Nanofibrillated Cellulose (NFC) coat weight predictions when coating onto paper

Finley Richmond and Douglas W. Bousfield

Department of Chemical and Biological Engineering

The University of Maine

Orono, ME 04469-5737

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Nanofibrillated cellulose (NFC) has the potential to be produced at low cost at paper mills through mechanical methods. NFC has been shown to create a layer with fine pores over paper fibers that can capture ink pigments, increasing the print density of the surface. However, NFC is produced at low solids. The rheology of NFC suspensions becomes complex as the solids are increased [1]. The method to coat moderate solids NFC onto paper is not clear in the literature.

Suspensions of NFC at different solids were coated onto paper surfaces with a forward roll coating system as depicted in Figure 1. NFC was produced as described earlier as well as the rheology of the NFC suspension was reported [1]. The NFC suspensions were filtered to change the solids level and to obtain the specific filtration cake resistance. Figure 2 shows that the filtration rate follows the standard behavior. Excess suspension was applied in front of the nip. The computer controlled rolls rotate one time at the speed of interest to apply the suspension to the paper. A commercial finite element package (COMSOL) using the Carreau model to describe the shear thinning nature of the suspension is used to predict the coat weight.

Figure 3 shows the pressure field predicted in the nip. The coat weight is calculated by integrating the velocity profile perpendicular to the flow direction at any location. The nip load is obtained by integrating the pressure pulse in the positive part of the curve. Coat weight predictions are shown in Figure 4.

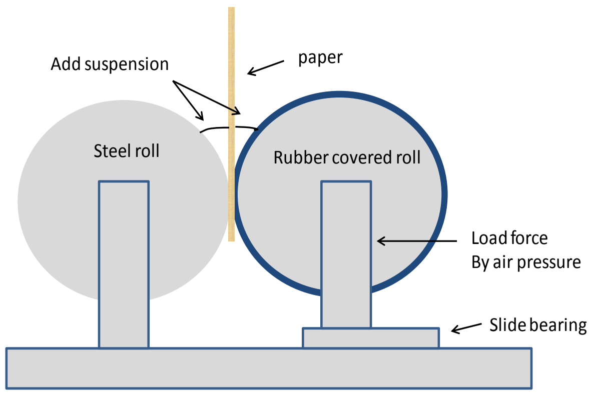

Figure 1. Flooded size press configuration.

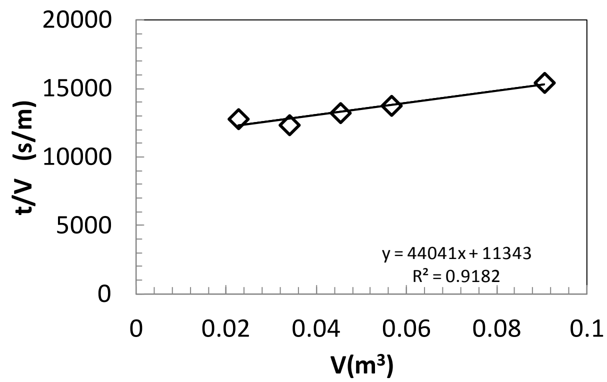

Figure 2. Filtration time (t) and volume (V).

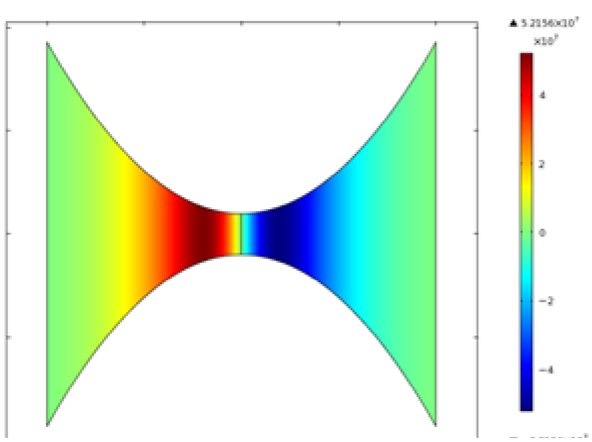

Figure 3. Pressure field predicted in nip.

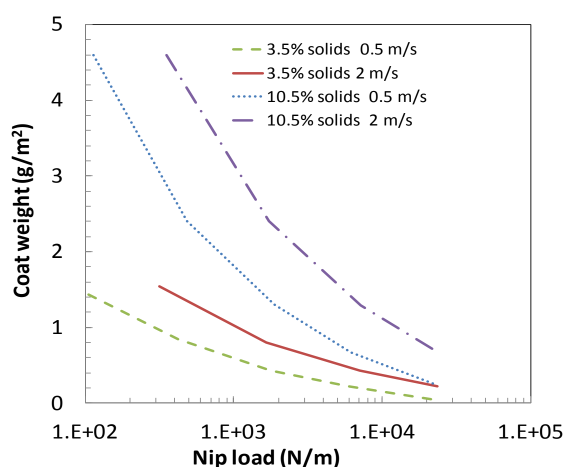

Figure 4. Coat weight predictions for flooded case.

