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A Study of the Effects of Nip Width on Plybond Separation of Board during Gravure Printing

Anne L. Liebeknecht
Western Michigan University

A STUDY OF
THE EFFECTS OF NIP WIDTH
ON PLYBOND SEPARATION OF BOARD
DURING GRAVURE PRINTING

by

Anne L. Liebeknecht

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ABSTRACT

W. Hildenbrand, W. Brecht and H.-J. Knittweis did work in Germany in the late 1960's concerning the relationship between roll hardness, pressure and plybond degradation of paper board in a gravure printing process. They showed that softer rubber covered rolls caused a decrease in plybond strength. Increased pressure at the nip also caused a similar decrease. This study attempted to quantify these decreases, but was unable to produce acceptable data. Poor samples and inconsistencies in the BRDA plybond test machine are the probable causes of the high variation in the data.

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INTRODUCTION

Plybond failure of board during gravure printing has been a serious problem. Board meeting the plybond specifications at the board mill may still fail at the printing press.

Considerable work was done on this problem in the late 1960's in Germany. The Germans were able to explain the effects of pressure, roll hardness and entry angle on plybond separation, but they did not relate their results to American testing equipment.

This study attempts to explain the effects of pressure and roll hardness in terms of the BRDA plybond tester and the ZDT plybond tester.

THEORETICAL DISCUSSION

Plybond Strength Types

Three types of plybond strength are associated with board: the normal strength, the bending shear strength, and the dynamic rolling shear strength (1).

As the board goes through a nip in a gravure press, it is exposed mostly to dynamic shear. Most existing methods for testing plybond strength only measure the normal strength.

W. Hildenbrand's Work

W. Hildenbrand recognized the need for a device that would examine the dynamic rolling shear strength of board after exposure to a press nip (2). Hildenbrand developed a machine that passed the board strip through the nip several times, keeping the web tension fixed. The nip was that point of contact between the steel printing cylinder and the rubber coated impression cylinder. With this device, plybond separation was a function of the number of times the board passed through the nip before splitting.

Hildenbrand determined several things with this method. Splitting occurred mostly at basis weights greater than 500 g/m^2 (102 lb/1000 ft^2) and never at basis weights below 400 g/m^2 (81.8 lb/1000 ft^2). Bending occurred above 700 g/m^2 (143 lb/1000 ft^2).

Of all the variables investigated, Hildenbrand found the angle between the web as it entered the nip and the tangent in the pressure area to have the greatest effect on separation. Impression pressure also had an important influence on splitting. If there was no pressure, no splitting was observed. This lead Hildenbrand to conclude the small guide rollers had no influence on separation and that splitting occurred only after nip exposure.

The other variable of primary importance was impression cylinder hardness. As the hardness increased, the plybond degradation decreased.

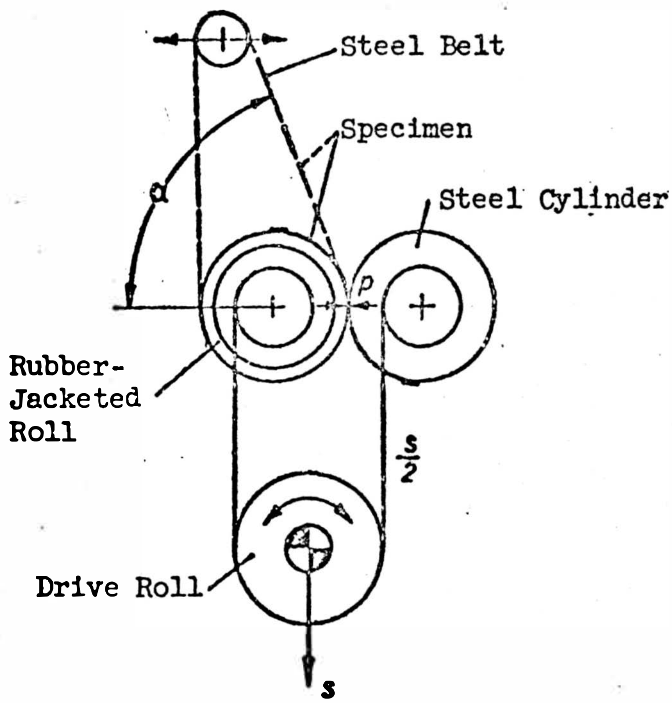
Among Hildenbrand's other conclusions were: 1) resistance to splitting was greater on the drive side than on the guide side; 2) moisture content was not important; and 3) resistance to splitting decreased with increased nip friction.

