Applications of Co-Processed Microfibrillated Cellulose and Mineral in Packaging

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ABSTRACT

FiberLean Technologies have developed and commercialised an efficient process for microfibrillated cellulose (mfc), which involves the co-grinding of pulp fibres with fine mineral particles.

In graphic paper, this technology can be used as an additive to increase initial wet web strength, tensile and surface strength, reduce porosity and allow the use of much-increased filler levels. In white-top liner, it can simultaneously increase the filler level and decrease the weight of the white layer, whilst maintaining or improving surface strength and printing properties. Substitution of white top grammage with the base layer can also increase the strength of the product. In folding boxboard, mfc allows the filler level in the bleached outer layers to be increased, increasing brightness or reducing layer weight. Both concepts have been demonstrated at production scale.

A suspension of 80/20 co-ground mineral/mfc has been applied at pilot scale on top of a forming sheet at the wet end. This coating is dewatered in situ, shows very little penetration into the base and efficient coverage. High brightness can be achieved on an unbleached Kraft base with just 6gsm of mfc. It could potentially be used as a white top layer for linerboard without the need for a multilayer former.

INTRODUCTION

Microfibrillated cellulose (mfc) and nanocellulose (nfc) are currently creating great interest both in paper and paperboard and in many applications beyond. For use in paper, low cost production methods are needed in order to make the use of these materials economically viable. We have developed such a method, which involves the co-grinding of pulp fibres with fine mineral particles to generate mfc. The main application of this technology has been as an additive to the papermachine wet end in fine paper grades to increase wet web, tensile and surface strength, reduce porosity and allow the use of much-increased filler levels.

Over 60 full scale machine trials of this mfc/mineral product have now been run, all of which have added the material to the wet end, in most cases with the aim of increasing filler level. A typical application might aim to use 2% mfc addition to achieve an increase in filler content from 20% to 30%. Figure 1 shows the mfc dose used and filler increase achieved in a range of printing and writing mills, many of which involved multiple trials. Three on-site, full scale plants have been constructed so far at paper mills for this purpose.

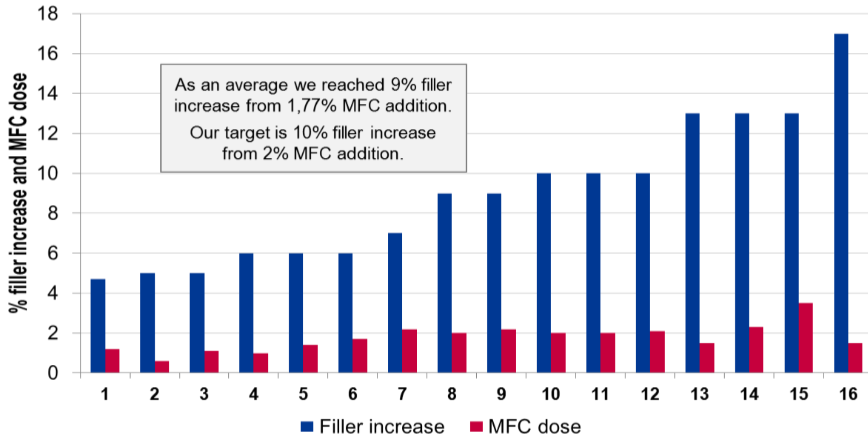

Figure 1. MFC dose and filler increase achieved in full scale trials at graphic paper (UWF/CWF) mills

MFC IN WHITE TOP LINER

Full scale trials of the product have also been carried out in packaging grades, where the maintenance or improvement of mechanical properties is of critical importance. White top liner is a 2-layer product for corrugated board, in which the bottom layer is typically made with unbleached long fibre for maximum stiffness and strength, whereas the top layer is made with bleached short fibre and some filler, and its principal role is to cover the bottom layer sufficiently to give good brightness and printing properties. Filler loading is typically limited by the surface strength requirements of the final product. By adding mfc to this layer the filler loading can be substantially increased, so that it becomes possible to reduce the basis weight of the layer needed to reach the target brightness. This reduction in weight can then be substituted by an increase in the weight of the stronger lower layer. Figure 2 shows the changes achieved in a full scale trial in this grade – with 2.5% mfc the filler content was increased by 9%, and the grammage of the top layer reduced from 52gsm to 42gsm, with the aim of keeping the top side brightness of the product constant.

