COMPONENTS FOR ELECTRIC HAND PROSTHESIS SYSTEM

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Summary

Five components, together forming the "SVEN-hand system", are presented. These are: adaptive hand with therylen cords, high-efficiency gearbox with DCPM motor and lock suited for the cord system, self-tracking mechanism for pro-supination and wrist flexion, servoelectronics for DCPM motor including force and velocity feed-back and lock control. They are long-life and temperature tested, and are maufactured in a small pilot series.

Introduction

The prosthetic system presented in this paper is the result of one major project within the "SVEN-group", which is a Swedish voluntary cooperation group for prosthetics and orthotics. As the project has been rather extensive, this paper is written only as a survey from a technical point of view. A more detailed description of the project will be found in the final report and in reports published during the project on different topics.

The Hand

The working principle of the hand is based on a system using therylen cords which are similar to the human finger flexor tendons (Fig. 1). The index and middle fingers have three joints while the ring-finger and the little finger have two joints. The fingers are extended by elastic ribbons on the dorsal side of the fingers. The cord runs from the finger-tip proximally through the finger over rollers. The fingers are coupled together two by two via pulleys in the palm of the hand. This arrangement makes the grip adaptive. From the pulleys two cords run through the wrist over rollers to the finger flexion mechanism in the forearm. The thumb is also rotated by a cord, and it is springloaded.

When the thumb cord is pulled, the thumb rotates up, forming a three-point grip together with the index and middle finger. The thumb can also be locked in an outwardly rotated position to provide a grip on a handle (Fig. 8).

The work as been performed at the Research Institute of the Swedish National Defence, coordinated by the Swedish Institute for the Handicapped and sponsored by the Swedish Board for Technical Development.

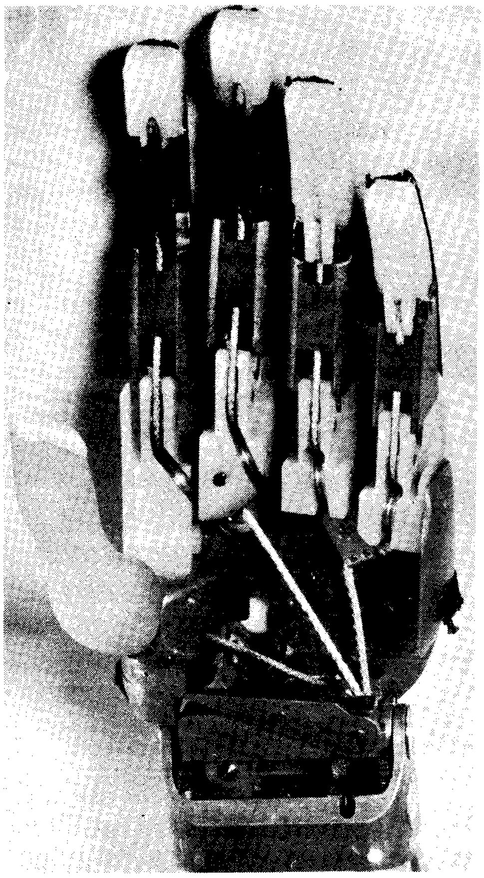

Fig. 1. The SVEN-hand without the palm of the hand and cosmetic details

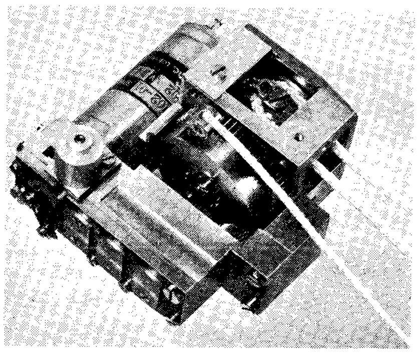

Fig. 2. Mechanism for finger flexion and thumb rotation

Construction material used for finger-details is nylon, and electron for other details. All pulleys and rollers have ball bearings, and the fingers have sleeve bearings.