W. Brecht and H.-J. Knittweis' Work

W. Brecht and H.-J. Knittweis designed a fatigue tester based on Hildenbrand's research (1). Their machine was smaller and better suited for laboratory purposes (Fig. I)(3) With this device, the sample traveled back and forth through the nip until the sample split.

Brecht and Knittweis found that if a steel cylinder replaced the rubber coated cylinder, there was no splitting; two steel cylinders, however, would not produce good print quality.

Other results confirmed Hildenbrand's work. Figure II shows the effects of input angle and line pressure on splitting. Increased line pressure at the nip increased the ten-



Strip Tension = f(s)

Line Pressure = p

Figure 1 Schematic Diagram of the I.f.P. Fatigue Tester for Rolling Shear Stress (3)

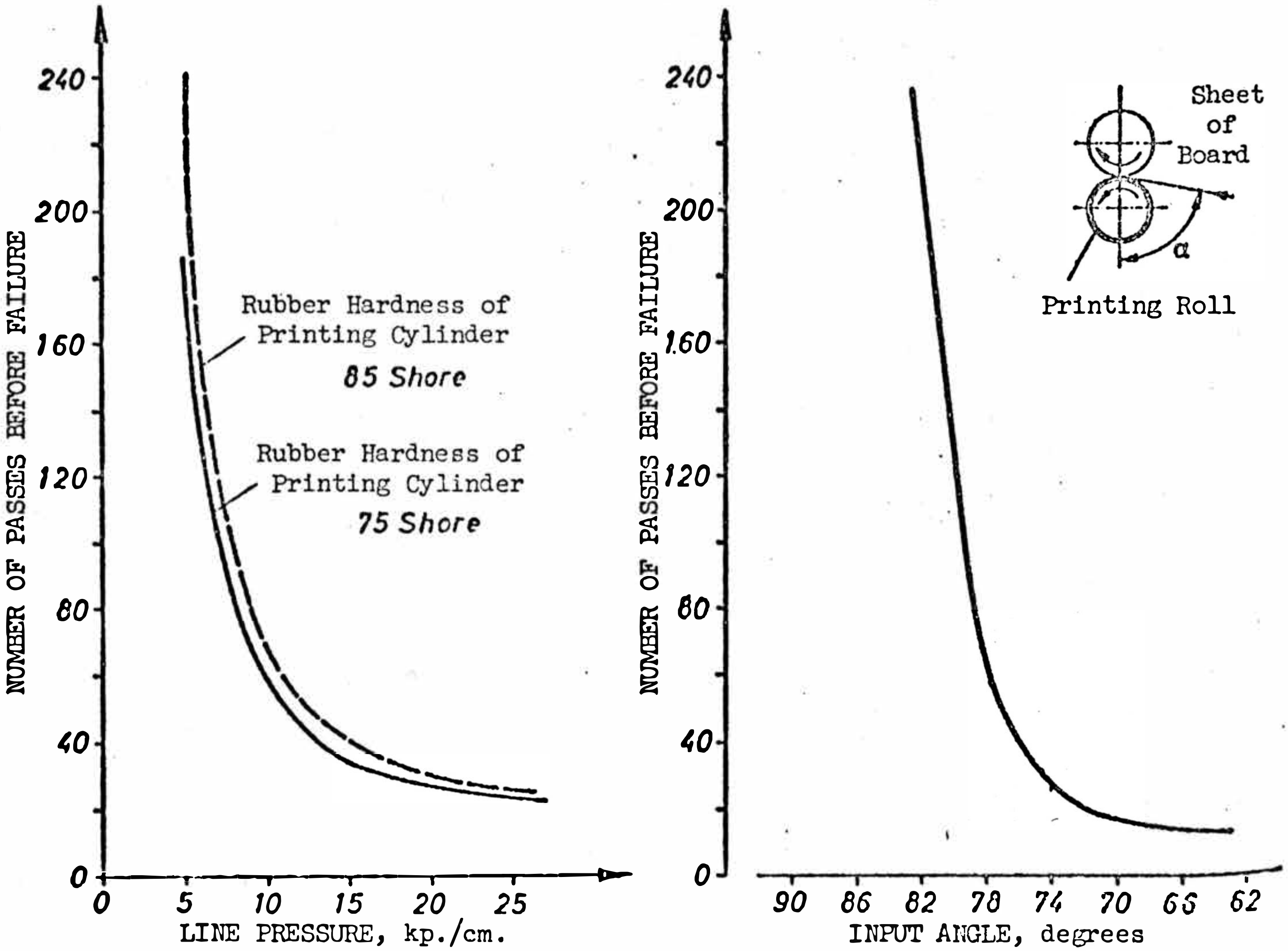


Figure 2 Effect of Pressing Conditions on the Rolling Shear Strength (3)

dency for separation dramatically. Figure II also shows the importance of input angle in relation to separation.

Literature Analysis

The studies done by Hildenbrand, Brecht and Knittweis represent the published research relating gravure printing to plybond separation. These studies showed the main variables were entry angle, line pressure and roll hardness. No correlation was made to plybond testers commonly used in the United States. This was basically because the researchers felt separation caused by nip variables related to dynamic splitting, whereas American testing devices examined normal separation. It would be simpler to repeat these studies using common testers than to have all board manufacturers purchase fatigue testers.

Another problem stemming from these results deals with the printer versus the board manufacturer. The above studies conclude plybond separation can be avoided or reduced by decreasing line pressure and/or increasing impression roll hardness. To the printer, however, this means sacrificing print quality, including snow and fine detail (4). This study **attempts** to quantify some of the variables to provide the two concerned parties with information to aid in a justifiable compromise.

EXPERIMENTAL PROCEDURE

Experimental Design

This study examined the effects of line pressure and roll hardness.

Western Michigan University's statistics lab designed a 3 X 3 X 2 X 3 factorial design experiment. The design had three blocks with eighteen trials per block. The randomization of trials is shown in Table I. Table II contains the analysis of variance (AOV) information necessary for statistical analysis.

