A NEW MODEL OF THE BELGRADE HAND

R. Tomović

Introduction

This research has been motivated by several factors. The clinical experiences with the present model of the Belgrade Hand have shown that it is desirable to reduce further the amount of the voluntary control involved in operation. It is also of theoretical interest to attempt to design the control system for the multifunctional artificial hand with an absolute minimum of voluntary control.

In the above-elbow amputation the multifunctional hand must be considered as the terminal device of the whole arm prosthesis. Therefore control must be applied to the wrist joint as well. This improvement has been incorporated in the new model.

Voluntary Control

In the existing model of the Belgrade Hand the following activities were controlled at the voluntary level:

start (closing)
stop
reverse (opening)
prehension force.

In terms of hardware this sequence required a simple switch and a function generator (potentiometer) whose output was proportional to the muscle contraction.

Closing, stop and opening of the hand must always be under the control of the man. However, the adjustment of the prehension force can be made automatic provided the appropriate bionic transducer is available. In this case voluntary control is concerned with the selection of only two decisions: start and stop. This is evidently the absolute minimum of voluntary control for the functioning of any hand.

Bionic Transducer

Several transducers have been developed for the automatic adjustment of prehension force. The instance when an object begins to slip out of the hand can be detected by a pick-up which is a part of the positioning servomechanism. This solution is, however, sensitive to mechanical noise due to vibration of the whole hand. In fact, the rejection of undesired vibrations to which the hand may be exposed is basic for this type of the transducer. As known, the human skin has this quality.

A special servomechanism for the control of the prehension force based on indirect measurements has also been used for multifunctional hands [1]. In this solution the ratio of the tangential and the normal force for the object held in the hand is automatically maintained constant. The normal force is the result of the pressure of the object against the hand while the tangential force is due to gravity. Although this servomechanism, when properly adjusted, functions well it may produce wrong results since the process of slippage is not directly detected.

In the present model of the Belgrade Hand a new bionic detector is used. Its functioning will be explained using Figure 1. The object is pressed by a preset minimal prehension force against the hand surface. If the object begins to slip the small uneven wheel is set into motion. Consequently, the spring is exposed to forced oscillations and a series of pulses is generated by interrupting a contact. The pulses are used as input to the positioning servomechanism which increases the pressure until the slippage stops. The details of the servomechanism are described elsewhere [2].

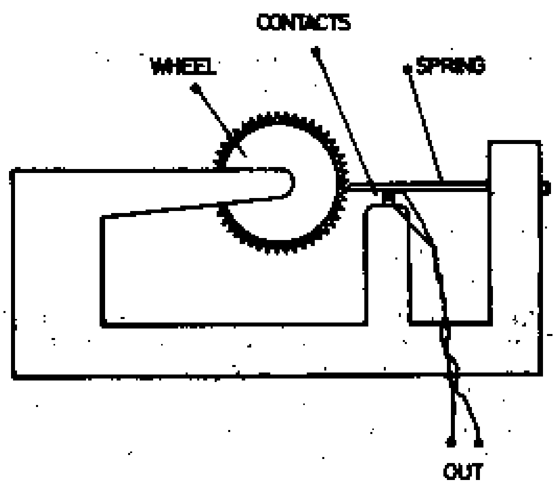

Fig. 1.

The spring force is adjusted so that no undesired hand vibrations can set the small wheel into motion. Besides, the transducer is embedded into the soft rubber part of the hand surface which acts as an additional damping environment. Several of these transducers are mounted in parallel over the whole hand surface so that the slippage is detected no matter what the shape of the objects is or the type of grasp. The rejection of the mechanical noise is absolute within the range of vibrations to which the hand is normally exposed.

Additional Improvements

In unifunctional hand prostheses having only pinching function it is practically irrelevant how hard the palm surface is. The situation is completely different with the multifunctional hands having pinch, fist and automatic adaptation to the shape of the object. Metallic palm and finger surfaces are not only unadaptive to the shape of the object but the friction coefficient is low as well.

All inner surfaces of the new model are covered with the rubber layer whose softness corresponds approximately to the human flesh. The soft mass is distributed on the palm and finger surfaces in a similar way as in the living tissue. Thus an excellent shape adaptation is obtained with high friction. The hand can be used with the glove or without it.

Active Wrist Joint

Active pronation and supination are desirable in any prosthesis. The new model therefore has a wrist joint with active pronation and supination.

The basic problem in the active wrist joint is not so much the mechanism itself but the corresponding control system. The solution used in the new model is very simple. The same motor and the same control system are used for both hand and wrist motion. For this purpose the motor is provided with an electromechanical clutch which alternatively couples it either to the driving mechanism of the hand or to the wrist. Since the same motor is used for both functions, the same control system is used for wrist positioning. The transition from the hand to the wrist joint control and vice-versa is obtained by pressing the start-stop switch for a longer period.

The Control System

The control system is of the multilevel type. It consits of the switch for voluntary control, the logic circuits, the control circuits and the mechanical part. The engineering details of the system are given elsewhere [2].

The switch for voluntary control can be placed at any convenient body site. Since the proportional muscle control is not needed the choice of the site and its use are much simpler than before. The man has simply to activate the switch when he desires to close or to stop the hand. This produces a series of pulses which the logic of the control system interprets as start-stop signals. At each stop of the hand the direction of the motor rotation is automatically changed.

Conclusion

The new model of the Belgrade Hand has remarkable features in that the following functions: fist, pinch, shape adaptation, prehension force adjustment, active wrist joint, start, stop and reverse, are controlled from just one body site. The role of the body site is to select one out of two decisions — start, stop — which is the absolute minimum.

Having thus simplified the voluntary control and using the same drive for hand and wrist activation, an anthropomorphic terminal device of very general use has been obtained. It may be applied as the hand prosthesis for below-elbow amputation, as a terminal device for the arm prosthesis as well as the terminal device for remote manipulation.

REFERENCES

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