Mechanisms

Finger Flexion

The mechanism for the finger motion has a DCPM-motor followed by 5 gear stages and cord-drums for the cords from the fingers (Fig. 2).

To keep the efficiency as high as possible (90% for the whole gear) high quality ball bearings and helical gear wheels have been used. As the gear, due to the high efficiency, is not self-braking a lock is needed. An electromechanical lock is used to lock the motor axis when no signal is fed to the servoelectronics. A spring-loaded catch holds a tooth on the motor axis and it is released by a small electromagnet.

The cords from the fingers and the thumb are wound on the same axis, though the thumb cord is connected via a clockspring. This arrangement makes it possible to lock the thumb in an outwardly rotated position and still flex the fingers. The gear ratio is 1:448 and with a motor producing a stall torque of 140 pcm (ARTUS MA 1292 XX 1B) the cord force is 40 kp.

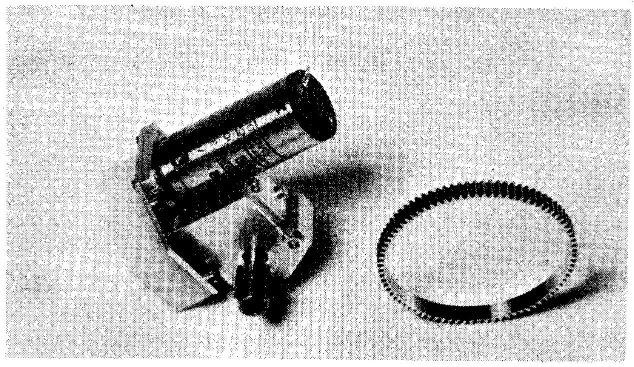

Fig. 3. Mechanism for prosupination

Pro-supination and Wrist Flexion

These mechanisms are self-braking wormgears (Figs. 3 and 4). The gear for wrist flexion is built into the wrist. The pro-supination gear works with a large tooth wheel attached directly on the stump socket. The whole prosthesis is rotating on a large ball bearing on the stump socket.

Electronics

When designing the servo-system, force and velocity feedback have been used to obtain a good proportional control of the motions under different environmental conditions. To be able to control the lock, a circuit is included which opens the lock when the input signal differs from zero. The force feedback signal is also included in this condition which gives a locking of the mechanism when maximum force is obtained in order to preserve maximum force of the grip.

