New opportunities in the paper and nonwovens industries with foam-assisted web forming and chemical application

ANTTI OKSANEN, TUOMO HJELT, JANI LEHMONEN, TIMO RANTANEN, JAAKKO ASIKAINEN, AND KRISTIAN SALMINEN

ABSTRACT: Foam-assisted web forming and chemical application technologies have great potential to improve manufacturing efficiency and product quality in the paper and nonwovens industries. In this study, the benefits of foam forming and foam-assisted application of chemicals were demonstrated in a pilot machine trial. Uniform high-bulk webs of unrefined bleached softwood kraft pulp (BSKP) and viscose fibers were manufactured by foam forming. It was shown that foam formed low-grammage and high-bulk viscose fiber webs can be strengthened by foam-assisted application of latex onto the wet web. Correspondingly, foam-assisted application of carboxymethyl cellulose (CMC) and anionic polyacrylamide (A-PAM) improved the strength of the foam formed low-grammage and high-bulk BSKP web. Overall, the pilot machine results indicated that material cost savings could be achieved and a high-performance product could be manufactured with foam-based technologies.

Application: Foam forming of the fiber web and foam-assisted application of chemicals on the wet web may enable manufacture of new products with older paper machines or enhance the production efficiency of the current product.

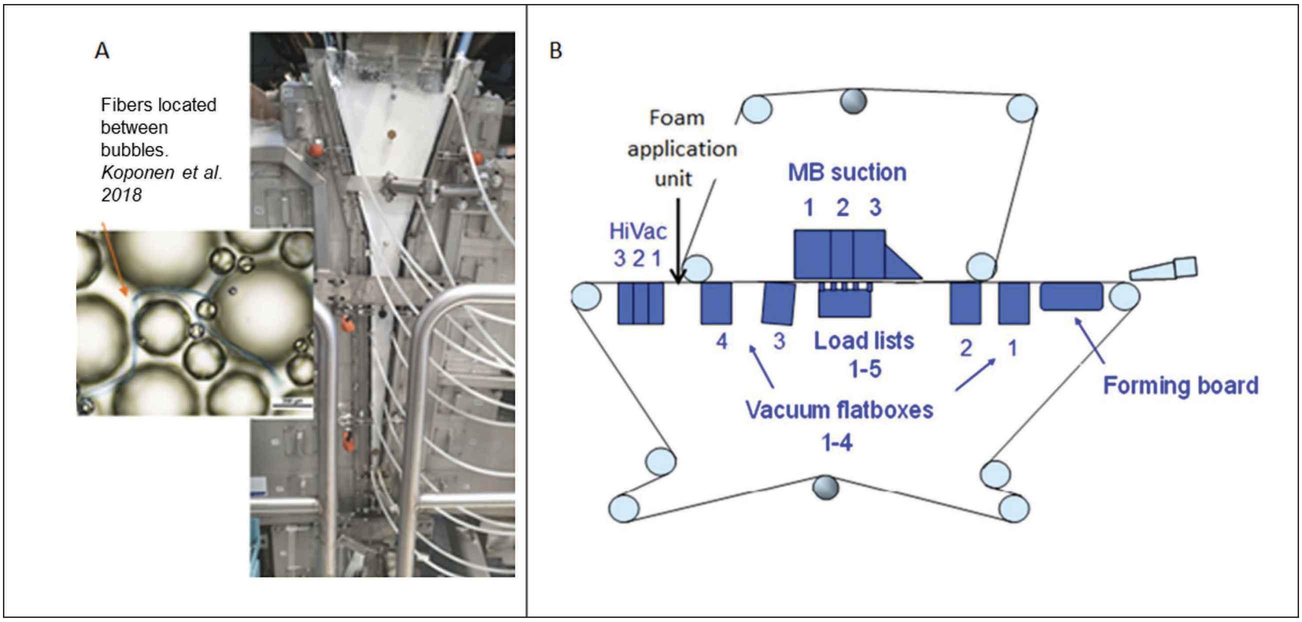
The forest industry is considered energy and raw materials intensive. Thus, sustainable solutions are constantly sought to make savings in these areas. In addition, finding new fiber products has become more and more important due to the strong digitalization trend. Likewise, in the nonwovens industry, novel efficient manufacturing processes, products, and sustainable fiber materials and binders are desired. Foam forming of the fiber web and foam-assisted application of chemicals can reduce manufacturing costs and enable production of novel sustainable high-performance products in the forest and nonwovens industries.

