Measurement system to determine the contraction time of the forearm skeletal muscle

S. Guttke[1], Ch. Rückerl[2]
[1] HTWK Leipzig, Waechterstrasse 13, 04107 Leipzig, Germany, sebastian.guttke@htwk-leipzig.de
[2] Research and Transfer Center at HTWK Leipzig, Germany

Abstract

A measurement system is described which can measure the contraction time of the forearm muscles. During muscle contraction, the circumference of the forearm increases as a function of the force applied. As sensor for measuring that minor expansion, a cuff as compressible volume, is placed around the arm. Compression of the cuff volume increases the pressure; that pressure measures the muscle contraction. In this way, for example, the latency time or the contraction time of the electrically stimulated muscle can be measured by a non-electrical signal. The results can be used for medical diagnostics or fundamental physiological examination. First tests showed that latency and contraction time can be determined with sufficient accuracy for fundamental studies.

Key words: muscle contraction, electrical stimulation, contraction time, pneumatic force sensor.

Introduction

The current through the body in an electric accident can cause contraction of the skelatal muscles. In case of alternating current which exceeds the let-go threshold the duration of the contraction is equal to the time for which the current flows. Therefore, when the let-go threshold is exceeded, the victim loses control of his/her muscles and cannot stop the contact. This type of behavior cannot be observed in case of direct current. The question is how the muscle contraction proceeds when the current is turned on. Four different phases are identified in [1]: Latency, shortening phase, tetanic state and attenuation phase. Details of these phases have not been reported. The present studies into the effects of direct currents (DC) on the human body [2] show that the contraction duration and therefore the maximum contact duration cannot be specified so far. The purpose of the measuring system described below is to provide a very simple method by which the temporal processes of an electrically induced muscle contraction can be studied. In [4] and [5] are shown comparable but more complicated sensors with a local resolution for such measurements of muscle contraction.

Electric current is also used in medicine. Often, the purpose of treatments by which nerves and muscles are stimulated by electric current are to build muscles [3]. In these cases, the current is increased until the therapist can see the contraction. A system for measuring the muscle contraction can objectify that subjective approach. Besides, it is also possible to develop controlled therapy devices.

A measuring system is presented which offers a simple solution both for fundamental studies and therapeutic application.

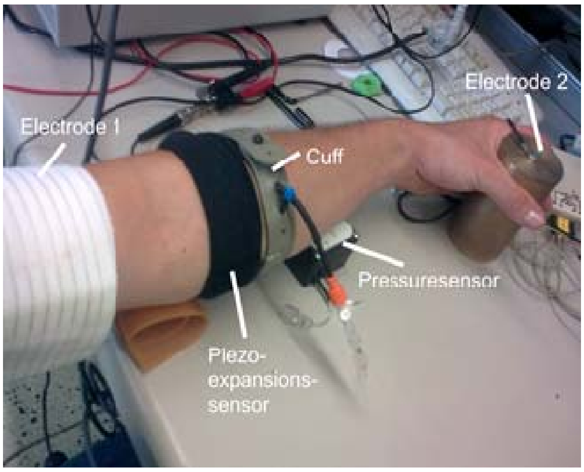

Fig. 2. Measurement setup at the forearm. Piezo sensor was applied for a test.

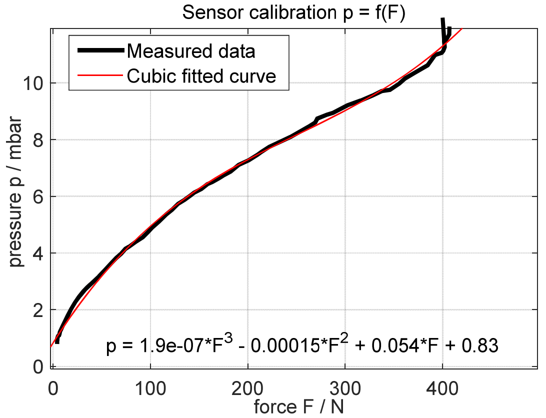

Fig. 3. Pressure measurement as a function of the force in the fist.

For determining the characteristic, the force was increased uniformly and the output voltage of the pressure sensor, U_{ak}, measured. Using

Results

The contraction times of the forearm muscles were determined by the measuring system. Fig. 4 shows the time characteristics of the electric current and the cuff pressure. The general course of the contraction can be seen. The maximum contraction occurs after about 0.1 s. The contraction has abated after approximately 0.5 s. When alternating current is applied (Fig. 5) the maximum contractive force occurs after about 0.2 s (Fig. 6). Contraction continues for about 0.1 s after the electric current is turned off (Fig. 7).

The change of the output voltage that can be obtained by voluntary muscle contraction (grip of about 400 N) is of the order of 450 mV. According to (2), this is equal to a pressure change of 11.2 mbar. Under conditions of electrically induced muscle contraction, maximum pressure changes of less than 2 mbar were measured. For improving the sensitivity and the SNR a pressure sensor with a measuring range from ±5 mbar to ±20 mbar should be used.

