ADAPTIVE EMG-CONTROLLED HANDPROSTHESIS FOR WRISTDISARTICULATED PATIENTS

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Abstract

The Swedish SVEN-hand project was originally presented at the Dubrovnik conference 1966. The results of the project was presented at the Dubrovnik conference 1972. At the following clinical evaluation it was found that the location of the actuating mechanisms to the forearm too much restricted the number of possible wearers due to the stumplength. Thus it was desirable to have an adaptive handprosthesis suited even for long stumps.

The new development called the ES-hand after the two companies involved (Een-Holmgren and Systemteknik) is based on the SVEN-hand actuating principles but has more versatile prehension capabilities and admits application to wristdisarticulated stumps. The prehension is improved by introducing an active thumb adduction. The thumb rotation is passively adjustable which gives a range of grips from the three point grip to the lateral grip between the thumb and the lateral side of the index.

The EMG-control philosophy is somewhat changed from the earlier fully proportional control. The freerunning velocity has two levels, one maximum and one slow. The gripforce control is timeproportional building up to maximum within approximately one second. The electronics hardware is designed to fit on the side of a forearm stumpsocket.

One prototype is at present evaluated on a patient and another five prostheses are manufactured at the moment.

Background and designphilosophy

The SVEN-hand system is well documented. See (1), (2) and (3). At a clinical evaluation of a version,with only the grip powered, it was found that the idea with an adaptive grip actuated by cords was promising enough to justify a further development to get rid of some drawbacks. The main desire was to get a handmodule with all mechanichs for the grip integrated in the palm of the hand to admit applications to wristdisarticulated stumps.

The new design should functionally be equivalent with, or better, than the SVEN-hand. Also the new design should be totally selfcontained.

Mechanical design

The cord actuating principle for the fingers is preserved. To obtain an appropuate pulling force in the main cord with an actuating unit that fits into the palm of the hand, a completly new and unique actuating unit was needed. The principles of this is shown in fig 1.

The rolling wormgear gives a gear ratio of 80:1 followed by a conventional gear stage giving a total gear ratio of 400:1. Mamimal pulling force at pulsed conditions (se control system) is 450 N. The total efficiency of the mechanism is 67%. To stop passive extension of the fingers the motorpower is transmitted to the worm-screw via a small patented discbrake operated by axial forces in the wormscrew.

The pulling force of the mechanism is transmitted to the fingers via a differential implying equal force from each finger independent of finger position.