Even in the 1970s, it was reported that foam as a carrier phase for fibers can create sheets having high uniformity and bulk, even at low basis weight [1-3]. An increasing need for more versatile and cost-efficient production methods capable of handling a variety of raw materials (e.g., longer fibers enabling production of new types of products) has raised interest in foam forming technology during the last decade [4-11] (**Fig. 1a**).

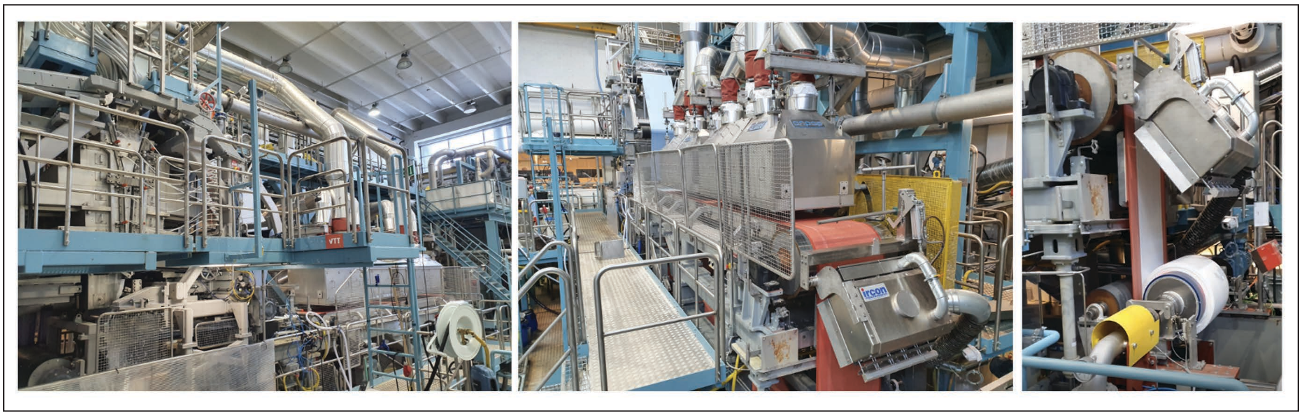
Foam-assisted application of materials onto the web is a versatile technology enabling the use of a large variety of materials, such as high viscous and gel-like materials (e.g., nanocellulose). Foam-assisted application gives even and adjustable distribution of the chemical in the paper, paperboard, or nonwovens product. In addition, foam-assisted chemical application is expected to enable high retention of uncharged (lower cost) polymers, because the dry solids content of the wet web in the application area is relatively high at typically ~20% (**Fig. 1b**). High amounts of strength aids such as starch or latex could be applied by foam onto the web without weakening the formation of the product. Chemical addition in the wet end and foam-assisted application onto the web could be also combined, for example, to maximize the dosage of the chemical in the product. Another benefit of foam-assisted application is that chemicals are expected to interact less with fines when they are externally applied to the wet web by foam instead of using wet-end application [12]. Furthermore, applying surfactants by foam or spraying on the top of paper increased dryness after wet pressing [13]. Lately, it has been shown that foam-assisted application can be used to chemically bond nonwoven structures [14]. Spray application is an efficient way to improve the ply-bond strength, but it causes problems with maintenance (clogging of spray nozzles and clogging of felts) and safety (e.g., airborne particles and slippery floors). Foam-assisted application is expected to solve those challenges.

MATERIALS AND METHODS

Two furnishes were used in the pilot machine trials: 100% viscose fiber (DANUFIL, Kelheim Fibres GmbH; Kelheim, Germany) of 5 mm length in 90 and 45 g/m^2 webs, and 100% unrefined bleached softwood kraft pulp (BSKP) in a 45 g/m^2 web. Sodium dodecyl sulphate (SDS) was used as a surfactant in foam forming and in foam-assisted



1. a) Foam forming with the vertical headbox [11], and b) one setup for the foam-assisted application of chemicals in the forming section.



