MEC-E5002 Mechatronic Project

Title, introduction and drafting of the paper

Niko Lappalainen 426095
Juho Piilola 475088
Antti Romo 719838

In this assignment, we chose 3 possible topics for our paper;

1. **Wet spinning cellulose nanofibril filaments in a continuous setup**
2. **Developing a continuous CNF spinning setup**
3. **Extrusion speed effect on drawing in continuous CNF spinning setup**

Since we are not yet certain what the final topic of our paper will be, we generated a bit more abstract Introductions to each of these topics and did a outline of the paper that we can use with any of the topics.

Version 1. Wet spinning CNF filaments in a continuous setup

1. Introduction

The environmental issues regarding plastics such as carbon emissions and microplastics ending up in the ocean have pushed material research towards bio-based options (Klar et al., 2018). Also the consumers, industry and governments are increasingly demanding for products that are made from renewable resources with low environmental impact (Moon et al., 2011).

A promising substitutive material is nanocellulose obtained from lignocellulosic biomass (Lee et al., 2014). Cellulose nanofibrils (CNFs) are lightweight, biodegradable and their stiffness is comparable to kevlar and steel (Lee et al., 2014; Lundahl et al., 2016). Nanocellulose nanoparticles are ideal materials for composite products and their potential applications include flexible displays, polymer fillers, biomedical implants, fibers and textiles, and many others (Moon et al., 2011).

Continuous fibers with a desired length can be formed by various spinning techniques, such as dry-spinning, wet-spinning or dry-jet wet-spinning. The only techniques applied to CNF spinning without added polymers are wet- and dry-spinning. (Lundahl et al., 2016)

Mechanical properties of man-made cellulosic materials depends on the cellulose crystallite alignment, which can be enhanced by drawing during the spinning. However, this can be difficult to implement because of the low aspect ratio of CNF. (Baez, Considine and Rowlands, 2014; Sehaqui et al., 2012; Lundahl et al., 2016)

Four grand challenges in cellulose nanoparticle processing have been identified that, when solved, would greatly increase the potential for expanding cellulose nanoparticle usage in new composite materials. These challenges are: 1) decreasing the internal damage in CNs as a result of the extraction process, 2) narrow the particle size range for a given CN processing methodology, 3) decrease the cost of the extraction process and 4) scaling up production to industrial quantities. (Moon et al., 2011)

In this paper, we focus on the challenge of scaling up production, which is challenging especially if controlled structure and characteristics of the material are demanded (Lundahl et al., 2016) and we examine how CNF filaments could be wet spun in a continuous way that would allow the production to be scaled up to industrial quantities.

The process used in this study is conducted in room temperature and salt solution is used in the solidification bath. The aqueous CNF suspension is pumped into the salt solution and a roll is used to transfer the CNF from solidification bath into the washing bath without breaking. Another roll is used at the end of the washing bath to allow the CNF transported into drying. The rotating speed of both rolls is interrelated to the extrusion speed of the spinneret and drawing speed at both baths is adjustable.

Version 2. Developing a continuous CNF spinning setup

1. Introduction

The environmental issues regarding plastics such as carbon emissions and microplastics ending up in the ocean have pushed material research towards bio-based options (Klar et al., 2018). Also the consumers, industry and governments are increasingly demanding for products that are made from renewable resources with low environmental impact (Moon et al., 2011).

A promising substitutive material is nanocellulose obtained from lignocellulosic biomass (Lee et al., 2014).Cellulose nanofibrils (CNFs) are lightweight, biodegradable and their stiffness is comparable to kevlar and steel (Lee et al., 2014; Lundahl et al., 2016). Nanocellulose nanoparticles are ideal materials for composite products and their potential applications include flexible displays, polymer fillers, biomedical implants, fibers and textiles, and many others (Moon et al., 2011).

Continuous fibers with a desired length can be formed by various spinning techniques, such as dry-spinning, wet-spinning or dry-jet wet-spinning. The only techniques applied to CNF spinning without added polymers are wet- and dry-spinning. (Lundahl et al., 2016)

Mechanical properties of man-made cellulosic materials depends on the cellulose crystallite alignment, which can be enhanced by drawing during the spinning. However, this can be difficult to implement because of the low aspect ratio of CNF. (Baez, Considine and Rowlands, 2014; Sehaqui et al., 2012; Lundahl et al., 2016)

Four grand challenges in cellulose nanoparticle processing have been identified that, when solved, would greatly increase the potential for expanding cellulose nanoparticle usage in new composite materials. These challenges are: 1) decreasing the internal damage in CNs as a result of the extraction process, 2) narrow the particle size range for a given CN processing methodology, 3) decrease the cost of the extraction process and 4) scaling up production to industrial quantities. (Moon et al., 2011)

In this paper, we focus on the challenge of scaling up production, which is challenging especially if controlled structure and characteristics of the material are demanded (Lundahl et al., 2016) and we present a prototype of a wet spinning line for CNF that would allow the production to be scaled up to industrial quantities.

The process used in this study is conducted in room temperature and salt solution is used in the solidification bath. The aqueous CNF suspension is pumped into the salt solution and a roll is used to transfer the CNF from solidification bath into the washing bath without breaking. Another roll is used at the end of the washing bath to allow the CNF transported into drying. The rotating speed of both rolls is interrelated to the extrusion speed of the spinneret and drawing speed at both baths is adjustable.

Version 3. Extrusion speed effect on drawing in continuous CNF spinning setup

1. Introduction

The environmental issues regarding plastics such as carbon emissions and microplastics ending up in the ocean have pushed material research towards bio-based options (Klar et al., 2018). Also the consumers, industry and governments are increasingly demanding for products that are made from renewable resources with low environmental impact (Moon et al., 2011).

