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Pilot study: Measurement of mechanical load using a glass-coated microwire for implantology applications

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MATERIAL AND METHODS - *Experimental design of a simlified model*

The design of the load measurement methodology for the experimental model was based on two basic parts:

1. Experimental design of a simplified model (cylinder)

2. Analysis of the change of the critical field of the glass-coated microwire in order to mechanically load the experimental model

The total number of experimental samples were 3.

- Sample 1 (diagonal fixation of a microwire in an experimental model)
- Sample 2 (horizontal fixation of a microwire in an experimental model)
- Sample 3 (vertical fixation of a microwire in an experimental model)

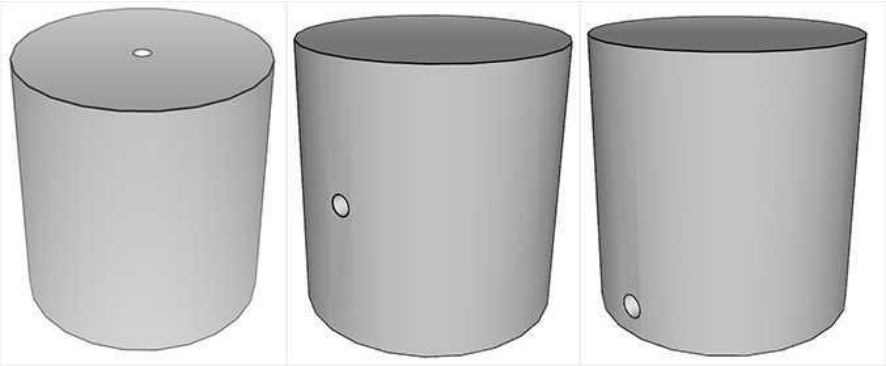


Fig. 1. Samples(left – vertical positioning of the microwire, middle – horizontal positioning of the microwire, right – diagonal positioning of the microwire)

- Sample material: Flexible polymer (FLEX – Black, Smart materials 3D company.
- The design of the models: cylinder 20mm x 20 mm
- Software: PTC Creo Parametric 3.0
- Microwire: Fe76Si19B10P5
  - D = 46 μm
  - d = 24 μm
- Fixation of microwires into experimental samples was preformed superglue

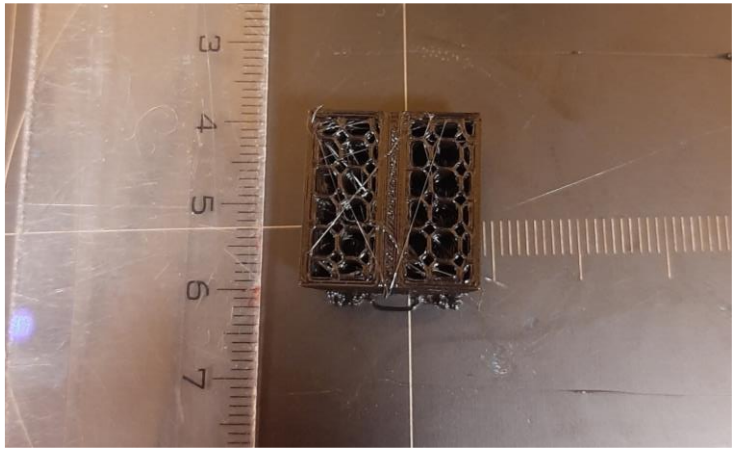


Fig. 2. The process of 3D printing an experimental sample with a vertical hole

MATERIAL AND METHODS - *Analysis of the change of the critical field of the glass-coated microwire in order to mechanically load the experimental model*

The aim of the analysis was to determine the changes in the critical field of the microwire in the measuring apparatus and whether it is possible to apply this type of microsensor to the cervical spine.