Summary

The measurements performed so far on individual subjects have shown that fault effects are low. The change of compliance when the cuff is put on can be neglected. The temperature effect should be eliminated by an offset adjustment after thermal stability is reached.

The muscle contraction of the arm, maybe also of the leg, can be measured by the system described. Latencies and the duration of contraction, in particular, can be measured in a simple way with this system. The system is neither dependent on the time characteristic of the stimulating current nor is it affected by it. The results include the contraction of several muscles. This sensor should be used on many subjects for the purpose of obtaining general data on the duration of contraction in the event of direct current accidents. A check-back of the pressure signal to the force is not necessary for these examinations.

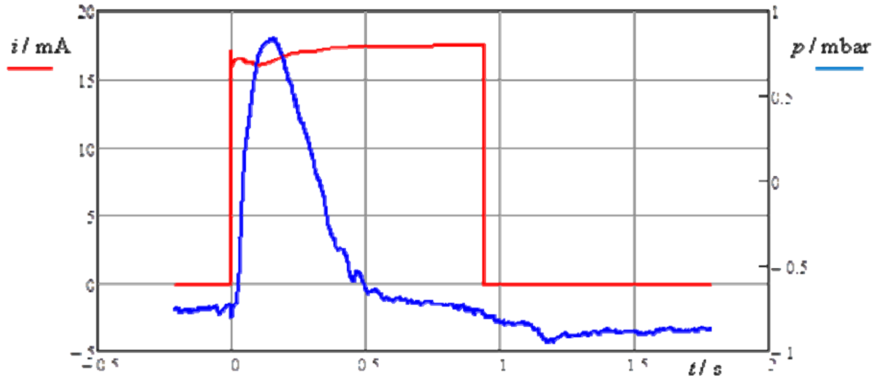

Fig. 4: Example for a current of 16 mA (red) and the pressure (blue).

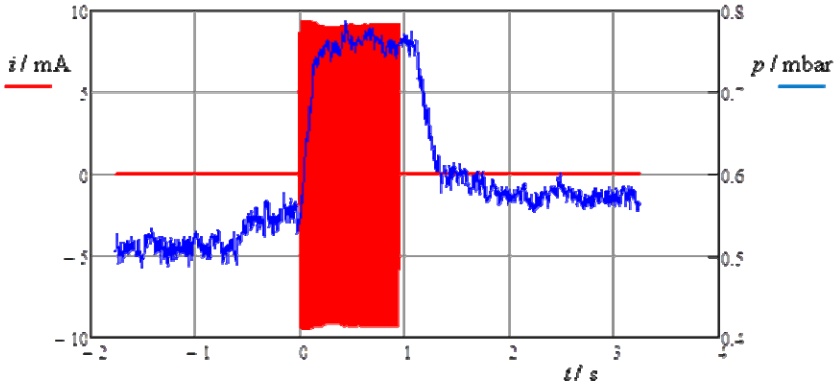

Fig. 5 Example for an alternating current (50 Hz) and the measured pressure (blue).

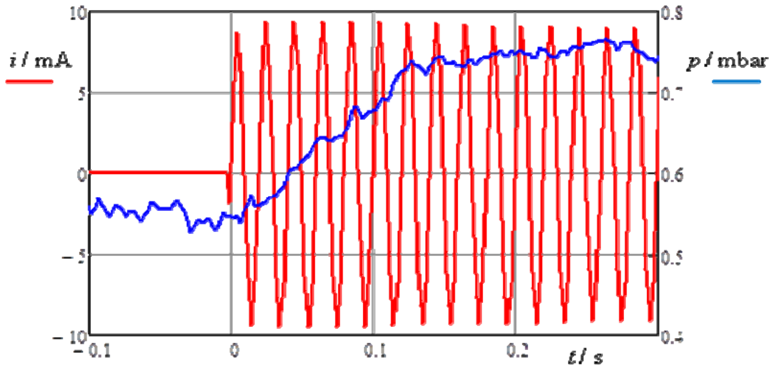

Fig. 6 Current and pressure at the beginning of the alternating current flow.

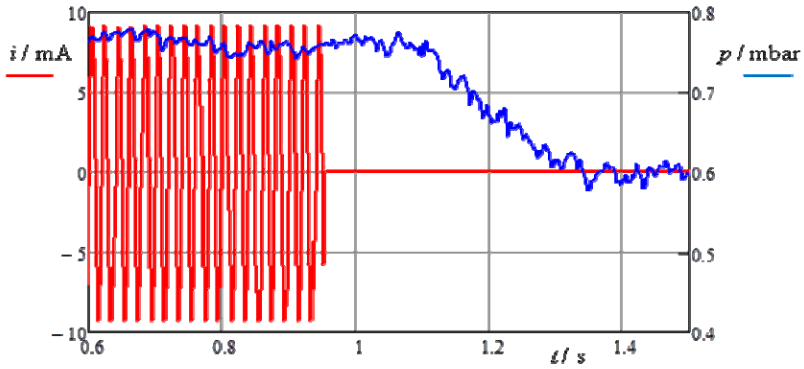

Fig. 7 Current and pressure after turning off the current.

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