Recycled Does Not Have to Mean Weaker

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Abstract

With today's population being more conscious and aware of the environmental footprint that an individual leaves on the planet, more pressure is being put on the manufacturing industry to use recyclable and renewable materials. The printing industry is far from safe from such pressures. This environmental push has introduced a higher variety of recycled paper fibers into the paper making process. This pushes one to think if the industry is sacrificing the folding endurance, in turn, the durability of our printed products by introducing more recycled materials into the production stream. Recycling paper has always been part of one of the branches of the paper making process. First invented by the Japanese in the 11th century and then popularized by William Rittenhouse in the 1690s, the manufacturing process of recycling paper fibers soon became a staple in the printing industry.

Both recycled and virgin fibers can be used interchangeably for all printed products with the exception of higher end products that are usually made out of virgin fibers. Some recycled fiber paper may give a product higher marketing value due to the label of "recycled". The issue at hand is that while mostly interchangeable in use, the fibers are not made equal. The process of recycling the paper fibers includes water being added to the paper to create a slurry that in theory separates all of the ink, glue, plastic film and staples. This process unfortunately is not perfect because throughout the recycling process the fibers in the paper loose length consistency and strength. Contaminants in the forms of binders, inks and solvents cannot be entirely removed and therefore they get carried over into future recycled products. With this information at hand it is easy to hypothesize that recycled fibers are generally weaker than virgin fibers with a further decrease in strength due to contamination in turn creating printed products that have a low folding endurance. The methods used for the experiments include folding endurance testing of both recycled and virgin fiber substrates with / without ink and the use of a microscope to evaluate the paper fibers. The papers were sourced from Spicers whom provided a variety

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of substrates from paper mills such as Domtar, Rolland, and International. Both Flexographic and Lithographic inks were used for a wider data set.

Throughout this research paper raw folding endurance data is analyzed to show the real effects that recycled fibers have on the durability of our printed products. The results showed that while environmentally friendly papers underperformed in retaining strength when inks are added to the folding endurance testing, the substrate on average has a higher endurance rate than virgin fiber paper. The theory is that the addition of binders to the recycled fiber papers strengthen the overall paper endurance. Perhaps recycled fiber papers can withstand the test of time better than virgin fiber papers as well however this is a test for another time.

Literature

For the purpose of this project James L. Minor and Rajai H. Atalla's paper on "strength loss in recycled fibers and methods of restoration" will be referenced and challenged. Both authors argue that recycling paper leads to loss in interfiber bonding therefore reducing the tensile strength of the final product. They argue that this happens because the drying processes used in recycling break down and stiffen the fibers to make them less flexible and susceptible to faster breakage when folded. In the research paper, smaller fibers and debris are called "fines". These fines are found more commonly in recycled papers due to breakage of fibers during the recycling process. It is possible to make recycled paper fibers stronger by adding starch, gums, chemicals however they do make the paper costlier. While more research is being done on how to make recycled fibers stronger the strongest scientists in the Forest Products Laboratory have gotten is 69% tensile strength of the original paper. While this research paper will not be focusing on the processes of recycling paper it is important to note how and why this substrate is deemed to be weaker than virgin pulp papers. This research will be used to aid in the conclusion of the experiment.

A Brief History of Paper Recyclability

In 1031 Japan, due to a shift in the central administration, there was a shortage of skilled workers and materials – including paper. Private estate owners saw an opportunity and made small paper mills that would use mulberry, gambit, hemp and wastepaper to supply the paper needs of their areas. It is said that the Chinese may have had an earlier method however this was the first recorded instance (Jeremy Norman, 2004). In 1690, the Rittenhouse Mill was introduced into Philadelphia USA. It brought recycling to the new world through the recycling of old linens and rags. The end product for most of these fibers ended up being either bibles or newspapers (American Disposal Service, 2011). 1896 was a good year for the recycling business with the opening of America's first major recycling plant by the Benedetto family. The plant collected rags, newspaper and other trash. Finally, in

1993 in America more paper was recycled than thrown away (USI, 2015). In the start of the new millennium more of the world had started to adopt paper recycling practices.

Paper Recycling Today

Today, paper is collected, sorted, transported, shredded, de-inked and dried through big machines available in almost every country around the world.

Paper strengthening agents such as Polyacrylamide, Glucomannan, Melamine and Starch are used to increase the strength between the paper fibers. Every paper mill and paper recycling company have their own recipe.

In the future it would be useful to assess just by how much the strength increases per each type of paper strengthening agent.

Equipment and Materials

Equipment

All of the equipment was supplied by the faculty of Graphic Communications Management at Ryerson University.

The folding endurance tester

- M.I.T. Tinius Olsen
- 1 kg of tension
- Used to assess the folding endurance of all the samples.

A microscope

- Dino-Lite
- Images are taken at 200x magnification
- Used to view and take pictures of the folding endurance samples up close.

A QuickPeek kit

- Thwing-Albert
- Used to apply offset lithographic ink on to the paper samples.

Phantom proofer QD

- HarperScientific
- Anilox Roller BPM 3.5 LPI 360
- Used to apply flexographic ink to the paper samples.