Used devices:

- Frequency generator (Function Generator GW instek GFG-3015) , f = 1111 Hz ; amplitude = 5V.
- Resistance R (100 ohm)
- Oscilloscope (Tektronix TDS 2001C), bandwidth = 200 MHz with a maximum sampling frequency of 2 GS / s.
- Excitation coil: copper wire , diameter 0.4 mm, number of turns 240
- Sensing coil: copper wire, diameter 0.056 mm, number of turns 700
- Force sensor (Lutron electronic FG-20KG-232)

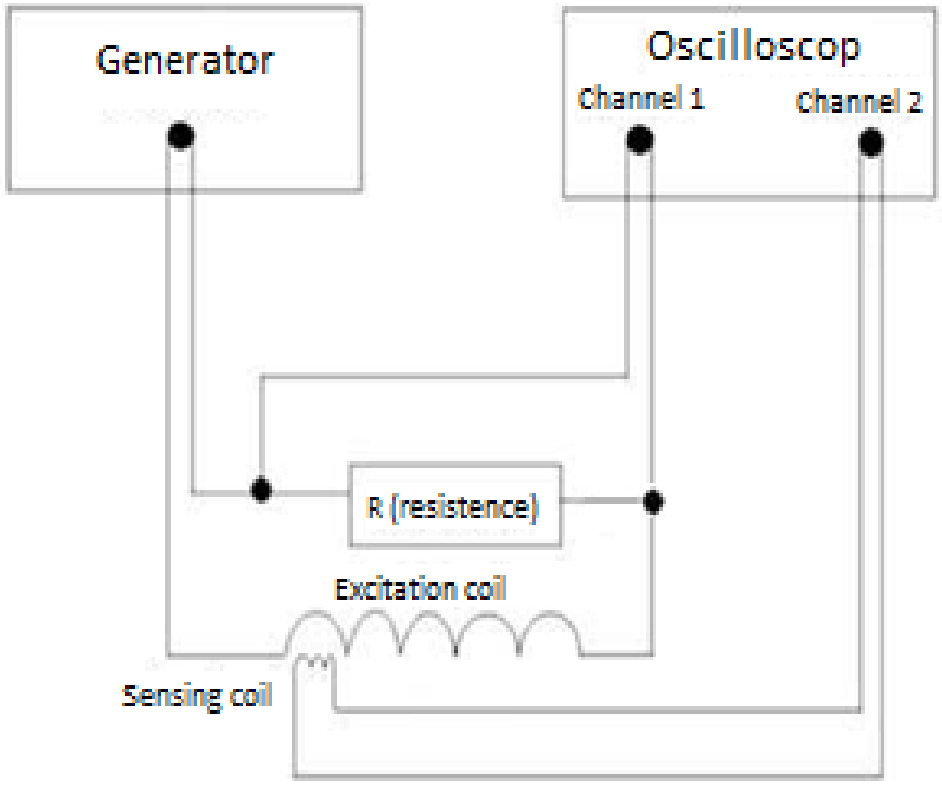


Fig. 2. Diagram of wiring measuring apparatus

MATERIAL AND METHODS - *Measurement process*

Preparation before measurements

- The beginning of the measurement consisted in the connection of individual electronic components to the required scheme.
- Subsequently, the frequency generator was set to the required parameters
- The next step was to insert the experimental model together with the glass-coated microwire between the excitation and sensing coils.
- In addition, the oscilloscope was set to the correct resolution so that a peak could be seen along with the sensing coil, which presents the critical field of the glass-coated microwire.

Measurement of mechanical load

- After setting the measurement technique, the experimental model was loaded with a force F = 40 N in the initial phase of the measurement.
- Subsequently, the function on the oscilloscope "stops" the course, while the cursor on the oscilloscope measures the initial time position of the peak.
- Then, the load on the experimental model, which represented the intervertebral plate in the static position, was increased by one force unit (F = 1 N) up to the value F = 50 N
- After each change in load, there was a change in the cursor of the sensing coil in the form of a time shift of the peak. All changes in individual load intervals were recorded.
- This measurement was performed on three experimental models for positioning the microwire in the horizontal, vertical, and diagonal positions.

