High-density papers and corrugator runnability

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ABSTRACT: High-performance corrugating liners and medium, with their increased fiber density and reduced moisture content, offer improved ring crush values. However, this increased density and reduced moisture make them more prone to overheating, poor adhesive interaction, dry cracking, and, in the case of medium, poor flute formation. One factor in reducing problems with these new papers is the careful control of their surface temperature during corrugating. An infrared optical pyrometer was extremely useful for monitoring surface temperatures. Addition of moisture to the singleface liner and extra moisture to the medium, by means of wet steam, improved bonding as measured by pin adhesion, edge crush test, and fiber pull.

KEYWORDS: Bonding strength, converting machines, corrugating machines, corrugating medium, high density, liners, mechanical properties, moisture, packaging papers, paper, paper board grades, paper converters, paper stock, runnability, surface properties, surface temperature, temperature, thermal properties.

Since the introduction of high-performance liners, the corrugating industry has faced many new challenges in achieving maximum results in quality and production. Some of the more troublesome problems corrugators have encountered are delamination of the sheet (either off the corrugator or after curing), "fractured liners," and "cracked scores."

Using photomicrographs, we will provide a better understanding of the new liners and medium. With a better understanding of paper properties, crews should be able to make more educated adjustments to ensure proper quality. We will also address the changes corrugator crews make on the machine that affect the finished sheet.

We will present data showing the effect of changes in liner temperature. In addition, we will show how conditioning the medium and liner with moisture affects corrugated board tests such as pin adhesion, fiber pull, and ECT (edge crush test). This data should be helpful in addressing quality and production problems with the new papers.

High-density liners: properties and challenges

High-density papers, high-ring-crush liners, and high-performance liners are all terms for a lightweight grade of linerboard that has a minimum ring crush value of 2 lb for every pound of basis weight.

These new liners are manufactured on paper machines equipped with the new high-intensity nip press, also known as the extended nip press. These shoe-type hydraulic presses improve compression strength (ring crush) by rapidly removing water from the sheet *(1)*.

Changes in pulp refining, fiber orientation, and chemical addition also increase paper strength to produce high-performance liners.

As loading increases in the press section, the sheet becomes more compressed, and the interfiber bonding (hydrogen bonding) improves. The sheet becomes tighter and more dense, resulting in higher ring crush values. However, the increased density also affects other properties of the papers. High-density liners have closer fibers, making the sheet much

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I. Effect of singleface liner temperature on bond strength

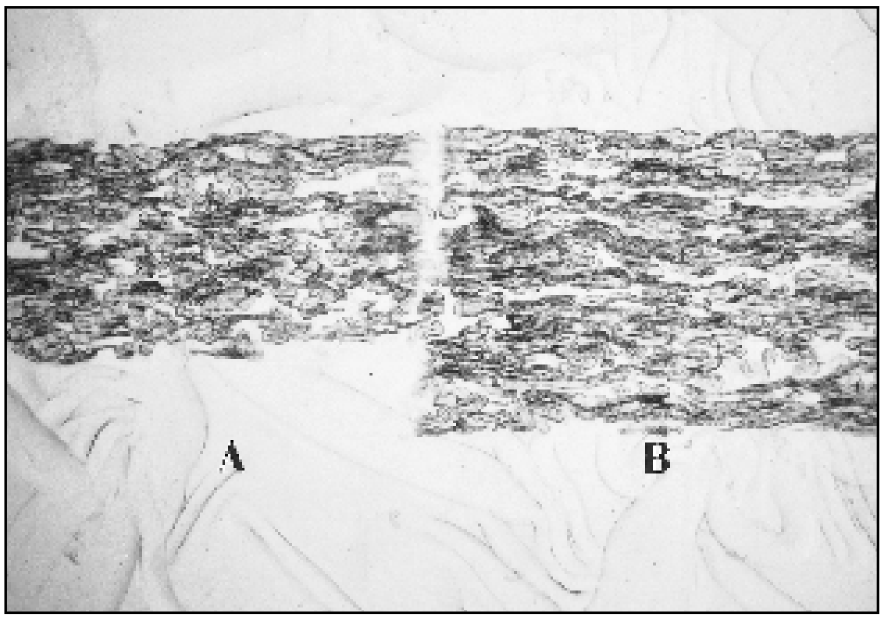
SF liner temp., °C (°F)	ECT, kN/m (lb/in.)	Pin adhesion, N/m (lb/ft)	Fiber pull, %	
			Fiber tear	Adhesive failure
71.1 (160)	5.6 (32)	510 (35)	5	95
82.2 (180)	7.2 (41)	831 (57)	75	25
87.8 (190)	7.4 (42)	875 (60)	90	10
93.3 (200)	7.4 (42)	919 (63)	100	0
98.9 (210)	7.2 (41)	919 (63)	100	0
104 (220)	7.0 (40)	875 (60)	85	15
110 (230)	6.8 (39)	860 (59)	70	30
116 (240)	6.5 (37)	817 (56)	50	50
127 (260)	6.1 (35)	802 (55)	30	70

