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A Study of the Relationship Between Compressibility and Printing Smoothness

Richard R. Teugh
Western Michigan University

A STUDY OF THE RELATIONSHIP BETWEEN COMPRESSIBILITY AND PRINTING SMOOTHNESS

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ABSTRACT

This investigation seems to indicate that printing smoothness, although dependent upon both smoothness of the sheet and compressibility, is much more dependent upon the smoothness of the paper being printed. For the samples tested printing pressure required seems to be a function of the smoothness and the deformation pressure with the smoothness apparently most important.

TABLE OF CONTENTS

Acknowledgment.....................................1

Abstract...2

Literature Survey..................................4

Literature Cited..................................11

Experimental Work.................................13

Results Obtained..................................16

Conclusions.......................................19

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Literature Survey

INTRODUCTION

Since the great majority of papers produced are ultimately printed, the printing characteristics of papers should be investigated both in their entirety, as printability, and in their parts, as smoothness or compressibility.

Compressibility is conceded by most authors to have a part in determining the printability of a sheet of paper in letterpress and rotogravure printing. The part this compressibility plays in relation to smoothness and other elements is a matter of some controversy in the literature, however.

Methods for measuring compressibility have been devised but no standard method has evolved and most of these methods leave something to be desired by way of equipment used, time required, or consistancy of results obtained.

A STUDY OF THE RELATIONSHIP BETWEEN COMPRESSIBILITY AND PRINTING SMOOTHNESS

To insure the terms used in the title will mean the same to everyone they are defined as follows to eliminate any slight variances.

Printing smoothness is defined by Chapman(1) as; "The fraction of surface which can be brought into contact with a smooth surface pressed against it under pressures comparable to printing pressures." This printing smoothness is dependent upon smoothness and compressibility of the paper among other factors.

Webster's New International Dictionary(2) defines compressibility as the ability of a substance to be pressed or squeezed together; to be forced into a narrower compass; or to be compacted. This compressibility is not the three dimensional deformation through the plane of the paper. Gavelin(3) and others subdivide this compression into two main components, primary and secondary or reversible and irreversible.

First is primary compression which is reversible and is further divided into elastic and delayed elastic flow. This compression leaves no permanent deformation of the sheet surface after printing letterpress or rotogravure.

The component which leaves a permanent deformation on

some printed sheet surfaces is secondary or irreversible compression or permanent set.

This action of a sheet of paper is illustrated by Steenburg's(3) mechanical model of paper with very good correlation.

The compressibility of paper is considered by different authors to be of different importance to printing. The Institute of Paper Chemistry(4) said "The compressibility of paper under dynamic load is an important property (of paper) since it is a determining factor in the quality of the printed sheet. Smoothness can be lower if compressibility is high."

Crane(5) agrees that the compression effect when exposed to several hundred P.S.I. in letterpress printing will allow a rough but compressible sheet to print better than a smooth but hard sheet. Roehr(6) says compressibility is most important for rotogravure printing; due to the low nip pressures used; important for letterpress; and not a factor in offset printability due to the "built in" cushion of the rubber blanket. He also says compressibility is not important to printability of higher coated weight sheets due in part to higher smoothnesses obtained.

Evanoff(7) and Laroque(8), testing letterpress and rotogravure news printing, respectively, found smoothness the most important constituent of printability with compressibility or softness of next importance.

Compressibility has been measured in various ways in the literature. Gavelin(3) tried the most ways and undoubt-

ably hit upon the most novel method also. He pushed rolls of newsprint off from a ten foot height and measured the rebound from a concrete floor as a measurement of elasticity. This method was impractical for a routine control test so he investigated further and compressed two rolls of newsprint by the weight of a calender roll and measured the deflection of the rolls due to compression, through several successive cycles. Next he drew further graphs using a screw piston and a two ton capacity pressure balance to test cut samples of newsprint. He found this later method the most reproducible and avoided the differences in tension encountered when testing rolls.

