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Introduction

One of the biggest challenges facing a designer of paper structures is its low resistance to moisture and water. Paper is a hydrophilic material that absorbs moisture from the outside. This causes the hydrogen bonds between the cellulose molecules to loosen, and as a result a rapid decrease in strength parameters. In order to be able to use paper as a construction material, there is a need to select and evaluate the effectiveness of the appropriate impregnant, as well as to know its impact on the mechanical properties of the impregnated paper.

Materials and Methods

The study analyzed the effect of the use of various impregnations, including wood oil, yacht lacquer and burnblock impregnation, on the destructive tensile force of various types of cellulose-derived materials, e.g. cardboard, corrugated cardboard, paper tubes and honeycomb. The effectiveness of the impregnation was also assessed using the method of measuring the contact angle of the reference and impregnated surfaces.



Fig. 1. The samples after impregnation

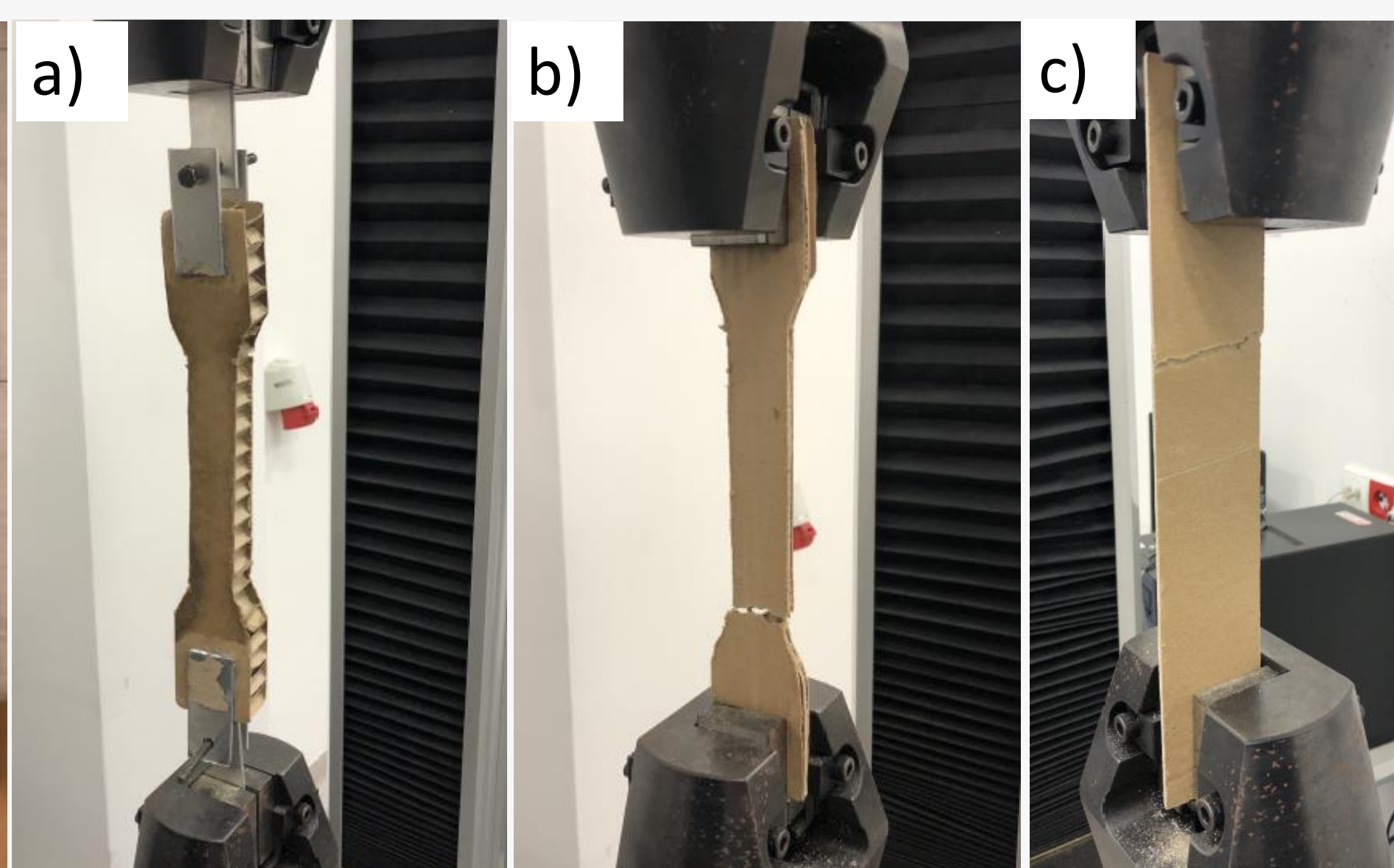


Fig. 2. View of tension test setup: a) honeycomb, b) corrugated cardboard, c) paper tube sample