less porous than conventional kraft papers (**Figs. 1 and 2**). Reducing porosity in the sheet increases the potential of bonding problems because of poor adhesive penetration *(1)*.

Moisture content of the new high-performance liners is very constant but usually much lower than conventional kraft liners. [Moisture content within a 35-lb (171 g/m^2) high-performance liner usually runs 4–4.5% compared to 8–9% moisture found in 42-lb (171 g/m^2) conventional kraft liners.] Running these lower-moisture papers reduces or eliminates "wet streaks" that were common in conventional kraft papers. However, this lower moisture can require the operator to make adjustments for optimum results.

With closer fiber contact and less insulating air space, heat easily passes through high-density paper. Thus, another property of the new papers is that they become hotter more quickly than conventional liners. By contrast, the larger air spaces around the fibers make kraft paper a good insulator of heat. Control of paper temperature on the corrugator is crucial and may require much closer monitoring of these papers.

1. Cross-sections of high-density liner (A) and conventional kraft liner (B) shows the difference in fiber spacing and caliper (120X).



High-density liners: corrective measures

Surface temperature control

Maintaining proper paper temperatures can result in better adhesive bonding. Singleface liner with a surface temperature too low (under 180°F or 82.2°C) usually produces a white glue line because of insufficient heat to properly cook the adhesive. If the liner is too hot (over 240°F or 115.6°C), the glue line appears glassy and feels raspy to the touch, like sandpaper. Overheating the papers can also contribute to fractured liners and cracked scores associated with high-density papers.

In addition to these visual indications of problems, laboratory measurements relating to bonding such as ECT, pin adhesion, and fiber pull show the effects of temperature variations.

The liner temperature data in **Table I** was obtained using an optical infrared pyrometer to measure the temperature of the singleface (SF) liner. This data shows the importance of controlling paper temperature. Because high-performance papers heat so quickly, temperature control is more challenging. The optical infrared pyrometer has been useful in controlling temperature to ensure that both liners and medium have reached the optimum temperature for bonding.

II. Effects of singleface liner moisture addition on bond strength

Moisture addition	*SF liner temp., °C (°F)*	*ECT, kN/m (lb/in.)*	*Pin adhesion, N/m (lb/ft)*	*Fiber pull, %*	
				Fiber tear	*Adhesive failure*
None	87.8 (190)	7.4 (42)	875 (60)	90	10
Inside	87.8 (190)	7.4 (42)	904 (62)	100	0
None	98.9 (210)	7.2 (41)	918 (63)	100	0
Both sides	98.9 (210)	7.4 (42)	933 (64)	100	0
None	104 (220)	7.0 (40)	875 (60)	85	15
Inside	104 (220)	7.5 (43)	933 (64)	100	0
None	110 (230)	6.8 (39)	860 (59)	70	30
Both sides	110 (230)	7.0 (40)	933 (64)	100	0

2. Cross-sections of high-density medium (A) and conventional kraft medium (B) shows the difference in fiber spacing and caliper (120X).

