Investigation of vibration parameters for needle insertion force reduction

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Introduction

- Most frequently performed routine diagnostics: blood test[1]
- Requires venipuncture
- Venipuncture success depending on the skills of the clinician
- May cause severe pain or internal bleeding
- Assumption: Lower needle penetration force allows less painful insertion
- Vibration of the needle during insertion reduces penetration force[2]

→ Which combination of vibration parameters enables the highest reduction?

→ How do the individual parameters affect the force phases during insertion?

Results

- Results can be seen in Table 1
- Insertion force was reduced by 73 % (100 Hz - 500 µm) and 67 % (200 Hz - 500 µm), respectively
- Friction force could be reduced by 74 % (10 Hz - 500 µm), or by up to 100 % (100 Hz - 500 µm and 200 Hz - 500 µm)

Discussion

Setup:

- Speaker is not able to maintain vibration movement continuously
- Needle is currently only supported by the loudspeaker membrane
- Sampling rate of 625 Hz ➔ Vibration frequencies are limited

Results:

- Reduction of penetration force and frictional force by vibrating needle penetration with certain parameters was achieved
- Not every combination of parameters leads to a reduction

Results for puncture force and shaft friction force

Table 1: Overview of results for shaft friction force and puncture force: Force values are given in Newton and the deviations from the control insertion are given in percentage (square brackets). Values that are significantly different are marked with an asterisk.

	Initial insertion force in Newton			
	0 Hz	**10 Hz**	**100 Hz**	**200 Hz**
0 µm	1.768 ± 0.046	-	-	-
20 µm	-	1.821 ± 0.028 [+3.04 %]	1.790 ± 0.033 [+1.26 %]	1.852* ± 0.031 [+4.76 %]
100 µm	-	1.794 ± 0.038 [+1.52 %]	1.852* ± 0.049 [+4.79 %]	1.527* ± 0.016 [-13.62 %]
500 µm	-	1.737 ± 0.035 [-1.71 %]	0.483* ± 0.014 [-72.69 %]	0.582* ± 0.047 [-67.09 %]
	Shaft friction force in Newton			
0 µm	0.103 ± 0.005	-	-	-
20 µm	-	0.119* ± 0.004 [+14.72 %]	0.122* ± 0.006 [+17.91 %]	0.170* ± 0.002 [+63.83 %]
100 µm	-	0.112* ± 0.004 [+8.09 %]	0.062* ± 0.005 [-40.44 %]	0.108± 0.006 [+4.39 %]
500 µm	-	0.027* ± 0.007 [-74.00 %]	-0.018* ± 0.002 [≥ -100.0 %]	-0.026* ± 0.002 [≥ -100.00 %]

Material and methods

- Experimental setup allows investigation of needle penetration forces during vibrating penetration
- Parameter study with different vibration frequencies and amplitudes
- 20 W loudspeaker to generate sinusoidal vibrations
- Linear motor generates linear movement for insertion procedure
- 5 N load cell with 625 Hz maximum sampling rate
- Skin simulant: 125 µm thin sheet of PET (commonly used as blood vessel replacement[3]), fixed with a sample holder
- Filtering: Moving Average Filter and 2nd order Notch Filter
- Two-sample t-tests with significance level of α = 5 %
- Investigated frequencies and amplitudes: 10, 100, 200 Hz; 20, 100, 500 µm