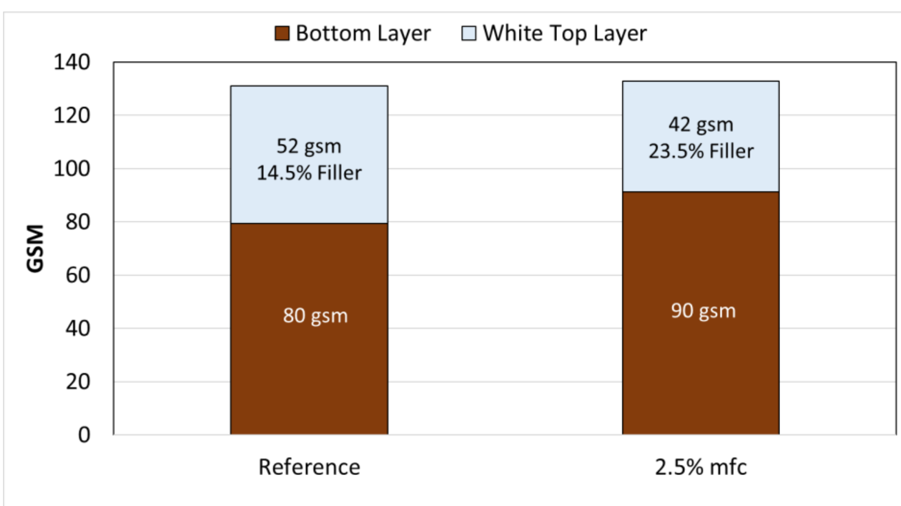

Figure 2. Top and bottom layer grammage and filler levels used in mfc trial at white top liner producer

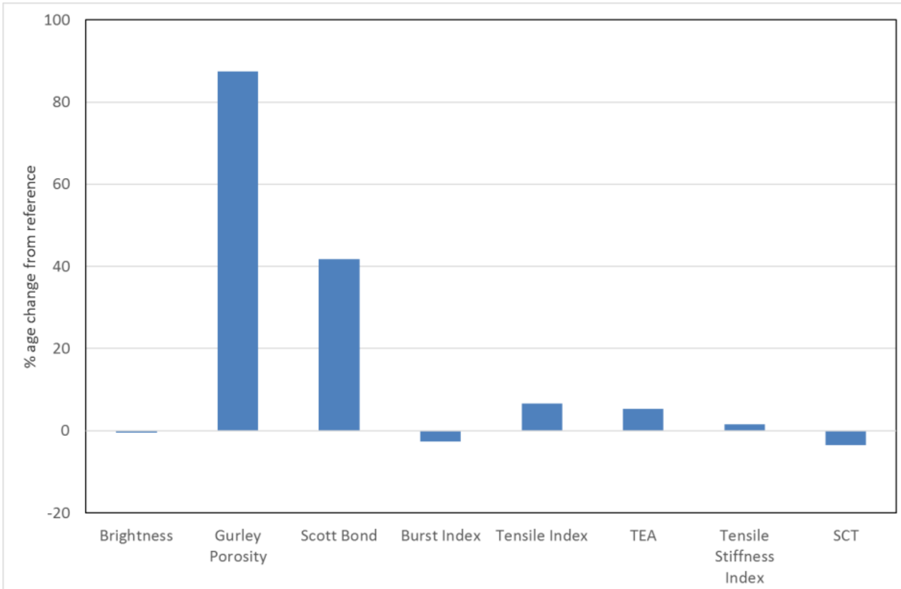

Figure 3. Percentage change in key white top liner properties with 2.5% mfc addition in top layer, 10% filler increase and basis weight reduction (details in Figure 2)

Figure 3 shows the effects of these changes on the key white top liner properties. Brightness was kept constant as expected, and there was a large increase in Scott Bond and Gurley porosity, confirming that the surface strength was not just maintained, but substantially increased. Other mechanical properties were kept approximately constant despite the large increase in filler loading, most notably the tensile stiffness index which determines the rigidity of the corrugated products made with the liner.