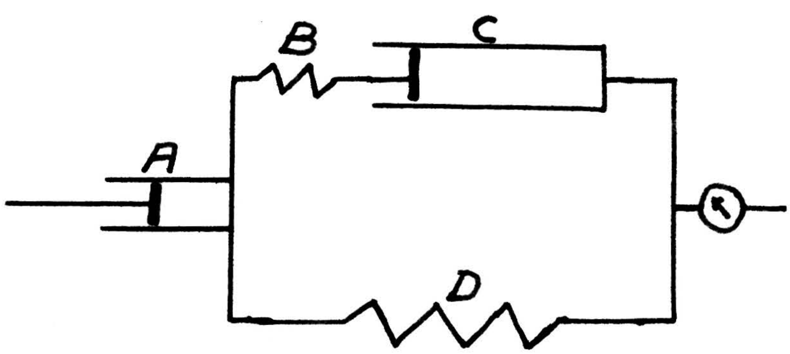
The Bekk Hardness Tester was modified by the Institute of Paper Chemistry(4) by testing a heavy pad of the sample and they were able to get fair correlation between elasticity and hardness using this method.

A calender equiped to measure deflection under varing pressure was used by Ant-Wourin(9) to test newsprint but his samples tested in different order using different pressures during calendering. A hydraulic press with a micrometer dial attached was used by Roehr(6) to test sheets and Ivarsson(10) used a motor driven screw fed press with an electronic transducer to measure deflection of wet pulp laps. Croney(11) pressed metal cylinders of different diameters into a sheet followed by a dial gauge to simulate letterpress printing stresses under controlled pressure.

These methods all have one thing in common. That is,

they all have something in their equipment or procedure that renders them unsuitable for routine control testing.

Gavelin(3) found in his studies that the behavior exhibited by the paper during his compression cycles could be explained by Steenburg's(3) mechanical model of paper.



The permanent or irreversible secondary compression is explained by the hydraulic cell A. The primary compression is explained by the spring and spring hydraulic cell in parallel. The elastic portion is the spring B recovering. The delayed elastic is the cell C recovering drawn by spring D. This basic behavior of paper was agreed upon by all the testing methods employed.

When measuring newsprint Gavelin(3) found that irreversible secondary creep was nearly proportional to the freeness of the pulp in the grinder room. The primary or reversible compression was nearly constant from sample to sample. After one cycle nearly all compression was reversible exhibiting a kind of

"conditioning" or "stain hardening" of the paper. He also was able to establish a correlation between Bendtsen Hardness and elasticity. As mentioned previously the Institute of Paper Chemistry(4) was also able to establish a correlation between Bekk Hardness and primary creep or reversible compression.

Ivarsson(10) in his studies of wet lap compression found compression reached a high constant value above thirty percent water probably due to a monomolecular layer of water covering the fibers and giving maximum flexibility.

Gavelin(3) and Diehm(12) both agree and state moisture is one of the most important variants in compressibility.

Ant-Wourin(9), Diehm(12), and Ivarsson(10) all found beating lowers compressibility and along with moisture content is critical with respect to compressibility. Fiber morphology, pulping process, mechanical treatment during beating, ash, and thickness all have a smaller and indeterminate part to play in the compressibility of the sheet as it was determined by the same investigaters.

For letterpress printing Croney(11) discovered that the size of the anvil printing the sheet is important as well as the total area printed. He showed that, due to edge effects, the penetration into the paper per unit pressure is less if this constant area is divided into several small printing surfaces. This is the same principle used when constructing foundations for buildings.

1. Chapman, S.M., "The Chapman Printing Smoothness Tester" TAPPI 38, No. 3; 90 (1955)
2. Webster's New International Dictionary, 2nd ed. Cambridge, G.C. Merrian Company, (1953)
3. Gavelin, G., "Compressible of Newsprint," Svensk Papperstidn, 52, No. 17: 4: 13-19 (1949)
4. I.P.C., "Instrumentation Studies XXIII," Paper Trade Journal 106, No. 2: 42-7 (Jan. 13, 1938)
5. Crane, L.P. and Majani, B.E., "Factors Which Effect the Printability of Coated Paper and How They Can be Controlled" TAPPI 4, No. 196-206A (Aug. 1958)
6. Roehr, W.W., "Effect of Smoothness and Compressibility, on the Printing Quality of Coated Paper," TAPPI 38, No. 11: 660-4 (Nov. 1955)
7. Evanoff, P., "Relationship Between Paper Surfaces and Printability," Paper Trade Journal 139, No. 40: 28-30 (Oct. 3, 1955)
8. Laroque, G.L., Axelrod, B. and Clark, S., "Measuring the Printing Quality of Newsprint," Pulp and Paper Magazine of Canada 52, No. 3: 66 (1951)
9. Ant-Wourin, O., "The Pressure Elasticity of Newsprint and Its Component," Finnish Paper Timber Journal 20, No. 15A: 73-4, 76-8, 90-2, No. 15: 569-72 (Aug. 15-16) (Aug. 15, 1938)
10. Ivarsson, B.W., "Compression of Cellulose Fiber Sheets," TAPPI 39, No. 2 (Feb. 1956)