Experimental setup

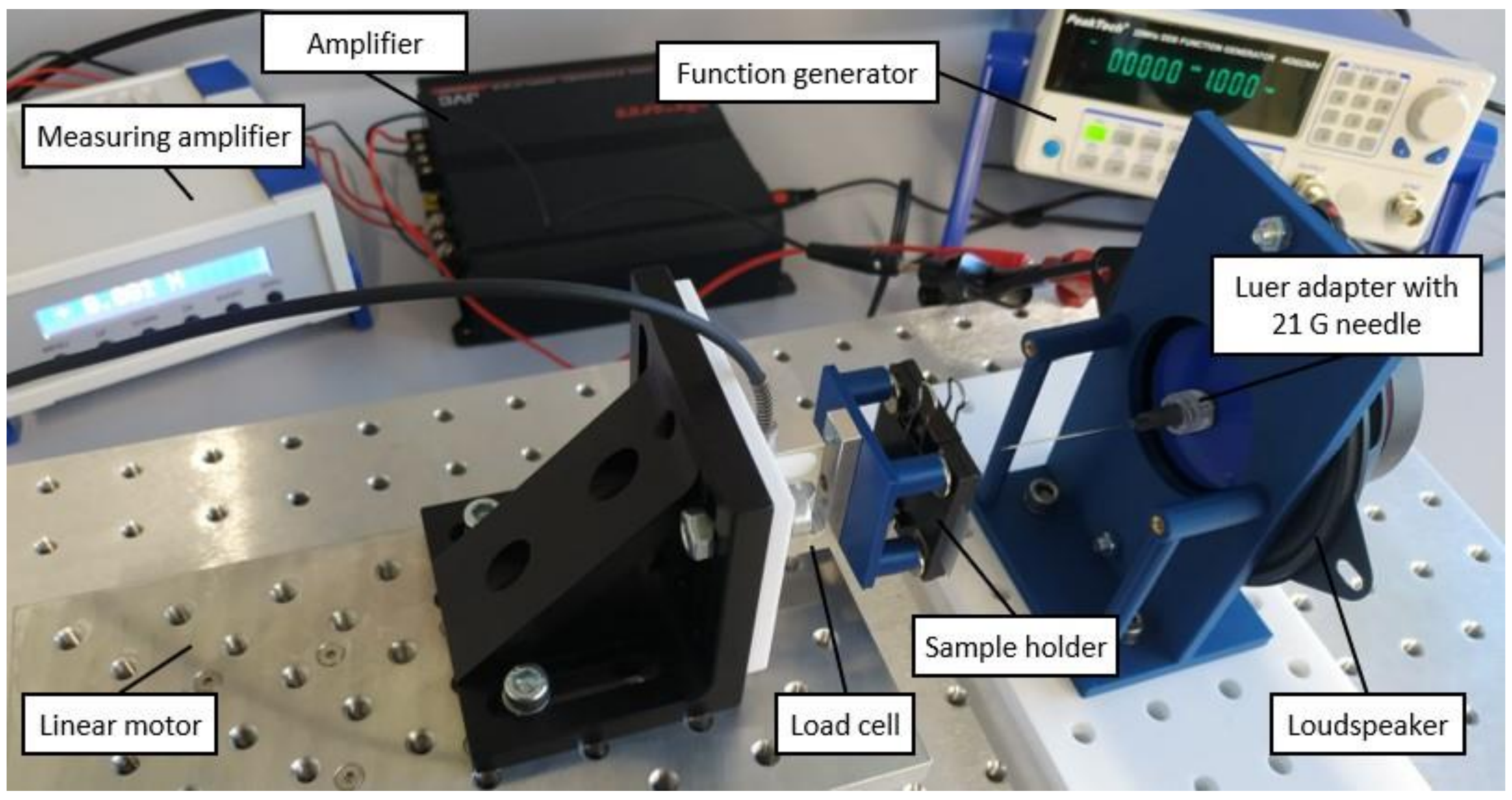

Figure 1: Experimental setup.