MFC IN FOLDING BOXBOARD

We have also carried out extensive trials in folding boxboard. These multilayer products typically consist of a middle layer (or several layers) of bulky TMP pulp with low strength and tensile stiffness, and outer layers of chemical pulp with much higher tensile properties. In these grades the key property is bending stiffness to which the outer layers are the major contributor.

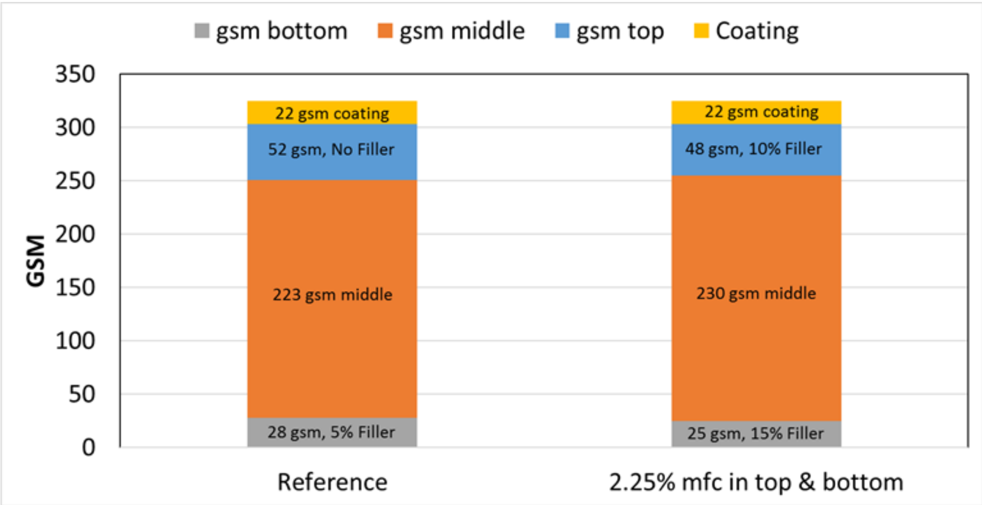

Figure 4. Layer grammage and filler levels used in mfc trial at folding boxboard producer

Figure 4 shows how mfc has been used in one mill to allow the addition of 10% filler to the top and bottom layers and to reduce the weight of the each by 3-4gsm whilst increasing the middle layer accordingly resulting in a significant cost saving. Despite the large increase in filler content and the grammage reduction of both of the layers, stiffness was unchanged (Figure 5). Brightness of the uncoated side was maintained as the increase opacity from the filler addition offset the effect of a reduction in grammage. The presence of mfc and the increase in filler also led to a substantial improvement in the smoothness of the board, which was also observed after coating. We believe this is a result of improved coating hold-out, which we have frequently shown to be a benefit of mfc addition in graphic paper grades. Mfc has also been added to the middle layers, where the increase in z-direction strength it brings has brought a large improvement to delamination resistance both on and off the machine.