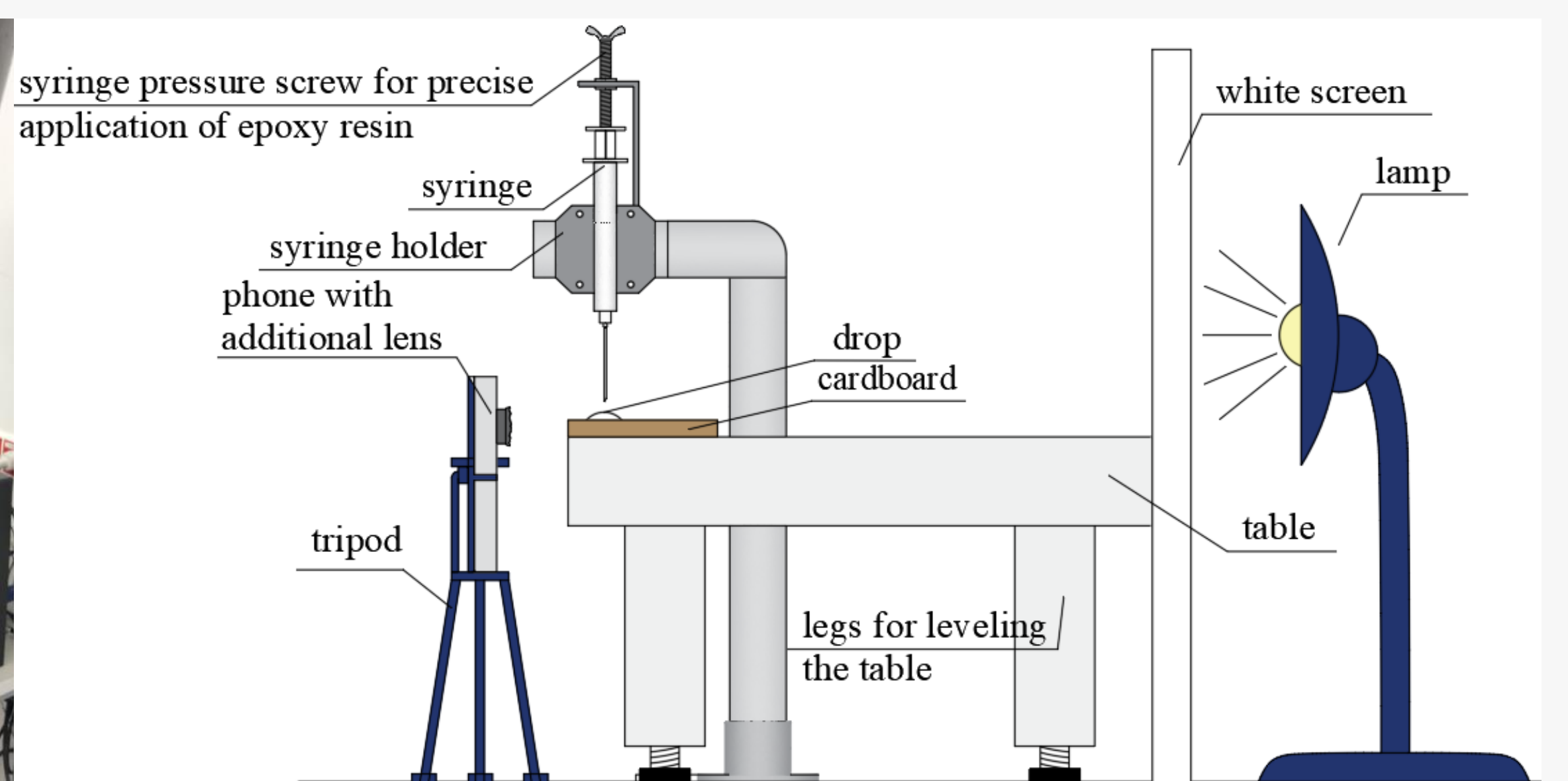


Fig. 3. Sketch of the test stand for contact angle measurements

Results

Tab. 1. Results of the strength tests

Sample series	Cardboard			Corrugated cardboard			Paper tubes			Honeycomb		
	Average [kN]	SD [kN]	Change [%]	Average [kN]	SD [kN]	Change [%]	Average [kN]	SD [kN]	Change [%]	Average [kN]	SD [kN]	Change [%]
No impregnation	0.73	0.08	-	0.35	0.04	-	2.66	0.04	-	0.26	0.04	-
Wood oil	0.89	0.11	+ 21.5	0.31	0.03	-11.0	2.72	0.08	+ 2.4	0.72	0.09	+ 180.0
Yacht lacquer	0.99	0.06	+ 34.0	0.36	0.02	+ 2.5	2.78	0.06	+ 4.7	0.73	0.02	+ 186.5
Burnblock	0.91	0.06	+ 24.0	0.32	0.02	- 9.5	2.71	0.05	+ 1.8	0.22	0.07	-14.0