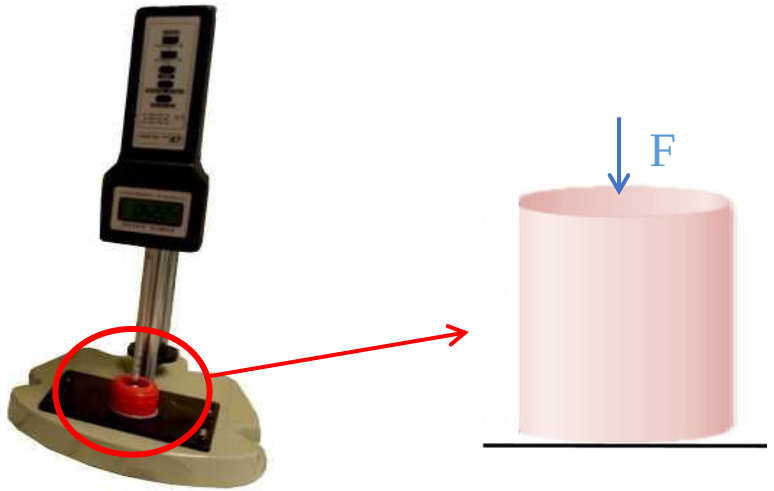


Fig. 4. Orientation of the experimental sample with the microwire during the mechanical load test