2. VTT's pilot-scale research environment for non-pressed materials (SAMPO).

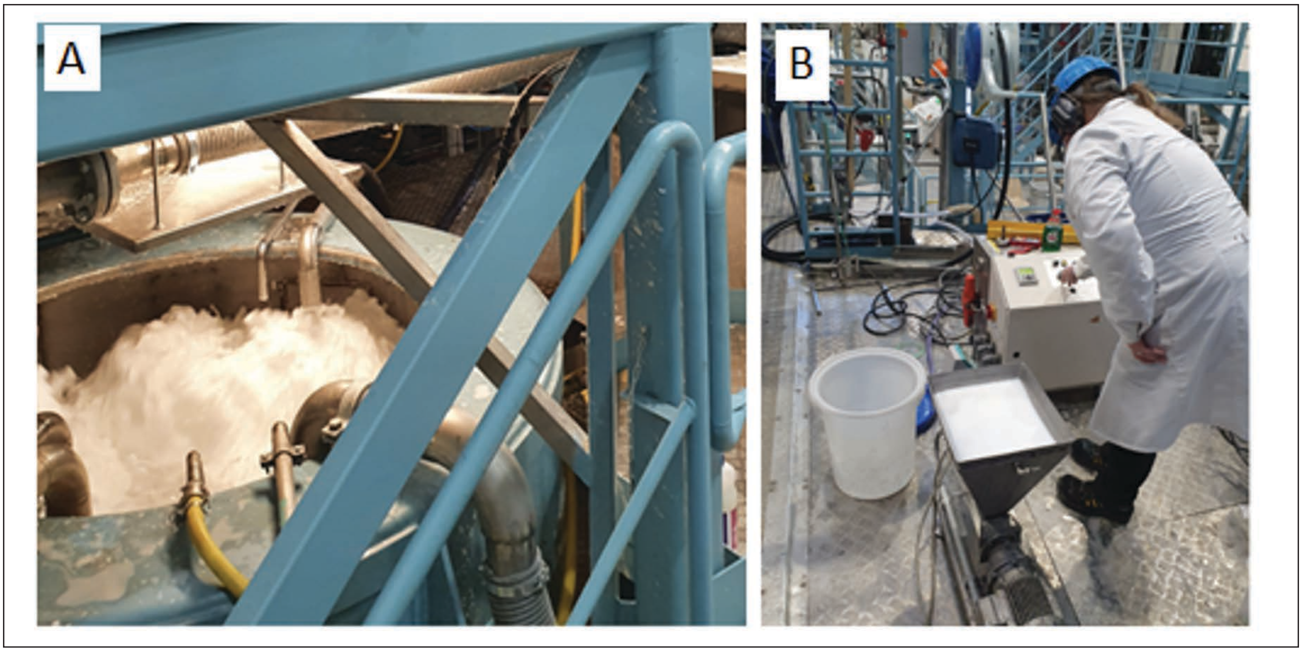
application of strength aid chemicals. Latex (CHP 676) was applied by foam on top of a wet viscose fiber web. The polyamide-epichlorohydrin (PAE, Kymene 725-EU; Solenis, Wilmington, DE, USA) was added in the wet end when carboxymethyl cellulose (CMC, Finnfix 4000 G; Nouryon, Amsterdam) and anionic polyacrylamide (A-PAM, FennoBond 6400; Kemira Oyj, Helsinki) were applied by foam on top of the wet unrefined BSKP web.

Figure 2 presents VTT Technical Research Center of Finland's pilot-scale research environment for non-pressed materials (SAMPO) in Jyväskylä, Finland, that was used to produce bulky fiber webs. The SAMPO pilot machine is run with foam forming technology. Its features include:

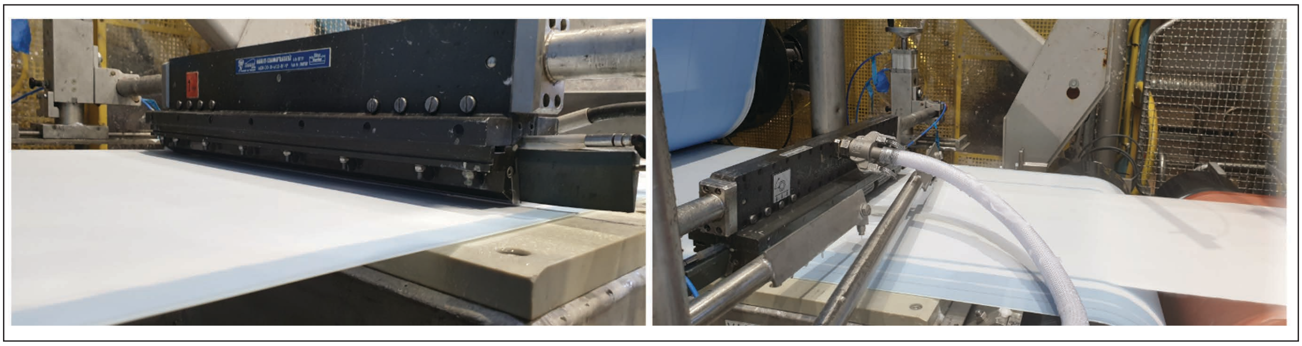
- Vertical headbox
- 600-mm width web
- Maximum speed of 200 m/min
- No wet pressing
- Non-contact impingement, through-air and infrared dryers

