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PROPORTIONALITY IN EMG-CONTROLLED PROSTHESIS. A PILOT STUDY

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Abstract

The value of proportional EMG-control in handprosthesis has been widely discussed. The application of the so-called "SVEN-hand" on a patient made it possible to measure parameters as input signal, motor velocity and torque in a control system with fairly good proportionality both in velocity and force while the patient was doing test tasks. The significance of proportionality of velocity and force is discussed with references to the measurement results.

Introduction

The application of EMG-controlled prosthesis is today routine-work at many clinics and workshops throughout the world. Although many development projects in the field envolving advanced techniques have been laid down, continuous improvements can be seen on commercial equipment telling that myoelectric control has come to stay.

One feature that has been considered as desirable is proportional control, i.e. some performance of the hand, usually the gripping force and/or speed should be proportional to some property of the EMG-signal, usually the intergrated EMG.

This has been obtained in technically different ways with a more or less true proportionality.

It is a wellknown fact that a true proportional servo implies some kind of feedback technique where the variable of interest is fed back in a control loop. The Swedish SVEN-hand is one of the few developments in the field where this feedback technique has been carried through consequently with both force and velocity feedback. Hence at free run the velocity is proportional to the input signal and when a grip is obtained the force is proportional to the input. See ref 1.

With this handprosthesis it is possible to measure parameters as input signal, grip-velocity and motor torque on line while the amputee is doing test tasks.

Substancial work has been done at many centers investigating the ability to perform tracking tasks in one or two dimensions with EMG-control. Unfortunately these investigations tell us little about the control situation in which a hand prosthesis is used.

When discussing these matters all arguments should be referred to a control strategy. For an externally powered handprosthesis two parts of totaly different nature can be discerned. The first one is to bring the fingers in contact with the object of interest as fast as possible. The second one is to apply a sufficient friction force to be able to manipulate the object without dropping it but also without breaking it. In the case of myoelectric control without any artificial biological feedback neither of these parts necessarily imply proportional control.

In the human hand, for instance, the sense of force is very poor. Matthews et al (ref 2) have shown that a test subject who has leaned to perform a certain grip force level with visual feedback from a force transducer has a very poor ability to reproduce the same force when the visual feedback is taken away even immediately afterwards.

The integrated EMG of the muscle is approximately proportional to the force developed. Hence the results by Matthews et al would indicate that the reproducability of the integrated EMG is poor.

If the proportional control would be found unnecessary it would imply much simpler systems. A proportional system also demands much higher signal to noise ratio than a conventional ON-OFF system, something that can cause trouble at weak signals.

With this background it was considered to be of great interest to study the role of proportional control when applied in a practical application of the so-called "SVEN-hand".

Measurements

At the time of the measurements only one amputee wearing the "SVEN-hand" was able to join the team for the measurements. The test subject (male) was at the time 28 years of age. The subject had been using the SVEN-hand for one year and a half and before that a conventional ON-OFF myoelectric prosthesis for one year. The amputation was 20 years old. Due to a change of occupation of the test subject the measurements could not be followed through completely.

The tests were performed as follows.

Test 1

The testsubject was told to seize, lift, put down and release a soft fragile plastic cup with water. This was performed 10 times. During these tasks the following parameters were registered.

Input signal (integrated EMG)

Motor velocity

The torque of the motor

Test 2

The testsubject was told to seize and lift an egg and then immediately apply the same force on an electric force transducer. This was repeated 10 times. The signal from the force transducer as well as parameters mentioned above was registered.

During both tests no information of the measured parameters was fed back to the test subject.

Results

Test 1

When studying the registered parameters a typical pattern is discerned. This pattern is seen in fig. 1. The figure shows the integrated EMG-signal (M), the velocity (V) and the motor torque (T) plotted in relative scales versus time.

The pattern is characterized by the distribution of the activities into subactivities. The first one with index "t" is the "transportation" phase where the fingers are brought to contact with the plastic cup. During the following phases with index "f" a grip of the cup is obtained. These phases are usually two but sometimes more. During these latter phases slight velocity deflections can be seen. These are due to deformation of the cup. The variable "T" unfortunately gives a rather poor information of the grip force at these low levels due the losses in the glove and transmission.

A basic statistic analysis of the maximum variables M_t and M_f and the time increments T_f has been done with results as follows.