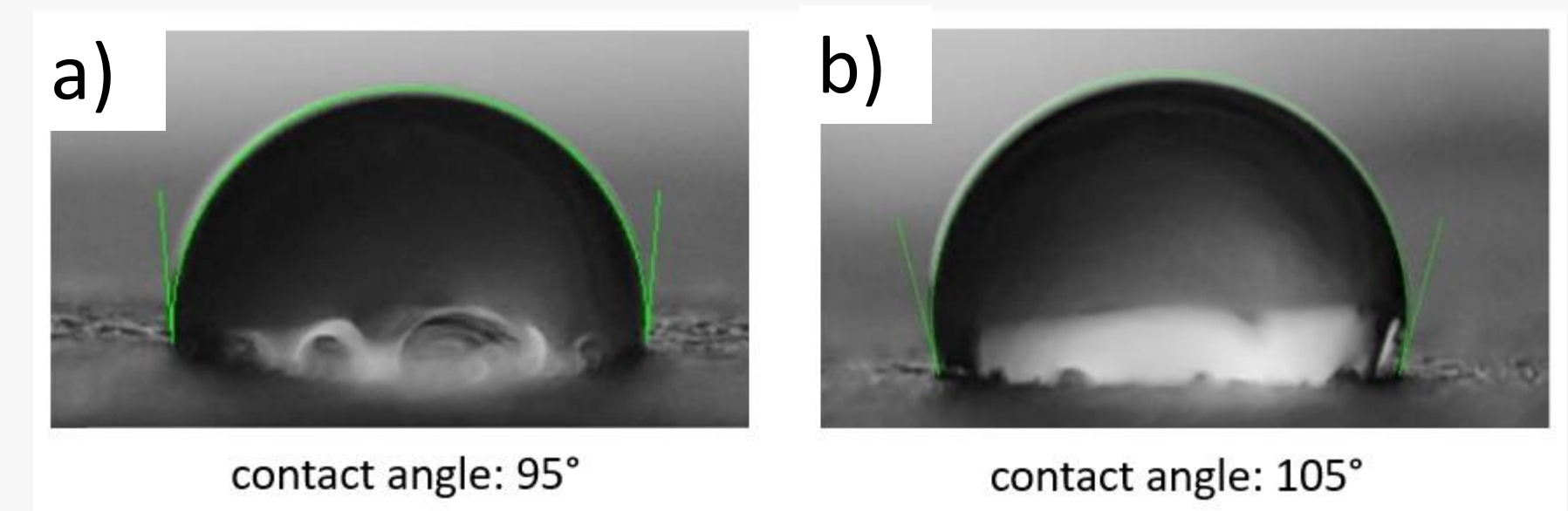


Fig. 4. Views of water contact angle measurements on a) non-impregnated samples, b) coated with Wood oil

Tab. 2. Results of contact angle measurements

Sample series	Average [°]	SD [°]	Change [%]
No impregnation	95	2.3	-
Wood oil	105	1.8	+10
Yacht lacquer	102	2.3	+6
Burnblock	97	1.9	+2

Conclusions

1. The results for cardboard show that the effect of impregnation improves the tensile strength of the material – the ultimate force value increases by 21% when using wood oil by 34% when using yacht oil and 24% when using burnblock.
2. In the case of corrugated cardboard the obtained results indicate that the impregnation methods are of little importance in the value of the destructive force. Wood oil slightly (11%) reduces the mean force value and the use of yacht oil very slightly (2.5%) increases this value.
3. In the case of paper tubes the value of the destructive force slightly differs when using different impregnants (up to 5%).
4. In the case of honeycomb a high increase in tensile strength when using liquid impregnation agents is observed. These are almost 3-fold increases (over 180%).
5. Contact angle measurements showed that impregnating agents increase the contact angle (by 2-10% depending on the impregnant), and thus reduce the wettability of the cardboard, which may have a positive effect on its strength. Wood oil has the best hydrophobic properties, followed by yacht lacquer.