DEVICE FOR CONTINUOUS CELLULOSE YARN DRYING AND FORMING


Abstract: Cotton fibres are widely used for manufacturing of fabrics but cotton farming requires heavy use of agrochemicals and irrigation. However, it is possible to produce yarn directly from pulp fibres with no dissolution or disintegration process. This research describes design, manufacture and testing for a device which is used to dry and form continuously flowing pulp fibre suspension into yarn. The developed device described in this paper was capable of continuous manufacturing of fibre yarn and it established solid basis for future research. Key words: cellulose, fibre, yarn, cotton, wire, rayon

1. INTRODUCTION

Cotton farming covers 5 % of world's farming area but it uses 11 % of all agrochemicals. Intensive farming of cotton has caused pollution to the waters, wear of the soil and it has changed the animal population. In the future highly pollutant cotton can be replaced by cellulose based materials. There are already alternatives to cotton. Rayon is a material produced from cellulose fibers but it still requires heavy chemical treatments [1].

One of the main motivations for this research was finding a method for taking advantage of new material by forming it mechanically into a yarn and enable of producing environmentally friendly material which can substitute for cotton and rayon [1][2]. New method described later to produce cellulose based yarn is cleaner to the environment and it can use harvesting surplus. Finland’s harvesting surplus alone could replace 20 % of the world’s cotton demand [3].

Starting point for this research was the invention of new method for the manufacture of fibrous yarn [3,8]. The method was invented in Technical Research Centre of Finland (VTT). In previous research VTT has successfully manufactured short samples of the yarn. [4]

Target of this research was to develop a device that can produce cellulose based yarn continuously. Main function of this device is forming of the cellulose yarn. Based on experiences from laboratory scale manufacturing excess water must be compressed out while the yarn is simultaneously twisted to maintain the round cross section during the pressing (Figure 1).

Fig. 1. Electron micrograph image of a rotated yarn where $\alpha$ is the turning angle of the yarn. [5]. Example is not from fibre yarn.
Research hypothesis was that if the pulp fibre suspension is extruded between two angled wires the compression will dewater the yarn and angular force element will twist the yarn and it will achieve its final form. The final result would resemble ordinary cotton yarn. [6]

This paper describes how the main functions of the process have been solved and how they are technically implemented. Part of this research was also seeking the proper parameters for producing the yarn and find out how speed, pressure and rotating angle affect to the quality and properties of the yarn in this case. [7]

2. MATERIALS AND METHODS

VTT has invented and patented a completely new method for producing cellulose based yarn [8]. The results from earlier experiments show that material properties of this new type of cellulose yarn are promising and good quality yarn has already been made. Previous experiments are made in laboratory scale and produced yarns have not been long enough for making e.g. fabric out of them.[4]

Initial shape of the yarn is achieved through fast suspension crosslinking right after the special nozzle before hitting the wire. In the nozzle rheology modifiers prevent clocking and the fibres are oriented with the flow [7]. Different compounds are pumped through the nozzle with synchronized speeds and as they get mixed the crosslinking prevents further mixing and initial dewatering with gravity. Figure 2 schematically illustrates the process in the nozzle.

Wet gel yarn is extruded directly to the lower wire which conveys the material between upper and lower wires. When the yarn encounters the upper wire the water begin to be compressed out of it. The diameter of yarn decreases when it moves along between the wires. Wires are aligned so that the gap between them decreases when approaching the output point and wire angle difference in X-Y direction maintains the yarn rotation while pressing. All free water is removed by pressing the yarn between the wires. At this point the strength of the yarn is sufficient for reeling and the final drying takes place there. In the future also drying is included to this device.

Angular adjusting of the wires is implemented by two-pieced frame. Lower frame part is solid and upper frame can be rotated. Upper frame rotates along two conductors and it is lockable. Conductors permit slight movements also in horizontal plane.

Frame of the device is designed to be easy to adjust and maintain. The final construction is seen on the Figure 3.
The frame of the device is required to have high stiffness because rollers are attached only from one end and they must stay well aligned to get the yarn to uniform quality. Adding features and modifying the placement of the rollers for possible upcoming needs should be easy. The speed of the wires must be accurately adjustable to get the operating speed synchronized with the pump that is feeding the material. The operation of wires is done individually with two PC controlled AC servo motors. The velocities can be automatically synchronized to each other by giving the amount of deviation in angularity of wires.

In the first operating tests the device is being used for drying woolen yarn that has been soaked into water. With this kind of yarn different parameters can be tested to get the yarn to go nicely between the wires while getting its shape.

3. RESULTS

As a result of this project a fully functional and highly adjustable device for drying and forming cellulose yarn is designed and manufactured. The device can handle yarn speeds up to 10 m/s. The preliminary tests were performed with speed of 1 m/s. At low speed it is possible to optimize nozzle position and relations of wire speeds.

Main production parameters were chosen by experimental tests, where effect of each parameter on the form of yarn was studied. The final parameters were wire speed, rotating angle and space between the upper and the lower wire. By changing the wire angle in X-Y plane the force rotating the yarn at horizontal plane is changed. Gap between the wires affect the compression pressure and it can also change the yarn rotation by changing friction force. Rough adjusting for these parameters was based on results of visual inspection of the yarn (Figure 4). The main goal at this point was to produce yarn continuously. The specific properties of yarn (constant diameter, tensile strength) were minor issues. The results of the preliminary tests were promising and established solid basis for future research.

4. DISCUSSION

The purpose of this project was to develop a device to continuously produce yarn directly from pulp suspension. The way of turning fibre suspension into a yarn is completely new and the developed device is first of its kind. Achieved results were compared to manually manufactured cellulose yarn and commercial yarn made from cotton. The yarn produced by the device has very similar properties compared to untreated cotton yarn. The device can be easily adjusted for future
needs. For example operating speed and reliability needs to be improved before commercial use. Upcoming needs have been taken into account when choosing materials and actuators. In the future this machine can produce cellulose yarn continuously at very high speeds. Even higher speeds than 10 m/s are possible but then at least motors and drive pulleys needs to be changed.

The results are giving a good basis for the further research and development. In this project goal was to find rough parameters for the speed and position of the wires. Correct wire speeds and positions make continuous process possible. Even if the device and process are still under development, the basic concept of the machine is fully working and adjustable.

The studies in the future can focus on improving the quality of the yarn when the parameters affecting yarn quality are more precisely defined. If the angle and distance of the wires could be accurately adjustable by computer while the process is ongoing even longer and better shape yarn could be manufactured.

With similar treatments as used with cotton yarn, cellulose yarn can reach comparable properties to cotton and can be utilized in fabrics. Raw cellulose material costs less than cotton which makes it also economically interesting. In addition, cellulose yarn is environmentally friendly. Raw material for cellulose can be gathered for example from harvesting surplus.

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