For this type of design, board samples would be put through the BRDA nip compression tester to examine nip effects, varying the number of passes through the nip. Zero, two, and four passes were chosen to simulate a two color and a four color press run.

Two levels of basis weight would be examined, each coming from the same board machine and ranging in basis weight from 450 g/m^2 (92.1 $lb/1000\ ft^2$) to 650 g/m^2 (133 $lb/1000\ ft^2$).

The roll hardness was not randomized due to the difficulty of changing rolls. The roll hardness, therefore, is the common variable to each block, ranging from 80 Shore to greater than 95 Shore.

The three line pressures examined should be in the range used in gravure printing.

Actual Experimental Procedure

The actual experimental procedure was not run according to the design. Only one basis weight was obtainable at the time of the study. James River Paper Company was the source of the samples. The average basis weight was 580 g/m^2.

The appropriate rubber covered roll was installed prior to running the trials of each block. Table III shows the trial order. Only two blocks were tested after it was apparent that the results were questionable. All trials in the same block were run through the nip compression tester in the same day. Nip width was measured with NCR paper after conditions were set for line pressure. The NCR paper was left in the nip for at least five minutes to insure a visible impression.

Each board sample was originally 5" X 24" and had to be cut into two 4" X 12" samples. Before being cut, arrows were placed on each half of the sample, running in the same direction. The two halves were also given the same letter. This was necessary for the BRDA plybond test. For each letter, one sample is tested in the direction of the arrow, while the other is tested in the opposite direction. After twenty samples were set aside for the BRDA plybond test, the remaining samples were used for the ZDT test.

Each sample was put through the nip compressor the correct number of times. Each time, the arrow pointed toward the nip.

The BRDA plybond test and the ZDT test were performed on each trial. The ZDT test was located at the James River Paper

Company. Ten 2" X 2" samples were tested on this device. The BRDA plybond testing was done in the paper department's constant humidity room. By testing ten samples in the machine direction and ten more samples turned 180°, compensation was made for the lapped nature of the fibers. Testing was done according to BRDA - Standard Test Method, File No. 3-T-18.