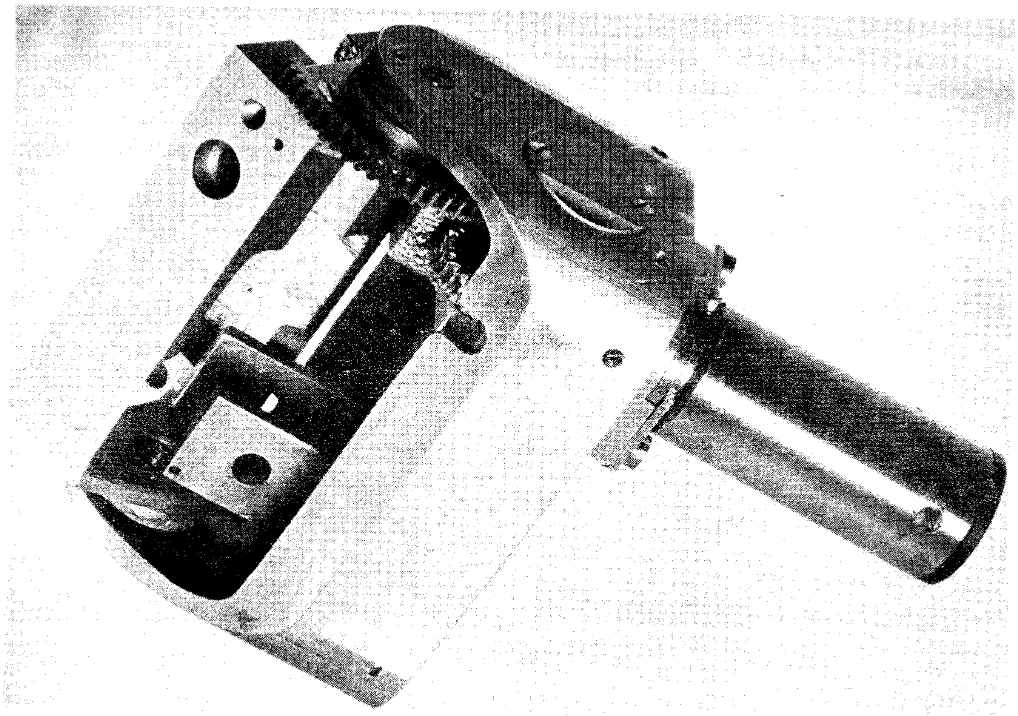

Fig. 4. Mechanism for wrist flexion

Motor Control and Feedback Systems

The torque from the motor is controlled by a pulse-width modulation system. Hence the motor armature voltage is pulsed with a constant frequency of 150 Hz and the pulse length is varied depending on the desired torque. The main reason for using a pulsed system is that it makes it possible to use an electronic velocity feedback without a tachometer because the motor between the pulses works like an unloaded generator or tachometer (Fig. 5). The generated voltage, proportional to the velocity, is measured via an electronic FET switch which is turned on between the motor pulses.

The circuitry can be seen in Figure 6. The pulse width modulator for positive input signals (from OP_2) consists of the transistors T_1 and T_2, and for negative signals, the complementary circuit below. These are followed by power amplifiers that feed the motor. The pulse frequency is generated by the flip-flop shown in the left bottom corner of the diagram.

The transistors, T_{12}, T_{13}, and T_{14} give the proper pulses to the FET switch, T_{15}, which feed the velocity signal via a storing capacitor, C_4, to the summing amplifier, OP_2, to which the input signal and force feedback signal also are fed. The force feedback signal is obtained by measuring the average current through the motor. (This circuitry is not included in Figure 6.)

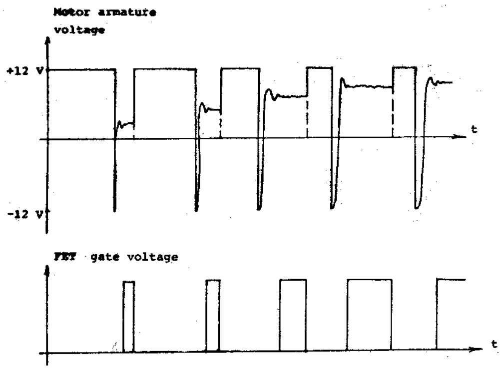

Fig. 5. Motor armature voltage and FET gate voltage plotted versus time

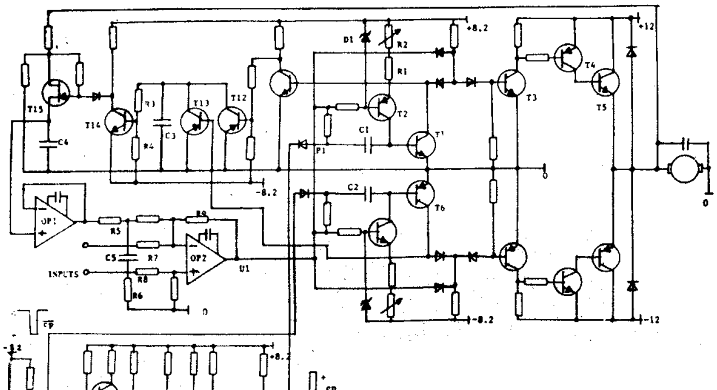

Fig. 6. Servo electronics for velocity control

System Properties

With the above described mechanical components, a system with one to three actuated movements can be put together. If a movement is not actuated, it can be passively adjustable by means of a friction coupling. The system can be used by below-elbow amputees with stumps within 8 cm proximal to the wrist. The center of gravity will be rather close to the elbow so that the torque on the elbow will be rather low (Fig. 7).

