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Standard Practice for Determining the Adhesion of Lamination Films to Prints Utilizing Mechanical Stress: Four Different Test Methods—Score/Tape, Cross Hatch, X-Cut, and Crease-Folding[1]

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1. Scope

1.1 This practice describes procedures for assessing the adhesion between lamination films and black and white or color images produced by printers, copies and other reprographic devices.

1.2 This practice can be used to test different laminates with a given set of inks and media or it can be used to evaluate inks and media with a given laminate.

1.3 This practice is applicable to laminated images, where the substrate surface is subject to failure under mechanical stress from mostly peel conditions (that is, paper, film, cloth, and so forth).

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F2226 Practice for Determining the Adhesion of Prints and Laminating Films

3. Significance and Use

3.1 The image life of printed media displayed in both typical office and outdoor environments can be extended by lamination or encapsulation. While natural aging is the most reliable method of assessing lamination adhesion, the length of the time required makes this method impractical for most materials. This practice utilizing mechanical stress allows comparative studies of prints and laminating films.

3.2 Factors in the office and outdoor environments, such as heat, cold, thermal shock, ultraviolet/visible radiation and water vapor can have effect on laminate stability. The resistance of the laminate to these factors can be assessed by applying mechanical stress.

3.3 Good adhesion is a prime consideration for laminating films and prints. A laminating film, which does not adhere to a print or vice versa generally, has no commercial value. This practice is used to obtain comparative data of adhesion strength of encapsulated or laminated media.

4. Interferences

4.1 Since the ability of laminating film to adhere to printed media is dependent on temperature and humidity, it is important that the effects of mechanical stress be assessed under the conditions appropriate to the end use applications. While printed media may be handled and displayed under a variety of conditions, this practice is intended to determine adhesion in indoor environments.

4.2 The laminate adhesion is dependent on lamination temperature and should be applied at the manufacturers' recommended temperature for the best performance.

4.3 The adhesion between lamination films and color images is dependent on the printing mode, the type of color and the amount of applied ink, lamination conditions such as lamination temperature, the lamination speed and the pressure on the nip.

4.4 This practice is intended to measure adhesion of printed media without specifying above-mentioned parameters.

5. Conditioning

5.1 It is recommended that samples be conditioned at 23°C and 50 % RH for at least 24 h prior to printing and for at least 24 h subsequent to lamination. Specimens should be visually inspected for surface irregularities, which could adversely affect lamination.

5.2 It is recommended that samples be conditioned at 23°C and 50 % RH for 24 h prior to delamination to provide additional time for equilibrium of adhesive containing interfaces.

[1] This practice is under the jurisdiction of ASTM Committee F05 on Business Imaging Products and is the direct responsibility of Subcommittee F05.03 on Research.

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5.3 The above conditioning steps are pertinent only where media evaluation or comparison is needed. Obviously, as a production tool, the conditioning period is not practical. Therefore, when media are coated in production, the specimens should be obtained from each roll and checked as soon as possible in a repeatable procedure appropriate to the operation. It is imperative that operators use caution in selecting and preparing specimens to maintain good uniformity.

6. Materials

6.1 Razor blade, single edge or cutting board, pressure sensitive tape (25 mm (1 in.) wide).

6.2 The adhesion strength of pressure-sensitive tapes is dependent on lot number due to batch production process and storage time. The same manufacturing tape with identical lot number should be used for testing conducted in different laboratories. The pressure-sensitive tape's adhesion varies depending on the coating and substrate. The adhesion strength of the tape should be agreed upon between the manufacturer of the tested coating and the end user.

6.3 At least three test specimens printed with a test image and subsequently laminated.

7. Test Specimens

7.1 The substrate, method of printing, ink or toner lay down, and handling of printed specimens shall be consistent with their anticipated end use.

7.2 The test image can be any picture printed using print files containing the appropriate printer setup specific for each application.

7.3 The same test image and printer set up should be used for comparison purposes.

7.4 The recommended test image should consist of a standardized arrangement of color patches printed using print files containing the appropriate printer setup specific for each application. This test image should contain color patches at maximum print density of 100 % for each of the primary colors of cyan, magenta, yellow and black, 200 % for the secondary colors of red, green, and blue, and 300 % for composite black.

7.5 The recommended color patches should be circular with minimum diameter of 125 mm (5 in.).

7.6 It is recommended that the samples be laminated 24 h after printing. The actual lamination time after printing should be presented in the report.

7.7 Laminating films that are 75 μ (3 mil) thick should be used for comparison purposes. Thinner or thicker laminating films can be used depending on application.

7.8 Speed of lamination for paper media having base weight in the range 90 to 170 g/m^2 should be 0.9 m/min (3 ft/min). Lower or higher speed can be used depending on film thickness, paper base weight, and lamination temperature.