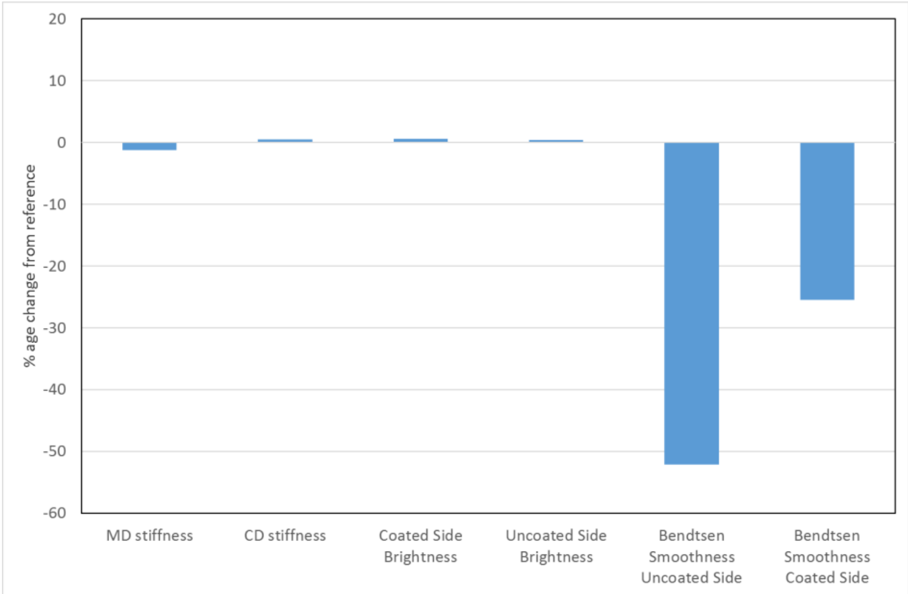

Figure 5. Percentage change in key folding boxboard properties with 2.25% mfc addition in top and bottom layer, 10% filler increase and basis weight reduction (details in Error! Reference source not found.**)**

COATING WITH MFC AT THE WET END

Both mfc and nfc have been considered as alternative binders for coatings by several groups. However, the highly viscous nature of suspensions of these materials restricts them to very low solids content (<5%) in order to achieve a flowable formulation for coating. Coating by conventional means is thus not possible, although it has been recently demonstrated[1] that good coverage can be achieved using a high shear slot coater; because the suspensions are extremely shear-thinning acceptable flow properties can be achieved with this configuration, but the amount of water to be evaporated remains very high and thus limits the practical coatweight that can be achieved.

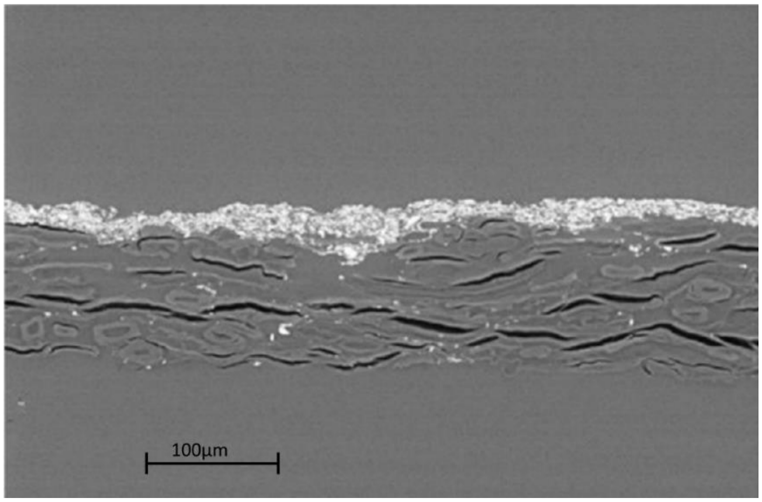

Figure 6. SEM Cross section of unbleached long fibre Kraft linerboard with 28gsm coating of 80% $CaCO_3$/20% mfc applied at the wet end

Alternatively, application of a coating of mfc and mineral pigments at the wet end eliminates the need for high solids content, as water can be removed by conventional drainage, pressing and drying on the machine. The challenge to overcome is the roughness of the base at that point; the coating needs exceptionally good holdout to avoid penetrating into the open spaces between fibres before consolidation in the presses and dryers.

We have demonstrated at laboratory and pilot scale that a suspension of co-ground mineral and mfc can be applied on top of a forming web with a curtain coater at mineral content of up to 80%. The coating can be dewatered on the web, shows very little penetration into the base and efficient coverage. Figure 6 shows an SEM cross-section of sample made on a pilot papermachine, where 28 gsm of an 80%/20% mix of ground $CaCO_3$/mfc has been applied via a curtain coater onto an 82gsm unbleached Kraft softwood base at the wet end. This coating contains only 5.6gsm of mfc. The formation of the base was quite poor, and the surface was extremely rough at point of contact of the curtain with the web, but nevertheless efficient coverage and minimal penetration have been obtained. An ISO brightness of 74% was obtained despite the very low brightness (15% ISO) of the base, because of the high $CaCO_3$ content of the layer. Increasing the coatweight to 40gsm allowed a brightness of above 80% ISO to be obtained. The effect of coatweight on brightness was also investigated in the lab using an adapted handsheet method to coat wet sheets before pressing. Data obtained at both lab and pilot scale agrees well with the Kubelka-Munk model for two distinct layers, and suggests that a brightness of 60% ISO can be achieved with around 10gsm of coating containing 2gsm of mfc (Figure 7).