Parameter	Mean value	Standard deviation	
M_t	10,77	1,85	relative units
M_f	7,31	1,59	$M_{max} = 20,0$
T_f	0,65	0,20 s	

Test 2

The amputee runs the fingers until contact with the egg is obtained. Then he does an attempt to lift it. If this fails he gives a small signal to increase the force until he can lift the egg. Unfortunately the motor torque registrations give little information of the same reasons as mentioned above. The only registration of interest was the signal from the force transducer. The statistics of the maximum value are as follows.

Mean value: 5,1 N (0,52 kp)

Standard deviation: 2,6 N (0,27 kp)

Discussion

The measurements have been done only on one amputee and furthermore further tests had to be cancelled due to practical conditions of the moment. The authors hope to be able to continue the measurements in the future. However, some interesting conclusions can be drawn of course with restrictions of the general significance.

The results of the first test indicate that the amputee applies a pulsed procedure until a desired grip is verified with the sight. It should be noted that in this case it is possible to verify the grip of the cup by watching the deformation of the cup.

The second test tells that the force control when no direct feedback by sight is possible (at least as long as the egg does not crack) is very poor.

No direct design implication can be derived from this work. A more extensive investigation should be carried through comparing proportional control with ON-OFF control in practice.

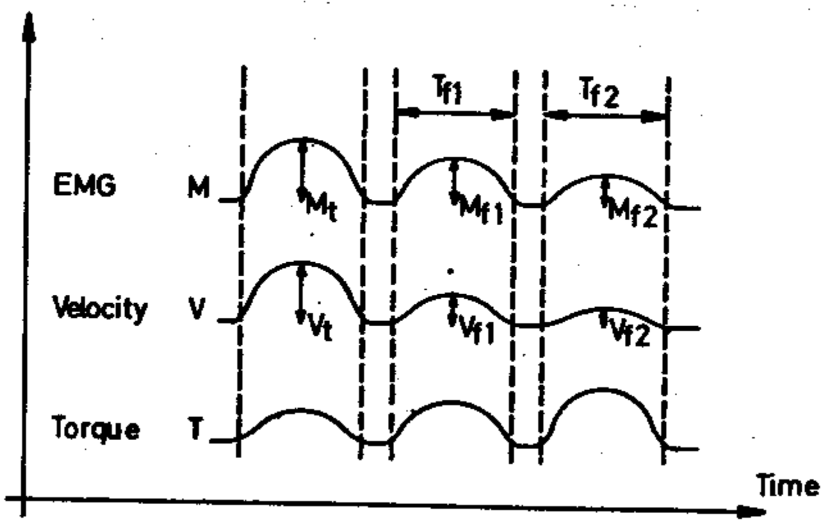

Fig. 1. Typical pattern.

References

(1) G. Hägg, K. Spets; SVEN-project I-Electrically controlled handprosthesis- Final report; Swedish institute for the handicapped 1973.

(2) L. Matthews, B. Klasson, C. Hirsch; The role of skin sensation in the perception of strength of grasp; Acta orthop. Scandinav. 43, 1972.

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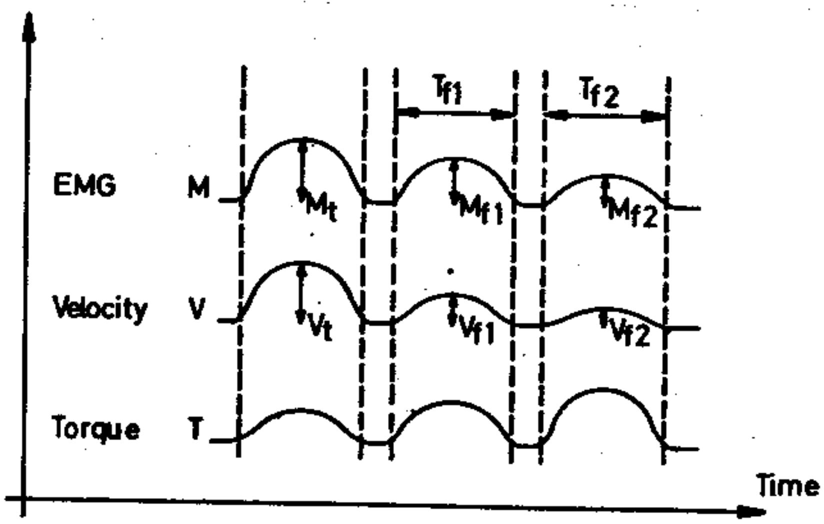

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