

DECREASING INTER-FIBER FRICTION WITH LUBRICANTS FOR EFFICIENT MECHANICAL RECYCLING OF TEXTILES

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ABSTRACT

To decrease the environmental burden of the textile industry and at the same time reduce textile waste, the fibers of discarded textiles can be re-used into new yarns and fabrics. The shortening of fibers during mechanical shredding direct the use of the recovered fibers to low value products. With the use of a lubricant pre-treatment on cotton and polyester fabrics, we decreased the friction during shredding. The reduction in friction was shown with a developed inter-fiber friction test. Further, the pre-treatment was shown to give longer recovered fibers and eliminate melted areas in polyester material.

Key Words: Textile Recycling, Yarn Spinning, Inter-Fiber Friction, Lubricant Treatment, Mechanical Shredding

1. INTRODUCTION

As environmental concerns are increasing, the urgency for textile recycling is growing. The high consumption of textiles and accumulation of textile waste, urge for resource efficient textile recycling. Mechanical recycling by shredding of textiles is a waste route that brings an alternative to virgin fibers as well as keeping textile waste away from landfill. The main drawback of shredding is its fiber length reduction that has referred the shredded fibers for rugs, insulation or other low value application. There has been some research on how to manage the short fiber content in yarn spinning, but we are missing information on how to get longer fibers from the shredded textiles [1, 2].

The main reason for fiber length reduction in the shredding process is friction between fibers. The friction cause wearing of the fibers as well as heat buildup which leads to melting of synthetic fibers and hornification of cellulose fibers. To mitigate friction in textile production, lubricants such as spin finishes are utilized. In the present research, we pre-treated textiles with lubricants with the aim to decrease the inter-fiber friction during shredding and thereby obtain longer fibers.

Friction in textiles was hugely studied by, among others, Olofsson, Gralén and Howell, during the 1940-60's, and methods to measure inter-fiber friction were developed [3-6]. Nowrouzieh, Sinoimeri and Drean published a new way of measuring inter-fiber friction in 2007, where they developed a method which consisted of a horizontal tensile tester in which they performed tests on a cotton sliver [7]. Lubricant effect on inter-fiber friction has been shown, with an optimum concentration giving the lowest friction [8-10]. Depending on fiber type and lubricant, the optimum concentration usually lies between 0.1 and 0.5 % weight of fiber [8-10].

In this paper, fiber webs and textiles of cotton and polyester were treated with different lubricants in various amounts in search for the best treatment for each material to minimize the inter-fiber friction. Lubricants used were polyethylene glycol (PEG) 1000 and 4000. To find suitable lubricant concentration, a friction test on fiber web was developed to determine the inter-fiber friction force. The developed friction test was inspired by the test described by

Nowrouzieh, Sinoimeri and Drean [7]. It consisted of a tensile test on treated carded fiber webs, and was performed on a tensile tester, a common equipment in most laboratories.

2. METHOD

2.1 Material

Cotton and polyester fibers were treated with PEG 1000 and 4000 supplied by Merck. The fabrics used for shredding were 100% cotton and 100% polyester of plain weave with a surface weight of 145 g/m².

2.2 Treatment

Deionized water was heated to 65°C and then mixed with PEG 1000 and PEG 4000 in weight of fiber percentage, as seen in Table 1. Cotton and polyester fibers were treated by spraying the water solution and then dried in oven at 60°C for 8 hours. Fabrics were sprayed with PEG 4000 solution and dried prior to shredding.

Table 1. Lubricant treatment concentration.

Lubricant	Cotton fiber	Cotton fabric	Polyester fiber	Polyester fabric
<i>PEG 1000</i> (wt.%)	0.0	-	0.0	-
	0.1		0.1	
	0.14		0.2	
	0.2		0.5	
	0.5		1.0	
	1.0			
	1.5			
<i>PEG 4000</i> (wt.%)	0.0	0.0	0.0	0.0
	0.1	0.1	0.1	0.2
	0.14	0.29	0.2	0.71
	0.2		0.5	
	0.5		1.0	
	1.0			
	1.5			

2.3 Friction Measurement

After drying and subsequently conditioning for 24 hours in 20°C and 65 % RH, fibers were carded two times on a Mesdan 337A laboratory carding machine. The carded webs were then cut into samples of size 250x100 mm with fiber direction lengthwise, and weighed. The samples were then tested on a Mesdan lab tensile tester equipped with yarn clamps and load cell 0.1 kN. The test was performed with gauge length 75 mm and speed 300 mm/min.

2.4 Shredding

Treated textiles were cut into smaller pieces with the fabric cutter machine NSX-QD350. The cut pieces were then fed into the shredding machine from New Shun Xing Environmental Technology. The machine consisted of four drums, first NSX-FS1040 with 8 mm long saw teeth followed by three drums NSX-QT310 with 4 mm saw teeth. Treatment concentrations for fabrics can be seen in Table 1.

