Machinery/Automation

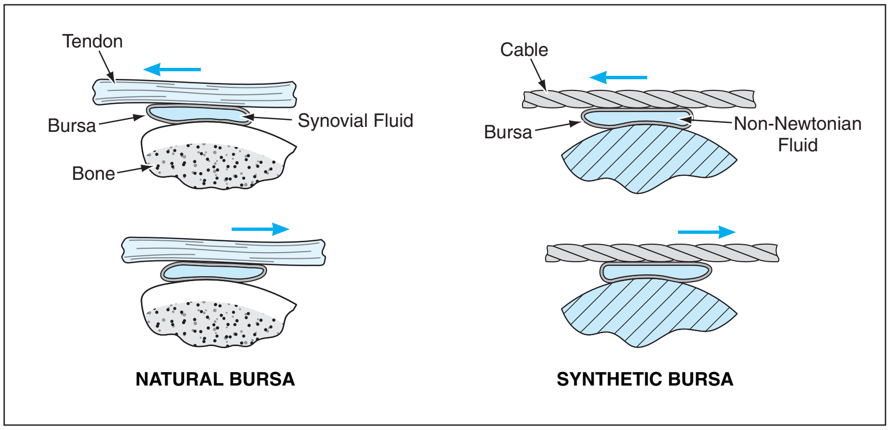
Synthetic Bursae for Robots

Functions would be similar to those of natural bursae.

Lyndon B. Johnson Space Center, Houston, Texas

Synthetic bursae are under development for incorporation into robot joints that are actuated by motor-driven cables in a manner similar to that of arthropod joints actuated by muscle-driven tendons. Like natural bursae, the synthetic bursae would serve as cushions and friction reducers.

A natural bursa is a thin bladder filled with synovial fluid, which serves to reduce friction and provide a cushion between a bone and a muscle or a tendon (see figure). A synthetic bursa would be similar in form and function: It would be, essentially, a compact, soft roller consisting of a bladder filled with a non-Newtonian fluid. The bladder would be constrained to approximately constant volume. The synthetic bursa would cushion an actuator cable against one of the members of a robot joint and would reduce the friction between the cable and the member. Under load, the pressure in the bladder would hold the opposite walls of the bladder apart, making it possible for them to move freely past each other without rubbing.



A **Bursa**, whether natural or synthetic, is a bladder that contains a cushioning, friction-reducing fluid; it functions essentially as a soft roller.

A synthetic bursa could be made by fabricating a bladder from a composite of lock-woven mesh and strong elastomer and filling the bladder with a non-Newtonian fluid. Depending on the specific application, it could be advantageous to use a dilatant or a thixotropic fluid. Ideally, a synthetic bursa would be designed so that it would bottom out before reaching its bust pressure. In the bottomed-out condition, the opposite walls would slide past each other on an almost capillary film of the non-Newtonian fluid.

At the time of reporting the information for this article, prototype synthetic bursae with simple spherical shapes were being fabricated. Subsequent prototypes would have more complex shapes somewhat like those of natural bursae.

This work was done by Christopher S. Lovchik of **Johnson Space Center**. *For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. MSC-23064.*

Robot Forearm and Dexterous Hand

The hand is highly anthropomorphic and even includes a folding palm.

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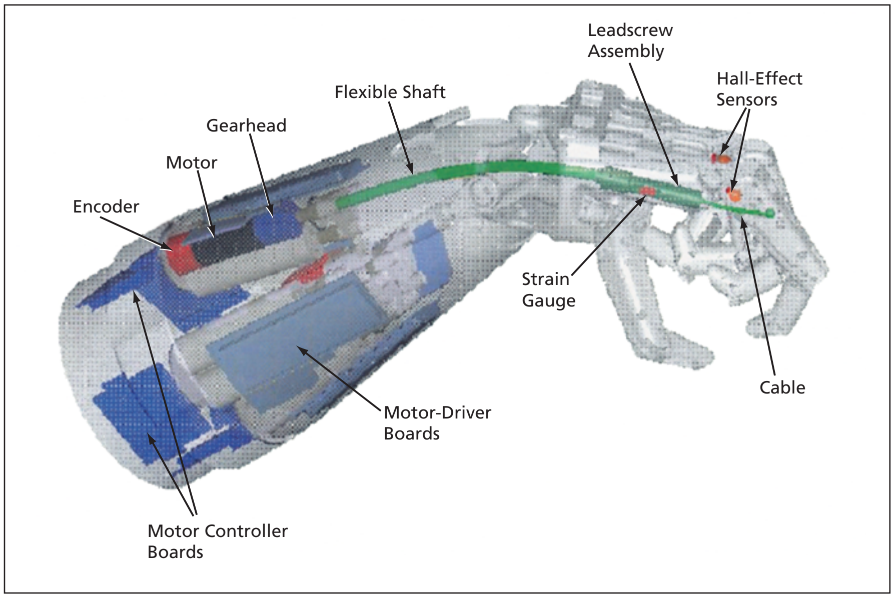
An electromechanical hand-and-forearm assembly has been developed for incorporation into an anthropomorphic robot that would be used in outer space. The assembly is designed to offer manual dexterity comparable to that of a hand inside an astronaut's suit; thus, the assembly may also be useful as a prosthesis or as an end effector on an industrial robot.

The assembly has a total of 14 degrees of freedom. It consists of a forearm, which houses the motors and drive electronics; a two-degree-of-freedom wrist; and a five-finger, 12-degree-of-freedom hand. The hand itself is broken down into two sections: a dexterous work set, which is used for manipulation, and a grasping set, which allows the hand to maintain a stable grasp while manipulating or actuating a given object. The dexterous set consists of two three-degree-of-freedom fingers (pointer and index) and a three-degree-of-freedom opposable thumb. The grasping set consists of two, one-degree-of-freedom fingers (ring and pinkie) and a palm.

The fingers are powered by motors mounted in the forearm (see figure). Mechanical power for the fingers is transmitted through the wrist via flex shafts. In the hand, small modular leadscrew assemblies convert the rotary motion of the flex shafts to linear motion. The outer shells of the leadscrew assemblies are instrumented as load cells to provide force feedback.

The leadscrews are linked to the fingers by short cables that lie in cammed grooves in the fingers. The use of cables reduces (in comparison with the use of gears or other drive mechanisms) the size and complexity of the fingers while allowing the fingers to be very compliant in the non-driven direction. The cammed grooves keep the bend radii of the cables large to prevent excessive stressing of the cables.

Two leadscrew assemblies that work in a differential manner drive the two-degree-of-freedom base joint of the dexterous fingers. The two distal pitch joints of these fingers are linked and driven by a third leadscrew assembly through a decoupling link in the base of the finger. The thumb is driven in a manner similar to that of the dexterous fingers, except that the base joints are skewed and the yaw is exaggerated in order to match the motion of the human thumb. In the gripping fingers, all three degrees of freedom are linked and are driven by one leadscrew assembly. Both of the gripping fingers are mounted on pivoting bases and driven by another leadscrew assembly in order to enable the palm to cup inward, allowing the hand to conform to an object being held.



One of the Finger Drive Trains is emphasized in this view of the robot forearm and hand. The motive forces for the fingers are generated in the forearm and are transmitted to the fingers by flexible shafts, leadscrews, and cables.

The wrist is designed as a large open hook joint (to allow the flexible shafts to pass through) and is driven by two linear actuators. The forearm is 4 in. (≈10 cm) in diameter at the base and 8 in. (≈20 cm) long.

This work was done by Christopher S. Lovchik of **Johnson Space Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22883.