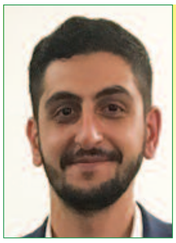

Patented Nanocellulose Strength Additives for Recycled Fibre

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What is Nanocellulose?

Cellulose is an abundant material that is found in plants. It is an inexpensive and sustainable natural polymer that presents an attractive material choice for researchers attempting to create environmentally friendly products. Nanocellulose is the microscopic building block that makes up the larger cellulose fibres after bundling together many fibrils. Nanocellulose is currently the focus of intense research as a sustainable nanomaterial that possesses many desirable material properties.

Cellulose is one of three components (namely cellulose, hemicellulose and lignin) that define the strength of plant matter. What is interesting about utilising the nano-component of cellulose is the access to innovative tailoring in its material chemistry. The macroscopic structure of cellulose can thus be considerably enhanced by functionalising the nanoscopic unit, nanocellulose, enabling existing cellulose products to be improved.

Similar to graphene, an allotrope of graphite found in your pencil lead, nanocellulose has extraordinary potential in various industry sectors, especially in paper and packaging. Depending on where it is added in a typical papermaking process, nanocellulose may enhance both the wet and dry strength of paper. Moreover, as a nanofibre, nanocellulose will help mesh the pulp together during formation. Thus, improved material utilisation may be achieved from nanocellulose acting both as a strength agent and retention aid.

The term nanocellulose encompasses three nano-forms/types of cellulose: Nano-fibrillated cellulose (NFC), Nano-crystalline cellulose (NCC), and Bacterial cellulose (BC). These forms can be attained through two approaches: the top-down route for NFC & NCC and bottom-up route for BC. At Brunel University London, intensive research has been conducted under Professor Mizzi Fan to explore both routes and has led to a unique patented process to achieve this wonder nanomaterial via the top-down approach. As seen in Figure 1, there are different yields depending on the processing parameters. The patent technologies are applicable to the full variety of cellulosic materials (wood and non-wood plant fibres) to produce functional nanocelloluses. These yields correspond to the nanocrystal form (termed Brunel's NCC (BNCC)) of the cellulose with the remainder corresponding to the fibrillated form (termed Brunel's NFC (BNFC)) of the nanocellulose.

Essentially NCC particles are cut-offs of NFC. This is similar to microcellulose, where microcrystalline cellulose (MCC) has a similar relationship with microfibrillated cellulose (MFC).

One of Brunel's nanocellulose technologies has successfully enhanced recycled fibre for paper production and thus a number of commercial pilot trials have been conducted. For the paper and packaging industry, it has been found that the ideal addition would be the fibrillated form of cellulose since it causes a higher retention of fines and is more likely to link with the paper structure rather than permeating through it compared to NCC.

Importance of Dry Strength Agents

Over the last two decades there has been a significant increase in the recovery and recycling of old corrugated containers (OCC), often referred to as kraft liner shavings (KLS). From 1997 to 2017, an increase from 67.7% to 88.8% rate of recovery was recorded [1]. With the increasing number of cycles a fibre is reused, there is a reduction in the mechanical properties of paper and board due to a reduction in both intrinsic fibre strength and inter-fibre bonding. This is where dry strength agents come in to play; cationic polyacrylamides and cationic starch are often used to increase the bonds between fibres and in addition to attract anionic trash, so increasing the strength of recycled paper.