MATERIAL AND METHODS - Measurement output

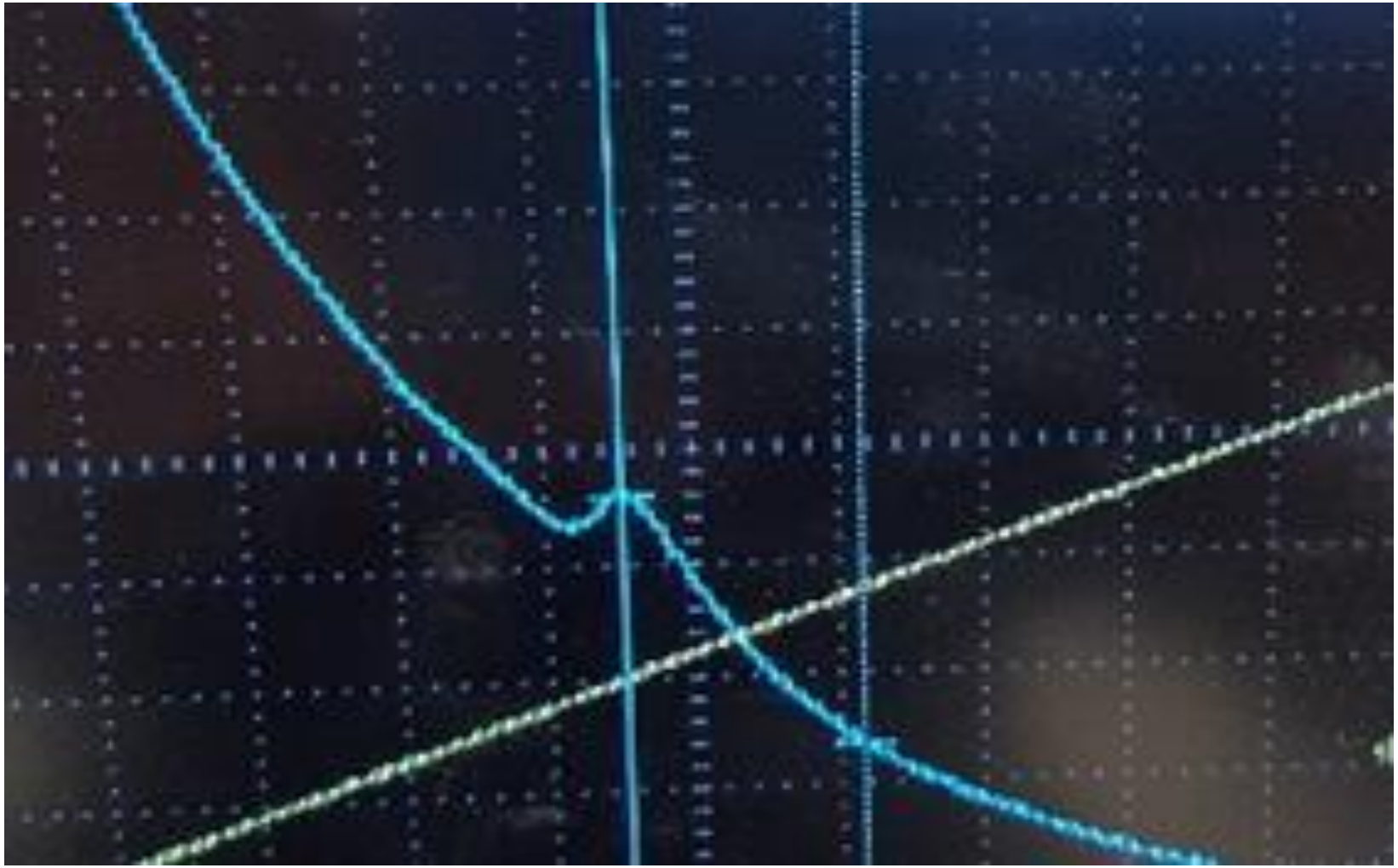
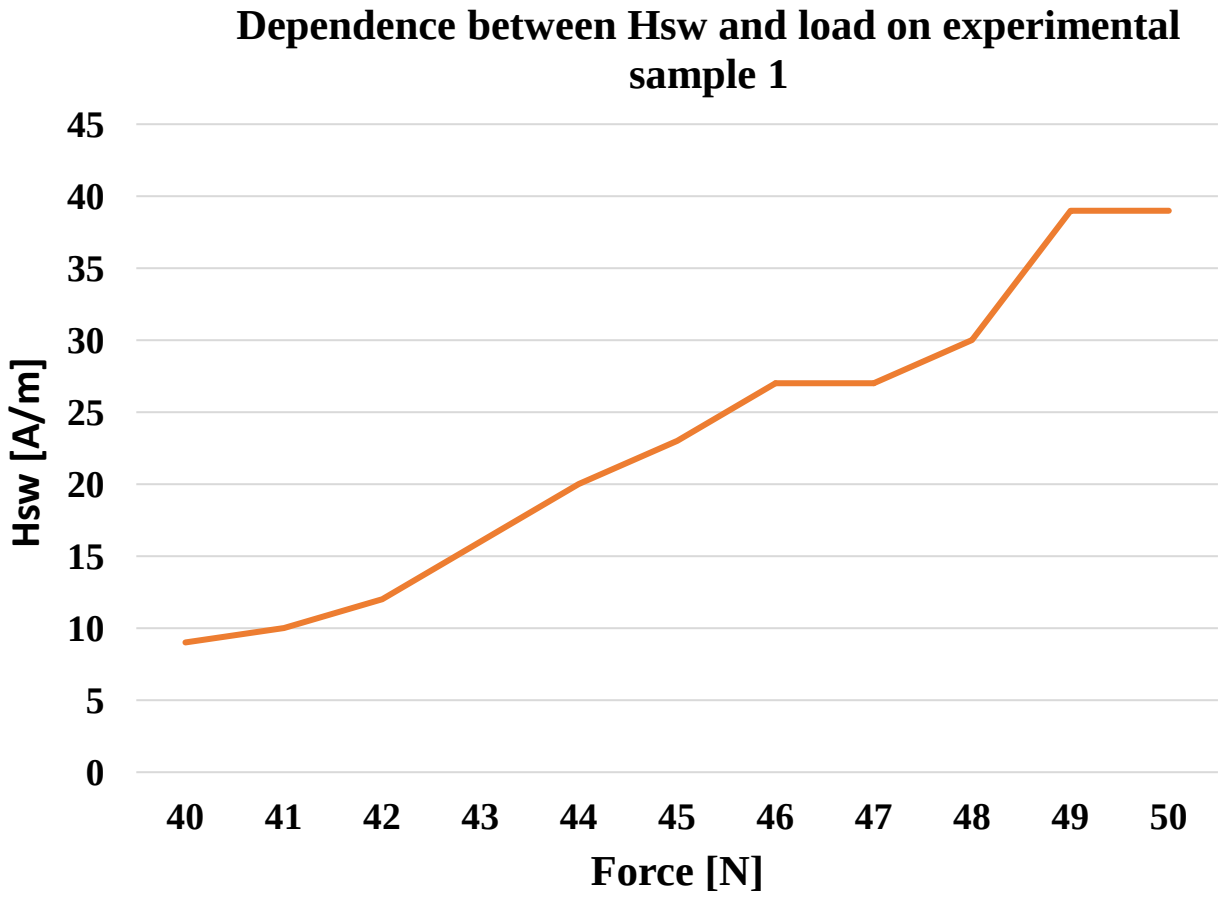


