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The Problem of Paper Curl

By Charles Green and Jim Atkins

Making a quality sheet of paper can be hard enough, but one problem that can make it almost impossible is paper curl. Curl affects almost every grade of paper and board. It causes paper jams in printer/copiers, print register problems in newspaper presses, and combined board warp (curl) issues for corrugators (Figure 1). As a papermaker, curl can be particularly frustrating because a sheet that appears to be flat “as manufactured” may curl quite badly in the customer’s converting operation.



Figure 1. Twist warp of corrugated board due to fiber alignment problems

Addressing curl problems requires that we look at the process and the very structure of paper to find out why curl is occurring. And it is very often the case that “the lack of information is all-pervasive; every link in the production and logistics chain can make a difference.”¹ Each problem is usually a unique combination of paper properties and end-use conditions.

SOME PRINCIPLES OF CURL

In order to understand why paper curls, there are a few basic facts about paper that we need to know.

Paper is alive.

It is alive in the sense that it reacts to changes in the environment. If the relative humidity increases, paper absorbs water, and if the humidity decreases, it loses water. Paper fibers are shaped like little drinking straws, and as they absorb water, they get fatter but not longer.

Paper is not homogenous.

Since paper is thin, we tend to think of it in one plane. But paper has a top and a bottom, and they are not the same (Figure 2). If the moisture content of the paper changes, the top and the bottom of the sheet often react differently. That

difference results in paper curl.

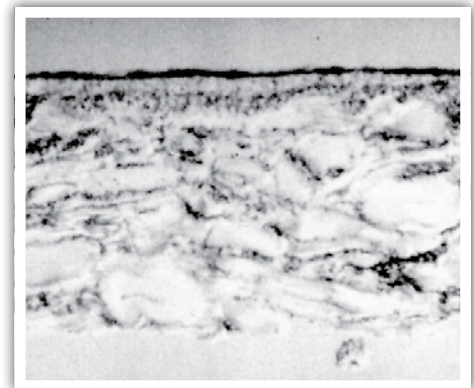


Figure 2. This cross-section of C1S paper shows that the top and the bottom are very different.

Paper is directional.

Due to the manufacturing process, more of the fibers are aligned in the web flow direction, or machine- direction (MD) sometimes referred to as “grain-long.” Since more of the fibers are aligned in the MD, when the fibers swell due to increased humidity, the sheet usually curls with the axis of curl in the MD.

Paper has built-in stresses due to the manufacturing process.

If paper is moistened on one side only, the fibers on that side swell and that side of the paper gets longer, so the paper curls away from the wet side. As the wetter side of the paper dries out, the paper slowly loses its curl and then is flat again. But then a curious thing happens. It does not stop there. The paper then begins to curl towards what was the wetter side. The moisture has relieved some of the stresses in the one side of the paper, and that side gets shorter. So curl forms (or moves)

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toward the side from which moisture moves last or toward the side from which moisture migrates last.

ILLUSTRATING WHY PAPER CURLS

In order to demonstrate how curl forms in paper, take a strip of paper one inch wide and 6 inches long. Now take a 5-inch length of transparent tape, pull on it to stretch it, place it on the paper strip, and release it. Immediately there is curl toward the tape, which has shrunk. The reason there is curl is because the tape becomes shorter than the paper.

To demonstrate curl due to increased moisture, blow on a paper strip and see how the moisture in your breath swells the exposed side of the strip, causing it to curl away. In a minute or so the strip will bend back as homogeneous moisture distribution is restored.

EXAMPLES OF HOW CURL PROBLEMS OCCUR

The curl principle in laser/copy paper:

The paper we made and shipped to a customer was nice and flat. The customer opens a new ream and loads it into his printer and experiences no curl problems. Some paper sits in the laser printer tray overnight, and the humidity is 80%. The next morning the customer gets lots of curl, with the curl away from the printed side. The reason for the curl is that the paper has picked up moisture. When it runs through the printer fuser, moisture is driven from the print side. More moisture remains on the unprinted side. This moisture migrates away from the unprinted side, and the paper curls to the unprinted side.

If copy paper is manufactured with moisture that is too high, for example 5.7% or higher, it more than likely will curl away from the printed side in a laser printer (Figure 3). This can also happen when paper is preprinted by offset, and too much moisture is added back into the sheet. If the paper machine has a metering size press instead of a conventional size press, then the moisture threshold may be as low as 4.2%. This difference is likely due to the fact that a metering size presses is run at higher solids content, which keeps the starch on the surface of the sheet.