Materials

Lithographic Ink

- HuberGroup
- PERFEXION-ECO Magenta

Flexographic Ink

- Siegwerk
- PS + PRO Magenta

Recycled and Virgin Fiber paper

- Sourced from Spicers
- 20 different samples (14 virgin fiber and 6 recycled)
- Domtar, Rolland and International paper co.
- Weight ranges from 50# to 70#
- Type of papers:
  - offset smooth text
  - cougar smooth text
  - Smooth text
  - Ultra smooth text
  - Satin text
  - Print text

Procedure

The results are assessed based off two factors: folding endurance, and folding endurance strength retention. Below are the formulas used for the data collected.

1. *Formula for folding endurance comparison (%):*
   (Folding endurance with no ink / Folding endurance with ink) *100

2. *Formula for overall folding endurance comparison (%):*
   ((Folding endurance comparison of grain long) + (folding endurance comparison of grain short)) /2

3. *Formula for final endurance retention (%):*
   sum of all overall folding endurance comparisons / number of all overall folding endurance comparisons

4. *Formula for folding endurance averaging(#):*
   sum of all data inputs / number of data inputs

The folding endurance machine was used to assess the durability of both virgin fiber and recycled substrates. The tension for the machine was set to 1Kg and 5 strips of both grain long and grain short assessed. All papers were tested 10

times and the gathered data was averaged in order to create assessments of both types of products.

The initial prediction of the experiment was that the virgin fiber paper would greatly outperform recycled fiber paper since virgin has the most uniform fibers.

Since the substrates in question are used for printing, flexographic and lithographic printing will be simulated through the Quick Peek kit and the phantom proofer. The testing material was set aside to dry for 24 hours. The folding test described above were repeated to check the endurance of the samples with the different ink coverage. Another prediction from this part of the testing was that the printed samples would break faster than the none printed samples because the ink contamination in the fibers. Another thing that is going to be assessed is how much endurance is retained between recycled fiber and virgin fiber substrates.

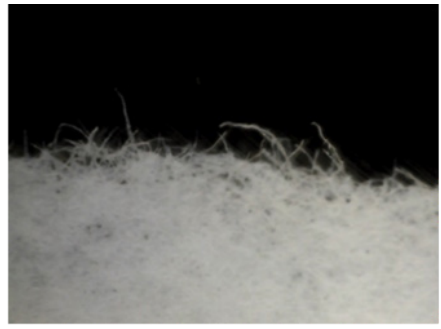
A microscope will be used to assess how the substrate tore and what damage was done. It will also be used to observe the difference in fiber consistency between recycled substrates and virgin fibers. The prediction is that there will be less consistency in the recycled papers with the observation of particle specs as well. While images on this scale may not be visible with the microscopes available at the Heidelberg building at Ryerson University, paper fibers should still be visible enough to show the differences between recycled and virgin fiber substrates.

Results

Microscopic Image Analysis

Please refer to the images below. When paper is recycled it is put through a cleaning process that includes water and a solvent that takes out most ink particles (sometimes along with the inked fiber). These ink particles float to the surface of a tank and are removed while unlinked paper fibers stay at the bottom (Kathryn Sukalich, 2016). This method is called floatation deinking. Unfortunately, some inks are dye-based (Recyclebank, 2017) that simply refuse to be removed from the pulp and float up and that is how recycled papers get their infamous particle. In the microscopic images, you can see the differences in fibers. The virgin fiber paper should be a lot more uniform than the recycled fiber paper. This is where the hypothesis of recycled fiber papers being weaker than virgin fiber papers arises. Unfortunately for the samples that were provided for this study there was not much of a difference when it came to the uniformity of the paper fibers. The image on the left shows a folding tear of virgin fiber paper while the image on the right shows recycled fiber paper.

60# smooth text virgin fiber



60# satin text recycled fiber

Folding Endurance Results

Weight	type	fiber	Company	grain long	grain short	grain long offset	grain short offset	grain long flexo	grain short flexo	Average
70#	offset smooth text	virgin	Domtar	29	18	10	6	4	5	11
60#	offset smooth text	virgin	Domtar	33	18	11	8	22	8	15
50#	offset smooth text	virgin	Domtar	61	19	23	8	3	15	19
70#	cougar smooth tex	virgin	Domtar	11	5	9	3	3	8	5
60#	cougar smooth tex	virgin	Domtar	12	9	5	7	19	14	9
50#	smooth text	virgin	Domtar	21	22	3	2	5	8	9
70#	smooth text	virgin	Rolland	11	6	8	5	7	6	6
60#	smooth text	virgin	Rolland	6	8	9	4	5	7	5
50#	smooth text	virgin	Rolland	25	16	5	7	4	9	10
70#	smooth text	virgin	International	6	13	3	6	7	4	6
60#	smooth text	virgin	International	14	15	8	8	10	8	9
50#	smooth text	virgin	International	9	7	4	5	7	8	5
70#	ultra smooth text	virgin	Domtar	32	8	12	3	7	5	10
60#	ultra smooth text	virgin	Domtar	19	14	5	6	7	27	9
50#	ultra smooth text	virgin	Domtar	54	9	36	9	10	33	20
70#	satin text	Environment	Rolland	21	16	8	5	7	6	10
60#	satin text	Environment	Rolland	30	33	19	10	20	9	19
50#	satin text	Environment	Rolland	11	18	7	5	12	5	9
70#	print text	Environment	Rolland	19	22	16	6	12	8	13
60#	print text	Environment	Rolland	14	23	22	12	28	27	17
50#	print text	Environment	Rolland	29	24	11	3	25	7	15

