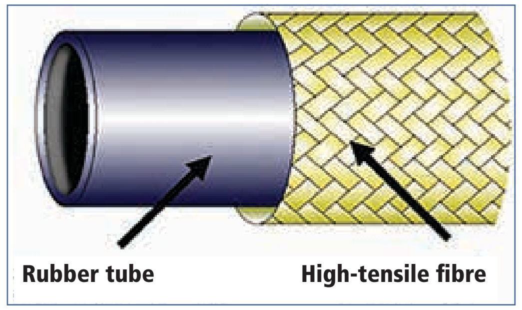


Figure 1: The McKibben-type artificial muscle structure.

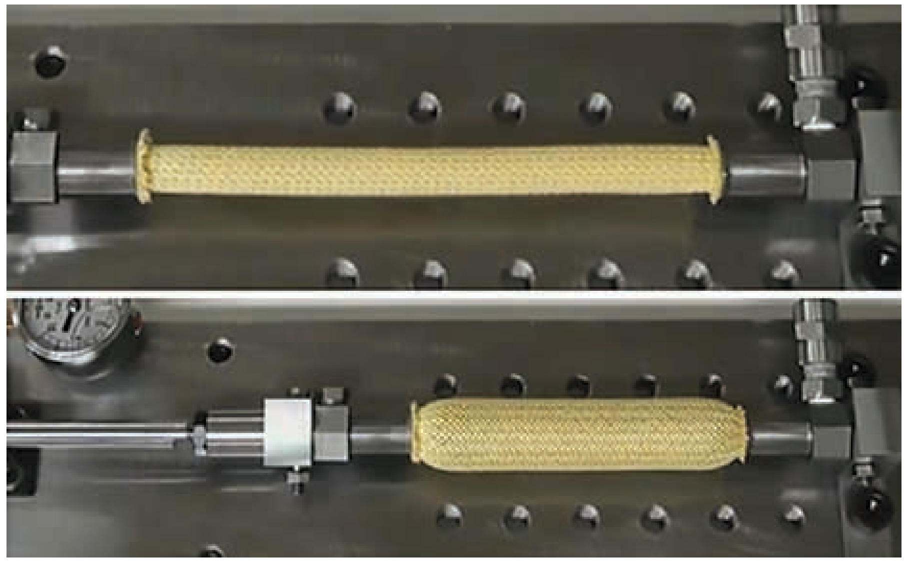


Figure 2: An example of the operation of the hydraulic, high-power artificial muscle' developed through the ImPACT programme.

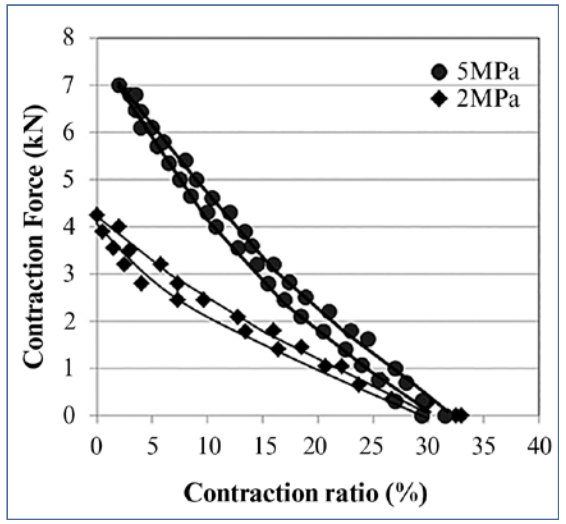
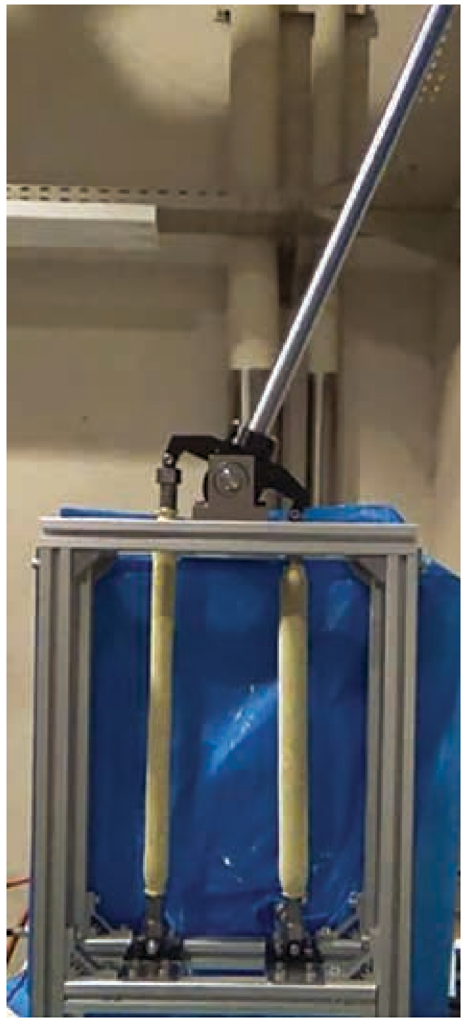


Figure 3: A summary of the operational characteristics of the artificial muscle: outer diameter, 15 mm; maximum contractile force, 7.0 kN; maximum shrinkage rate 30%.

The research team has developed a new rubber material that has excellent oil resistance and deformation characteristics. In addition the method for weaving the high-tension chemical fibres has been modified and a technique for connecting the tube ends has been developed so that high pressures can be accommodated. As a result, an innovative, lightweight, and highly powerful artificial muscle with excellent pressure resistance and oil resistance has been realised, which is capable of converting high hydraulic pressure into efficient power generation. It is an innovative actuator with a 'strength-to-weight ratio' that is five to ten times greater than conventional electric motors and hydraulic cylinders.

*Figure 4: Application to the robot arm. **Right:** two robotic arms using the artificial muscle. **Below:** A wrist of a robot with six artificial muscles.*



The artificial muscle developed in this research (shown in Figure 2) consists of a rubber tube surrounded by a woven sleeve, thus it is highly resistant to strong external shocks and vibrations. It is expected to lead to tough robots that can handle work where shocks loading is common – making holes in walls using an impact drill, chipping concrete walls, etc – which is difficult for existing robots driven by electric motors to handle.

Future development

The researchers will now go on to develop robots that are able to use this artificial muscle with the intention of contributing to the advancement of robot deployment for a safe and secure society. In addition, they are aiming to achieve higher performance and to help spread its use and development as a consumer-use robot actuator. ❑

***Reference:** The Cabinet Office: Impulsing Paradigm Change through Disruptive Technologies Programme (ImPACT); programme manager: Satoshi Tadokoro.*