Fig. 5. The course of recording the measurement of the critical field – domain wall (blue course – sensing coil with „peak“, yellow course – excitation coil in a triangular shape). The strong blue cursor represents the position of the change of the critical field (t-). The intermittent blue cursor represents the initial value of the critical field (t +) at load F = 0 N.

RESULTS

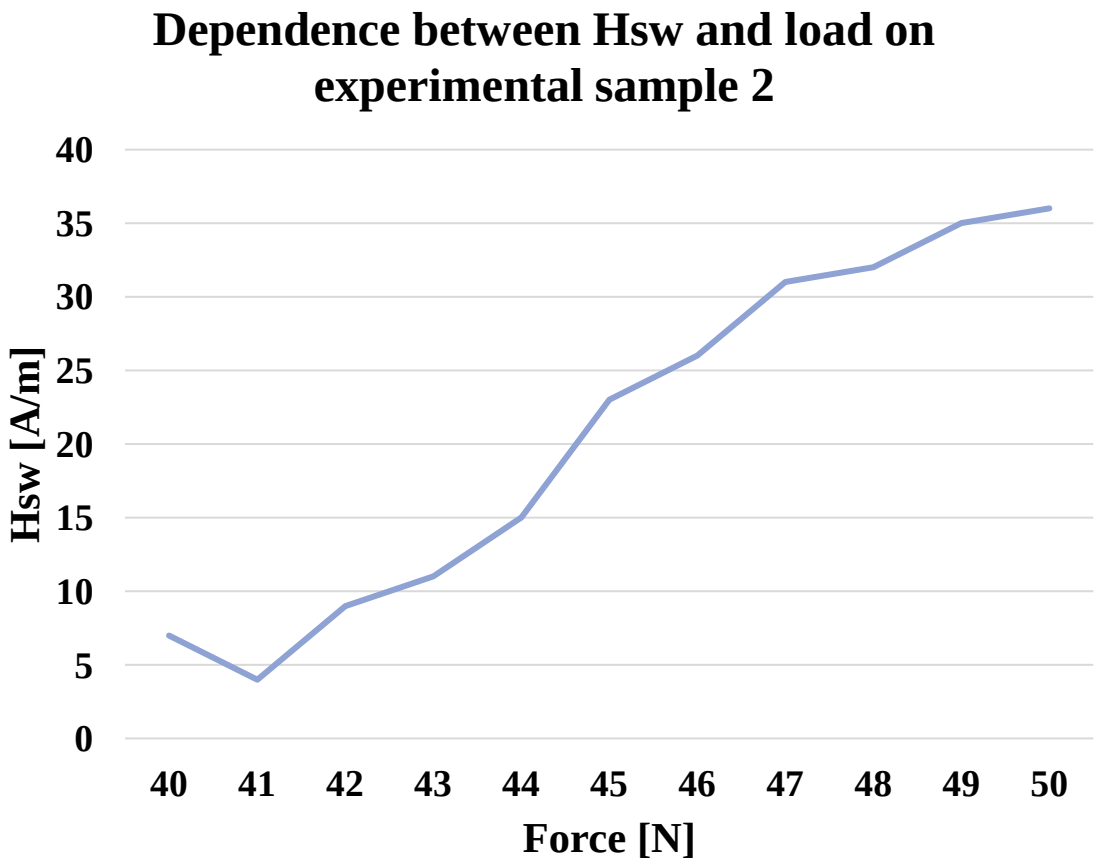
Tab. 1 Measured values of t+ and t- after application mechanical load