Above are the overall results of the folding endurance testing. Please note that each number present (except for the last column) is an average of 10 endurance tests done on that specific paper. The columns are conditionally color coded to have the highest numbers of the column green and the lowest in red. This is to help visualize the overall results.

While the average folding endurance of recycled fiber paper was 22, the average folding endurance of virgin fibers was only 19, these numbers changed rapidly with the addition of ink. The overall folding endurance average for all the papers is 11, 4 out of 6 of the recycled fiber papers performed above the average.

Result Breakdown:

No ink

For the virgin fiber samples with no ink grain long averaged 25 folding endurance throughout all substrates while grain short was at 13 folds. The results for recycled fiber samples with no ink the grain long average at 21, while the grain short averaged at 23. The recycled fiber paper outperformed the virgin fiber paper by 14.46%.

Offset Lithographic ink

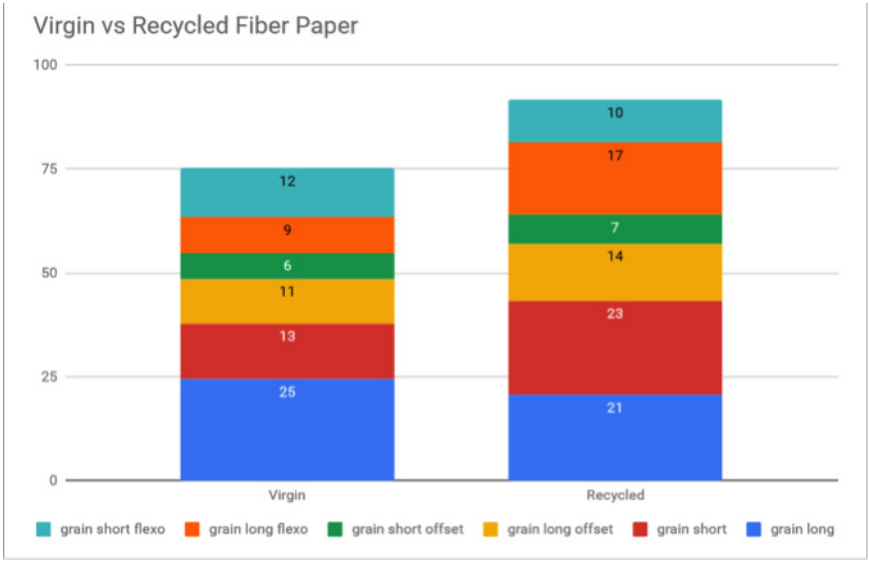
For the virgin fiber samples with offset ink grain long averaged 11 folding endurance throughout all substrates while grain short was at 6 folds. The results for recycled fiber samples with offset ink the grain long average at 14 while the grain short averaged at 7. The recycled fiber paper outperformed the virgin fiber paper by 21.56%

Flexographic Ink

For the virgin fiber samples with flexographic ink grain long averaged 9 folding endurance throughout all substrates while grain short was at 12 folds. The results for recycled fiber samples with flexographic ink the grain long average at 17 while the grain short averaged at 10. The recycled fiber paper outperformed the virgin fiber paper by 35.9%.

Folding Endurance Retention after Introduction of Ink

On average virgin fiber paper retained 45.27% of the original endurance when introduced to offset lithographic ink and 61.61% of the endurance when introduced to flexographic ink. On the other hand, the recycled fibers performed with retaining 48.54% of the original endurance with offset lithographic ink and 64.72% of the original endurance with the introduction of flexographic ink. These numbers have been calculated using formula #2 and #3.



The Average folding endurance for all papers is 11. 4 out of 6 of the recycled fiber papers exceeded the average.

Concluding Thoughts

Recycled fiber papers have come a long way from being "The Weaker Paper". The study shows that in some cases recycled fibers may be able to be as good or even outperform virgin fiber papers. Please note that this a small sample of all the available papers products out there and is not a perfect representation of the performance of all recycled fiber papers in the industry. Choosing a recycled product may not always jeopardize the folding strength of your prints and could just be a wonderful environmentally friendly alternative for a company.

What Does this mean for the future?

Since recycled fiber papers can retain most of their strength already, the industry's current recycled products are not that far off from competing with virgin fiber papers. Perhaps an increase in research into different paper bonds that could strengthen paper folding endurance further would be beneficial towards future paper production. Testing on how different concentrations of paper bonds increase/ decrease strength and durability would also be beneficial as not much research is currently out there.

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