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Adhesion strength of temperature varied nanocellulose enhanced water based paper and cardboard adhesives

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Introduction

Adhesives are used to bond cardboard surfaces together and create a permanent bond. The type of adhesive typically used to bond coated paperboard substrates is based on polyvinyl acetate (PVAc) chemistry together with water and other additives for functionality. Previous research on some adhesives of plywood to paper has shown the positive effect of adding nanocellulose on adhesion strength and has enabled a remarkable increase in shear strength values to be achieved. The introduction of cellulose nanoparticles has had a positive influence on mechanical properties such as flexural bending strength and modulus of elasticity.

Advantages of using nanocellulose as reinforcement in adhesives for the production of wood-based panels are the possibility to modify the properties of the adhesives, the improvement of the mechanical and physical properties of the panels and the reduction of formaldehyde emissions through the use of synthetic adhesives. Previous research showed promising results in CNC and CNF increasing the overlap joint strength and adhesion strength (Damásio et al., 2017) and (Jiang et al., 2018). In a review by Heinrich (2019) some problems with nanocellulose as an additive in adhesives has been pointed out. The water content of nanocellulose, which is generally up to 97%, and its price. A solution to the first problem seems to be cold pressing the water after slurry, while a solution to the second problem could be the use of lignocellulose nanofibers obtained from recycled particleboards or other sources. If these developments are successful, the nanocellulose could have a function both as structural reinforcement and as an adhesive material in the product.

Since the addition of nanocellulose as an additive in PVAc adhesives for paper and board (mainly for wood panels) is not being extensively investigated, we have tested two PVAc adhesives with two different types of nanocellulose.

Methods

Two types of PVAc adhesives MEKOL 1301/1 (M1) and MEKOL 1413/G (M2) (produced by Mitol d.d., Slovenia) were used on a 235 g/m^2 commerical cardboard. For the nanocellulose, we used two different types of it: nanocrystalline (NCC) with a solid content of 7,8 % and a diameter of 10-20 nm and a length of 40-200 nm and commercial nanofibrillated cellulose (NFC) with a solid content of 4% and a diameter of 10-200 nm and a length of <50 µm.

The nanocellulose was added in the ratio of 0,5, 1 and 2 % content (weight %). For the application of the adhesive, a laboratory-scale rod coater was used. We have applied the rod with the number 4 and the speed 6. In the second series of adhesive applications performed, the applied elevated temperature was 45°C. The determination of the adhesive strength between the two adhered cardboard sheets was carried out with mechanical testing device ZWICK/Roell Z010 using the analytical methods Z direction tensile strength (ISO 15754:2009) and T- peel test (ASTM D1876-08).

Results

The results for the z-direction tensile strength for the different amounts of NCC and NFC (for both temperatures) are shown in Figure 1.

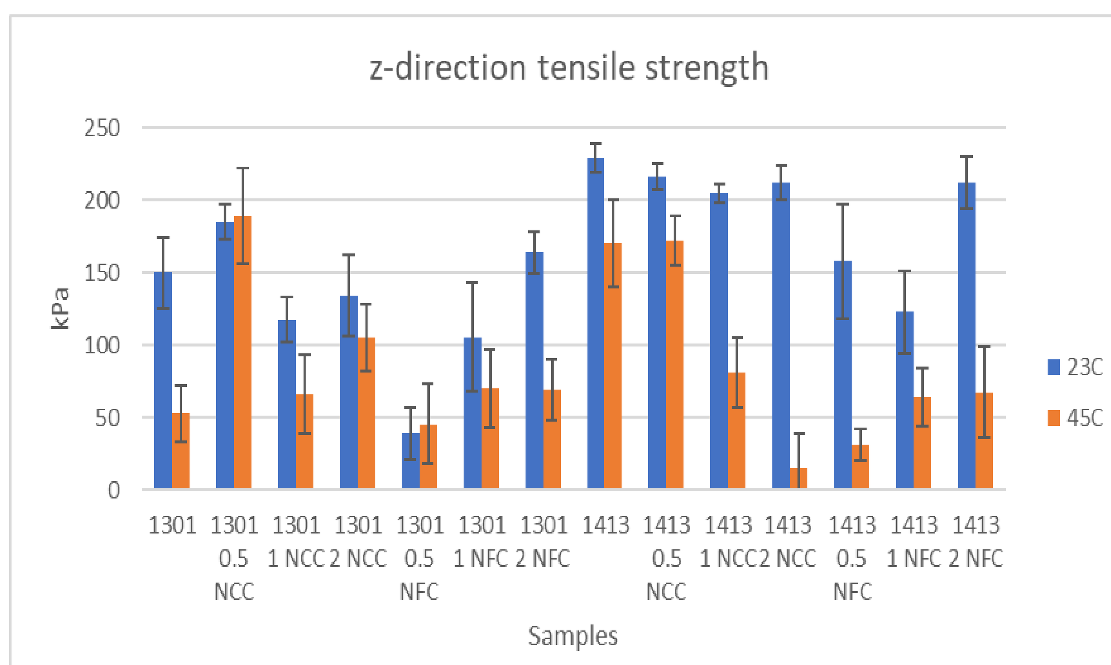

Figure 1

Z- direction tensile strength

From the tensile strength results in the z-direction, it can be seen that at room temperature (and in the optimum temperature range concerning the base adhesive) the addition of NCC and NFC has improved the tensile strength of the samples in the z-direction compared to the M1 adhesive alone.

