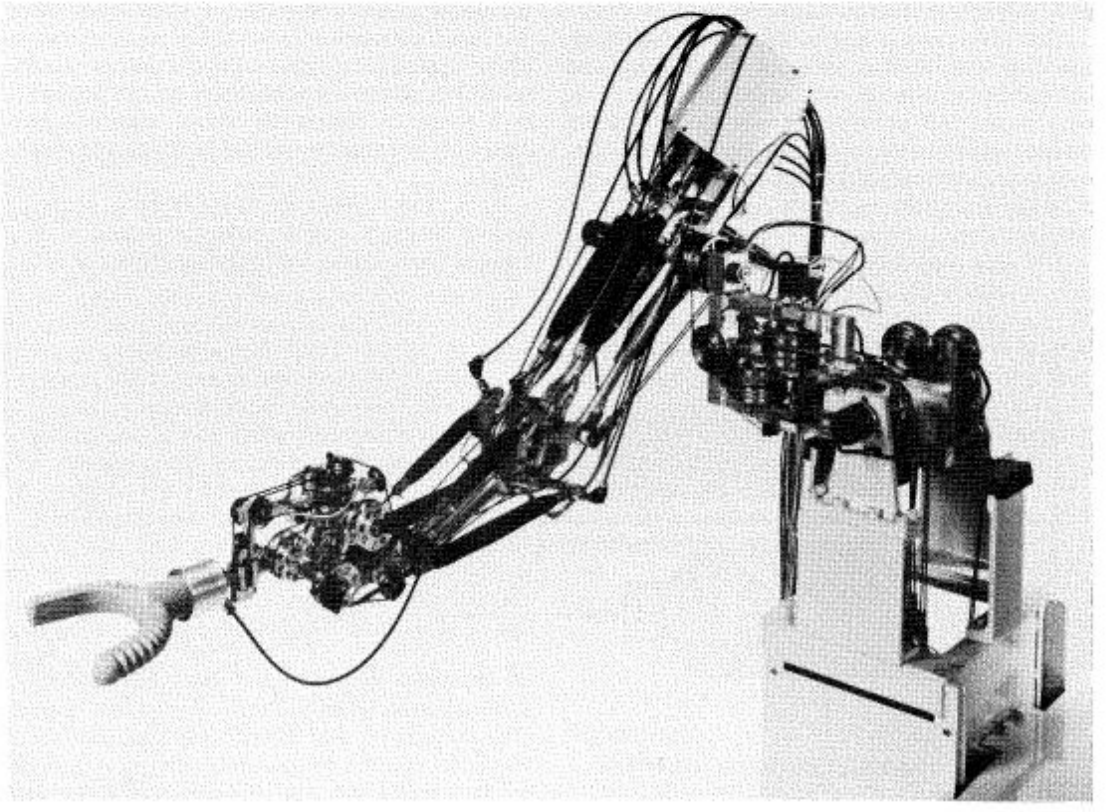
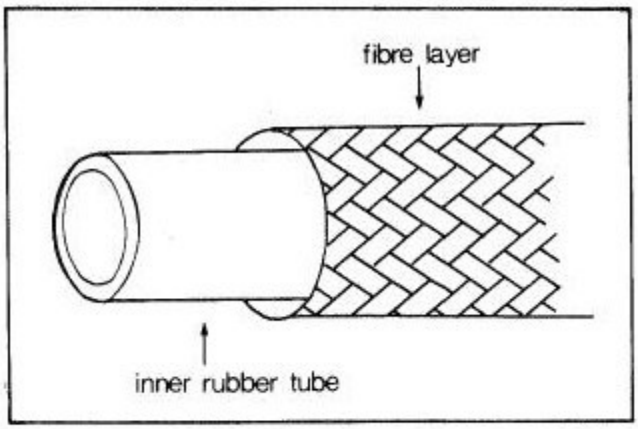
Rubber muscles take robotics one step further

IT HAS become something of a cliché to describe the human body as a marvellous piece of engineering. Now a robot arm developed in Japan by the Bridgestone Corporation and Hitachi has provided an opportunity to do the reverse and compare a piece of machinery to a part of the human form. The robot arm in question has been designed for assembly line work and relies for its complex series of movements on rubber actuators powered by compressed air. Like the human arm it has a shoulder, elbow and wrist joint, which allow it seven degrees of freedom of movement, and it has a soft rubber hand for gripping.