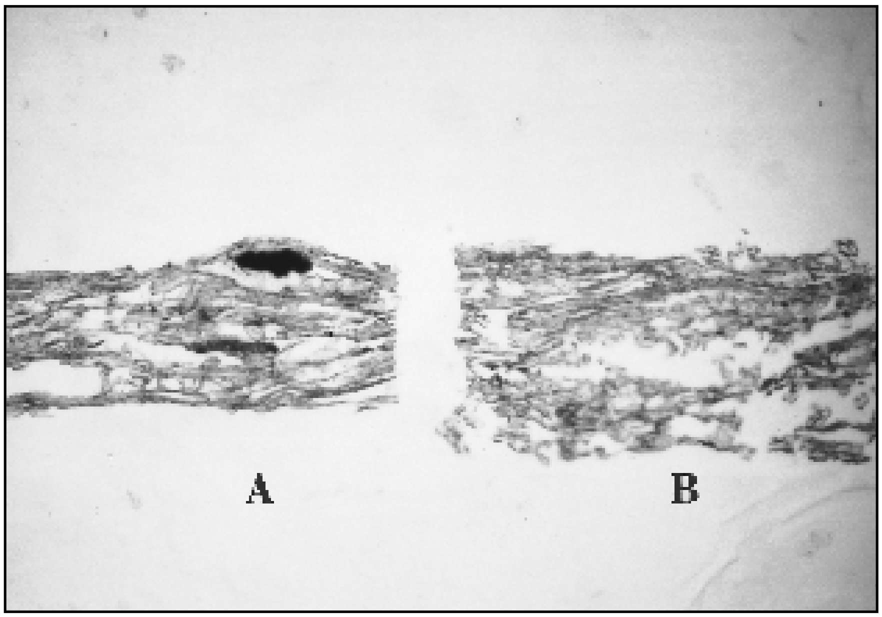


Table I shows the effect of changing liner temperature when running 35-lb (171 g/m^2) high-performance liners on the singlefacer. For this trial, paper was wrapped on the 36-in. (91.5 cm) preheater to drive moisture into the sheet. Liner temperatures were measured after the preheaters. The machine speed was 450 ft/min (137 m/min) for all samples taken for testing. Starch settings did not change during the testing period. Moisture readings of the liner ranged from 4.0% to 5.0% and were taken by the corrugator crew while the machine was running. All board samples were the same paper combination: 35-lb (171 g/m^2) high-performance liners with 100% recycled 26-lb (127 g/m^2) medium. For convenience this board combination is abbreviated 35-26-35. An independent laboratory completed the testing of all board samples.

Figure 3 shows that ECT, pin adhesion, and fiber pull all have an optimum peak at singleface liner temperatures of 200–210°F (93.9–98.9°C). This shows most dramatically for fiber pull. A slightly wider temperature range produced acceptable results; however, liner temperatures below 180°F (82.2°C) or above 240°F (115.6°C) showed problems.

Using an optical infrared pyrometer to measure the surface temperature on well-running board of different types, we have seen that, in general, the doubleback liner is best maintained around 200°F (93.3°C) on the glue side, going into the hot plates. The medium temperature should be around 180°F (82.2°C). The singleface web temperature (combined singleface liner and medium) should be around 250°F (121.1°C) (measured on the liner side) *(2)*. The singleface liner should be between 180°F and 240°F (82.2–115.6°C). Table I supports this generalization for singleface liners. It also shows that for specific board combinations, improved results can be obtained with closer temperature control.

Moisture addition to high-performance liners

Paper surface temperature is only one factor. Some corrugators have reported bonding problems with the high-performance liners even when paper temperatures have been controlled. The problem usually appears as poor fiber pull or even "zipper" board.

