

Paper Wrinkles

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ABSTRACT

Cellulose in the wood, the most important material that is used in the paper, has many links between the fibers of it. After paper was soaked in water and water evaporates a little water is still remained between fibers which causes stress between fibers. Stress will cause deformation and wrinkling. In this study different parameters are investigated by experiments.

Keywords : Cellulose, Paper, Wrinkle, Parameters

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1. Introduction

Paper is one of the materials that people have been using in their life to note many important things (for example, the application form to enter an university) all around the history. But, every thing can be loosed even if the paper wrinkles a little. One of the worst accidents that may happen to us is when water pour on the paper and water can impair it. After paper dries, it wrinkles. Hence, it can cause many problems. In this situation knowing that why does paper wrinkle after being wet is really important to remove wrinkles.

Over the centuries, paper has been made from a wide variety of materials (such as wood pulp, rice, water plants, cotton and even old clothes). But, any way for making paper fiber is needed [1]. Paper is manufactured by raw wood, which is made up of fibers called cellulose [2] Wood fiber sources are classified as hardwoods (a.k.a. deciduous, angiosperms) and softwoods (a.k.a. conifers, gymnosperms). While hardwoods form smoother surfaces, softwood fibers give paper more tear strength. The pulp fiber mixture, called the furnish, is carefully controlled to optimize paper properties[3]. Secondary fibers do not bond as well as virgin cellulose fibers. They do not wet to the same degree and the fiber-fiber bond strength is weaker [3]. But studding related phenomena takes very much time and requires expensive tools because fibers of paper are too small and following events happening is hard.

In here, we proved why paper wrinkles in another way that did not take much time and did not need expensive tools.

2. Experiments

The experiment was with such kind of paper with the qualities as shown in Table (1).

The most common method of testing smoothness or roughness in the paper is by one of three air leakage methods. Bendsten roughness is achieved by clamping the test piece between a flat glass plate and a circular metal head and measuring the rate of airflow in ml/ minute between the paper and head.

The weight of a piece of paper was measured. Then it was soaked in water and was put away to get dried. After drying the weight of the wrinkled paper was measured.

The fibers of paper were studied because if the weight of

the paper does not change means that the fibers are changing. A picture of the piece of paper under microscope is taken (Fig. 1a and b). The microscope was German Leitz Wetzlar with magnifying of 500.

Table 1. The qualities and properties of the paper used in the most of the experiments [4]

Sl. NO	Particulars	Unit	JKC	JKC
			75	80
1	Caliper	Micron	102+/- 2	108+/- 2
2	Breaking length	Meter	4500 ± 500	4500 ± 500
3	Tear factor	--	65 ± 5	65 ± 5
4	Moisture	%	4.0 ± 0.5	4.0 ± 0.5
5	Roughness (Bendsten)	ML. / Min.	300 Max	300 Max
6	Wax pick (Min)	No.	14A	14A
7	Brightness	% ISO	94 +/- 1	94 +/- 1
8	Opacity (Min)	% ISO	92	92

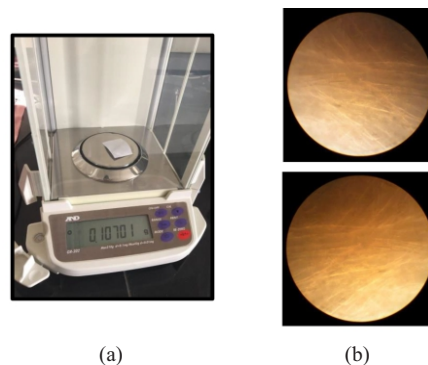


Fig.1: a) The paper on scale; b)The fibers of the paper under microscope

The paper was soaked in water and it got dried while wrinkling. Then the fibers of the wrinkled paper was seen under microscope and taken pictures of it (Fig. 3).

