The effect of coherent fiber flocs on the shear strength and yield stress of cellulosic fiber suspensions

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INTRODUCTION

We assess a new concept for energy savings and laboratory flow experiments based on flocculation of fibrous and elongated particle suspensions. Results show that the potential is as much as a 50 percent increase in dewatering capacity and a decrease in pressure loss in pipe flow, indicated by yield stress in rheology measurements, to a factor of 6 to 10. The flocculation process is based on a well-known technic described by Jacquelin[1] and is applicable for fibers with large enough length to diameter ratio[2] and when the fiber concentration is above a critical value given by the sediment volume concentration.

EXPERIIMENTAL

For the purpose of oscillatory rheometry measurements we used home built plate plate-reservoir geometry shown in Fig. 1, mounted in Kinexus Pro rotational rheometer (Malvern Instruments Ltd, England). In order to maintain the no slip condition at the top and bottom walls we used rough top serrated plate and rough sand paper (grit Num. 180) glued to the bottom of the plate-reservoir. Known amounts of coherent fiber flocs (CFF), produced in a decelerating-turning flow using a rotating inclined laboratory beaker, were mixed with dispersed fiber suspensions. The portions of CFF and dispersed fibers were tuned so that the total consistency of the suspensions, calculated according to the total amount of fibers in dispersed and CFF forms, remained in the range of 3.5-4.5 % w/w.

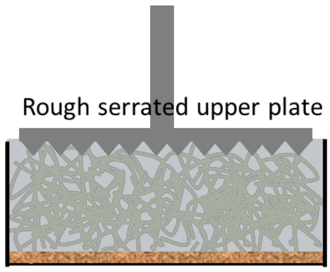

Figure 1. Rheometer geometry. Rough upper plate (serrated) is placed inside bottom plate-reservoir geometry, with rough bottom made of sand paper.

Shown in Fig. 2 is the behavior of the elastic modulus of suspensions with total consistencies in the range of 3.5-4.3 % w/w. While the CFF portion of the suspension is increased from 0% to 100%, the elastic modulus in the linear response regime (at low strain values) is decreased from $66 \cdot 10^3$ Pa to $3.5 \cdot 10^3$ Pa, respectively. On the same time, the critical strain (the strain value above which the elastic modulus starts to decrease) remains almost constant, implying that the yield stress, given by the multiplicity of elastic shear modulus in the linear response regime by the critical strain[3; 4], is decreased by a factor of between 6 and 10.

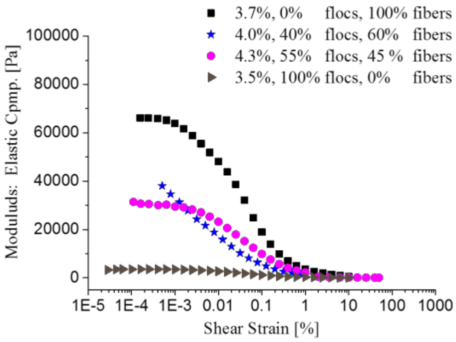

Figure 2. Elastic modulus versus shear strain of fiber suspension. The parameters specified in the legends are in this order: consistency, Flocs (CFF) percentage and (dispersed) fibers percentage.

These effects are opposite that of chemical flocculants which increase the shear strength. We suggest that the underlying mechanism for the dramatic decrease in yield stress as an effect of the CFF flocculation is the transformation of a gel like state of fibrous suspension, where inter-fiber mechanical entanglement occurs almost continuously across the volume, to a suspension of large particles in the shape of CFF, where the inter-fiber mechanical entanglement is non-continuous and limited to the regions inside single CFF particles.

SUMAARY AND FORESIGHT

The results have obvious implications for increased pumping efficiency of fibrous suspensions. The concept would require a new design of some of the machinery equipment such as stirred tanks in combination with pipe flow but the energy-saving potential is great. The foreseen industrial applications are primarily in biomass conversion but could also be in other sectors, such as waste water treatment, or any application rich in fibrous material and where there are substantial bottlenecks in dewatering capacity, and high pressure loss in pipe flow resulting in the need to use low solids with loss in production efficiency.

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