A promising substitutive material is nanocellulose obtained from lignocellulosic biomass (Lee et al., 2014).Cellulose nanofibrils (CNFs) are lightweight, biodegradable and their stiffness is comparable to kevlar and steel (Lee et al., 2014; Lundahl et al., 2016). Nanocellulose nanoparticles are ideal materials for composite products and their potential applications include flexible displays, polymer fillers, biomedical implants, fibers and textiles, and many others (Moon et al., 2011).

Continuous fibers with a desired length can be formed by various spinning techniques, such as dry-spinning, wet-spinning or dry-jet wet-spinning. The only techniques applied to CNF spinning without added polymers are wet- and dry-spinning. (Lundahl et al., 2016)

Mechanical properties of man-made cellulosic materials depends on the cellulose crystallite alignment, which can be enhanced by drawing during the spinning. However, this can be difficult to implement because of the low aspect ratio of CNF. (Baez, Considine and Rowlands, 2014; Sehaqui et al., 2012; Lundahl et al., 2016)

Four grand challenges in cellulose nanoparticle processing have been identified that, when solved, would greatly increase the potential for expanding cellulose nanoparticle usage in new composite materials. These challenges are: 1) decreasing the internal damage in CNs as a result of the extraction process, 2) narrow the particle size range for a given CN processing methodology, 3) decrease the cost of the extraction process and 4) scaling up production to industrial quantities. (Moon et al., 2011)

In this paper, we examine how the extrusion speed of the cellulose nanofibrils affects the drawing capability of the nanofibrils during the solidification and washing.

One of these introductions would then be followed by chapters:

2. (Methods)

- What are we solving
- Why are we solving it
- Restrictions for the study

3. (Results)

- Results

4. (Discussion/Conclusions)

- Repeat why we did what we did, why it is important
- Results
- Further studies/problems

5. References

5. References

Baez, C., Considine, J. and Rowlands, R. (2014). Influence of drying restraint on physical and mechanical properties of nanofibrillated cellulose films. Cellulose, [online] 21(1), pp.347-356. Available at: http://web.a.ebscohost.com.libproxy.aalto.fi/ehost/detail/detail?vid=0&sid=eb3dbcdc-2d25-474f-9ff4-b20dc26823f3%40sessionmgr4010&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#db=teh&AN=93894121 [Accessed 3 Feb. 2019].

Klar, V., Orelma, H., Rautkoski, H., Kuosmanen, P. and Harlin, A. (2018). Spinning Approach for Cellulose Fiber Yarn Using a Deep Eutectic Solvent and an Inclined Channel. ACS Omega, [online] 3(9), pp.10918-10926. Available at: https://pubs.acs.org/doi/10.1021/acsomega.8b01458 [Accessed 3 Feb. 2019].

Klemm, D., Kramer, F., Moritz, S., Lindström, T., Ankerfors, M., Gray, D. and Dorris, A. (2011). Nanocelluloses: A New Family of Nature-Based Materials. Angewandte Chemie International Edition, [online] 50(24), pp.5438-5466. Available at: https://onlinelibrary-wiley-com.libproxy.aalto.fi/doi/full/10.1002/anie.201001273 [Accessed 2 Feb. 2019].

Lee, H., Hamid, S., Zain, S.(2014). Conversion of Lignocellulosic Biomass to Nanocellulose: Structure and Chemical Process. The Scientific World Journal, pp.1-20. Available at: http://search.proquest.com/docview/1560860676/abstract/967744725B0F4D82PQ/1 [Accessed: 3 February 2019].

Lundahl, M., Klar, V., Wang, L., Ago, M. and Rojas, O. (2016). Spinning of Cellulose Nanofibrils into Filaments: A Review. Industrial & Engineering Chemistry Research, [online] 56(1), pp.8-19. Available at: https://pubs.acs.org/doi/10.1021/acs.iecr.6b04010 [Accessed 2 Feb. 2019].

Moon, R., Martini, A., Nairn, J., Simonsen, J. and Youngblood, J. (2011). Cellulose nanomaterials review: structure, properties and nanocomposites. Chemical Society Reviews, [online] 40(7), p.3941. Available at: https://pubs-rsc-org.libproxy.aalto.fi/en/content/articlepdf/2011/cs/c0cs00108b [Accessed 2 Feb. 2019].

Sehaqui, H., Ezekiel Mushi, N., Morimune, S., Salajkova, M., Nishino, T. and Berglund, L. (2012). Cellulose Nanofiber Orientation in Nanopaper and Nanocomposites by Cold Drawing. ACS Applied Materials & Interfaces, [online] 4(2), pp.1043-1049. Available at: https://pubs-acs-org.libproxy.aalto.fi/doi/abs/10.1021/am2016766 [Accessed 3 Feb. 2019].

Tang, H., Butchosa, N. and Zhou, Q. (2015). A Transparent, Hazy, and Strong Macroscopic Ribbon of Oriented Cellulose Nanofibrils Bearing Poly(ethylene glycol). Advanced Materials, [online] 27(12), pp.2070-2076. Available at: https://onlinelibrary-wiley-com.libproxy.aalto.fi/doi/full/10.1002/adma.201404565 [Accessed 3 Feb. 2019].

Torres-Rendon, J., Schacher, F., Ifuku, S. and Walther, A. (2014). Mechanical Performance of Macrofibers of Cellulose and Chitin Nanofibrils Aligned by Wet-Stretching: A Critical Comparison. Biomacromolecules, [online] 15(7), pp.2709-2717. Available at: https://pubs-acs-org.libproxy.aalto.fi/doi/abs/10.1021/bm500566m [Accessed 3 Feb. 2019].