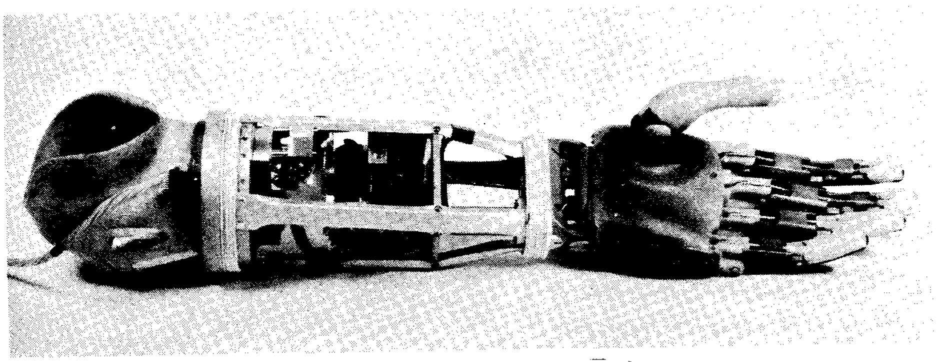

Fig. 7. The SVEN-hand system without electronics and cosmetic details

Some dimensions of interest:

The grip:	Maximum grip-force in a threepoint grip		6 kp
	Maximum grip-width		90 mm
	Power consumption at maximum force	2A at	12 V
	Minimum flexion time		1 s

Some grip examples can be seen in Figures 8, 9, and 10.

Other movements:		End to end minimum time
Wrist flexion	± 45°	1 s
Supination	90°	2 s
Pronation	220°	(2 s)
Passive ulnar deviation	30°	-
Weight for a complete system	1200 - 1500 gr	

All components are tested for 200,000 working cycles.

For a hand with just the grip actuated, all electronics can be put into the construction. EMG-control electronics are attached to the stump socket. Different ways of controlling all three movements have been studied in our laboratories and a portable prototype is ready for tests on patients.

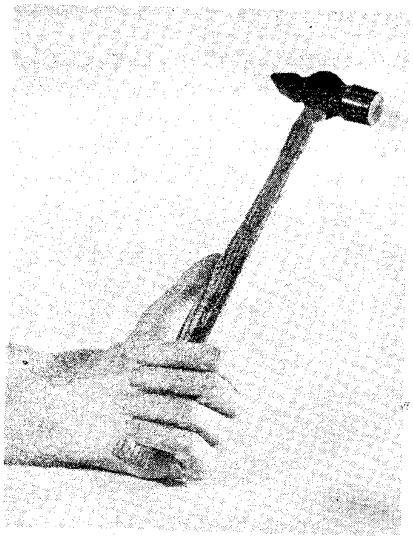

Fig. 8. Grip with the thumb in an outrotated position

Fig. 9. Adaptive grip

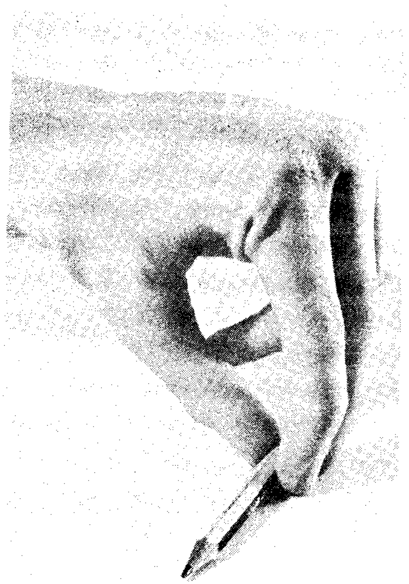

Fig. 10. Three point grip

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