Development of Biomimetic Prosthetic Hand

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The purpose of this study was to develop a new type of the sensory feedback system for the myoelectrically controlled biomimetic prosthetic hand. One of the characteristic features of the neuromuscular control system in man is an increase in the compliance around the joint, with the decreasing activity of the muscle. For the sensory feedback system the interferential current with two waves was used, and low frequency current in the body was synthesized. Whether the difference of stimulus can be detected by the interference current was examined in our previous study. These results show that the subjects can distinguish the change of the stimulus frequency when one frequency is fixed and the other frequency is changed. The interference current was confirmed to be a useful method for the sensory feedback system of the prosthetic hand. However, this method can transfer only one kind of information. We want to transfer two kinds of information, such as the grasping force and the finger angle. Therefore, the aim of the examination was whether the point of the stimulus could be moved with fixed electrodes. Our experimental results show that the phase change can be successfully used to move the stimulus point.

Keywords: prosthetic hand, sensory feedback system, interference current

1. Introduction

Powered hand prostheses are used to substitute for functions of the lost natural hand. The common commercial prosthetic hands, which are used clinically, are often controlled by myoelectric signals (electromyogram, EMG), and they are referred to as myoelectric hands.

If the prosthetic hand had the same mechanisms and mechanical properties as the neuromuscular control system of the human hand, an amputee may be able to utilize almost the same subconscious control as used before the amputation of the natural hand. Consequently, training periods required to operate such a prosthetic
hand would be much shorter than for the conventional myoelectric hand. The amputee would be able to perform tasks precisely or to handle soft objects more dexterously with this hand.

The goal of our study was to develop a new type of the biomimetic myoelectric hand prosthesis with an artificial sensory system. The prosthesis consists of one degree-of-freedom end-effector, an electromyogram signal processing unit, a microprocessor-based servo system for the DC motor and artificial sensory system. The key feature of this hand was the ability of the subjects to control the compliance and the finger angle of the prosthesis with the EMG signals. The basic functions of the neuromuscular control system were realized by using a position control, force feedback and a variable gain modulated by amplitude of EMG signal.

If the prosthetic hand has ability to transmit the status of the hand, such as the finger angle or the grasping force, to the amputee, the amputee will be able to perform tasks precisely or to handle breakable objects more deftly with this hand than with conventional myoelectric prosthetic hands.

The purpose of this study is to develop an artificial sensory feedback system that could transmit the status of the prosthetic hand. In this study, the main point of our interest was whether it was possible to move the stimulus point with the fixed electrodes by using the interference current.

2. Stimulating Method

When a sensory feedback system for a prosthetic hand is considered, it is very important that the control system of the prosthetic hand should constitute its own support and be a built-in type. From this point of view, electrical stimulation is superior to the mechanical stimulus, because it is possible to make the system small and its energy consumption is low. But electrical stimulation has some problems, such as skin impedance, pain and interference with the myoelectric control system when the electric stimulation is applied near an electrode for electromyogram.

Normally, the electric stimulation uses frequencies from 2 Hz to about 200 Hz. The skin impedance for this frequency range is high. Therefore, quite high frequency signal are used, such as from 4000 Hz to 5000 Hz. If two electric fields of different frequencies, or out-of-phase medium frequencies cross, the superimposition of the amplitudes in the points of crossing results in a new frequency, this is called the interference current (IFC) [1, 2]. With the aid of the two-field medium frequency, through the procedure described above, the desired low frequency stimulation can be “displaced” out of the immediate vicinity of the electrodes into the depth of the body.

The advantages of IFC are following:
1) the electric current takes the path through the body;
2) the stimulating point can be selected by fixing the position of the electrodes and changing the size;
3) the skin impedance is low, because the frequency of the current going through the skin is high.

In this study, the main point of our interest was whether such an interference wave can work as sensibility feedback equipment for the prosthetic hand.

3. Method

The aim of the examination here was how to change the sensing position of the stimulation, without moving the position of the electrode attached onto the subjects. Attention was paid to the phase difference between two stimulus waves. IFC wave stimulus device that can change the phase difference was constructed. Figure 1 shows the diagram. The output voltage is changed from 0V to 8V, and the phase difference is changed from 0 degrees to 180 degrees. The output frequency is fixed at 5000 Hz. F1 is the output before changing the phase, F2 is the output after changing the phase and G indicates the ground.

![Diagram of IFC equipment](image)

4. Experiment

The subjects were normal young volunteers. The upper arm was chosen for the stimulation position. Before the stainless steel electrodes were attached on the biceps brachii muscle, the skin was wiped with alcohol and some paste was put onto the skin. Figure 2 shows the positions of the stainless steel electrodes. The subject sits on the chair and his arm is relaxed. These two stimulant signals with the phase difference were applied to the subject.

When the subject feels the stimulation, he/she points to the position of stimulation sensed point on the scale, which is divided by equal 5 lengths, as shown in Fig. 2. There were four stimulation patterns.
(A) The phase difference is changed from 0 degrees to 180 degrees each 10 degrees.  
(B) The phase difference is changed from 180 degrees to 0 degrees each 10 degrees.  
(C) The phase difference is changed from 0 degrees to 180 degrees continuously.  
(D) The phase difference is changed from 0 degrees to 180 degrees continuously.

To prevent habituation, the order of above mentioned four patterns can be changed.

5. Results

Figure 3 shows the relation between the phase difference and the position of sensing stimulation in the case of pattern A and B. The values shown in Fig. 3 are the average value of the whole subject’s sensing position of stimulation. These results show that the sensing positions of pattern B are high comparing to those of pattern A.

6. Discussion

Our results show that point of sensing stimulation moved with the position of the electrode fixed. When the phase difference decreased from 0 degrees to 180 degrees...
degrees, the subjects felt the position different from that of the reverse mode. This means that there is hysteresis. Whether this hysteresis affects the sensory feedback system or not should be a subject of our further studies.

7. Conclusion

This study has confirmed that the phase difference of the interference current can transmit information by the stimulus sensing point. Therefore, this system can be informative of the state of the prosthetic hand in amputee. An endeavour to produce a sensibility feedback device for a prosthetic hand, using the interference current, should be a part of our future research.

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References