		Sample 1	Sample 2	Sample 3
t+ [µs]	F = 0 N	81	77	78
t- [µs]	F = 40 N	72	70	71
	F = 41 N	71	73	70
	F = 42 N	69	68	68
	F = 43 N	65	66	67
	F = 44 N	61	62	61
	F = 45 N	58	54	54
	F = 46 N	54	51	53
	F = 47 N	54	46	49
	F = 48 N	51	45	46
	F = 49 N	42	42	42
	F = 50 N	42	41	41

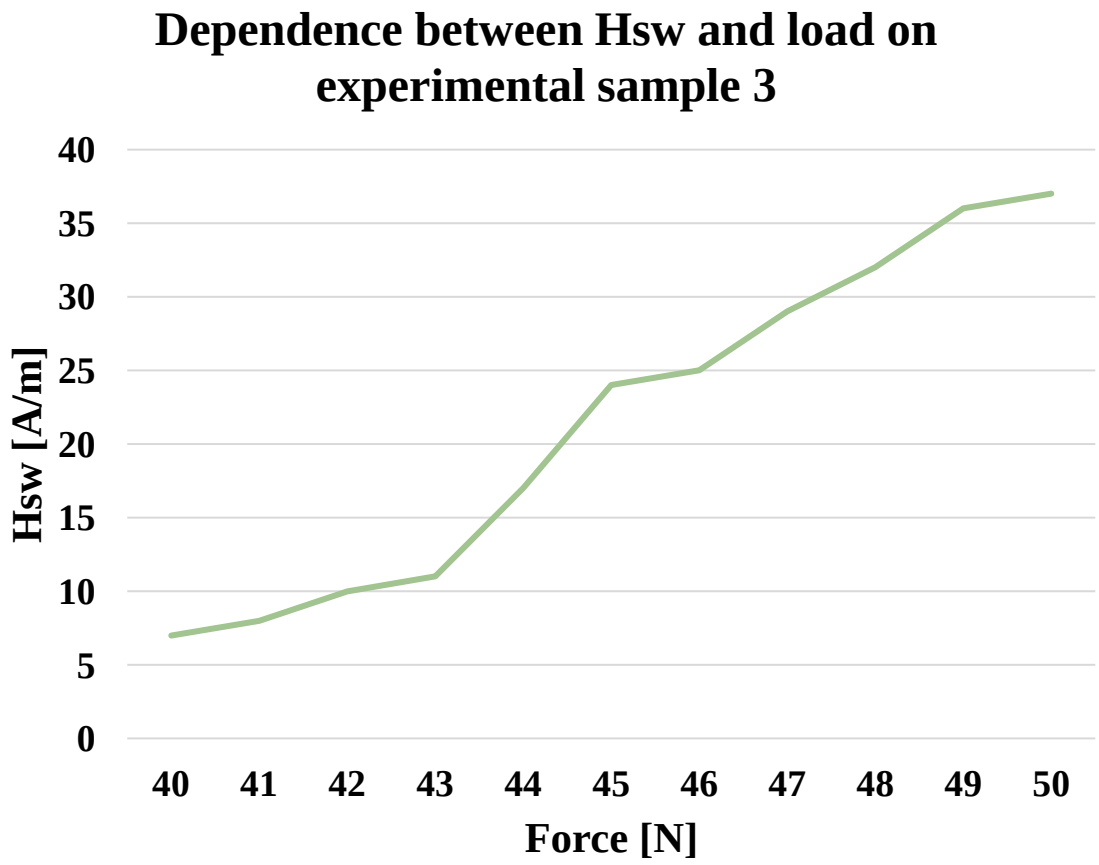


Graph 1. Dependence between Hsw and mechanical load on sample 1

RESULTS



Graph 2. Dependence between Hsw and mechanical load on sample 2



Graph 3. Dependence between Hsw and mechanical load on sample 3

CONCLUSION

- A pilot study showed that in all 3 experimental samples with a microwire it was possible to detect the mechanical load on the examined object.

- Comparing experimental samples with the microwire, it was found out that experimental sample 3 (vertical positioning of the microwire in the model) showed the best results of all.

- Microwire fixation in the samples plays a significant role in recording the measured results.

- It can be stated that by solving the fixation of the glass-coated microwire in the implanted objects, this type of microsensor is a suitable candidate for applications in the field of implantation.

Thank you for attention