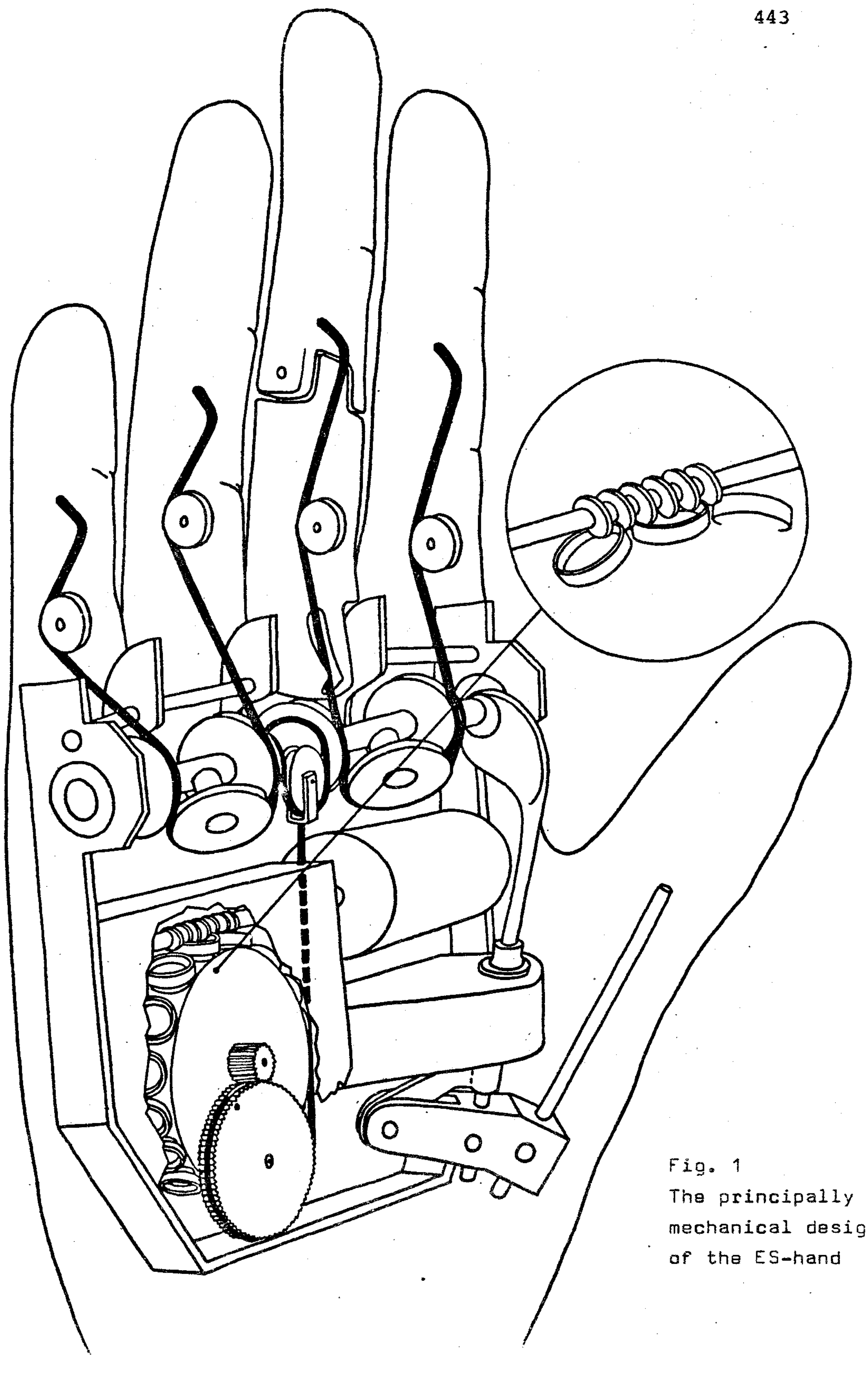


Fig. 1
The principally
mechanical design
of the ES-hand

The thumbadduction is actuated via a pulling rod coupled together with the index and longfinger. The thumbrotation is passively adjustable to any position between the threepoint grip position and a lateral position giving the lateral grip between the thumb and the lateral side of the index. Hence the actuated thumbadduction is working in any thumbposition. The variety of grips possible can be seen in fig. 2, 3, 4 and 5.

An overall view of the whole system together with battery charger is seen in fig. 6.

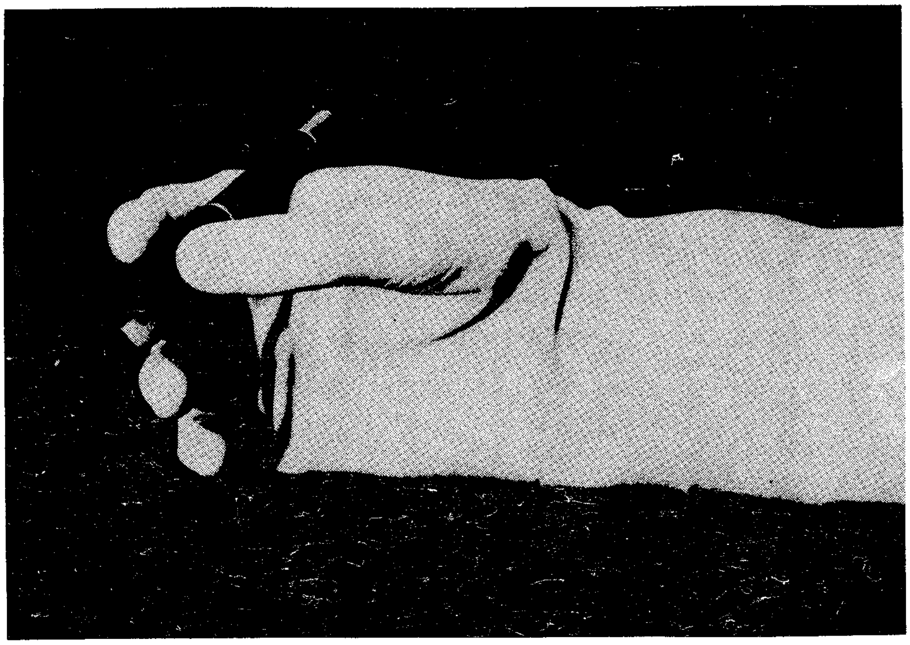


Fig. 2
Three point grip.