The coat weights obtained with the flooded nip conditions are shown in Figures 5 and 6. Three key unexpected results are clear:

1. The coat weight slowly decreases with increasing nip load, much different than predicted in Fig. 4,
2. The coat weight moderately increases with increasing solids, much less than predicted in Fig. 4,
3. And the coat weight is insensitive to speed.

In Fig 6, as the solids increase by a factor of three, the coat weight increases less than a factor of two.

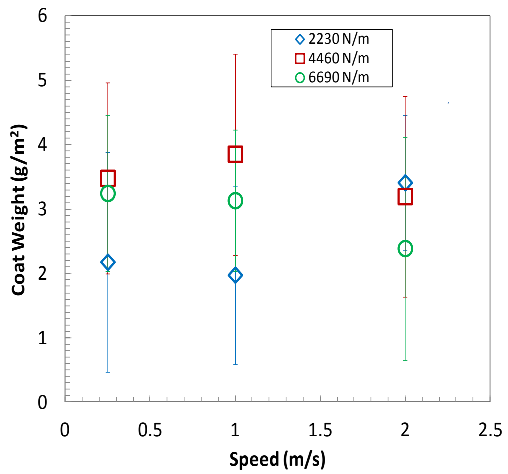

Figure 5. Coat weight measured at different speeds for 3% solids suspension. Error bars are standard deviation from five repeats.

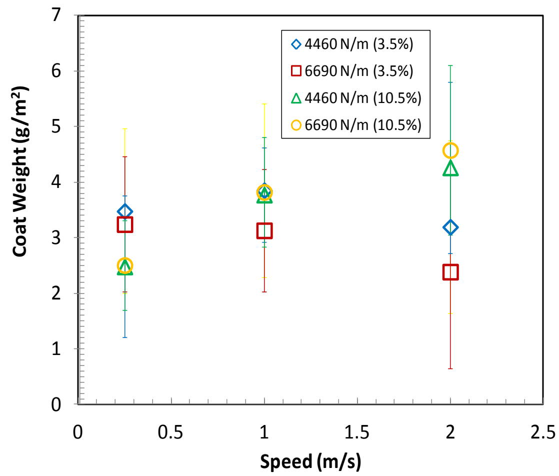

Figure 6. Coat weight measured at different speeds for 3% and 10.5% solids suspension at two loads. Error bars are standard deviation from five repeats.

The results indicate that the coat weight is determined by two separate mechanisms. At low speeds, water is forced into the paper substrate, forming a filtercake of NFC on the paper surface. This material increases the amount of NFC that is able to pass through the nip. This filtration event seems to dominate at low speeds because there is more time for dewatering in the nip. At high speeds, the coat weight is determined by the hydrodynamic forces generated in the nip. This is the amount of NFC that passes in the fluid phase through the nip.

The amount of time for filtration can be estimated by the length of the "puddle" in front of the nip divided by the nip length. The average filtration pressure is the nip loading divided also by this nip length. Therefore, with use of the standard filtration equations, using parameters to fit the results in Fig. 2, the amount of material that would be deposited on the web can be predicted. This is similar to the method used by Devisetti and Bousfield to predict penetration in the nip for a pure fluid [2]. As the nip speed increases, there is less time for dewatering. As nip pressure increases, more dewatering is predicted. By looking at the coat weight predictions from the fluid flow through the nip compared to the amount of dewatering, the trends of the experimental results make sense. The lack of sensitivity to speed comes from large dewatering at slow speeds that would deposit more NFC on the paper web but at high speeds, large hydrodynamic forces would generate a more open gap allowing more NFC onto the paper. As nip load increases, the gap should decrease to generate less coat weight, but these loads would increase the dewatering mechanism.

By a simple addition of the coat weight predicted by fluid flow, as in figure 4, to the amount of dewatering predicted by the standard filtration equations, a method to predict coat weight is obtained. In reality, a number of other factors can be at play and the dewatering mechanism would interact with the fluid flow calculation through a mass balance. For most cases, the predicted results are less than the measured results, but they are in the same order of magnitude.

Concluding Remarks

NFC is able to be coated onto paper with metered and flooded size press methods up to solids levels of 10%. The coat weights are insensitive to speed and moderately sensitive to nip loading and solids. The results can be explained by two different mechanisms. At low speeds, the dewatering in the nip gives rise to a filtercake of material on the paper web. At high speeds, the hydrodynamic forces balance the nip loading to control the coat weight. A model is presented that predicts the general trends and the correct range of values.

1. Finley Richmond, Albert. Co, and Douglas. W. Bousfield, “The coating of nanofibrillated cellulose onto paper using metered and flooded size press methods”., Proc. Technical Association of Pulp and Paper, PAPERCON, 2012.
2. Devisetti S.K. and D. W. Bousfield, “Fluid absorption during forward roll coating of porous webs”, Chem. Eng. Sci., (2010) 65: 3528-3537.