For the adhesive M2, the addition resulted in similar or slightly lower tensile strength. The temperature increase of the adhesive mixtures resulted in lower kPa values in almost all samples except the mixtures with the lowest concentration (0,5% wt). The increased temperature and lower water content resulted in lower z tensile strength values for both NCC and NFC compounds.

The results for the T-peel test for the samples joined at room temperature (23^{0}C), and elevated temperature is shown in Figure 2.

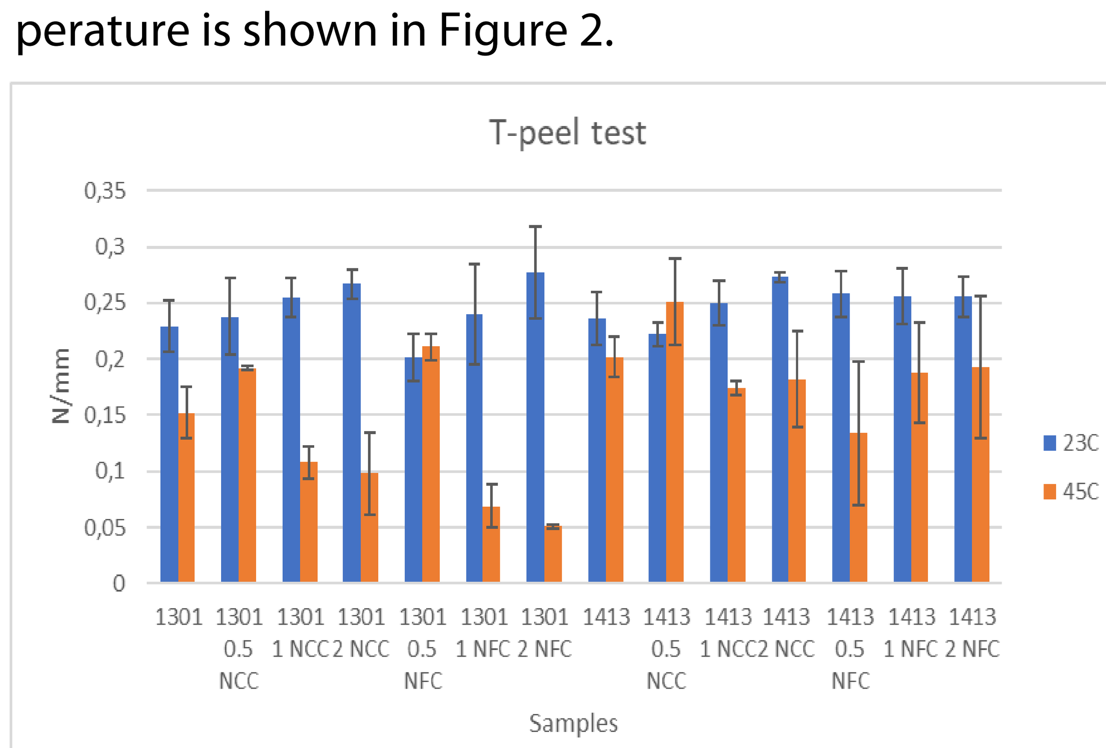

Figure 2

T peel adhesion strength

From Figure 2, we can observe that the addition of NCC and NFC positively influences the average N/mm values for all combinations (0,5%, 1% and 2%) athe peel adhesion strength was higher (except M1 NFC 0,5%) and M2 (0,5 % NCC) which may indicate that higher concentrations of NCC and NFC at room temperature lead to higher peel strength values. The increased temperature lowered the adhesion strength values for all adhesives and adhesive formulation combinations, but the NCC and NFC additives had even higher values for the M1 base adhesive and similar values for the M2 adhesive.

Discussion / Conclusion

Replacing synthetic components in adhesives with natural ones is a challenge from various aspects regarding chemical compatibility, pricing and application technology. The addition of NCC and NFC in adhesives has proved useful in wood composites, while our results show mixed results, with the addition of NFC and NCC in some cases giving higher and slightly lower values in the z-direction tensile strength measurements. In the T peel adhesion test at room temperature, the addition was beneficial for both additives as the average peel force (N/mm) increased. One of the possible reasons for differences between the two test methods could also be the variation in the adhesive application, where the rod system creates a slight time delay between the sample sides, with the bottom side having more moisture at the moment of contact of two cardboard layers. Due to this effect, the z- strength method can lead to a higher variation of results. The increased temperature caused a deterioration of the basic components, and the results were not as consistent. The ambiguous results indicate that in our future research we need to optimize the mixtures, procedures further, and compatibilities of the NCC and NFC addition with the base adhesive formulations and investigate the influence of the water content on the adhesive strengths of the paper and board compound.

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