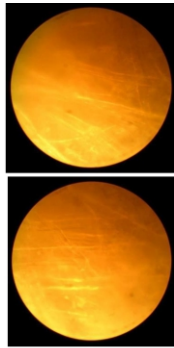


Fig. 3: The fibers of the wrinkled paper under microscope

A strip of paper was made sized 5mm in 10mm and it was soaked in 25ml of water for 3 minutes. It was put on a glass dish for getting dried but because of the hydrogen bonding of water it was stuck to the glass dish so wrinkling would not be the result. After it dried the length of the paper was measured and it was 101mm (Fig.4).



Fig. 4: The paper after getting dried and increasing of the length

Seven strips of paper was made sized 3mm in 70mm and they were soaked in water respectively for 300s, 180s, 60s, 30s, 15s, 10s and 5s. After getting dried and wrinkling the new length of the papers were measured by paint application. Then in the paint application pixels which a line was drawn in a millimeter are shown. That is the way of understanding how many pixels are in a millimeter of the picture (Fig.5).



Fig. 5: The pixels of the line from one side to the other side of a millimeter of ruler drawn is shown in paint application

Then lines should be drawn on the length of the paper in the picture to see how many pixels are in a wrinkle of the paper. The pixels of a line of a wrinkle is shown as the length and breadth of a right triangle in paint application (Fig. 6).

Therefore, the line that was drawn on the wrinkle is hypotenuse of the right triangle and the length of hypotenuse can be measured by Pythagoras rule. Then the additional of all hypotenuses is the whole length of paper but unite of it should be changed to millimeter from pixels. “1mm = (A) px, So, L'(mm) = L'(px) / A” can help for finding length of the wrinkled paper.

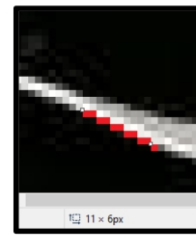


Fig. 6: The line drawn on the wrinkle of 15 seconds soaked paper and the pixels of the right triangle shown

For measuring resistance of wrinkled paper and a smooth paper, six strips of paper were made sized 29.5cm in 0.3cm. Five of them were soaked in water for 2, 10, 30, 60, 300 seconds and the other one was not soaked in water to be smooth. After drying some loops were made by strips that the top of the loop was 23cm. Then 4cm of it was put on surface and the edge of the surface was on the fourth cm of strip that the other piece of paper was hung. Some weights were hung to the loop. If the paper tore with heavier weights means it has more resistance.

For removing wrinkles of a wrinkled paper an iron that worked with humidity was put on some wrinkled strips of paper that were soaked in water for 10 seconds and 30 seconds. Then the new surface of the paper was measured to see if there is any shrinkage with ironing.

3. Results

The weight of the paper before soaking in water and after getting dried was the same (Table 2).

Table 2: The exact weight of paper before soaking in water and after getting dried

Weight of thw paper before soaking in water	Wieght of the paper after getting dried
0.10698 g	0.10701 g

Not changing in the weight of the smooth paper and the wrinkled one, shows that there was not any substances in the paper added or reduced. But, something that is causing wrinkling is the fibers.

When strips of paper were wrinkled, the length of the strips was measured (Table 3).

Table 3 :Average length of the wrinkled paper and the difference between length of the wrinkled paper (L') and the first length of the paper in different times soaked in water

The time paper The time paper was soaked in water (s)	Average length of the wrinkled papers (mm)	L' - L
5	66.24063	-3.75937
10	66.22374	-3.77626
15	65.459645	-4.540355
30	63.92412	-6.07588
60	63.525535	-6.474465
180	64.678555	-5.321445
300	66.534525	-3.45475

The length of the paper in the different times of soaking in water differs. Wrinkling has the result of shrinkage. According to the chart if soaking in water is nearer to 60s means that it had the highest length decreasing (Fig. 7). But if paper's length increased when it was stuck to the dish after soaking in water is because of that the fibers could not get as close as they should. Hydrogen bonding between water and glass dish did not allow papers have its shrinkage.

