Functional Electro Stimulation monitoring by bending sensitive magnetostrictive bilayer Sensors

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Abstract. A novel sensor system is presented utilizing bending sensitive bilayers. The sensor system detects the contraction-dynamics of the upper femoral musculature during electric stimulation for diagnostics of muscle fibre recruitment and muscle twitch-dynamics in Functional Electro Stimulation.

1 Introduction

Recent experimental and clinical work gives strong evidence that functional electrical stimulation (FES) is a powerful tool for regeneration, functional restoration and maintenance of skeletal musculature. To monitor the muscle status the used methods imply several disadvantages. For force or stiffness measurement the patient has to be fixed to the measurement equipment. Ultrasonic or Computer-tomography pictures can also only be made in the laboratory, needing heavy and complex equipment and can hardly be used in a control loop. Muscle-myography and plethysmography use electric measurements which are interfered by the FES directly and therefore need compensation. For closed loop control in mobile applications, mobile and light weight sensor systems are needed [1,2].

2 Method

In this work we present a novel magnetostrictive bilayer sensor system based on the magneto elastic effect [3], which is not affected by the high voltages of the FES. The sensor element consists of a magnetostrictive layer fixed on a non-magnetic counter-layer and a pickup coil. Bending the bilayer introduces pure tensile or compressive stress σ in the magnetostrictive layer, if the counter-layer thickness is large enough to shift the neutral bending area out of the magnetostrictive layer. Due to the magnetoelastic effect, σ induces changes in the magnetic permeability, which can be measured by the pickup coil. For this study the sensor was applied between the stimulation electrodes detecting muscle deformations of specific femoral muscles (see Fig. 1). Its signal was generated by a specifically developed handheld unit. As a reference a force sensor was attached to the foot by the help of a cuff and a deflection roller, measuring the lower leg movement force.

3 Results

The recruitment characteristics can be seen via the bending signal amplitude S in Fig. 2. The amplitude of S is primarily characterized by a stimulation threshold of the musculature and a saturation effect. The saturation is reached if all muscle fibres are activated by the stimulation.

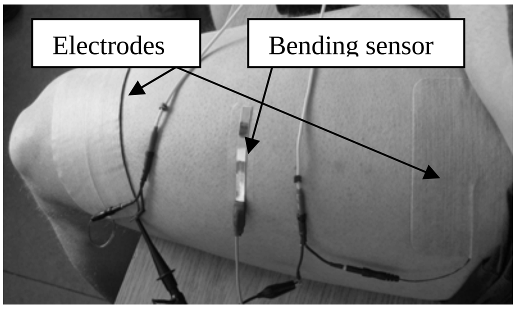

Fig. 1: Bending sensor applied between stimulation electrodes.

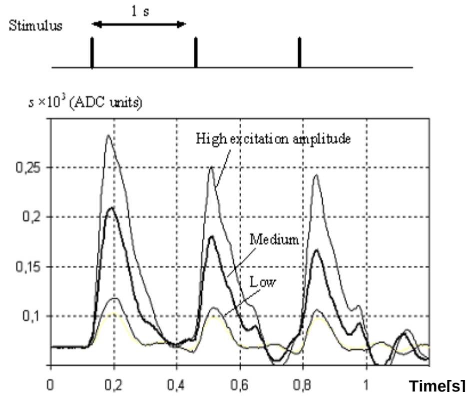

Fig. 2: Recruitment characteristics at 3 Hz and rising stimulation amplitude, detected by the bending sensor.

Figure 3 demonstrates the detection of the fusion frequency by gradually increasing the stimulation frequency gradually from 3 Hz to 20 Hz until a smooth muscle contraction is reached. Additionally, the muscle force increases, reaching a maximum.

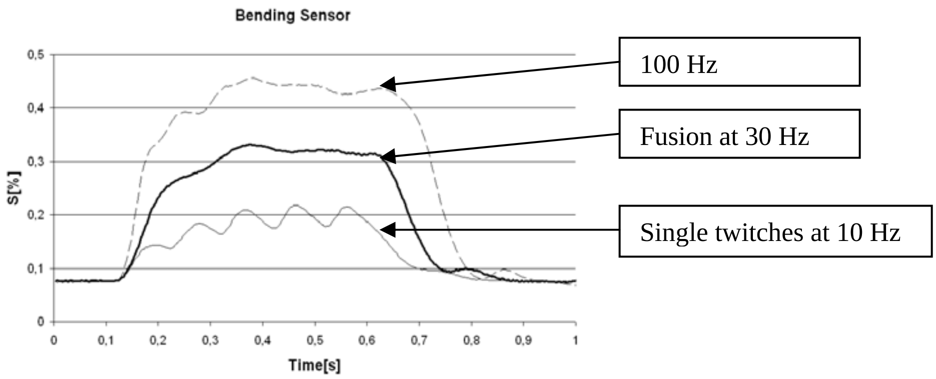

Fig. 3: Sensor signal *S* of magnetostrictive bilayer, sample rate 300 Hz, femoral position, impulse duration 1 ms fusion frequency reached at about 30 Hz with a stimulation amplitude of 21 V.

4 Conclusion

A handheld technology [4] of the bending sensor enables a mobile assistance of a leg pace maker, analysing and optimizing the muscle contraction characteristics of disabled people. Due to the used technology no electrical coupling of the stimulation impulses to the sensor signal is possible, which facilitates the detection of the muscle contraction during stimulation. Especially in the case of functional muscle stimulation where low weight and size, mobility, robustness and compactness are of high relevance the technology has proven to be highly suitable. The muscle twitch-dynamics and muscle fibre recruitment can be detected easily , with no need of an expert, with high sensitivity. We conclude that the bending sensor offers a highly effective possibility to determine physiological muscle parameters.

References

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