Fiber foam was created in a tank by mixing an SDS dose of 0.02%–0.05% of web dry solids content in the foam forming trials (Fig. 3a). Air content of the fiber foam was adjusted to between 55% and 60%. The PAE was mixed with the unrefined BSKP before foaming the furnish. In the foam-assisted application of the chemicals (CMC and A-PAM) on top of the wet web, a Hansa Mixer foam generator (Hansa Industrie-Mixer GmbH; Stuhr, Germany) was used to generate the foamed additives by shear forces created between stator and rotor units and applied pressurized air (**Fig. 3b**). Air content of foamed chemicals was ~90% in the trials.

Foamed chemicals were introduced on top of the wet web with the Zimmer foam applicator (Zimmer



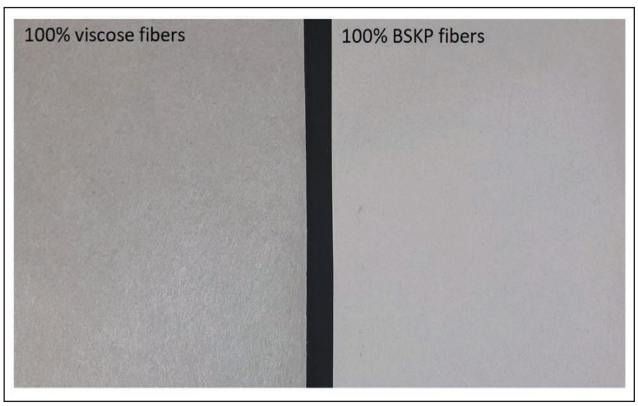
3. a) Creation of fiber foam in a tank, and b) foaming of chemicals with a Hansa mixer foam generator.



4. Foam applicator above the vacuum unit in the forming section of the pilot machine. A 100% viscose fiber base was used, and latex was applied by foam on top of the wet web.

Maschinenbau GmbH; Klagenfurt, Austria) shown in **Fig. 4**. The Zimmer foam applicator (width 500 mm) was placed above the vacuum unit in the pilot machine (Fig. 4) in the forming section. The distance (adjustable) of the foam applicator from the fabric was 3–5 mm. The applied vacuum below the foam applicator was ~10 kPa. Chemicals are absorbed inside of the wet web by the applied vacuum. In addition, the viscosity of the applied material influences the penetration to the web.

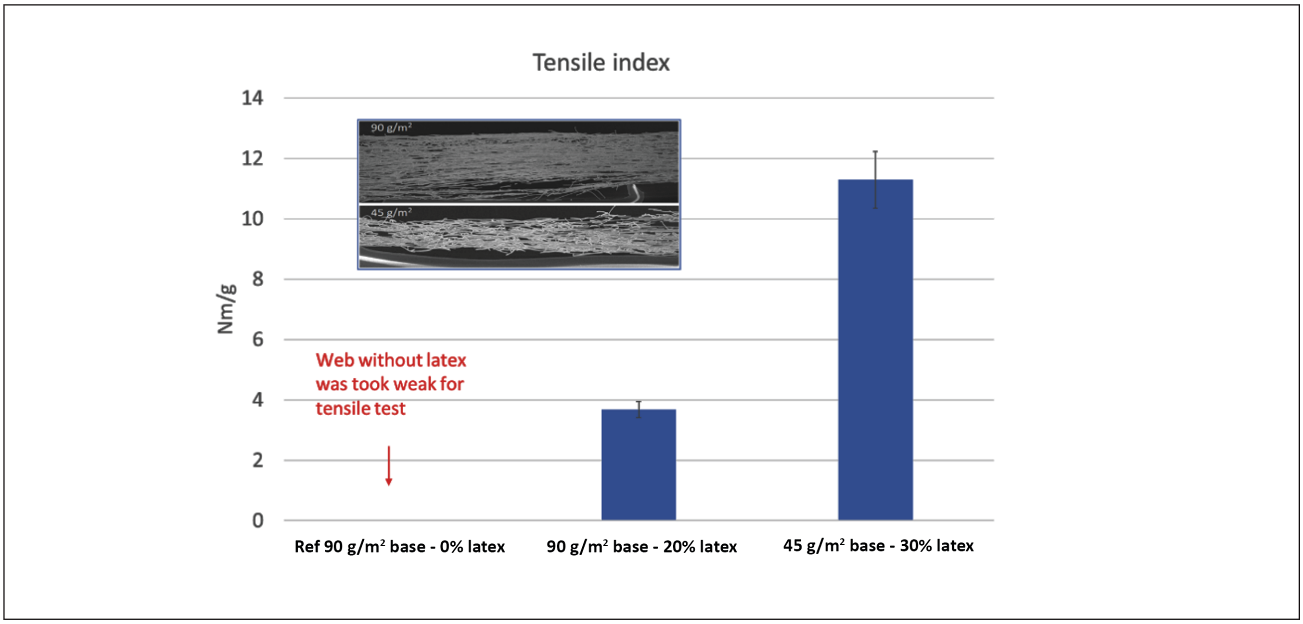
The temperature of the drying air in the hoods was 150°C. The final solids content of the web was ~90%. In addition, the samples containing PAE were cured in an oven at 105°C for 10 min.



