

THE CONTRIBUTION OF NEWSPRINT ON OFFSET PRINT QUALITY

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Abstract: The physical properties of 6 twin wire newsprints were compared to the visual ranking of a panel of technical experts. The properties of surface roughness, color, printing opacity and brightness did not directly explain the ranking of visual print quality. Print contrast, ink rub off, and show through were a significant predictor of visual ranking. The visual ranking was independent of fiber source and hemicellulose content but it was related to lignin content. In the majority of cases, the physical and optical properties of the two surfaces of a given newsprint were significantly different. Print contrast, rub off, and show through exhibited a two side difference.

INTRODUCTION

Newsprint offset printability defines the influence of newsprint characteristics on the visual appearance of a non-heatset web offset reproduction. The only means to determine this illusive newsprint property is the subjective evaluation of printing quality by a panel of viewers. Our preliminary research demonstrated a commonality in the subjective evaluations by technically trained viewers, newsprint manufacturers and newspaper production personnel, and the average reader. Only the optical brightness of the newsprint had a limited influence on the preference of these viewers. The major portion of the subjective evaluation was dependent on the integration of multiple discriminations by the viewer of unknown newsprint characteristics not measured by traditional physical properties of newsprint.

The print quality preference by these viewers was consistent when the "best" newsprint was compared to the "worst" newsprint but the choice became random and arbitrary when a printing quality difference between two newsprints were not as great. Since there is a continuum of print quality from the "best" newsprint to the "worst" instead of discrete steps, discriminations between the "best" and "average" newsprint and "average" and "worst" were not predictable or consistent among different viewers. This jumble of arbitrary preferences between newsprint with multiple variations of physical characteristics and the inability to define what within the printed image that the viewers are basing their judgements has made the development of an offset printability model from measurable physical properties difficult.

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Several newsprint manufacturers, often using a viewer panel of their newsprint consumers, have reported success in developing predictive offset printability models (Vanya 1989 , Engeldrum 1990). A common element of these models has been the development of a method to evaluate print mottle or image consistency within a printed solid ink film. Little or no emphasis on the role of traditional physical or optical properties of newsprint is included in the models. These models often were developed using same group of viewers and their applicability to a general population needs to be evaluated.

Modern newsprint manufacturing techniques have reduced the differences in the appearance and physical attributes between the two sides of the newsprint sheet. These modern techniques, however, have not eliminated the intra-sheet differences. This two sided nature of newsprint requires that an offset printability model integrate printing quality differences for the two sides into a single evaluation. The inter-sheet differences for corresponding sides of two different newsprints may be less than this intra-sheet difference of a single newsprint.

An offset printability study was undertaken to: 1) evaluate the importance of the two-sided characteristics of newsprint, 2) determine if there are chemical or physical attributes that influence perceptible printing quality, 3) investigate what measurable property of printing quality the viewers might be basing their preference.

The confidential contributions by six newsprint manufacturers of the test newsprints made this study possible.

Experimental

From previous offset printability results of an all-pairs comparison of fourteen different newsprints, five test newsprints representing the “best”, better than “average”, “average”, worse than “average”, and “worst” were chosen. A newsprint made from 100% recycled fiber was included in the test group. The pulp source, pulp type, and machine type are shown in Table 1.

Each newsprint was printed to a solid ink density between 1.03 - 1.07 on a single Urbanite offset press unit at 27,000 impressions per hour. The same artwork, ink and neutral fountain solution was used for all pressruns. Page one contained an AP wire black and white photograph with little midtone detail, a black and white photograph whose tonal range was balanced for newspaper reproduction, and text copy of different typefaces. Page two was a typical newspaper page with a small reverse advertisement, story text, and two black and white halftones. Page three was a classified advertisement page with a 6 x 9 cm nonprinted area that corresponded to a solid reverse on Page 4. This page was used for the rub off and show through determinations. The ANPA black and white test negative used as Page 4 provided test targets for the evaluation of printing quality.

