Developing a Machine for Efficient Nanopaper Manufacturing or Analysing the Relationship Between the Wire Tension, Headbox Pressure and Layer Thickness in a Nanopaper Machine or Keeping Constant Control of the Pressure in a Nano Paper Machine Headbox while Varying the Paper Layer Thickness

TABLE OF CONTENTS

Results and Discussion	• The result of the finished product, how well does the machine function, what is left to be desired, how could the machine be improved even more, etc.
Conclusion	• Summary of what was done in the project and the result

INTRODUCTION

This paper will introduce the work surrounding the construction undertaken of a nanopaper machine. Nanopaper is a type of paper which is made up of much smaller fibres than regular paper. It generally has a lower weight, higher abundance, better biodegradability and renewability as well as higher strength and rigidity [1]. The goal of nanopaper research is to find even more environmentally friendly paper materials and substitutes for plastic. Nanopaper can also be used for electrical purposes by inserting highly conductive electrical circuits into the nanopaper during the manufacturing process [2]. The main problem with this type of paper, however, is that the draining and drying can take a long time, up to a few days [1].This machine was constructed in order to provide a more efficient way of creating different nanopaper samples, both in terms of the nanopaper samples' composition but also in terms of their dimensions. Currently, several different methods exist for creating nano paper including several drawing methods, cellulose synthesis, spray deposition, electrospinning, and more [3, 4, 5, 6, 7, 8]. Some of these methods are efficient and fast due some optimisation of the methods, but there is still lots of room for improvement in terms of the availability and feasibility of these [7, 9].

METHODS

Our paper machine was built by attaching all the components as separate modules to cuboid aluminium frame. Frame was build so that there's space to work with the nanopaper web from the front of the machine, as machine is built for research purposes.

Main module attached to the frame is the conveyor belt system, which was built simple as possible from conveyor roll system connected to AC-motor with timing pulley. Roll system consists of four rolls. One of them is driving roll, which has motor attaches to it with timing pulley and rotary encoder to measure belt speed. Second one has angle control to make sure belt won't wander off of the rolls over time. This angle control was made with manual slot control and has to be adjusted if the belt seems to be out of place. Third roll has simple screw system for distance control to manually adjust belt tension in between runs. Last one is for supporting belt at the level of the driving roll. Basic AC-motor is used to drive the roll through the timing belt.

Second module attached to frame is headbox with stepper motor controlled height control of the gap between headbox and the belt, with increments of 1µm. Headbox is just a clear plastic box with hole in the bottom. Size of the hole was constant 16x5mm in our version of the machine to make 16mm wide paper. Stepper motor and headbox were placed on a plane which is connected to a screw system controlled by the stepper itself to adjust the gap accurately. Gap can be measured with both the stepper and with micrometer from reference plane next to driving roll to the headbox plane. Pressured air we get straight from laborator wall and adjust it to wanted level with pressure gauge before opening on-off-valve to the headbox simultaneously as the motor of the belt is turned on.

In addition to these main modules the machine had few other modules and space to add wanted modules for additional research. Machine had electronics module controlled by rasperry pi to drive the motor and measure its speed. As power we used standard wall outlets with suitable transformers. Machine also had to have web removing module to scrap exces cellulose to plastic bucket so it won't take extra rounds on the belt.

The testing for the nanopaper machine involved testing the entire machine that had been built and whether it ran smoothly, but it also, and perhaps more importantly tested the parameters of the machine and their relationship. The main parameters which had been a requirement for incorporation into the design from the start were the tension of the wire, the speed of the wire (0-10 m/min), the pressure inside the headbox (which controls the speed of the extrusion of the cellulose, around 1 bar), and the thickness of the extruded nanopaper sample (0-5mm in 1µm increments). In order to obtain a relationship between these, they had to be tested and this was done by keeping each one constant in turn to see how the others changed. Ultimately, the goal was to have the machine producing the perfect nanopaper sample, so it was necessary to play around with these parameters in order to see how the parameters needed to be adjusted in order to obtain the desired properties of the nanopaper. Results for this can be seen in the results section.

REFERENCES

1. I. Gonzalez, M. Alcala, G. Chinga-Carrasco, F. Vilaseca, S. Bou, and P. Mutje, “From paper to nanopaper: evolution of mechanical and physical properties,” Cellulose, vol. 21, no. 4, pp. 2599 - 2609, Aug 2014. [Online]. Available: https://doi.org/10.1007/s10570-014-0341-0
2. M.-C. Hsieh, C. Kim, M. Nogi, and K. Suganuma, “Electrically conductive lines on cellulose nanopaper for flexible electrical devices,” Nanoscale, vol. 5, pp. 9289 - 9295, 2013. [Online]. Available: http://dx.doi.org/10.1039/C3NR01951A
3. H. Sehaqui, N. Ezekiel Mushi, S. Morimune, M. Salajkova, T. Nishino, and L. A. Berglund, “Cellulose nanofiber orientation in nanopaper and nanocomposites by cold drawing,” ACS Applied Materials & Interfaces, vol. 4, no. 2, pp. 1043 - 1049, 2012, pMID: 22257144. [Online]. Available: https://doi.org/10.1021/am2016766
4. L. Rozenberga, M. Skute, L. Belkova, I. Sable, L. Vikele, P. Semjonovs, M. Saka, M. Ruklisha, and L. Paegle, “Characterisation of films and nanopaper obtained from cellulose synthesised by acetic acid bacteria,” Carbohydrate Polymers, vol. 144, pp. 33 - 40, 2016. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0144861716300819
5. K. Uetani, T. Okada, and H. T. Oyama, “In-plane anisotropic thermally conductive nanopapers by drawing bacterial cellulose hydrogels,” ACS Macro Letters, vol. 6, no. 4, pp. 345 - 349, 2017. [Online]. Available: https://doi.org/10.1021/acsmacrolett.7b00087
6. L. F. Krol, D. Beneventi, F. Alloin, and D. Chaussy, “Microfibrillated cellulose-SiO2 composite nanopapers produced by spray deposition,” Journal of Materials Science, vol. 50, no. 11, pp. 4095 - 4103, Jun 2015. [Online]. Available: https://doi.org/10.1007/s10853-015-8965-5
7. D. Beneventi, E. Zeno, and D. Chaussy, “Rapid nanopaper production by spray deposition of concentrated microfibrillated cellulose slurries,” Industrial Crops and Products, vol. 72, pp. 200 - 205, 2015, special issue derived from International Conference on Bio-based Materials and Composites. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0926669014007109
8. S. Lingaiah and K. Shivakumar, “Electrospun high temperature polyimide nanopaper,” European Polymer Journal, vol. 49, no. 8, pp. 2101 - 2108, 2013. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S001430571300222X
9. H. Sehaqui, A. Liu, Q. Zhou, and L. A. Berglund, “Fast preparation procedure for large, flat cellulose and cellulose/inorganic nanopaper structures,” Biomacromolecules, vol. 11, no. 9, pp. 2195 - 2198, 2010, pMID: 20698565. [Online]. Available: https://doi.org/10.1021/bm100490s
10. S. Lingaiah, K. Shivakumar, and R. Sadler, “Electrospun nanopaper and its applications to microsystems,” International Journal for Computational Methods in Engineering Science and Mechanics, vol. 15, no. 1, pp. 2 - 8, 2014. [Online]. Available: https://doi.org/10.1080/15502287.2013.833996