3. RESULT

3.1 Inter-fiber friction

The result from the tests gave similar curves to the one shown in Figure 1. In the start of the test, the fibers are straightened until a max force (F_{max}) where the fibers start to slide past each other. Past this point, sliding continues until the web is completely separated. The max force indicate static friction of the fiber web and is the value that will be compared in this study.

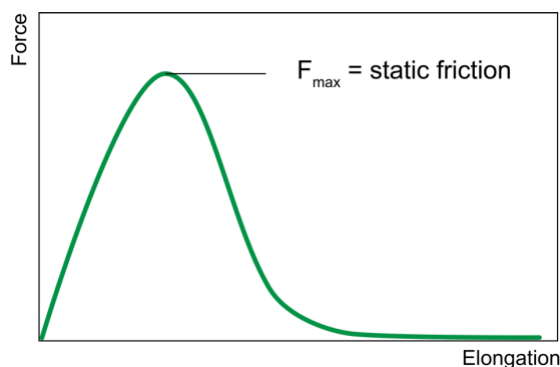


Figure 1. Tensile test curve of fiber webs.

The tensile test result of cotton and polyester is shown in Figure 2 and 3 respectively. The result shows that PEG 4000 was most efficient in lowering the static friction for both fiber materials. The curve for PEG 4000 shows a minima before increasing, while PEG 1000 have a different shape and can be suspected not to have reached its minima with these concentrations.

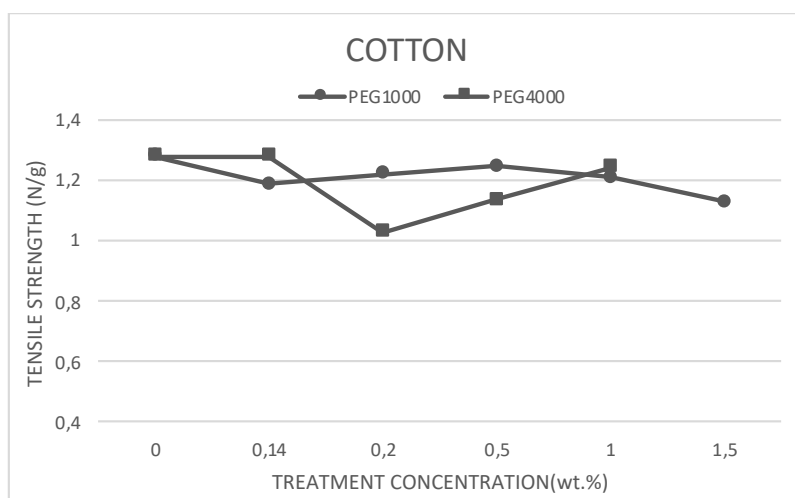


Figure 2. Tensile test curve of cotton fiber webs.

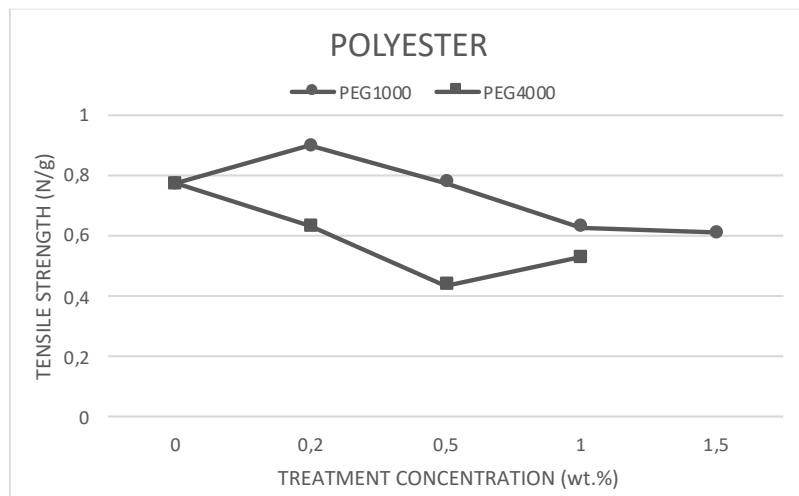


Figure 3. Tensile test curve of polyester fiber webs.

3.2 Mechanical recycling

The effect of the PEG 4000 treatment on fabrics prior to shredding is shown in Figure 4 and 5 on cotton and polyester respectively. On both cotton and polyester it seems that the higher concentration of lubricant was most efficient with less threads visible and longer fibers which is more evident on polyester samples. For polyester samples, it could be seen that the untreated material had some melted areas which is an indication of high friction during the shredding process. This was completely eliminated in the pre-treated materials.