To demonstrate this, take 10-20 sheets from a “fresh” ream of copy paper and allow it to sit for 24 hours in a high humidity environment. First, run some of the paper remaining in the ream in a copier, and then run the humidified sheets to see the difference in curl. Tendency for the paper to curl can be measured by this procedure.

The curl principle in offset printing:

In offset printing, fountain solution (water) is used to wet the printed side of the paper. Initially, the sheet will curl away from the printed side. At the same time, stresses built in during the papermaking process are released, so the printed side begins to shrink making the sheet flatter. Finally, the excess moisture on the printed side exits by evaporation and migration to the unprinted side. Now the printed side of the sheet becomes shorter, and the sheet curls toward the printed side.

Drying on the paper machine:

When paper is dried too much on one side, we end up with the other side having more moisture. And from the principles of curl, we know that we will get more curl toward the wetter side.

Papermakers can use this principle to their advantage, if they have separate control over the top and bottom dryers in the last section of the paper machine.

For example, if the sheet is curling towards the topside, then if we make the bottom side of the sheet wetter, we can counteract the topside curl. How do we do that? Make the top dryers, which are touching the bottom of the sheet, cooler than the bottom dryers. This will leave more moisture in the bottom of the sheet, and the sheet will then curl in that direction. Control the top and bottom dryer temperatures correctly, and the sheet comes out flat.

In recent years, single tier dryers have been installed on paper machines for the entire length of the dryer section. By drying only the bottom side of the paper, the topside is wetter and therefore shrinks more, so there is significant curl to the topside. This problem is addressed by having a final two tier dryer section or by re-adding moisture to the bottom of the sheet.

QUESTIONS FOR THE PAPERMAKER TO ASK

1. Where should we look?

The unfortunate answer is, almost everywhere. Curl can be affected by many areas in the papermaking process including:

- headbox
- wet end former
- wet presses
- size press/metering size press
- dryers
- converting or “downstream” operations

Curl can be the result of a combination of these areas, so their interaction can complicate things for us. Another issue is that we may make a sheet that is flat off the paper machine, but when the customer prints or converts the paper, curl problems occur.

2. Is there a great deal of difference in sheet structure on the top and bottom of the sheet?

Using sheet-splitting techniques, analyze the top and the bottom of the sheet separately. Is the filler or fines content much higher on one side? Evaluate jet to wire speed, jet impingement angle, sheet agitation during drainage, and other wet end factors including the forming fabric.

Curl can be evaluated by printing paper on almost any laser printer. Take ten sheets of paper and print them on the “top side” and another ten sheets and print them on the bottom or “wire side.” If the curl is essentially equal on both sides of the paper, then the paper has a balanced structure. More curl to the top or bottom indicates a two-sided sheet. Another curl test, which can be useful is the Hot Bend Test described in Reference ¹.

3. Is fiber orientation a problem resulting in TSO angles exceeding +/- 3 degrees?

Use a TSO tester to evaluate the sheet. Changing jet-to-wire speed may help the problem, since running near zero makes fiber orientation problems worse. Headbox problems can cause cross-flows that lead to TSO problems.

4. In the press section, is the press fabric always on the same

side of the sheet?

Pressing can result in increased two-sidedness in paper, and an inherent tendency to curl.

5. Is there too much drying on one side of the sheet?

Single tier dryers cause moisture to be higher on the side of the sheet that does not touch the heated dryers, so some compensation needs to be made. With a normal two-tier dryer section, are you spraying water on one side of the sheet for CD moisture profile control? Can you adjust top vs. bottom dryer temperatures on the last dryer section, remembering that curl will move towards the wetter (cooler) side of the paper?

6. Are the coatings different on one side vs. the other?

The side with the higher hydrophilic binder weight has higher coefficient of moisture expansion (CME) and causes curl to that side with a loss of moisture.

7. Is the reel moisture content too high in copy paper (90gsm or less)?

If the moisture is above 5.5- 5.7%, curl may be away from the



FIGURE 3. CURL AWAY FROM PRINTED SIDE OF LASER COPY PAPER DUE TO HIGH MOISTURE CONTENT.

printed side (Figure 3). Forms printed by offset can have high moisture.