8. Delamination Tests

8.1 Tests should be carried out under temperature and humidity conditions similar to those of end use applications.

8.2 *Score/Tape Procedure:*

8.2.1 Place a sample of the laminated print media to be tested on a flat surface, printed side up.

8.2.2 Take a 75 by 25 mm (3 by 1 in.) piece of the pressure-sensitive tape and firmly adhere 50 mm (2 in.) of it to the surface of each of the colored patches and a non-printed area by pressing down with the flat of a finger.

8.2.3 While holding the specimen against a flat, horizontal surface, grasp the loose end of the tape and pull the tape away sharply from the sample at a 90° angle from the sample (altering the 90° angle may cause the results to be invalid).

8.2.4 All tests are to be conducted in the CD (cross direction) of the sample.

8.2.5 Examine the laminated surface and the tape for coating removal.

8.2.6 Results shall be reported as Pass or Fail.

8.2.7 A passing result is one where the delamination does not occur between the laminate and the first interface after the adhesive, but in a later layer(s).

8.3 *Cross Hatch Procedure—Non Paper Substrate:*

8.3.1 Place a sample of the laminated print media to be tested on a flat surface, printed side up.

8.3.2 Using a sharp razor blade, cut cross hatch lines 3 mm (0.125 in.) apart through the laminating film for each of the colored patches and a non-printed area, being careful not to cut through the ink jet coating and the base material.

8.3.3 Take a 75 by 25 mm (3 by 1 in.) piece of the pressure-sensitive tape and firmly adhere 50 mm (2 in.) of it to the cross hatched surface to be tested by pressing it down with the flat of a finger.

8.3.4 While holding the specimen against a flat, horizontal surface, grasp the loose end of the tape and pull the tape away sharply from the sample at a 90° angle (altering the 90° angle may cause the results to be invalid).

8.3.5 All tests are to be conducted in the CD (cross direction) of the sample

8.3.6 Examine the laminate surface and the tape for coating removal.

8.3.7 The results are to be reported as Pass or Fail.

8.3.8 A passing result is one where the delamination does not occur between the laminate and the first interface after the adhesive, but in a later layer(s).

8.4 *Cross Hatch Procedure—Porous Paper Substrate:*

8.4.1 Place a sample of the laminated print media to be tested on a flat surface, printed side up.

8.4.2 Using a sharp razor blade, cut cross hatch lines 3 mm (0.125 in.) apart through the laminating film for each of the colored patches and a non-printed area, being careful not to cut through the ink jet coating and the base material.

8.4.3 Take a 75 by 25 mm (3 by 1 in.) piece of the pressure-sensitive tape and firmly adhere 50 mm (2 in.) of it to the cross hatched surface to be tested by pressing it down with the flat of a finger.

8.4.4 While holding the specimen against a flat, horizontal surface, grasp the loose end of the tape and pull the tape away sharply from the sample at a 90° angle (altering the 90° angle may cause the results to be invalid).

8.4.5 Under some conditions, a quick stripping of the tape may not cause separation or may otherwise yield misleading results. A slow strip, at a rate of about 50-mm (2 in.) in 3 s may start separation.

8.4.6 All tests are to be conducted in the CD (cross direction) of the sample.

8.4.7 Examine the laminate surface and the tape for coating removal.

8.4.8 If the lamination separates, attempt to delaminate the specimen by pulling the plies apart.

8.4.9 Rate the adhesion according to the descriptions shown in Table 1, where 5 is excellent and 1 is poor.

8.4.10 *Calculation:*

8.4.10.1 Adhesion ratings are defined as "poor" for the lowest rating and "excellent" for the highest rating. The average rating from five test specimens determines the final rating applied to the laminate structure being tested. Each rating is assigned points as noted in Table 1 for adhesion and the points are averaged. Example: Five specimens were tested from a sample and three were rated as excellent and two good. Since each excellent rating is worth 5 points, then $3 \times 5 = 15$ points; each good rating is worth 3 points, so $2 \times 3 = 6$ points; for a total of 21 points.

$$\text{Average rating} = (\text{Total points/Number of specimens}) = (21/5) = 4.1$$

The average test result would thus be reported as "good (4.1)."

8.5 *"X" Cut Procedure :*

8.5.1 Place a sample of the laminated print media to be tested on a flat surface, printed side up.

8.5.2 Using a sharp razor blade make 63 to 76 mm (2.5 to 3 in.) "X" cut in the laminating film for each of the colored patches and a non-printed area, being careful not to cut through the ink jet coating and the base material.