Robotics is a rapidly developing technology. The capacity of machines to perform sophisticated manual tasks has increased dramatically during the past few years and assembly lines manned by robots are no longer a futuristic dream: they are becoming commonplace in a variety of industries. Despite this growing exploitation of robots for repetitive tasks, a major problem for designers of 'machines to replace people' is how to imitate the complex and intricate manipulations that can be performed by the human hand and arm. Great delicacy of movement and fine control is possible with flesh



BELOW *Bridgestone/Hitachi's test robot arm*



ABOVE *Bridgestone's 'rubbertuator' consists of a straight piece of hollow braided sleeving covering a gas-tight inner tube. This rubber tube, which contains natural rubber, can be inflated using air pressure, causing axial contraction and radial expansion, as shown below. The contractive force is used to pull wires round pulleys. When the muscles are arranged as in the test arm* (RIGHT), *complex series of movements can be performed with fine control. In this test arm the forearm and upper arm are each 280mm in length.*

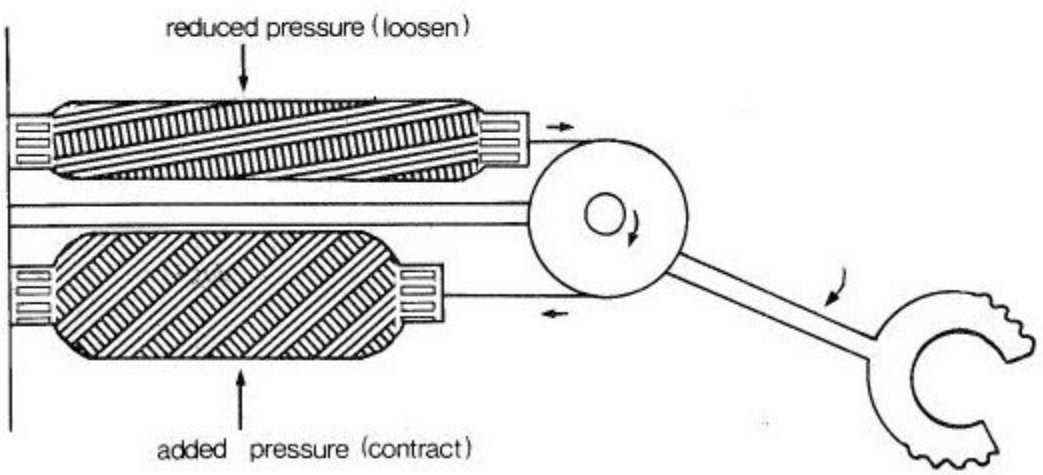
and bone: to mimic all these capabilities will be unnecessary for most tasks. Some of the movements of the human arm can also be eliminated from a particular process by careful design, so that the task involves less complicated movements. Nevertheless many assembly procedures require delicate operations and it is here that the new arm scores over previous types.