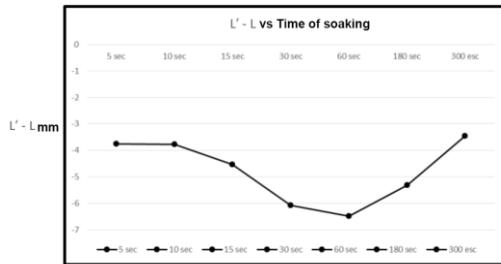


Fig. 7: L'-L in different times of paper soaked in water

When the weights were hung to the strips of papers the weights that paper tore with was measured (Table 4). Paper which has soaked in water nearer to 30s has more resistance and also wrinkled paper has more resistance than a piece of paper that has not soaked in water .

Table 4: Average of the weights which paper tore in different times soaked in water

Time paper was soaked in water (s)	Average of the weights paper tore with (g)
0	222.5
2	302.5
10	330
30	390
60	302.5
300	261

When strips of paper wrinkled after soaking in water , the length of them was measured. For removing wrinkles a steam iron was used. Then the length of the ironed strips of paper were measured (Table 5).

Table 5: Average difference between length of ironed paper and wrinkled paper

The time paper was soaked in water (s)	Average length of the paper after wrinkling (mm)	Average length of the paper after ironing (mm)	L'' - L'	L'' - L
10	67.857	63.107	-4.749	-6.892
30	67.019	63.257	-3.762	-6.742

As it is shown in the table the length of paper was decreased after ironing. Therefore, ironing with steam irons that work with humidity is not helpful for removing wrinkles and shrinkages because humidity can cause wrinkling as water do. For short period of time the iron can remove wrinkles but it would wrinkle after some minutes. Therefore electric irons that humidity does not

have effect on their work should be used.

For removing wrinkles and shrinkage of a piece of paper cross-linked fibers should be made. For making cross-linked fibers there is a method that includes heating the treated cellulosic fibers to promote intrafiber cross-linking [5] (Fig. 8).

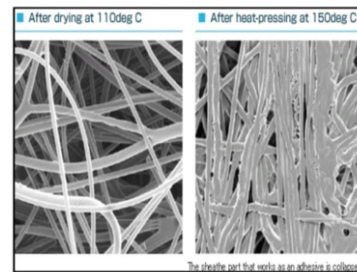


Fig. 8: The difference between heat and heat-pressing for removing wrinkles of paper [6]

Heating and pressing without humidity and water is a good way for removing wrinkles. In the factories, that paper is made, paper is under the pressure of some heavy rollers that make the pulp into sheets (Fig. 9). But when the paper is soaked and not drying with an arrangement, the paper would be wrinkled.



Fig.9: Paper making factory [8]

A sheet of paper that is made up of cellulosic fibers are attracted to each other cross-linking. When paper is soaked in water the fibers get far from each other. When paper got dried a little part of the water is still remained between fibers, water from another sides evaporates. Because of the electronegativity fibers and water are attracted to each other (Fig. 10). Hence, the internal force is not 0. If internal force is not 0, there would be stress between fibers. Stress is the force per unite area [9]. Stress will cause deformation and area of paper would be decreased.

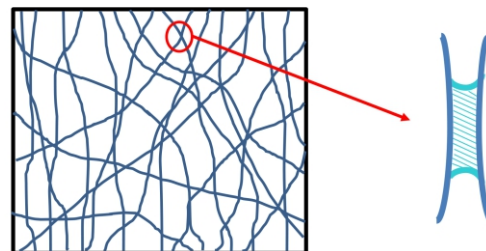


Fig. 10: Cross-linked fibers of paper after water evaporates and the water remaining that is causing stress and deformation

4. Conclusion

From all these information it is concluded that in the factories, wood pulp was converted into thin sheets by some hot rollers, to make water evaporate and make fibers stick together. Hence, there would be more attracting between fibers and because water causes stress and deformation, the result would be wrinkling. Water.

causes stress and deformation and the result would be wrinkling so in factories water should be evaporated. Wrinkled paper has more resistance than a piece of paper that was not soaked in water. Every time with wrinkling, shrinkage would be the result for paper. For converting a wrinkled paper to an smooth paper heat and pressing is needed while there is the least of moisture.

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