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One-cable control of the mechanical elbow with flexion-extension and locking

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During the last few years, development in upper limb prosthetics has been focused on the use of external power. Now the introduction of the endoskeletal structure of body-powered arm prostheses requires completely new developments of such traditionally established designs as the mechanical elbow joint. The standard exoskeletal elbow requires for operation two control movements, one for flexion-extension and one for locking. Operation of this traditional elbow is not easy for patients and it is far from being an optimal design.

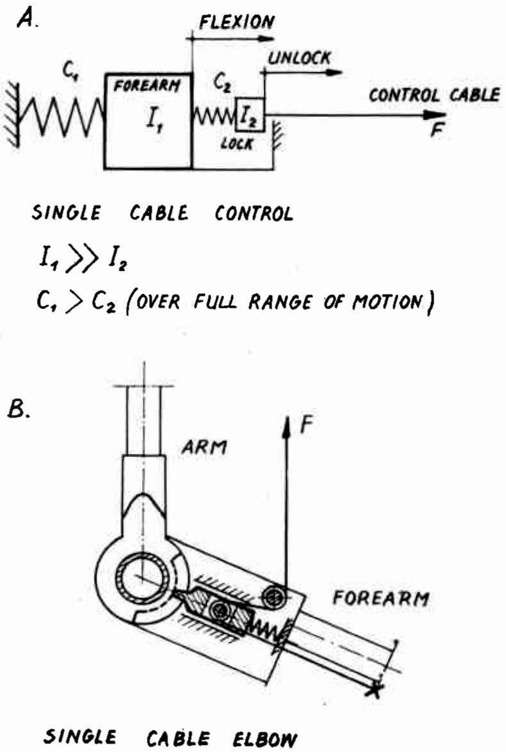

Fig. 1

A new mechanical endoskeletal elbow has been developed that can be controlled with only one cable. The flexion-extension and locking actions are carried out with only one movement of the single control harness. The model of elbow operation is presented in Fig. 1a. The separation of elbow extension and locking is possible due to the inherent difference in inertia of the forearm and the lock. The forearm as a whole presents a large inertial force I_1 to rotation in the elbow joint. The inertia of the mechanical lock I_2 is much smaller. Both mechanical systems are connected in series to one control cable. The cable runs through the elbow mechanism passing through two pulleys (Fig. 1b). The first pulley, placed on the forearm, creates the point of application of the forearm flexion force. The second pulley mounted on the lock creates the point of application of the force pulling out the lock from the cut-out of the arm portion. The lock return spring C_2 is weaker than the forearm extension spring C_1 which, in the given case, is due to gravity on the forearm.

The sequence of elbow operation is as follows: when the cable is pulled, the lock goes to the unlocked position and then the elbow flexes. The extension or locking functions depend on the velocity of the cable release. Slow release of the cable keeps the lock in the unlocked position and the elbow extends. When the cable is released rapidly, the lock, owing to its smaller inertia, moves faster and locks the elbow in the desired flexion position. This mode of elbow control is more physiological and easier for patients to use than a standard two-cable elbow. The lock-control harness is not required.

The control cable runs through the elbow mechanism and afterwards goes outside the elbow and may be connected with some other

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prosthetic mechanisms. This makes it possible to operate additional devices using the same cable which controls the elbow. For example, the pull-switch controlling the electric hand, coupled with the elbow, forms the single cable controlled hybrid arm prosthesis, which in our experience is actually the optimal fitting for high level bilateral above-elbow amputees.

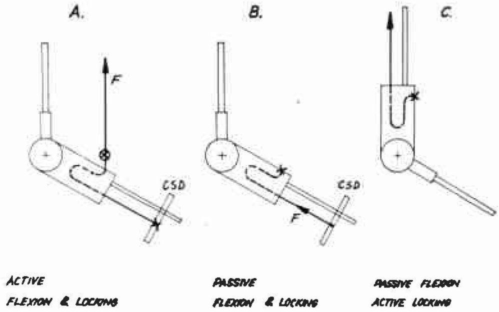

Fig. 2

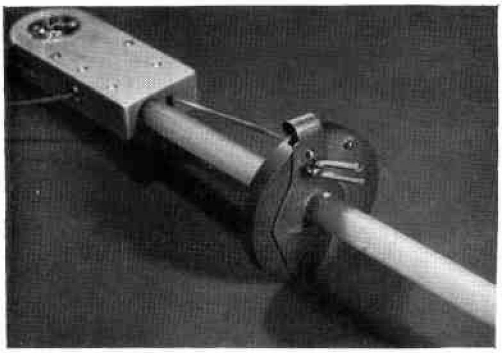

Fig. 3

The operation of the elbow locking device is possible from the upper arm, as well as from the forearm side (Fig. 2). The end of the control cable may be fixed within the forearm, directly on the elbow housing or coupled with the cable shortening device (CSD) as can be seen in Fig. 2a. The cable shortening device presented in Fig. 3 is provided for easy elbow control in the upper range of elbow flexion, especially when the patient is sitting and working at a table surface.

For patients requiring free forearm swinging during walking, the CSD serves for stable unlocking of the elbow. The only modification needed is to make a knot on the control cable (the x in the circle, Fig. 2a). The same configuration of the elbow and CSD may be used for a cosmetic arm, with passive elbow flexion and locking (Fig. 2b).

If the locking mechanism is placed in the forearm position, even extra long stumps can be fitted with the described elbow. In the case of the elbow exarticulation stump, the distance between the stump end and the axis of the elbow joint may be reduced to 15 mm.

The elbow mechanism can be used also in reversed position (Fig. 2c) and it then offers the patient active "rapid" locking and semi-active flexion. By swinging the upper arm, the forearm swings up and can be locked in the desired position ("inertia" forearm flexion).

Due to the small dimensions and light weight there is only one elbow size, the same for children and adults.

This universal elbow control offers a wide variety of elbow configurations, stimulating the development of the new kinds of arm prostheses.