8. What is happening to the paper after it leaves the mill? How is the sheet being used and/or converted?

Is the converting operation climate controlled, and if not, what are the summer to winter variations in humidity? How is the paper

stored? If it is properly wrapped, then it will not be affected by humidity to a great degree. But if a roll or ream is partially used, and then left unwrapped, the paper can pick up moisture. If the paper is being printed, what moisture and heat is being applied to the paper and to which side of the sheet?

CONCLUSIONS

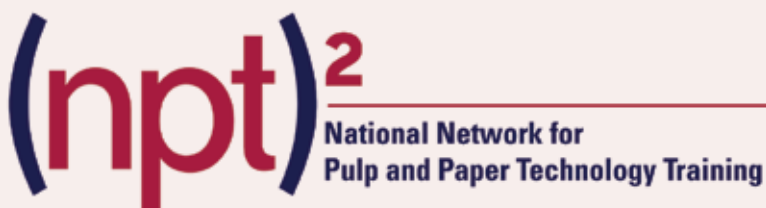
The basic principles that describe why paper curls, are quite simple. It is the complexity of the interactions of the various parts of the process that make controlling paper curl so difficult for the papermaker. When curl problems occur, it is important to look at all the possible variables, and determine which ones have the greatest effect on the paper. Since paper is inherently "alive," it is not always possible to eliminate curl completely, but the goal should be to produce a quality sheet of paper that performs its end-use with a level of curl that is acceptable to the customer.

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REFERENCES

¹Green, C. and Atkins, J., "Curls Aren't Always Cute", *Paper360°* Magazine, November 2007, TAPPI Press, Atlanta.

"Control the top and bottom dryer temperatures correctly, and the sheet comes out flat."



Mission:

...to provide the pulp and paper sector of the United States forest products industry with a globally competitive, technologically advanced workforce and to give students and incumbent workers around the nation exciting and effective education and training opportunities.

Turn-key maintenance services extend existing mill resources

With pressures to keep maintenance costs down the importance of having your equipment operating efficiently and reliably is paramount. Metso offers turn-key maintenance services to ensure that your equipment is in top operating condition.

Our turn-key maintenance services are customized to satisfy each mill's needs and optimizes the use of your own maintenance resources. The services can include all or just some of the following depending on the scope of work to be accomplished: pre-maintenance shutdown planning meeting, supervision, millwrights, tooling, parts, exchange units, upgrades and follow-up visits. All work and products supplied are covered by Metso's warranty.

All work is conducted in accordance to state and mill safety regulations and Metso carries the necessary insurance coverage to protect customers.



Metso meets with mill personnel during scope pre-meeting.

Case Study – Tolko, La Pas

Tolko contacted Metso Paper in 2010 requesting an inspection of their DWA1255 Twin Roll Press. The initial visit by Metso identified the fact that both rolls required repairs and an overhaul of the press would also be needed. Since Tolko would be conducting their annual outage, they realized that they would not have the resources to conduct the rebuild themselves.

The Tolko mill site is located just outside of La Pas, in Manitoba, Canada which is about a seven hour drive north of Winnipeg.

Metso recommended their turn-key maintenance concept. The press would be rebuilt according to OEM specifications and Metso would supply the rolls, wear parts, supervision, manpower and tools. Due to the scope of work and the mill's lack of resources, this approach would suit the mill

perfectly. By relying on Metso's expertise, the mill personnel could devote their time to other tasks during the outage.

A mill visit was made in May 2011 and at that time Metso and Tolko personnel met to discuss the scope. Metso presented the plan and discussed any concerns the customer may have had.

Once the scope and schedule was agreed to Metso began preparing for the outage. Rolls, spare parts and tools were shipped to site two weeks prior to the outage which was to take place in August 2011.

Outage week

Metso personnel travelled to the mill and were ready to start on the Tuesday morning of that week. Crews, which consisted of 13 people, worked around the o'clock. Metso performed a complete rebuild. Bearings, sleeves, v-rings, o-rings, seals and brushes were replaced along with the two rebuilt rolls. The job was completed on the Thursday of the same week, earlier than scheduled.

The customer was extremely pleased with the outcome. Metso had delivered on its promise to safely complete the job on time and on budget.

"Thank you for the turn-key service. The job was completed last Thursday, a bit ahead of schedule. We were very pleased with the work force you provided and the preparation that was put into the job. The crews worked safely and were very productive on all shifts."

– Doug Goldstrand, Maintenance Planner, Tolko Kraft Papers.