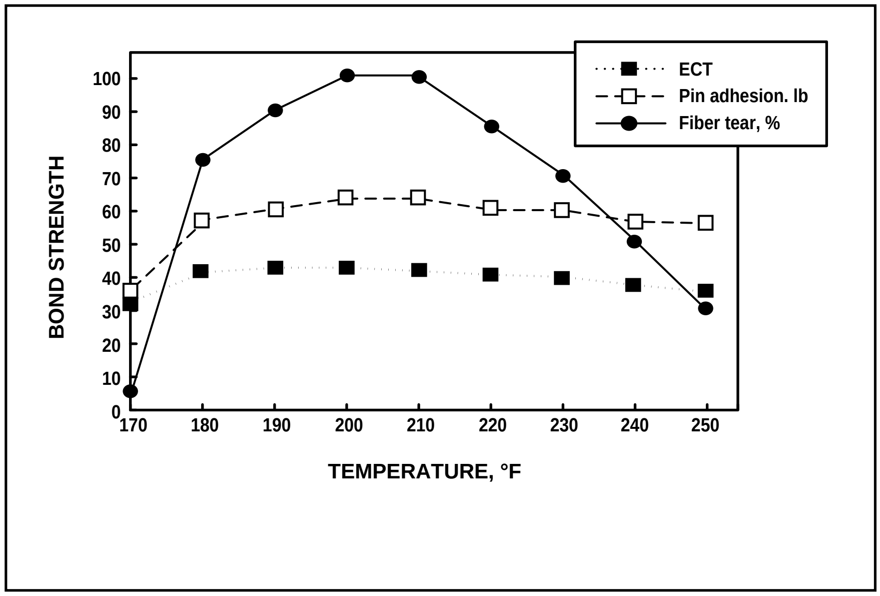
It has been speculated that the addition of wet steam to the inside of the liner (the glue side) will help make the sheet more receptive to adhesive, improving fiber pull. By improving the fiber pull values of the finished sheet, the pin adhesion will also improve. Steam has been used on both the top and bottom side of the high-performance liner for better warp control on some machines.

In our second experiment, wet steam was added to the singleface liner. **Table II** shows the test results of board samples when wet steam was added to the singleface liner, either on the glue side or to both sides. The paper combination was the same as above, 35-26-35, with 100% recycled medium. Moisture of the singleface liner before "conditioning" was from 4.5% to 5.0%.

The moisture applied to the liner was the same moisture that supplies the steam shower and preconditioning drum. It is very important to have the ability to increase the moisture and not increase paper temperature. It is helpful to wrap high-density liners so that the moisture is driven toward the glue line surface. The wrap should be controlled to avoid overheating the paper.

When wet steam was added to the singleface liner, both pin adhesion and fiber pull values increased. However, ECT did not show much improvement. We did not experience warp for either one-sided or two-sided moisture addition. Nevertheless, controlling the amount of moisture is important. Too much moisture will cause post warp and result in soft board off the corrugator.

3. Singleface liner temperature vs. bond strength



III. Bond strength without additional moisture

Flute type	ECT, kN/m (lb/in.)	Pin adhesion, N/m (lb/ft)	Fiber pull, %	
			Fiber tear	Adhesive failure
C	6.5 (37)	846 (58)	10	90
C	6.8 (39)	860 (59)	0	100
C	7.0 (40)	875 (60)	15	85
B	6.8 (39)	846 (58)	20	80
B	7.4 (42)	890 (61)	40	60
B	7.0 (40)	802 (55)	35	65