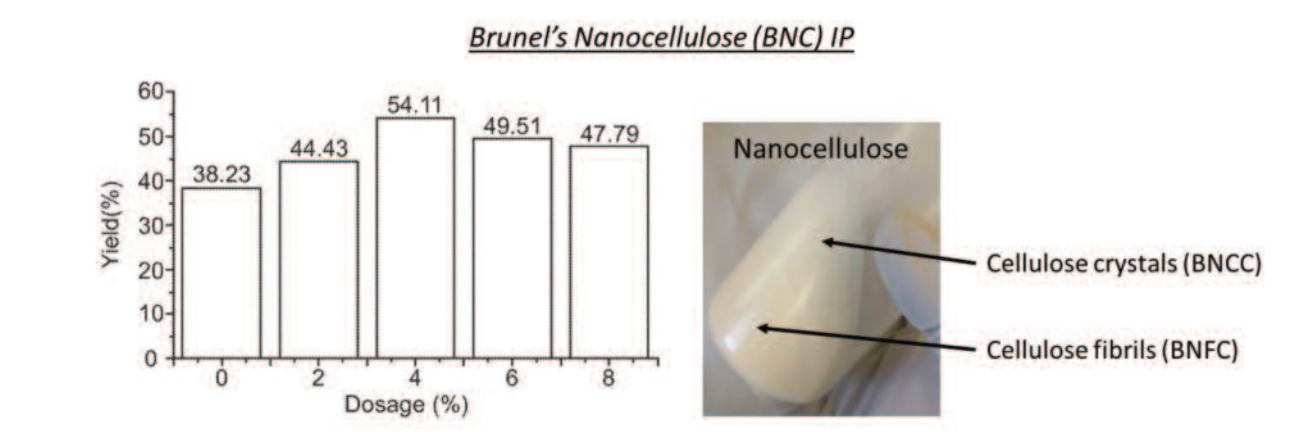

Figure 1. Brunel's patented production process of nanocellulose (BNC)

Materials and Methods

OCC/KLS pulp was received from a commercial mill that only processes recovered fibre. It was supplied at 4% consistency, and was then diluted to 1% consistency for ease of use and accuracy in the laboratory setting.

The Axform Dynamic Sheet Former (DSF) replicates a paper machine process in that pulp is sprayed on to a wire producing a 900x250mm sheet of paper, with the ability to alter the efflux ratio via changes to the drum speed, pressure of the pulp pump and diameter of the nozzle used. The sheet is then couched and pressed using the Axform Press and Dryer and dried at 120°C on an oil filled drum dryer.

Three sheets were made at 100gsm per dose of nanocellulose (0.5-2.5%) and four 10x10cm squares were cut from each sheet. Each square was weighed for indexing the results and three burst tests were carried out on each square. Burst index (kPa.m2/g) and Bendtsen air permeability index (ml.m2/min.g) were measured on the test squares.

In a separate experiment, commercial blank paper sheets made from recycled fibre were sprayed with three layers of BNC coat to examine the feasibility of this method of application. The paper sheets were characterised through a Scanning Electron Microscope (SEM) using a Zeiss Supra 35VP FEG-SEM at Brunel's Experimental Techniques Centre.

Results and Discussion

Nanocellulose Addition in Stock Preparation

Trials conducted at Axchem UK with BNC addition in the wet end show exciting results (Figure 2). Both BNC types show an approximately 50% increase in burst strength at only 0.5% addition level and positive correlation with increasing BNC increments thereafter. Similarly, the air permeability index also shows a negative correlation with BNC increments, inferring that more fines are likely to be retained.

Concentrating on the BNFC results, it can be seen that around double (91%) the burst strength is reached with only a 2% addition of BNFC. At the same time, 2% of BNFC halves the porosity index of paper sheets which as explained above, suggests BNC to be an excellent retention aid.

BNFC was found to exhibit a larger burst index than BNCC when reinforcing paper sheets. An overview of the results may seem that BNFC is a better option than BNCC, but actually if the burst index is divided by the air permeability index, BNCC gives a higher burst strength for every unit reduction in permeability. This means that if more BNCC were to be retained, it may be more effective and significant.