Case Study – IP, Riegelwood

The mill had significant wear on the end rings on both rolls, along with some advanced wear on the screen plate at the roll ends. Rolls were to be sent to a Metso shop for repair and then returned to the mill site.

Phase 1: Mill A

- Metso arrived at site (Supervisor and crew)
- Press disassembled; components prepared for reassembly
- Both rolls handed to dedicated truck for delivery to Metso shop



- In the interim Metso demobilizes and heads to another nearby mill for another Turn-Key Project

Interim Phase: Mill B – Nearby

- Metso performs maintenance on a couple of presses, including at least one bearing change on a press roll
- Metso demobilizes and heads back to millsite A

Phase 2

- Press rolls arrive
- Both rolls dressed and reinstalled into press
- All normal PM work (seals, etc) also performed
- Metso demobilized and leaves the millsite

Both projects were completed on time and as a result of the proper planning with Mill B, Metso was able to minimize demobilization and travel expenses to both mills.

This is what Jeff Carland of IP Riegelwood had to say about Metso's Turn Key Maintenance Services:

"Being a maintenance planner I have dealt with many different contractors and companies, but I will have to say my experience with Metso has been a pleasant one. Metso is a professional company that's easy to deal with. From the sales department to the completed job every employee knows the task and the job set before them. I will gladly use Metso for additional upcoming work and I highly recommend Metso to anyone else."

For more information on the scope and availability of Metso's maintenance services, and how a turn-key approach can benefit your mill, contact your Metso representative.



Turn-key maintenance services - a wise choice

In these difficult economic times mills are faced with many challenges. Making the most out of limited internal resources is a neverending process. Using outside turn-key maintenance services to augment existing maintenance personnel is a wise choice. Metso turn-key maintenance services provide our OEM expertise to optimize your equipment performance, increase production and improve quality.

Call your Metso representative to learn how turn-key maintenance can help you accomplish more during your next shutdown.

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Around the Industry

AN EDUCATION/EMPLOYMENT CONNECTION

Anyone questioning the value of education in the workplace need look no further. The unemployment rate for those with less than a high school diploma was 14.0% in September, while the rate for high school graduates with no college was 9.7%. The unemployment rate for those with some college or an Associate's degree was 8.4%, while the unemployment rate for those with a Bachelor's degree or higher was a low 4.2%.

From The Tea Leaf by Jeff Thredgold, October 12, 2011

NEW EDUCATIONAL MATERIALS FROM TAPPI

2011 Corrugated Conference Proceedings CD

The 2011 TAPPI International Corrugated Packaging Conference and CorrExpo were held September 26-27, 2011 at the Worthington Renaissance Hotel in Fort Worth, Texas. This CD-ROM contains the proceedings from the six of the seven sessions. Highlights of the conference content include:



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Available only on this fully searchable CD-ROM.

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The Pulp and Paper Technology book series is a new industry resource for improving the knowledge base of new and incumbent hourly workers. It is the first in a series of resources developed jointly with TAPPI and the community college network (npt)².

Volume 1- Pulp Manufacturing tackles the "how" and "why" of pulp making. Topics include wood fiber fundamentals, overviews of the pulp mill, wood prep, kraft pulping, mechanical pulping, chemical recovery, bleaching and more. This series complements the two-year associate curriculum at (npt)² community colleges.

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The Pulp and Paper Technology Advanced Workforce Training and Education Series: Volume 2: Paper Manufacturing

Volume 2- Paper Manufacturing provides an overview of the paper mill as well as the entire papermaking process from stock preparation to pressing and drying. Topics include: wet end chemistry, paper machine wet end, size press operation, and coating operation. The training series also includes a review at the end of each chapter. 2007. 146 pages, soft cover.

Item Number: 0101R320. List Price: \$60, TAPPI Member: \$45

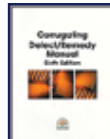


Handbook for Pulp and Paper Technologists (The Smook Book) Third Edition

By Gary A. Smook

This best-selling text provides an introduction to the entire technology of pulp and paper manufacture. The book features 27 chapters covering all aspects of pulping and papermaking. Hundreds of illustrations, charts, and tables help the reader grasp the concepts being presented. The third edition features additional material on secondary fiber recovery and utilization, mechanical pulping, kraft pulping and bleaching, and papermaking. 2002. 425 pages, hard cover.

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By Alan W. Rudie and Peter Hart

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