Exemplary force curve

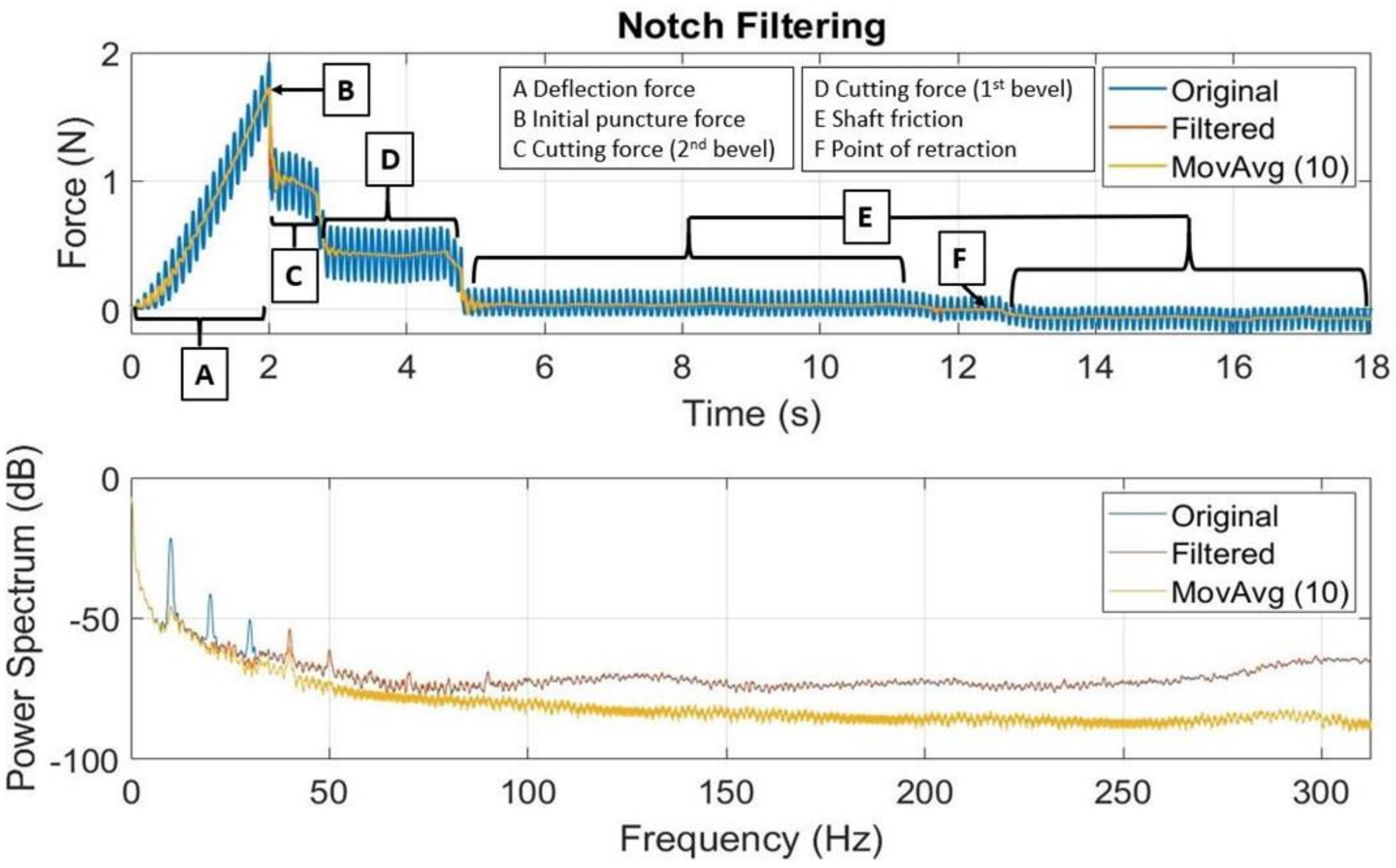

Figure 2: Exemplary force data of a measurement with a 10 Hz – 500 µm vibration mode. The blue line indicates the original data containing force oscillations induced by the vibration. The curves after notch filtering and after application of a moving average filter can be seen in orange and yellow, respectively. In the power spectrum in the lower graph, the increased signal amplitude at 10, 20, and 30 Hz is visible.

Conclusion

- Active position control of the vibrating loudspeaker membrane
- Investigation of more parameter combinations

Literature

1. I. Lavery and P. Ingram, "Venepuncture: best practice," Nursing standard, vol. 19, no. 49, 55-65; quiz 66, 2005.
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3. V. Catto, S. Farè, G. Freddi, and M. C. Tanzi, "Vascular Tissue Engineering: Recent Advances in Small Diameter Blood Vessel Regeneration," ISRN Vascular Medicine, vol. 2014, pp. 1–27, 2014.