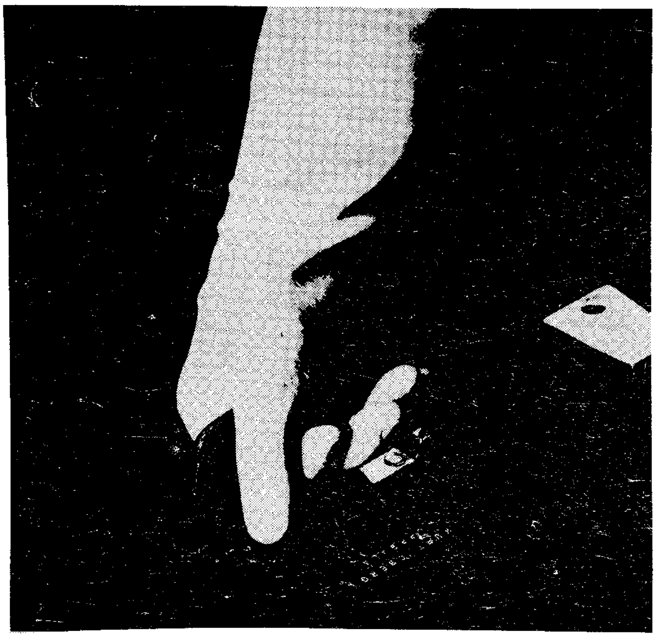


Fig. 3
Handlegrip.

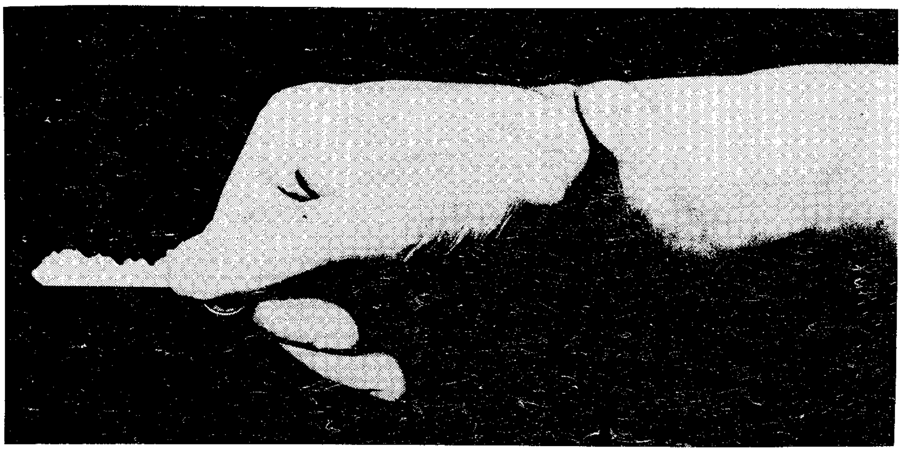
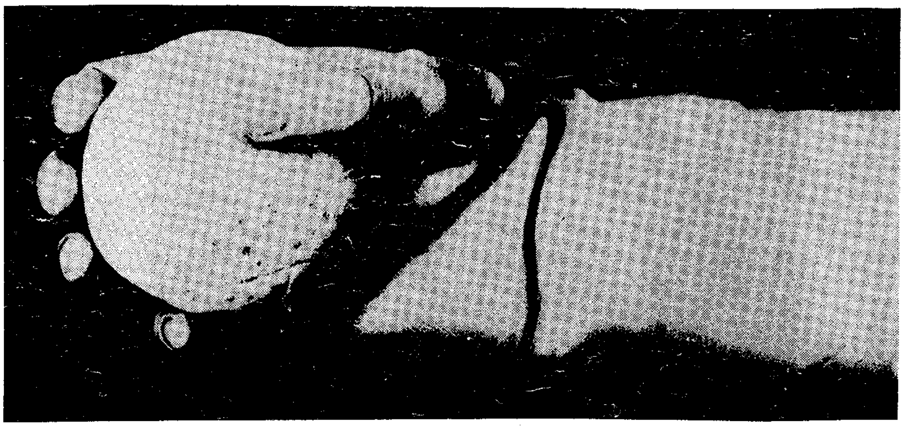


Fig. 4
Lateral grip.



Adaptive grip.