Nanocellulose as a Coating Material

Trials conducted with BNC addition as a spray coat show an alternative route to its addition in the wet stock (Figure 3). SEM images show a smoother surface when a BNC coat is applied in comparison to uncoated paper. It can also be seen that there are fewer pores when a BNC coat is applied. This means that as well as adding BNC in the wet end, BNC can also be applied in the dry end of the paper machine alongside starch coating or as a replacement to starch due to its abundance and renewability.

Summary and Outlook

Overall, the data presented indicate that the addition of BNC in the wet mix enhanced the dry strength of paper and thus may

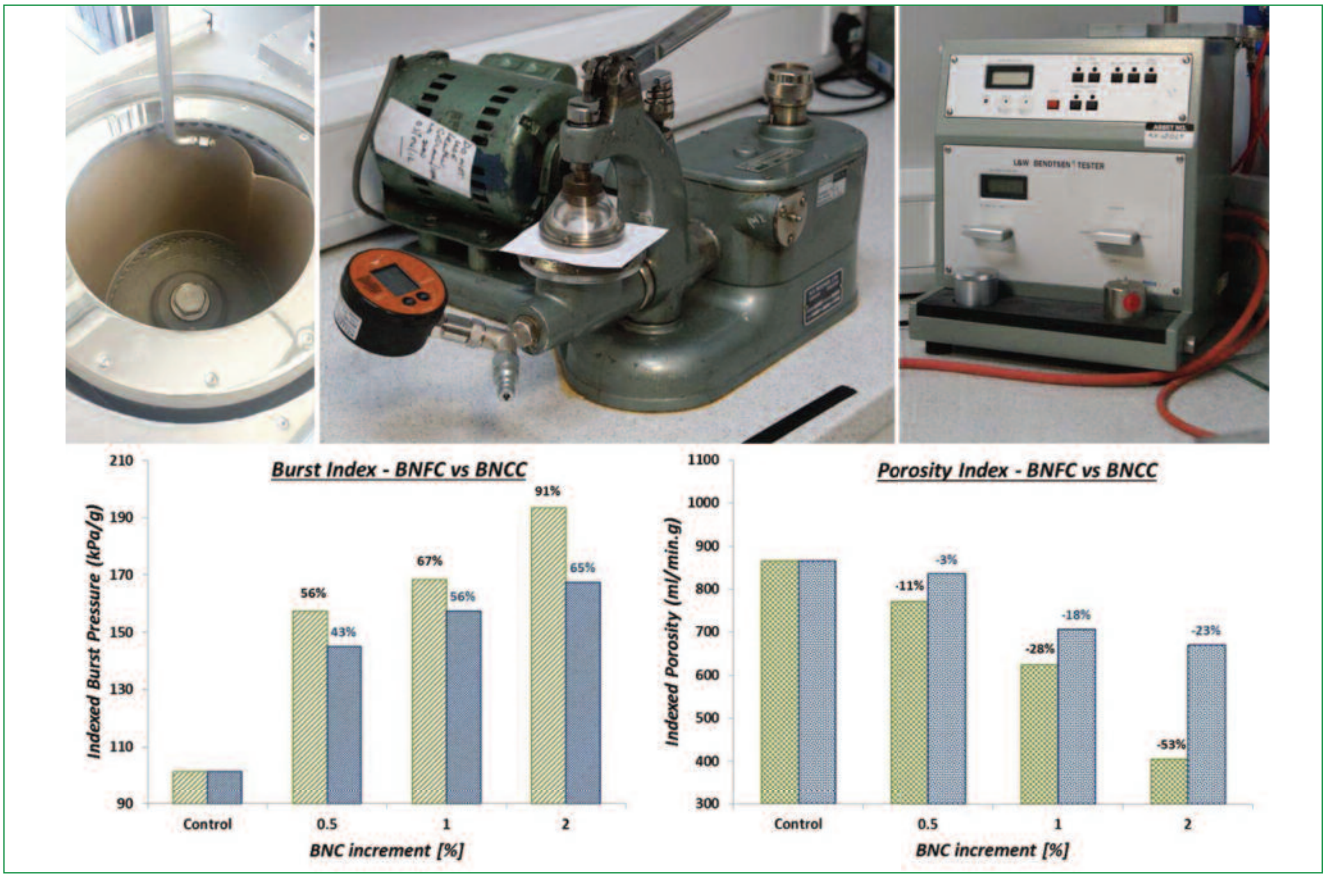

Figure 2. Charts showing burst index and air permeability index comparison of BNFC and BNCC against blank paper sheets.