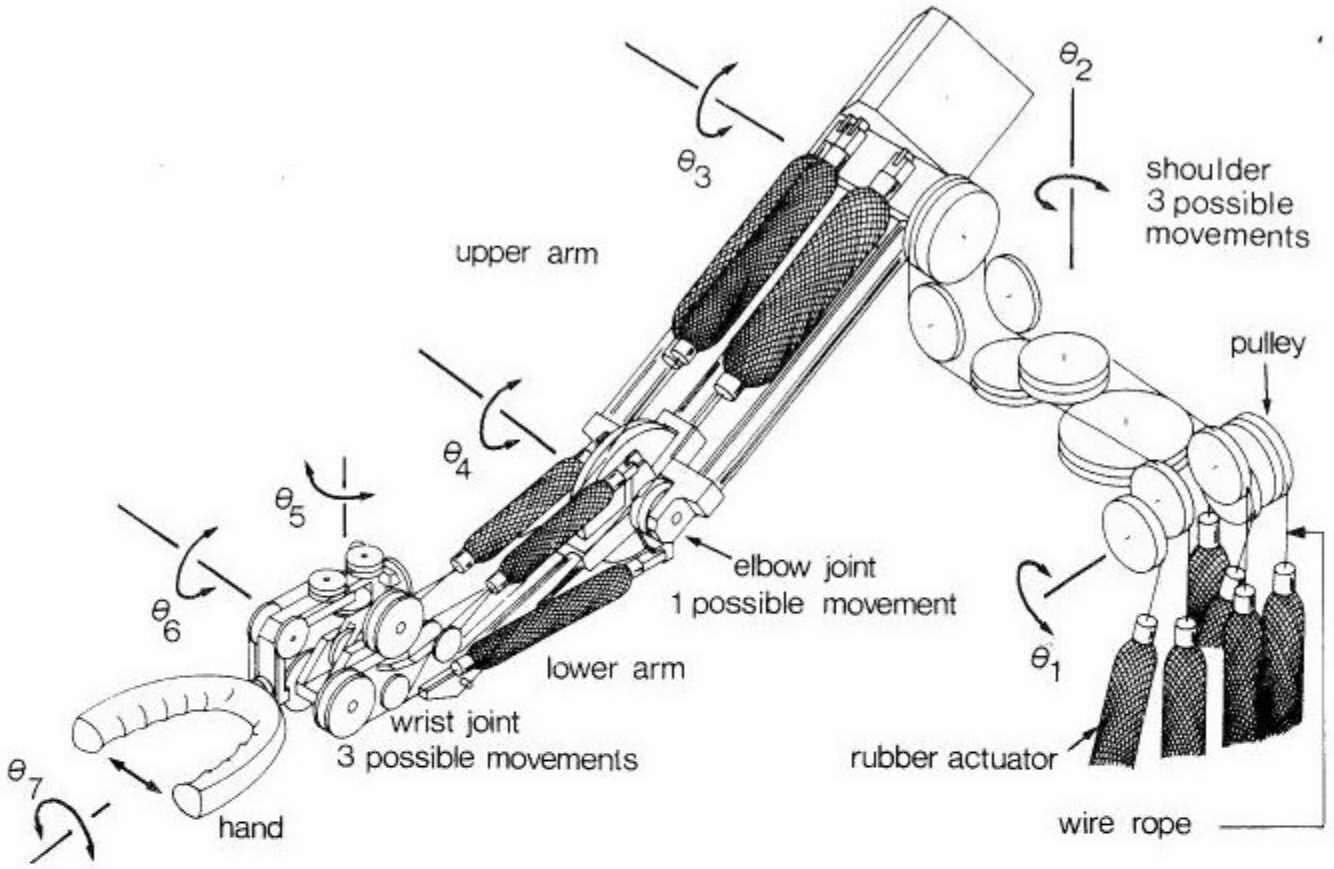
The arm uses a series of rubber actuators working like human muscles, expanding and contracting to control movement of the arm *via* wire ropes and pulleys. The necessary rubber technology was developed by Bridgestone's Research and Development section and the mechanics of the unit were designed by Hitachi Machine Development.

The arm also has a rubber hand, which can handle objects up to 2kg in weight. The total weight of the arm itself is 6kg. The soft rubber grip enables delicate items to be handled, and the horseshoe-shaped hand can open and close under the control of a 16-bit micro-circuit.

The seven degrees of freedom of movement, three each in the shoulder and wrist and one in the elbow, coupled with the gripping capability of the hand, produce a remarkably close imitation of the human arm. This makes the unit extremely versatile and the manufacturers aim to market it to a range of companies whose assembly processes require precise control and accurate movements.

Each rubber 'muscle' consists of a piece of hollow gas-tight rubber tubing covered with a braided fibre sleeve. End closures allow the tubes





to be pressurized and one end is fixed in position, while the other is attached to a wire rope. Inflation of the inner tube using air pressure causes the tube to contract in an axial direction and expand radially under the constraint of the fabric sleeve. This contraction of the tube pulls the wire round a pulley causing the joint to move in the required direction. This type of actuator has high power – the contractive force is three to ten times greater than the force of a piston-type actuator having the same cross-sectional area. The 'rubbertuator', as Bridgestone call it, is also light-weight, frictionless and flexible.

Bridgestone says the arm is lighter and smaller than other arms currently on the market, and points out that it can be used in locations where space is limited because the power source, the compressor, can be located at a distance from the unit.

Rubber has long been used in attempts to replace parts of the human body with artificial substitutes and this journal has mentioned speculation about the dawning of an 'age of bionic man' in which muscle, skin and bone can be simulated by rubber components[1]. In contrast, this exploitation of the flexibility and frictionless movement of an inflating rubber tube to imitate human muscles is part of another process – one in which, on assembly lines in factories, people are being replaced by artificial devices. While this process has many implications for the future of society, it can be seen as part of a logical progression in the use of machines and the development of automation. Innovations such as the Bridgestone/Hitachi arm, with its rubber muscles, could be another step in eliminating human drudgery, freeing people from repetitive and monotonous work for more interesting and creative tasks.

E.P.W.

Reference

1. Small-scale spare-part surgery uses natural rubber latex, RUBBER DEVELOPMENTS, 1980, **33**, 106.