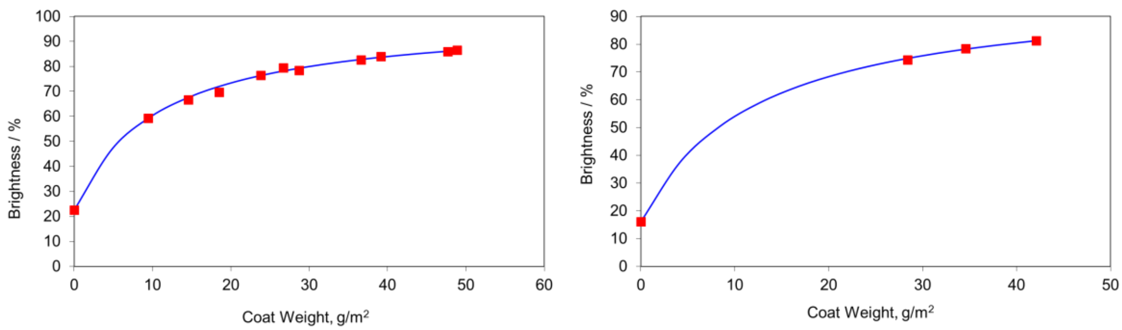

Figure 7. Brightness vs coatweight for 80% $CaCO_3$/20% mfc on unbleached Kraft base, fitted to Kubelka-Munk model. Handsheet data (left), Pilot machine data (right)

The mechanical properties of the pilot scale wet-end coated sheet were very promising. In particular, the Scott Bond was the same as the base sheet – delamination occurred in the brown layer and not at the interface or in the coating. The overall burst index was reduced; not surprisingly the coating of 80% $CaCO_3$ is weaker than the 100% long fibre base. However, a comparison with similar pilot scale work we have done with white top liner shows that the burst index of this layer is equivalent to that of a conventional, all bleached hardwood white top layer at 15% loading of scalenohedral precipitated calcium carbonate, where a 60gsm top layer was required to achieve 80% ISO brightness on a 25% ISO brightness base. Hence the lower weight of the white layer made by the new method would allow more unbleached fibre to be used to make a stronger product at the same overall grammage.

The most remarkable effect of the wet end mfc coating is on sheet surface properties. The base paper used is very porous – the uncoated base had a Gurley porosity value of less than 10s/100ml. With the 28 gsm 80/20 $CaCO_3$/mfc coating layer this is increased to 185s/100ml, and with a 42gsm coating it rises further to 400s/100ml. Likewise with 28gsm of coating the Bendtsen smoothness was improved from 1580 ml/min to 520 ml/min.

This work demonstrates that the co-ground mineral/mfc product can potentially be used as a white top layer for linerboard by applying it to the wet end with a curtain coater. This could be achieved on a Fourdrinier machine with relatively minor modifications, and crucially without the need for a multilayer former.

CONCLUSIONS

Co-grinding of fine mineral particles and pulp has been proven to be a cost-effective method of producing microfibrillated cellulose which has many potential applications in paper and paperboard. Addition of a few percent of mfc greatly increases the in-plane and out-of-plane strength properties of the web, so that very substantial filler increases can be achieved without loss of properties. This can be used in various packaging grades to improve properties and reduce costs, principally by allowing the substitution of bleached chemical pulp with filler and unbleached fibres. Mfc also shows great promise as a binder for coatings which can be applied at the wet end, thus enabling the production of two-layer structures without the need for multiformers or conventional coating and drying equipment.

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[1] Kumar, V., Elfving, A., Koivula, H., Bousfield, D. and Toivakka, M., 2016. Roll-to-roll processed cellulose nanofiber coatings. Industrial & Engineering Chemistry Research, 55(12), pp.3603-3613