Newsprint	Pulp Source	Pulp type	Machine
1	Western Hemlock	12% Kraft 88% TMP	BEL BAIE II
2	Black Spruce Balsam Fir	45% Groundwood 35% TMP 20% Sulfit	BEL BAIE II
3	Black Spruce Balsam Fir	67% Groundwood 28% Sulfit 5% Kraft	BEL BOND
4	60% Lobolly 40% Virginia Pine	96% TMP 4% CTMP	BEL BAIE II
5	100% Recycle		PAPRIFORMER
6	Black Spruce Balsam Fir	65% Groundwood 30 % SCMP 5% Kraft	BEL BAIE II

Table 1. Pulp Source, pulp type, and machine type for the six test newsprints

The plate imposition permitted Pages 1 and 4 to be printed on the wrapper side of the newsprint, designated as top side, in Section 1 and Page 1 and 4 to be printed on the core side, designated as bottom side, in Section 2. Section 2 was refolded by hand so that test sheets printed on the bottom side had the same appearance to the viewer as Section 1.

Printed samples were paired in a six x six factorial design shown in Figure 1. These paired samples were assigned using a random number table to two randomized groups for panel judging. Two duplicate samples were included in each judging group so that each viewer judged only twenty sample pairs. By pre-pairing the samples and reducing the number of judgements required of each viewer, the bias from comparing known samples of the all-pairs comparison design and viewer fatigue from making 36 judgements was reduced. This design allowed the inclusion of duplicate pairs to test the ability of the viewer to make consistent judgements.

Newsprint manufactures,, newspaper production personnel, or typical newspaper readers was asked to compare Sample A to Sample B for each pair and to note his/her preference. The option of no preference was included. The preference of Sample A scored +1 and the preference of Sample B scored -

1. No preference scored 0. The sum of each cell within the matrix was calculated (Figure 1) and the non-zero (significant preference) cells were identified using a chi-square test. Initially, the samples were assigned a rank by comparing their overall preference for all judgments. Final placement within a group ranking of similar quality was confirmed by use of logical triads.

1T - 1B N.S. N = 51	1T - 2T N.S. N = 41	1T - 3T 1T N = 51	1T - 4T 4T. N = 41	1T - 5T 1T. N = 51	1T - 6T 6T N = 51
2T - 1B N.S. N = 41	2T - 2B 2B N = 41	2T - 3T 2T N = 51	2T - 4T N.S. N = 51	2T - 5T 2T N = 41	2T - 6T 2T N = 51
3T - 1B 1B N = 51	3T - 2B 2B N = 51	3T - 3B 3B N = 51	3T - 4T 4T N = 51	3T - 5T N.S. N = 51	3T - 6T 6T N = 51
4T - 1B N.S. N = 51	4T - 2B 2B N = 41	4T - 3B 4T N = 41	4T - 4B N.S. N = 51	4T - 5T 4T N = 41	4T - 6T 4T N = 41
5T - 1B 1B N = 41	5T - 2B 2B N = 51	5T - 3B N.S. N = 41	5T - 4B 4B N = 41	5T - 5B 5B N = 51	5T - 6T 6T N = 41
6T - 1B N.S. N = 51	6T - 2B N.S. N = 41	6T - 3B N.S. N = 41	6T - 4B 4B N = 41	6T - 5B N.S. N = 41	6T - 6B N.S. N = 41

SAMPLES COMPARED → 4T - 3B
 PREFERRED SAMPLE → 4T
 NUMBER OF COMPARISONS → N = 41

Figure 1. Sample comparisons and results of panel rankings. T = wrapper side of the newsprint. B = core side of newsprint. A preferred sample of N.S. mean judges did not have a significant preference by a chi square test ($p = 0.05$).

The top and bottom side of each newsprint, where appropriate, was evaluated for the physical and chemical properties listed in Table 2. In addition, printing quality parameters of print contrast for the 75% dot, ink rub off, and show through were determined.