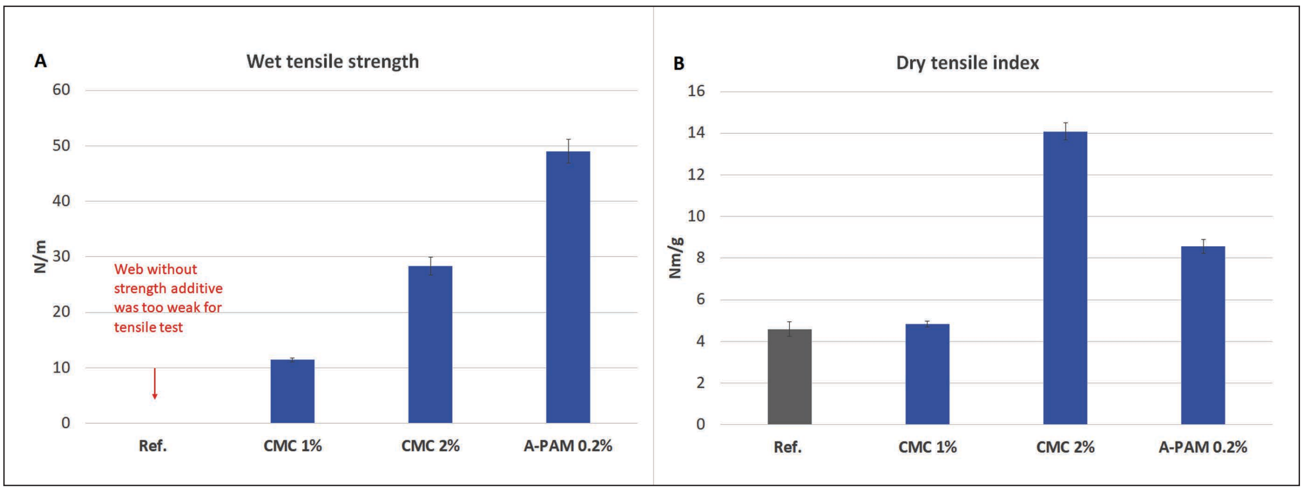
5. Foam-formed 100% viscose fiber and 100% BSKP fiber web samples. Grammage is 45 g/m^2.

RESULTS

Foam forming enabled creation of uniform, low grammage (45 g/m^2) web samples with 5 mm viscose fibers and unrefined BSKP fibers (**Fig. 5**). The cationic wet strength agent PAE (4 kg/metric ton) was mixed with BSKP fibers in the wet end before foaming the furnish without deterioration of the web formation. The bulk of the web samples with the viscose fiber base was between 5 and 10 cm^3/g, and with the unrefined BSKP fiber base, it was between 4 and 6 cm^3/g.



6. Tensile index and crosscut images of foam-formed viscose fiber webs, and the foam-assisted application of latex on top of the wet web.



7. a) Wet strength (re-wetted) and tensile index values of foam-formed high-bulk BSKP 50 g/m² webs, and b) foam-assisted application of strength aids on top of the wet web.

