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DESIGN FOR A THREE-FINGERED HAND

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Design Rationale

At the start this question was posed: if an end effector of a manipulator arm is to be more than just a pair of parallel-acting jaws, what is the next step up? Should it have three or four fingers or jaws? Should it be anthropomorphic at all? The commission we received from NASA-MSFC (as interpreted) was for a general-purpose end-effector for use on the space manipulator proposed for the Shuttle program; moreover it should optimistically possess most of the capabilities of a human hand, and should also have peel-off value as a human prosthetic device, with this difference, that it must be separable at the wrist (distal to the wrist joint) from whatever arm it should be attached to.

A study was made of the capabilities of the human hand. It is known that mostly the hand is used for static gripping, and the present jaw-type device fulfills this reasonably well. We define a "manipulation" as an action (movement) of the fingers while holding something. The two most important manipulations for a garage mechanic were identified as:

a) the pistol grip and trigger pulling,
b) the transferring of an object from a finger-tip pick-up position to a firmly nested palmar grasp.

For both of these at least three fingers are necessary: two in apposition to hold the object, in the manner of parallel jaws; a third for the trigger or to retract the object held. (See Fig. 1)

Several controls are going to be necessary, and if these are to be operated successfully with television feedback an anthropomorphic form is desirable.

The design evolved through two mock-up stages. The final form is shown in the figure. It contains four electric motors. While thumb and forefinger bend, their ultimate phalanges maintain a parallel stance to one another. The grip centerline is at 45 degrees to the mounting base.

Design Details

New Finger Activation Mechanism

Several alternative mechanisms are in present use as finger activators. A crossed-four-bar linkwork design is used, for example, by Tomovic and others. All designs can be distinguished by the point at which the mechanism introduces the needed mechanical advantage. In the chain of the drive from motor to pressure surface the later that this velocity reduction can occur the better, for then the force-transmitting links can be lighter.

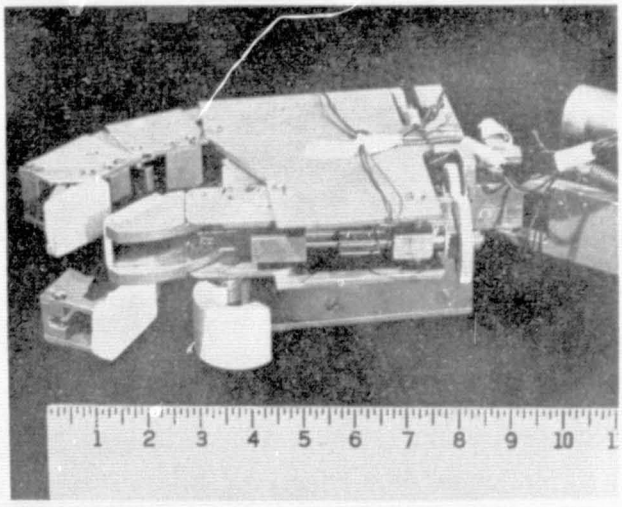

Figure 1

Photograph of A Three Fingered Hand

This design incorporates a new form of screw-operated turnbuckle to bend each interphalangeal joint. The screws are driven at an intermediate speed by electric motors.

The Thumb Nail

In tests on a preliminary model hand, the provision of a fixed thumb nail, projecting about 15 mm, with serrated and sharpened edge, allowed one to pick up certain objects otherwise very difficult, for instance a flat steel rule and a draftsman's triangular rule lying on a table. Because the extended nail would sometimes get in the way and hinder a simple grip, it was made retractable. An additional motor is needed to move it in curved guides. This adds to weight of course, and was probably a mistake: the fixed nail was better.

Controls

A set of button and switch controls were mounted on the hand of an exoskeletal master arm. These could be arranged on a joystick equally well. The controls were arranged in two sets: preset and run. Preset switches controlled whether thumb and forefinger moved together or independently, also whether the fingers open or close, also the thumb-nail motor. If the two opposing fingers run together, two buttons control when the motors drive the two or the third finger in the directions prechosen.