SOME ASPECTS OF THE DESIGN OF AN EMG-CONTROLLED ARTIFICIAL HAND WITH TWO FUNCTIONS

F.H. Germans, F. E. M. Brekelmans, and D. W. Wijkmans

Summary

Our group has tried to develop the concept of a two-function hand controlled with four EMG signals. The choice of an electrical system instead of a pneumatic one is discussed briefly.

Pronation and supination will influence the performance of our original system. A method to overcome this is described.

A simple design for a hand with two functions is given.

Introduction

On the preceding conference in Dubrovnik, Beeker, et al [1] reported on our work done on isolating at least four surface EMG signals obtained from the stumps of below-elbow amputees. The control system based on our findings consisted of EMG pre-amplifiers, adjustable thresholds, pulse-circuits and electropneumatic valves.

A proportionality between the myo-pulses and the gas-pulses was obtained. This system is described in more detail by During, et al. The feasibility of the system was demonstrated by fitting it on a below-elbow amputee with pneumatic prosthesis with one hand function and wrist-rotation.

Due to practical considerations we decided to give up a further development of the electropneumatic system. The main reasons were the weight and the shape of the CO_2 bottle and the difficulties of refilling. Moreover a system with one power-source seems to be more elegant.

Choice of System

If gas is eliminated as a power source there remains at least two possibilities, a hydraulic and an electrical solution. For the time being we have chosen for an electrical solution.

Specifications of the Hand Prosthesis

In the case of below-elbow amputees we would like to make ultimate use of the possibilities of the patients. In our case this amounts to the use of the pro- and supination possibilities of the stump (eventually with the aid of a mechanical amplification system of the remaining rotation), for controlling the wrist-rotation.

By doing so we have four EMG signals for the control of the hand functions. Our ultimate goal is to make two independent movements of the hand with these four signals.

The first can be to give the thumb a motion which is a combination of rotation, flexion and extension. The second can be flexion and extension of the four fingers.

In this way it will be possible to make three grips, viz.: lateral grip, pinch grip and power grip.

The design described below must be considered as a first step in this direction, because the two movements are not independent. Therefore only two of the three possible grips can be made.

Electrical System

As During [2] described already, four surface EMG signals can be successfully isolated, as long as the stump is in the neutral position. If however pro- or supination is applied, the amplitude of the EMG signals (and more seriously) the crosstalk will alter. This is illustrated in Table I.

TABLE 1

Estimated value of E.M.G. signals and crosstalk in adjacent channels.

	type of movement	neutral arm position	90° supination	90° pronation
Channel 1	flexing of fore-finger	(38) 28 < <	(42) 20 < <	(28) 32 < <
Channel 2	flexing of ring and little finger	8 (41) < <	5 (60) < <	8 (50) < <
Channel 3	stretching fore-finger	< < (24) 20	< < (18) 13	< < (28) 22
Channel 4	stretching of ring and little finger	< < 12 (49)	< < 11 (30)	< < 18 (40)

Four pair of electrodes were put on the below-arm in the spots where the output of the EMG signals were optimal.

In Table I the estimated value of the EMG signal (measured in an arbitrary way) is given for a given movement by an encircled number. This is done in three different positions of the arm. The crosstalk in the other channels is also given.

If the system is to be of any use to the patient, there has to be a fixed threshold, in each of the channels, which must be at least as high as the maximum "crosstalk" in any position of the forearm.

The ratio between signal and crosstalk must of course be > 1. From Table I, it can be seen that this is not always the case (f.i. channel 1, 90° pronation 28/32 and channel 3, 90° supination 18/22).

Owing to this fact this method does not allow an independent control of a two-degree of freedom device in any position of the below-elbow stump. Therefore a new approach of signal-isolation has to be made.

It can be seen from Table I that the signal from the muscle, though varying considerably, is always larger than the crosstalk in the adjoining channels in all three positions.