Results

The newsprints tested in this study (Table 1) represented the three geographical fiber sources used to make newsprint for United States newspapers and a newsprint derived from recycled fiber. These 48.8 g/m²

PROPERTY	METHOD
Moisture	TAPPI T412
Grammage	TAPPI T410
Caliper	TAPPI T411
Printing Opacity	TAPPI T519
ISO Brightness	ISO 2470
Elmendorf Tear Strength	
Newsprint Color	CPPA E.7P
Parker Print-Surf Roughness	10 kgf/cm ² 20 kgf/cm ²
Larocque Printability	
Hypo Number	TAPPI T253
1% NaOH Solubility	TAPPI T212

Table 2. Physical and chemical properties analyzed

nominal newsprints were formed on various types of twin-wire newsprint machines. The range for the physical properties of the test newsprints approximated the 1989 all industry range of 1438 samples tested in ANPA's national survey of newsprint used by our member newspapers (Table 3). All surface and optical properties exhibited a statistically significant two-sided difference ($p = 0.05$) for the six test newsprints. The probability was greater that the intersheet difference for a given side (e. g. top side compared to top side) would be less than intrasheet difference between the top and bottom of a given sheet. The majority of the surface and optical properties for newsprints had a significant intersheet ($p = 0.05$) difference. These differences and the experimental design was equivalent to evaluating the printing response of 12 different newsprints.

PROPERTY	INDUSTRY RANGE	TEST RANGE
ISO Brightness	53.0 - 60.3	54.3 - 59.2
Parker roughness 10 kgf/cm ²	3.0 - 4.6	3.4 - 4.5
Printing Opacity	92.4 - 96.3	93.2 - 95.7
Caliper	67.6 - 85.4	74.6 - 85.9

Table 3. Comparison of the test newsprints physical properties to the 1989 all industrial range for 48.8 g/m² newsprint. All industry range (plus or minus 2 standard deviations) derived from 1438 samples measured for the ANPA Newsprint Quality Program in 1989.

The lignin and hemicellulose content of newsprint has the potential to affect the offset printability by determining the absorption rate of ink oil or water. Lignin which is associated with the cellulose fiber of the paper increases the hydrophobic characteristic of the paper and is the major contributor to newsprint color. The hypo number, an estimate of the lignin content of a paper, showed a variation for fiber source and pulping technique (Table 4). The 1% sodium hydroxide solubility estimates the hemicellulose content of the paper. Hemicellulose portion of cellulose fiber is responsible for the interfiber hydrogen bonds and the absorption of water. The hemicellulose content was affected by the pulping method and fiber source (Table 4). Each of the test newsprints had an unique lignin/hemicellulose ratio ranging between 1.5 and 2.9. The deinking process may decrease the hemicellulose and lignin content.

Newsprint	Hypo Number	Sodium Hydroxide (NaOH) solubility	Hypo /NaOH
1	24.2	9.7%	2.5
2	26.7	13.0%	2.1
3	18.3	12.0%	1.5
4	27.3	12.0%	2.3
5	22.5	10.4%	2.2
6	26.2	9.1%	2.3

Table 4. Hypo numbers and 1% sodium hydroxide solubilities of the test newsprints.

Ninety-two viewers returned evaluations of their 20 sample judging group. An overall ranking of no preference occurred for thirteen of the matched-pairs comparisons (Figure 1). Comparison of the printing quality of the top side and bottom side of the same newsprint produced a significant preference in 3 of the 6 possible cases. The overall ability of the viewers to make consistent judgements was confirmed by similar rankings for the duplicate pairs included in each judging group. Because of the unique surface and optical properties, each side of the newsprint can be treated as an individual sample in determining the overall printability ranking of the samples. This relationship was determined by calculating the average score received by a given sample in all of the comparisons. A negative value indicated that the other sample in the match pair was preferred. Using this method, the samples had ranking from 28.7 for the most preferred newsprint to -20.9 for the least preferred sample. The samples were then assigned to five groups of similar offset printability by the use of logical triads (Table 5). The order within any printability group is arbitrary. Five of the twelve samples were judged to have similar offset printability.