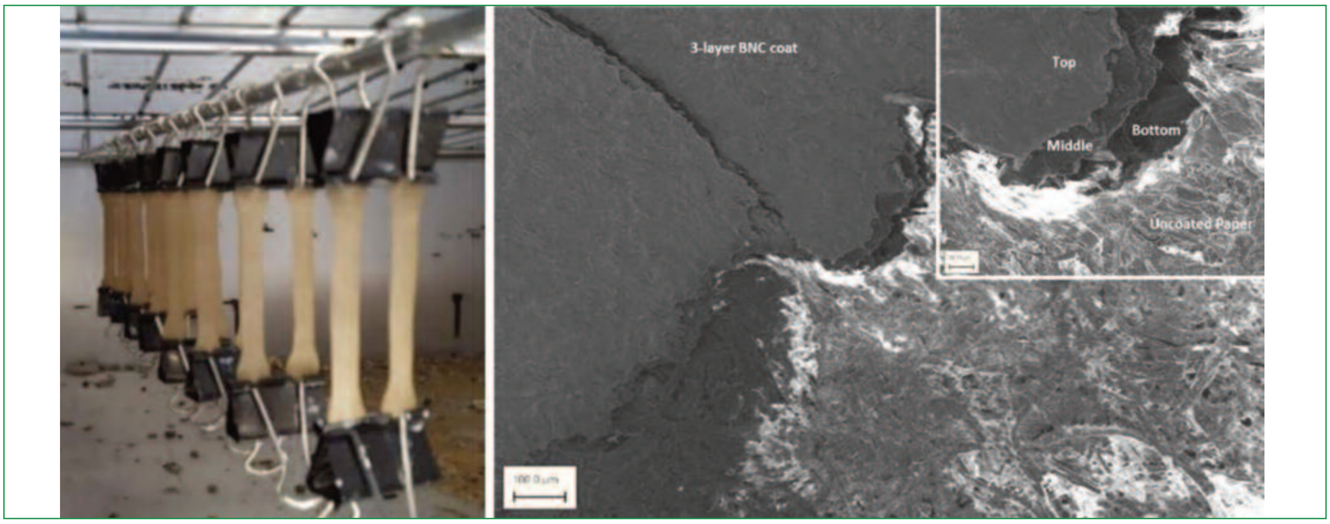

Figure 3. Facilities at Brunel University used to investigate BNC coating on paper sheets. BNC is stained to differentiate in the SEM between the BNC coat and the uncoated paper sheet.

help reduce breaks during papermaking. This offers papermakers options, allowing them to provide enhanced strength products, or take the opportunity of reducing basis weight, which in turn may allow an increase in machine speed and so better efficiency and lower unit operating cost in addition to lower raw material costs. Also, it allows the use of lower quality furnish, consequently increasing the number of times the recycled fibres can be used without the addition of virgin fibre.

The data also suggest that the patented technology is able to increase retention, which should allow the wet end to run cleaner.

Future developments will include assessing what addition of BNC by coating methods can offer. Finally, one may envisage that with developments in nanocellulose manufacturing technology, discrete cellulose fibrils rather than bundles may be isolated, which could allow still further innovations.

Acknowledgments

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References

[1] Paperrecycles. Recovery - use of Old Corrugated Containers (OCC) n.d. https://www.paperrecycles.org/statistics/recovery-use-of-old-corrugated-containers-(occ) (accessed October 3, 2018).