11. Croney, R.G., "Fundamental Problems of Letterpress Impression," <u>Britain Printer</u>, No. 63: 373-4 (1950)

12. Diehm, R.A., "The Elimination of the Human Element in the Determination of Print Quality," TAPPI 33, No. 2: 47 (1950)

EXPERIMENTAL WORK

My literature survey contained no simple test to evaluate paper in respect to compressibility. The testing methods used were too cumbersome or time consuming to be of any value in routine testing, although they were entirely suited for the research work performed.

After preliminary tests it was decided to subject the surface of the test sheets to a controlled simulated letterpress printing utilizing the I.G.T. instrument and a lined wheel. Paper test strips were mounted on the I.G.T. instrument in the same manner used for coating pick tests except the lined wheel was used to imprint the samples. The strips of samples about 1¼ inches by 12 inches were mounted, felt side out, and imprinted at various pressures utilizing the pendulum drive. The surface of the samples were then examined under grazing light for surface deformation in the form of lines from the lined impression wheel. A value, in kilogram printing pressure, was obtained at which the surface was just deformed.

This deformation is a form of irreversible compression that is sometimes evident on the surface of a letterpress printed sheet when the printer used too much pressure while printing.

A promising approach was to graph a surface profile across a test strip using the Brush Surface Analyzer and then

to imprint it as described above and to regraph the same surface hoping to pick up the first sign of surface deformation on the graph. This would enable the operator to obtain a specific value for each paper tested without any human variation by arbitrarily defining the depth of the groves on the graph. However, the results using the surface analyzer were inconclusive.

Next an attempt to determine the surface deformation after impression, by various methods of overprinting, presented problems in trying to put a specific value on the results obtained for each sample.

The method adopted for this investigation was to independently determine the pressure at which each sample exhibited surface deformation after imprinting, as described above, and the pressure needed to obtain printing smoothness with the half tone etched wheel on the I.G.T. instrument. The resultant values for surface deformation and printing smoothness were examined along with Gurly Smoothness and Hardness values for the same samples.

The pressure required to obtain printing smoothness was obtained by printing the felt side of samples, 1¼ inches by 12 inches, using number two tack ink and a half tone screen printing wheel designed for use with the I.G.T. instrument. This wheel was graduated into sections of 10-50-70-90 percent etch but the 10 percent etch was the segment used to determine

our printing smoothness.

The wheel was inked using a standard I.G.T. inking apparatus and ink metering pipette according to a procedure established by Pritchett(1).

Inking procedure:

1. An initial application of 0.5 cc of number two tack ink to the ink roller with a ten minute period for ink distribution.

2. Inking of the etched wheel for 90 seconds.

3. After four inkings of the printing wheel an application of 0.09 cc of ink was applied followed by a five minute distribution period.

The ink and printing speed were kept constant for each paper tested and the pressure was varied to determine what pressure was needed to print the 10 percent etch half tone on each sample utilizing a hand lens to aid in evaluation of dot reproduction.

The paper samples were then tested for smoothness and softness using the Gurley Instrument in the standard manner.

Equipment used:

I.G.T. Inking Apparatus

I.G.T. Printing Apparatus

I.G.T. Measuring Pipette

Printing wheel with Half tone Screen of 10-50-70-90- percent Etch.

Gurley Smoothness Softness and Porosity Tester

1. Pritchett, W.A., Unpublished Thesis, Western Michigan University, (1959)

RESULTS OBTAINED

Five samples of paper of different varieties were tested for the four characteristics described. These results for smoothness, softness, and pressures required for printing smoothness and surface deformation were tabulated and an attempt was made to divide printing smoothness into component parts.

Graph number two seems to indicate, for the samples tested, that the pressure required to obtain printing smoothness is a function of smoothness and deformation pressure with smoothness appearing the most important.

CONCLUSION

My investigation illustrates that compressibility is an elusive quality of paper to measure. Its importance to letter-press printing is agreed upon but a method to measure compressibility objectively and to assign a value to it has not been developed.

Printability of paper is still best determined by proof press trials under simulated printing conditions and not by testing for the individual components of printability and synthesizing a value for printability.

June 10, 1960 Richard R. Teugh