	RANK	SAMPLES WITHIN RANK
BEST	1	2B, 4B
	2	4T, 2T, 6T, 6B, 1B
	3	3B, 1T
	4	5B
WORST	5	3T, 5T

Table 5. Summary of panel ranking of the six test newsprints. Samples placed within a given rank did not have a significant viewer preference and the order within rank is arbitrary. Number refers to the newsprint in Table 1. T = top (wrapper) side of the newsprint B = bottom (core) side of the newsprint

Print contrast, show through, and ink rub-off were used as three objective measurements of printing quality. Print contrast is a specialized measurement of dot gain that estimates the ability to maintain the shadow detail within a halftone photograph. Optimization of print contrast for a set of printing conditions indicates the best printing detail obtainable for a given solid ink density. A typical response of one of the test newsprints (Figure 2) demonstrates that the print contrast was essentially constant for solid ink densities from 0.95 to 1.11. For all of the test newsprints, the bottom side (core) printed with more detail than the top side (wrapper) of the same paper (Table 6). The intrasheet print contrast difference ranged from 0.6 to 3.1. The

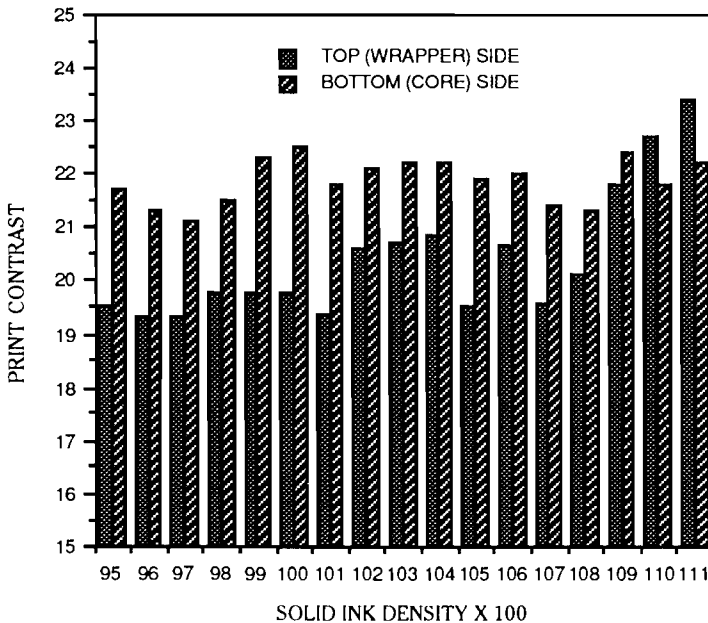


Figure 2. Typical relationship between print contrast, solid ink density, and the side of the newsprint that the image is printed.

intersheet print contrast difference was 1.9 for the top side and 2.5 for the bottom side. Ink rub off, measured by the ANPA-NAPIM weighted tissue method, exhibited an inter and intrasheet variation. The bottom side (core) always had less rub off than the top side (wrapper). The newsprint with the lowest amount of bottom side rub off had the most top side rub off. The amount that the ink rub off was reduced as the ink penetrated the surface of the sheet for two hours range from 0 to 40%. This rub off reduction had a high degree of intra and intersheet variability. Show through compared the reduction in the brightness of a newsprint surface on the side opposite a solid printed area versus the brightness of an unprinted sheet. The brightness of the test newsprints could be reduced from 5% to 10% by the image printed on the opposite of the page. There was no clear relationship between the show through and the side of the sheet. Show through was dependent on the composition of the individual sheet.

NEWSPRINT	TOP (WRAPPER)	BOTTOM (CORE)
1	20.95	22.45
2	21.16	21.75
3	20.63	22.52
4	20.65	23.72
5	19.29	21.19
6	20.85	21.91

Table 6. Average print contrast for solid ink densities from 1.01 to 1.10

The physical, optical, and print quality measurements were compared to this viewer ranking using a forward stepping multiple linear regression model. For the purpose of this model, the best printability group was assigned the ranking of 1 and the worst printability group was assigned a ranking of 5. Show through alone was a significant predictor of viewer ranking ($p = 0.008$) and would explained 52% of the viewer ranking. When show through is combined with print contrast, the regression equation predicted 71% of the viewer ranking. The individual regression coefficients were significant ($p < 0.05$). As show through increased the viewer preference decreased. Viewer preference increased as the print contrast increased. The inclusion of ISO brightness ($p = 0.13$) and difference in rub off values between the initial value and the value after 2 hours ($p = 0.2$) explained 81% of the viewer ranking and the sum of square due to regression was significant ($p = 0.01$). The ISO brightness and rub off difference, although not a statistically significant, increased the ability of the model to accurately predict the viewer ranking by lowering the unexplained residual data interactions (Table 7).