High bulk values were achieved due to the foam forming technology distributing fibers evenly in the high air content (bulky) structure and because the web was not wet pressed.

Foam-assisted application of latex on top of the viscose fiber web enhanced the strength of the viscose web so that tensile index could be measured on the high-bulk samples. Based on the strength results, especially in the lower grammage 45 g/m² trial point, the applied latex efficiently penetrated inside of the viscose web, increasing the strength of the high-bulk 10 cm³/g structure. Tensile index values and crosscut images of the foam-formed viscose fiber webs are presented in **Fig. 6**. The penetration of the latex to a high-grammage web in foam-assisted application can be enhanced by increasing vacuum level below the foam applicator and by decreasing the viscosity of the chemical.

Foam-assisted application of CMC increased re-wetted wet strength of the 50 g/m² BSKP web as a function of the dosage (**Fig. 7a**). The highest re-wetted wet strength improvement was observed when foamed A-PAM was applied on the top of the wet web. Anionic additives are known to enhance the performance of the wet strength agent PAE in papermaking [15]. Foam-assisted application of CMC (2% in dry weight) increased dry tensile index by ~200% for the weak, high-bulk (~4.5 cm³/g) webs (**Fig. 7b**). Addition of A-PAM also had a significant influence on the dry tensile index; the dry tensile index was almost doubled when the A-PAM was applied by foam on top of the wet web.

CONCLUSIONS

These pilot machine trials successfully demonstrated that foam forming enables manufacture of uniform low-grammage, high-bulk structures with viscose and BSKP fibers. It was shown that longer synthetic fibers (or natural nonwood fibers, respectively) are applicable in foam forming. The weak fiber webs were strengthened with foam-assisted application of strength aids in the forming section of the pilot machine. Foam-assisted application of a chemical can be used for surface or whole (bulk) structure treatment of the web.

The strengthening of the web can be done by using two different approaches. One is the application of strengthening agent to the structure. This was done with latex in this work. Another way is to use the synergy of two chemicals. In this work, we added PAE to the pulp and CMC and A-PAM were applied with foam application. With this approach, one can reduce the use of the strength aid chemicals in the product.

High-quality lightweight and low-density products for the paper or nonwovens industries (e.g., filters or insulating materials) could be cost-efficiently manufactured by utilizing the foam-based technologies presented in this paper. **TJ**

ACKNOWLEDGMENTS

This research was funded by the VTT Technical Research Center of Finland. The authors wish to thank chemical companies for providing chemicals used in the pilot machine trials. In addition, discussions with Business Finland parties from the ChemFunc project were very valuable in interpretation of the results.

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ABOUT THE AUTHORS

Foam application of chemicals in the forming section of the paper or paperboard machine enables manufacture of enhanced or even new products with the current machine. The possibility of applying chemicals by foam to the wet web has not been widely studied. Even more rare are pilot trial demonstrations with this technology.

The challenge of adjusting the foam-assisted application of chemicals in the pilot machine was solved by trial and error. Interestingly, the location of the foam applicator on top of the wet web was not found to be that critical.

We discovered that foam-assisted application can be used to apply both very small or high dosages of the chemical, depending on the need. Suprisingly, foam-assisted application of chemicals enables application of very viscous materials, which is not possible in the case of spray application, for example.

With the information presented here, mills can start to clarify the potential of foam-assisted application of chemicals in their process, first in laboratory studies and then in pilot or in mill trials. The next steps for foam-assisted application technology will be presented at pulp and paper industry conferences and through direct contact with companies. New projects will then be started in this area between industry and research parties.

Oksanen

Hjelt

Lehmonen

Rantanen

Asikainen

Salminen

Oksanen is senior scientist, Hjelt is senior scientist, Lehmonen is senior scientist, Rantanen is senior reserarch technician, Asikainen is research team leader, and Salminen is lead at VTT Technical Research Center of Finland Ltd., Jyväskylä, Finland. Email Oksanen at antti.oksanen@vtt.fi.

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ABOUT THIS PAPER

Cite this article as:
Oksanen, A., Hjelt, T., Lehmonen, J., et al., *TAPPI J.* 22(1): 61(2023). https://doi.org/10.32964/TJ22.1.61

DOI: https://doi.org/10.32964/TJ22.1.61

ISSN: 0734-1415

Publisher: TAPPI Press

About this journal