High-density medium: properties and challenges

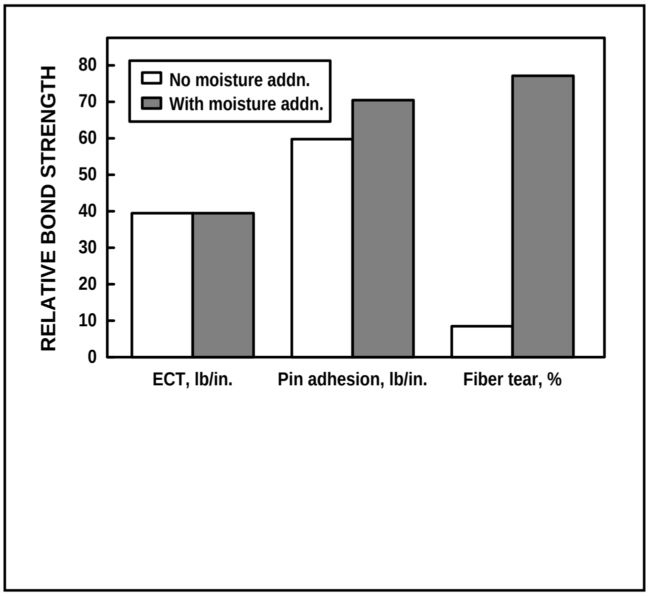
In addition to high-density liners, many corrugators are now running high-density medium. Like high-density liners, high-density medium is also manufactured on paper machines equipped with the extended nip press. Some of these new presses have the capability of operating with several thousand pounds of pressure.

These new mediums have high ring crush values, lower moisture content, are more dense, tighter, and become hotter more rapidly than the conventional semichemical mediums. As a result, many corrugators using these new mediums have experienced quality problems similar to those with high-density liners. When steam is increased in the steam showers, the medium can become overheated (in excess of 200°F (93.3°C)). When low moisture in the medium remains uncorrected, problems in the finished board can be extreme. The finished sheet will be dry, and the fiber tear results will be poor. This situation leads to cracked scores, fractured liners, and delamination of the sheet after stack curing. Running the medium too "hot" can also increase starch consumption at the singlefacer. Starch requires water to form a proper bond. When the temperature of the medium is excessively high, water in the glue line can flash away. The operator often adds more adhesive to try to compensate.

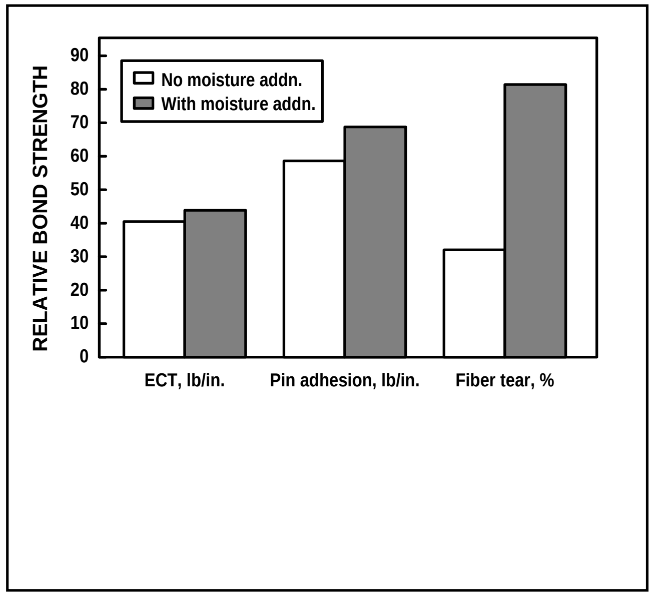
The moisture content of these new mediums is usually around 5%. Some manufacturers are able to produce paper with higher levels, but corrugators have also reported moisture levels as low as 3–3.5%. The lower moisture presents problems similar to those discussed for high-performance liners. Similarly, proper conditioning of the medium is important.

Some corrugators running these new mediums have reported a problem with low paper caliper. Usually the caliper of medium is less than 9 mils (0.229 mm), but when the caliper is around 6 mils (0.152 mm) transferring the adhesive from the glue roll to the tips of the flutes is difficult. The glue roll will be against the