TABLE I

3 x 3 x 2 x 3 FACTORIAL DESIGN

A = Pressure
3 levels
B = # Passes
3 levels
C = Basis Weight
2 levels
D = Roll Hardness
3 levels

BLOCK 1				BLOCK 2				BLOCK 3			
A	B	C	D	A	B	C	D	A	B	C	D
2	2	0	0	1	0	1	1	0	1	0	2
1	0	0	0	1	2	0	1	2	2	0	2
1	1	0	0	2	1	1	1	2	0	0	2
2	0	1	0	1	0	0	1	2	1	0	2
0	2	0	0	0	2	1	1	1	1	1	2
0	0	0	0	2	0	0	1	0	1	1	2
1	2	1	0	1	1	0	1	1	2	0	2
2	1	0	0	2	0	1	1	2	2	1	2
2	2	1	0	0	1	0	1	0	0	1	2
2	0	0	0	2	1	0	1	0	0	0	2
0	0	1	0	0	1	1	1	1	0	1	2
1	0	1	0	0	0	0	1	0	2	0	2
0	1	0	0	2	2	0	1	1	0	0	2
0	1	1	0	0	0	1	1	2	0	1	2
1	2	0	0	1	2	1	1	2	1	1	2
1	1	1	0	0	2	0	1	1	2	1	2
2	1	1	0	2	2	1	1	0	2	1	2
0	2	1	0	1	1	1	1	1	1	0	2

TABLE II

AOV Table

Source	df
Total Corrected	53
Between blocks	2
Within blocks	17
A	2
B	2
C	1
AB	4
AC	2
BC	2
ABC	4
Intra block error	34
AxBlock	4
BxBlock	4
CxBlock	2
ABxBlock	8
ACxBlock	4
BCxBlock	4
ABCxBlock	8

TABLE III

Order of Trials

Block: 1

Trial	Pressure (pli)	Passes	Nip Width (inches) Without sample	With sample
1	200	4	7/8	15/16
2	100	0	5/8	21/32
3	100	2	5/8	21/32
4	200	2	7/8	15/16
5	100	4	5/8	21/32

Block: 2

Trial	Pressure (pli)	Passes	Nip Width (inches) Without sample	With sample
6	100	4	1/2	9/16
7	100	0	1/2	9/16
8	100	2	1/2	9/16
9	200	2	3/4	13/16
10	200	4	3/4	13/16

RESULTS

Discussion and Presentation of Results

The following data tables show no evidence of correlation between the BRDA plybond test and the ZDT test. Most of this discussion will deal with the results from the BRDA plybond test.

Table IV shows the results of the first block using the 95 Shore rubber covered roll in the nip compressor.

TABLE IV

Block: 1
Rubber hardness: 95 Shore
Pressure: varied (pli)
Number of passes: constant

	2 PASSES		4 PASSES	
Pressure	BRDA	ZDT	BRDA	ZDT
0	275	43.0	275	43.0
100	245	42.8	265	43.1
200	260	41.9	250	41.2

The plybond strength was expected to decrease with an increase in pressure. This was the case for four passes on the BRDA test, but not for two passes. The opposite was true for the ZDT test.

Table V contains the same data as in Table IV, but with the pressure constant and the number of passes varied.

TABLE V

Block: 1
Rubber hardness: 95 Shore
Pressure: constant (pli)
Number of passes: varied

	Pressure: 100		Pressure: 200	
Passes	BRDA	ZDT	BRDA	ZDT
0	275	43.0	275	43.0
2	245	42.8	260	41.9
4	265	43.1	250	41.2

Plybond strength was expected to decrease as the number of passes increased. This was true at 200 pli for both the BRDA and the ZDT tests, but was not the case for either test at 100 pli.

Table VI shows the results of the second block using the 86 Shore rubber covered roll in the nip compressor.

TABLE VI

Block: 2
Rubber hardness: 86 Shore
Pressure: varied (pli)
Number of Passes: constant

	2 PASSES		4 PASSES	
Pressure	BRDA	ZDT	BRDA	ZDT
0	255	42.0	255	42.0
100	215	43.3	240	42.9
200	210	42.1	245	43.0

The expected decrease in plybond strength was observed only in the BRDA test for two passes. The four-pass ZDT actually increased with increased pressure.