$$\text{panel ranking} = 25.53 - 0.3134 \text{ ISO BRIGHTNESS} + 0.5101 \text{ PRINT SHOW THROUGH} - 0.3893 \text{ PRINT CONTRAST} - 0.2589 \text{ RUBOFF DIFFERENCE}$$

	MULTIPLE R	R-SQUARE
UNADJUSTED	0.9014	0.8126
ADJUSTED	0.8399	0.7055

STANDARD ERROR OF ESTIMATE = 0.7439

MEAN SUM SQUARES DUE TO REGRESSION SIGNIFICANT AT P = (0.01)

Table 7. Offset printability prediction model

Discussion

The relationship between the physical properties of newsprint and the resulting print quality is a major concern of newspaper printers trying to print a consistent, quality newspaper for their readers and advertisers. Newsprint may be derived from one of four fiber sources which influence the appearance and printing characteristics. The Northeast wood source of spruce and fir species produces a bright paper with moderate tear strength. The Western paper is characterized by a very strong fiber that is less bright while the Southern pine produces a paper that falls between the Northeast and Western paper. Newsprint derived from recycled fiber has the tendency to emulate the characteristics of the geographical region forming the majority of the input fiber. An identification of the physical properties of newsprint that influences offset print quality would aid the efforts of the manufacturers to improve the printability of newsprint.

The offset printability model proposed here should not be considered as an absolute. The model needs further verification with other ink characteristics and newsprints. Although this model is limited it does provide some insights into the newsprint characteristics that influence offset printability.

Show through was the major determining factor influencing viewer preference. Show through in this model was defined as the reduction in brightness of the newsprint due to printing on the opposite side. As expected the printing opacity of the newsprint was the major contributor in predicting the observed show through. An inclusion of initial ink rub off to a show through prediction model incorporated 13% more of the data and greatly improved the accuracy of the prediction. As the rub off increased and printing opacity decreased, the show through increased. Newsprints with a larger hypo number, a measure of the hydrophobic characteristic of newsprint, generally had less show through. These results suggest that in addition to newsprint characteristics that increase printing opacity, the ability of the surface of the newsprint to absorb

the ink oil rapidly and preventing it from being transferred into the fiber layers below is a major factor affecting show through.

The contribution of print contrast on viewer preference reflects the importance of maintaining shadow detail and controlling dot gain in the halftone reproduction. Ink rub off, surface roughness, printing opacity and the amount that ink rub off is reduced in 2 hours influence the print contrast of a newsprint. The amount of ink rub off, the major factor predicting print contrast (58%), decreases as the print contrast increases. Inclusion of Parker Print-Surf roughness and printing opacity results in a prediction model for print contrast that will explain 86% of the newsprint contribution to dot gain. A rough, opaque newsprint prints with less dot gain. The print contrast generally improves as the hypo number of the newsprint increases. A covariance of the reduction in ink rub off as the oil is absorbed into the paper and the other factors affecting print contrast exist. The results suggest that the newsprint contribution to dot gain is determined by the ability to absorb the ink oil rapidly. Hydrophobic and rougher surfaces influence this absorption rate.

The ISO brightness of the newsprint establishes the tonal contrast available to the printer. The weak correlation between the initial brightness of the newsprint and viewer preference indicates tonal contrast does contribute to the preference of the viewer. The data suggest that the real role of the newsprint brightness is to establish a baseline that is reduced by show through to the final printed brightness. The printed brightness is what the viewer judges. A brighter newsprint with a large degree of show through would have a equivalent offset printability to a less bright newsprint with moderate show through.

The observed differences in the printing response of different sides of the newsprints strongly suggest that surface characteristics of the paper determine the printing response. The printing response results from the interactions between the ink and the surface fibers. Ink oil absorption appears to be a major factor in determining both the show through and dot gain. Once the internal mat of fibers provides the necessary bulk and strength, these fibers do not play a significant role in determining the printability of the newsprint. Further research to verify the findings of this study and determine the role of ink characteristics on oil penetration into the surface fibers is needed before an universal offset printability model can be developed.

A final practical application of this research is that newspapers should attempt to print their process color on the core side of the newsprint. The expected dot gain and printed brightness should then be superior.

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