4. Effects of adding moisture to medium (C-flute)



5. Effects of adding moisture to medium (B-flute)



IV. Bond strength with additional moisture to the medium

Flute type	*ECT, kN/m (lb/in.)*	*Pin adhesion, N/m (lb/ft)*	*Fiber pull, %*	
			Fiber tear	*Adhesive failure*
C	6.7 (38)	1006 (69)	70	30
C	7.0 (40)	1020 (70)	80	20
C	6.8 (39)	1020 (70)	80	20
B	7.2 (41)	1020 (70)	80	20
B	7.4 (42)	948 (65)	75	25
B	8.4 (48)	1020 (70)	90	10

stops inside the machine but not close enough to make proper transfer of the adhesive. Trying to maintain proper machine speed will result in adhesive slinging into the valleys of the flutes, usually causing post warp and higher than normal starch consumption. Running a low-caliper medium can also create problems in flute formation such as "highs and lows" (on finger-type machines) affecting both machine speeds and top-to-bottom compression.

High-density medium: corrective measures

As with the high-density liners, controlling surface temperature of the medium helps avoid many problems, including bonding problems after the sheet has stack cured. The preconditioner drum should have a surface temperature of about 250°F (121°C). This drum temperature will drive the moisture into the sheet, but not through the sheet. The preconditioning drum must be driven at least 6% faster than the paper speed to reduce excess drag on the medium *(3)*.

An experiment was run to determine what effect adding additional moisture to these new mediums had on pin adhesion, ECT, and fiber pull when compared to board samples without the added moisture. For our study of high-density medium, the preconditioning drum at the singlefacer was equipped with wet steam on the feed side of the drum. The conditioning steam used at the singlefacer and preconditioning drum was supplied through the condensate return line from the machine. The moisture level for the steam shower was adjustable so that the amount of moisture could be increased without increasing the surface temperature of the paper. Unfortunately, not all corrugators are equipped to make this adjustment, which can require some modification in the steam system.

Tables III and IV show the test results for board samples without (Table III) and with (Table IV) the addition of extra moisture to the medium. The moisture was added at the preconditioning drum and steam showers. Moisture content of the medium was 3.5% to 5% on the machine. All the medium was 100% recycled material. Again, the paper combination was 35-26-35. The medium temperature was kept at 180°F (82.2°C). (These tables show that a corrugator can manufacture board with acceptable pin adhesion values and actually have no fiber pull!)

In **Fig. 4**, averages of the test values in Tables III and IV for C-flute board were used to compare the effects of adding moisture to the medium. **Figure 5** shows similar comparisons for B-flute board.

By increasing moisture in the steam shower and the preconditioning drum (but not increasing paper temperature), we saw an increase in both pin adhesion and fiber pull. The finished sheet was firm, not overheated [medium temperature was 180°F (82.2°C) in the singleface web]. The converting side of the plant reported no fractured liners or cracked scores.

Using a larger amount of moisture in the medium resulted in soft board coming off the corrugator and didn't show any added benefit to board quality.

When trying to improve ECT, the corrugator must form the best flutes it is capable of producing. Many factors need attention, but the reduced moisture of the high-performance mediums makes proper conditioning of the medium necessary. The operator must understand when to apply steam to increase the moisture within the paper for better conditioning.

When the medium roll is being prepared for the splicer, the operator should take a small sample of the paper and drop it in water. Should the paper absorb the water very quickly (i.e., less than 5 seconds), this medium will need extra conditioning (increased moisture) to prevent the sheet from pulling water out of the glue line and causing surface bonding or zipper board. If the paper sample absorbs water slowly (i.e., takes more than a minute to wet out), this roll of medium will require both steam and moisture to make the fibers more receptive to adhesive for better penetration and improved fiber tear. Performing this test on the outside of the roll will only show how the medium will perform right after the crew makes a splice. Therefore this test should be repeated during operation and changes made accordingly.

Conclusion

Two major factors contribute to improved corrugator runnability with high-density papers:

1. The ability to control the surface temperature of both liners and medium
2. The ability to condition both liners and medium with moisture, making them more receptive to the adhesive.

An optical infrared pyrometer has been useful for keeping paper surfaces at the optimum temperatures for bonding. The addition of wet steam for preconditioning the paper has also been successful in increasing bond strength. TJ

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