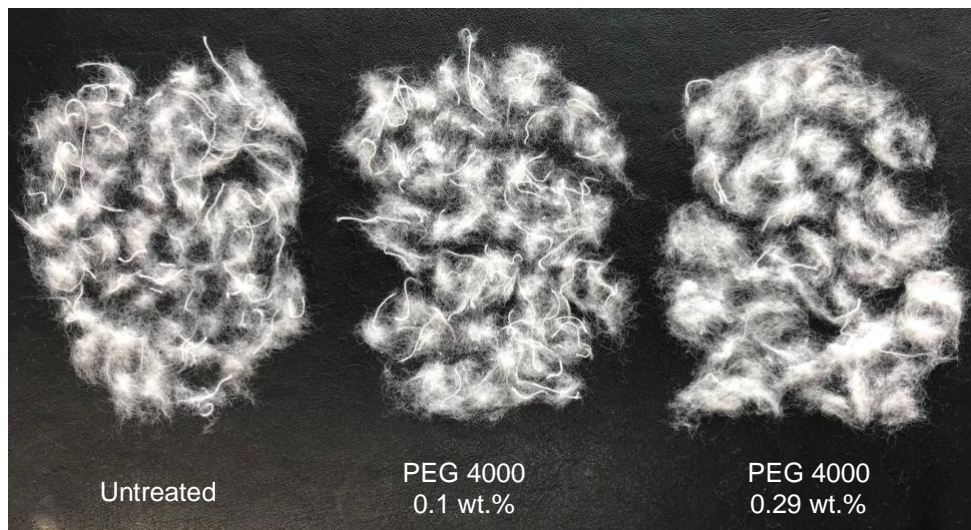


Figure 4. Shredded cotton fibers, 0.2 grams of each sample.

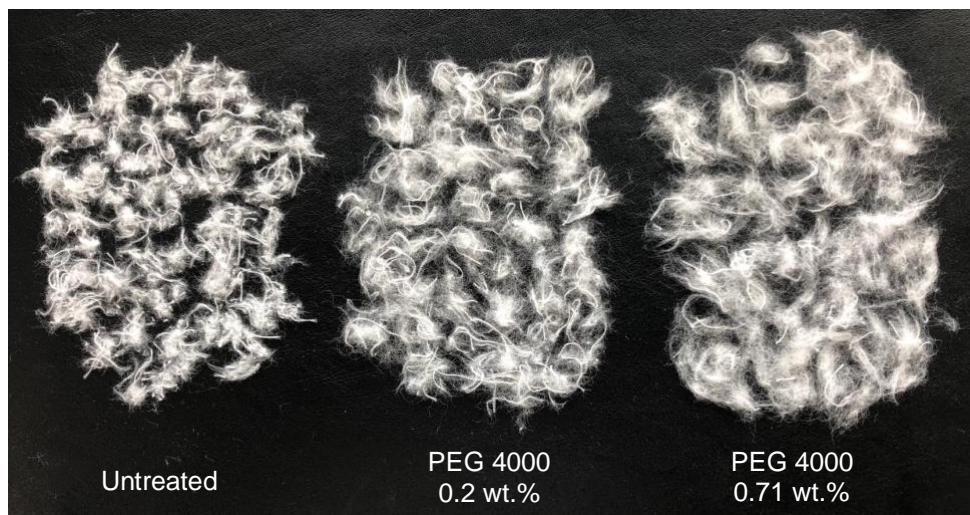


Figure 5. Shredded polyester fibers, 0.2 grams of each sample.

4. DISCUSSION

The inter-fiber friction test showed a similar curve to that of Nowrouzieh, Sinoimeri and Drean [7] although decreasing more rapidly after reaching maximum force. This may be due to the difference in the method, especially the gauge length at test start should affect the result significantly.

It could be seen that lubricant PEG 4000 had a more positive effect on both cotton and polyester, which could be seen in the inter-fiber friction test as well as the in the shredding process. The inter-fiber friction test for PEG 4000 showed that the static friction came to a minima before increasing, which is consistent with literature [8-10]. Finally, the shredding result showed that the inter-fiber friction did indeed affect the shredding efficiency with longer fibers, less threads, and eliminated melted areas in polyester sample.

5. CONCLUSION

The result presented in this paper showed that the treatment with a lubricant on fibers affected the inter-fiber friction, and can predict the effect of the lubricant on the shredding process. With a higher loading of lubricant, the shredding process seemed to be more efficient. The major findings are listed below:

- New method to measure inter-fiber friction.
- Lubricant treatment affect the inter-fiber friction.
- Lubricant pre-treatment affected the shredding process with visibly longer fibers as a result.

The result showed that the developed test method predicted the shredding gentleness. Appropriate lubricant loading maintained more fiber length upon shredding. The conclusion is that with the help of lubricants it is possible to make textile shredding gentler and thereby economically sustainable for the tested commodity fabrics.

Further analysis of the shredded material needs to be made in order to have a full picture of how the lubricant treatment affected the shredding process, which is planned and will be presented in future publication.

6. REFERENCES

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