Table VII contains the same data as in Table VI, but with the pressure constant and the number of passes varied.

TABLE VII

Block: 2
Rubber hardness: 86 Shore
Pressure: constant (pli)
Number of passes: varied

	Pressure: 100		Pressure: 200	
Passes	BRDA	ZDT	BRDA	ZDT
0	255	42.0	255	42.0
2	215	43.3	210	42.1
4	240	42.9	245	43.0

Here, none of the expected decreases in plybond strength occurred with an increase in the number of passes.

Examining just the high and low levels of pressure and number of passes, the expected decreases in plybond strength are observed. It should be noted, however, that six of the eight decreases were less than 20. The difference between the zero trials of the two blocks was 20, although each trial was treated identically. This brings into question the significance of the above differences. Statistical significance would require many more trials for a meaningful standard deviation.

Table VIII combines the data of the two blocks to compare the effects of roll hardness.

TABLE VIII

Block: 1 and 2
Pressure: varied (pli)
Number of passes: 2

Roll hardness	Pressure	BRDA	ZDT
95	0	275	43.0
86	0	255	42.0
95	100	245	42.8
86	100	215	43.3
95	200	260	41.9
86	200	210	42.1

Number of passes: 4

Roll hardness	Pressure	BRDA	ZDT
95	0	275	43.0
86	0	255	42.0
95	100	265	43.1
86	100	240	42.9
95	200	250	42.1
86	200	245	43.0

The softer roll, 86 Shore, consistently tested lower plybond strength, although in most cases the decrease was small. If a t test is run on the differences between the hard and soft roll values, the significance of the decreases can be examined.

$\bar{D} = 25$ (mean difference)
$s = 14.8$ (standard deviation)
$n = 6$
$df = 5$ (degrees of freedom = n - 1)
$t_{0.05} = 2.015$ (95% confidence)

H_o: $d = 0$ vs. H_1: $d > 0$
reject H_o if $t > 2.015$

$$t = \frac{\bar{D} - d}{s / n} = \frac{25 - 0}{14.8/6} = 4.14$$

Since 4.14 2.015, H_o is rejected. There is 95% probability that the difference is significant. Actually there is a 99.5% probability of significance as the t value for that corresponding confidence is 4.032.

An alternate way to examine these differences is to give d the value of 20, which is the difference in the zero trials. If this is done, the t value drops to 0.83. Now there is only a 75% probability of significant differences.

Table IX contains the same data as in Table VIII, but with pressure constant and the number of passes varied.

TABLE IX

Block: 1 and 2
Number of passes: varied
Pressure: 100 pli

Roll hardness	Passes	BRDA	ZDT
95	0	275	43.0
86	0	255	42.0
95	2	245	42.8
86	2	215	43.3
95	4	265	43.1
86	4	240	42.9

Pressure: 200 pli

Roll hardness	Passes	BRDA	ZDT
95	0	275	43.0
86	0	255	42.0
95	2	260	41.9
86	2	210	42.1
95	4	250	41.2
86	4	245	43.0

Significant statistical differences in the data of Table IX are the same as in Table VIII, since the differences are the manipulated numbers.

CONCLUSIONS

The data does not lend itself to easy interpretation of the quantitative effects of roll pressure or the number of passes through a nip. The high degree of variability in the data prohibits specific conclusions. Only speculation can be made as to the cause of the variability.

Variation within the samples is one possible source. Many different samples would have to be examined to determine if the samples used in this experiment were at fault.

The BRDA plybond testing machine could be the source of error. Current fluctuations were a constant problem. The effects of this are difficult to assess.

The ZDT test also produced erratic results, possibly because this test examined normal forces, whereas the stresses applied at the nip were basically shear stresses.

The results seem to support the previous work concerning roll hardness, although the degree to which softer rolls cause degradation was unable to be determined.

RECOMMENDATIONS

Two main problems are encountered when assessing the effects of nip pressure and roll hardness on plybond degradation. In order to get good results, samples with low variability are needed. A machine that will accurately measure dynamic plybond strength is also necessary.

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