Other workers in this field have used the difference between the control signal and the crosstalk for the control of velocity or force of the hand prosthesis. If there is much crosstalk as in our case, the difference between two rather big signals tends to be small and subject to large variations. Therefore we choose to use the polarity of the difference for opening and closing a linear gate. (See Figure 1)

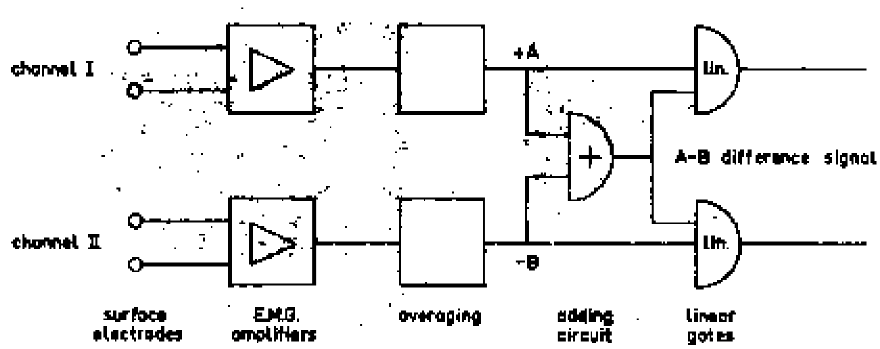

Fig. 1. Block diagram of a pair of linear gates as a part of control circuit.

If, for example, A > B the gate of channel I will be opened and that of channel II will be closed. If A < B the gate of channel II will be opened and that of channel I will be closed.

It is known, that if a linear gate is opened the whole analog signal can pass and the proportionality with the EMG is maintained.

The relation between muscle force, EMG and output is provided by transforming the analog signal, that passes the gate, into a signal with constant pulse-repetition rate from which the pulsewidth is varied by the EMG signal. This is done in the manner described already by Hierton, et al. [4].

An advantage of our system is that each degree of freedom is controlled by the pair of muscles that have the greatest mutual influence.

Mechanical Construction

Choice of movements.

As may be seen from the literature the three main grips are the precision grip, the power grip and the lateral grip. The EMG controlled hands which are now commercially available are nearly

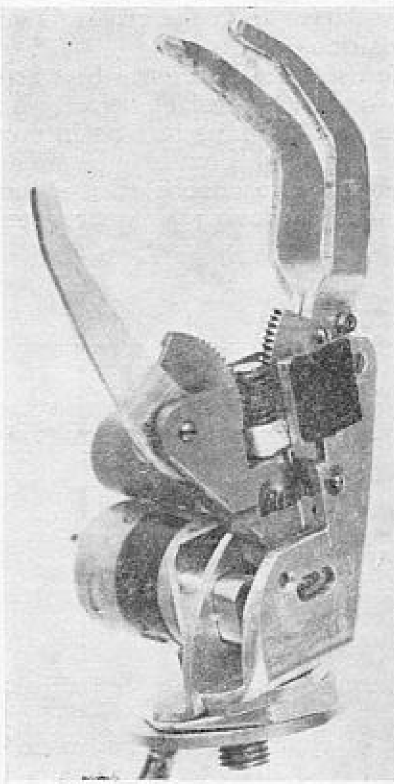

Fig. 2. View of the first design of the mechanical construction.

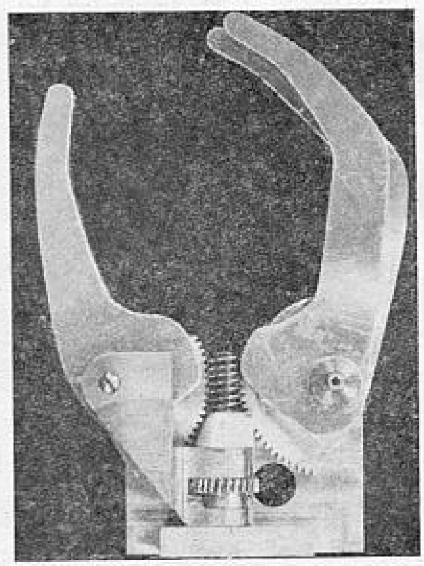

Fig. 3. Close-up of a second design of the mechanical construction.

all of the precision grip type and seems to be readily accepted by the patients. Starting from this we considered a construction as simple as possible and which will add a second movement to those, which poved to be of value in praxis.

As a first trial we chose a circumducting movement of the thumb. In this way we added the lateral grip to the precision grip. In every position the thumb and the forefinger are coupled together. The construction can be seen in Figures 2 and 3.

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