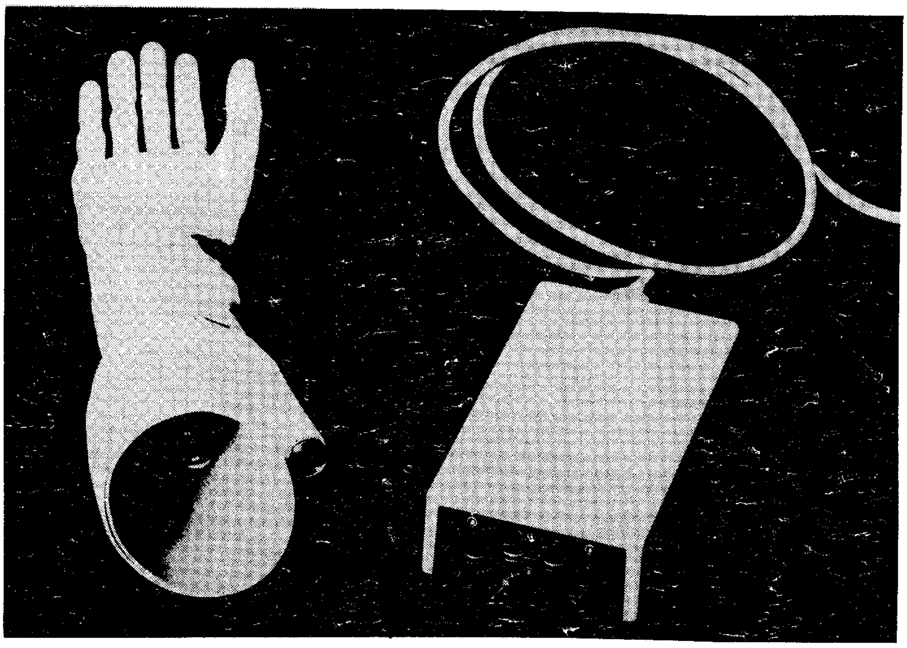


Fig. 6
Overall view of the ES-hand with charger.

Control system

A new EMG-control system is used. The philosophy is based on the foundings presented in (4). Two proportional electrodes are used, placed on two antagonists in the forarm in a conventional manner. Both opening and closing has two actuation levels, depending on the EMG-amplitude. The different actuation levels and the corresponding motor feeding is shown in the tabel below.

EMG-level \ Mowement	Opening	Closing	
		Peak Motorcurrent < 1A	Peak Motorcurrent > 1A
High	Full DC	Full DC	Pulsed Pulsduration 20 ms Freq. 15 Hz
Low	Pulsed Pulsduration 5 ms Freq. 15 Hz	Pulsed Pulsduration 20 ms Freq. 15 Hz	

At high level opening and freerunning dosing the motor is fed with DC (6 V) giving maximum velocity. When the motorcurrent at closing exceeds 1A, indicating that the fingers are in contact with an object (or eachother), the motor is pulsed with comparatively long pulses (20 ms). Each pulse will add a force-increment to the total gripforce, giving a timeproportional gripforce. The high current pulsing also considerably reduces the energy consumption at motor stall.

At low level the motor is pulsed with shorter pulses (5 ms), which at freerun gives a very slow velocity. No appreciable gripforce is obtained. At this level an obtained gripforce can be gradually reduced.

The limits of high and low levels are set by setting the sensitivity of the electrodes and the relation between high and low level is set by at trimpotentiometer on the PC board of the control electronics.

Electronic hardwear design

Great effort is devoted to get a cosmetically acceptable self-contained system. The solution can be seen in fig. 6 and 7. The PC board is made of a flexible material. The holder for the battery cartridge is placed in the middle of the board. The electronic components are moulded into silicone rubber with a slightly curved PC-board. The hole electronic package preserves a certain flexibility making it possible to put it between the inner and outer socket.

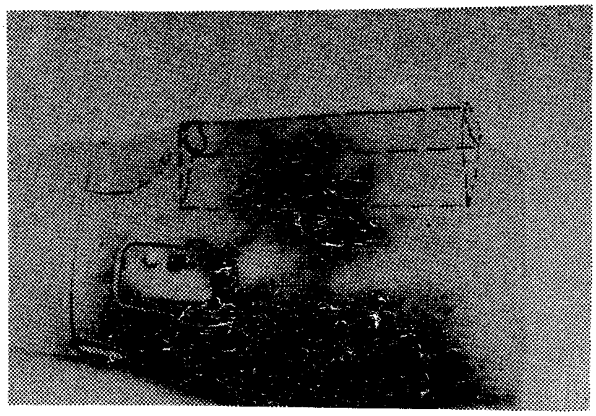


Fig. 7.
Selfcontained battery and electronics. The broken line indicates the position of the battery and the PC board.

Patient application

One patient application is made so far, giving valuable information on functional and cosmetic details to be changed. Another five systems are manufactured for further evaluation.

Further development

The described system is aimed for wristdisarticulated amputees. However, development is going on in designing forearm-modules for wristflexion and pro- and supination to be used together with the Swedish pattern recognition control system (5).

References

(1) H. Lymark, Dubrovnik symposium 1966

(2) G.M. Hägg, K. Spets, Final report, FOA 2

(3) G.M. Hägg, K. Spets, Dubrovnik symposium 1972

(4) G.M. Hägg, L. Wärnberg, Dubrovnik symposium 1975

(5) C. Almström, P. Herberts, Pattern recognition control system, Dubrovnik symposium 1975