TABLE 1 Adhesion Ratings

Assigned Value	Adhesion Characteristic	Rating Points/ Test Sample
Lamination cannot be separated by tape.	Excellent	5
Lamination separates with 100 % fiber tear of a porous substrate (paper, cloth, etc.).	Very good	4
Lamination has considerable resistance to delamination Lamination separates with more than 50 % fiber tear of a porous substrate.	Good	3
Lamination has slight resistance to delamination. Lamination separates with less than 50 % fiber tear of a porous substrate.	Fair	2
Lamination has no resistance to delamination. Lamination separates with no evidence of fiber tear of a porous substrate.	Poor	1

8.5.3 Try to separate the laminate from the media by wedging the razor blade at the one of the 4 points created at the center of the X.

8.5.4 An intentional separation is made and then the laminate is pulled back to see if it can be removed from the media.

8.5.5 The results are to be reported as Pass or Fail.

8.5.6 A passing result is one where the delamination does not occur between the laminate and the first interface after the adhesive, but in a later layer(s).

8.6 *Crease-Folding Procedure:*

8.6.1 Place a sample of the laminated print media to be tested on a flat surface, printed side up.

8.6.2 The sample used in this practical test can bear any colors and size image.

8.6.3 One corner of the laminate is fan folded at about 45° to the laminate with about 25-mm (1 in.) fold heights. The fan is made of 8 to 10 folds.

8.6.4 Keep the laminate folded for one minute.

8.6.5 The peaks and valleys are examined to determine if any failure occurred between the laminate and the media

8.6.6 The results are to be reported as Pass or Fail.

8.6.7 A passing result is one where the delamination does not occur between the laminate and the first interface after the adhesive, but in a later layer(s).

9. Report

9.1 Report the following information:

9.1.1 Specimen identification, including the printer, method of printing, and the media type.

9.1.2 Lamination temperature, speed, applied pressure on nip, relative humidity and temperature in the room, where lamination is carried out, and time after printing.

9.1.3 The delamination test used and the temperature and relative humidity conditions during the test.

9.1.4 Each specimen rating.

9.1.5 Average test result.

9.1.6 Any unusual characteristics, that is, extremes or irregularities noted in test results. Include backing if required and the conditioning cycle if other than standard.

10. Precision and Bias

10.1 A statement of bias is not applicable in view of the unavailability of a standard reference for these properties.

11. Keywords

11.1 accelerate aging; adhesion; bond strength; debonding; delamination; encapsulating; folding; high temperature laminates; ink jet; lamination; low temperature laminates; media; mounting; pressure-sensitive laminates; printing; thickness

APPENDIX

X1. COMMENTARY

X1.1 The Tape Selection

X1.1.1 Major limitations of the tape test are its low sensitivity and applicability to coatings of relatively low bond strength. The test is determined as pass for the most outside layer through failure. Adhesion can still occur on the interface between two other layers in multi coating or between the first coating and substrate.

X1.1.2 The adhesion strength of pressure-sensitive tapes is dependent on lot number due to batch production process and aging during storage because bond strength of the tape may change over time.

X1.1.3 Small changes in back stiffness and adhesive rheology of the tape can cause significant changes in the tension area. Some commercial tapes are manufactured to meet minimum standards. However, adhesion strength of most commercially available tapes can vary up to 50 % from the value claimed by the manufacturer.

X1.1.4 Different tapes can lead to different results. The pressure-sensitive tape's adhesion varies depending on the coating and the substrate. The data in Table X1.1 show peel strength of four tapes: 3M 899, 3M 600, 3M 610, and Permacel 99. Depending on paper substrate or coating layer, adhesion to all tapes could be nearly the same or vary significantly. It is recommended to use 2 to 3 tapes for comprehensive evaluation.

X1.2 Reproducibility

X1.2.1 The precision and reproducibility depend largely upon the skill of the operator. The angle and rate of tape removal and the visual assessment of the tested sample are dependent on the operator's skills. It is important to perform the test in a consistent manner. It is very common that different operators might obtain different results.

TABLE X1.1 Peel Strength Comparison[A]

Tested Material	Tape	Static Peak	Kinetic Peak	Valley	Average	RPS	Test Average
Paper I	3M 898, 0.71 in.	322.9	439.8	175.5	292.2	41.4	372
Coating A	3M 610, 1 in.	202.9	232.1	124.8	194.4	16.7	
	3M 600, 1 in.	568	702.5	457.8	635.5	47.4	
	Permacel 99, 1 in.	397.7	723.0	191.0	367.4	82.4	
Paper II	3M 898, 0.71 in.	926.4	1206.7	143.6	760.2	208.2	748
Coating B	3M 610, 1 in.	631.5	641.2	549.8	603.2	16.2	
	3M 600, 1 in.	718.7	816.1	655.5	730.8	29.6	
	Permacel 99, 1 in.	1371.0	1359.0	472.6	899.7	160.5	
Paper III	3M 898, 0.71 in.	734.5	946.6	478.9	705.1	81.4	707.0
Coating B	3M 610, 1 in.	563.2	618.2	506.7	582.8	25.4	
	3M 600, 1 in.	771.3	736.3	611.4	678.5	20.9	
	Permacel 99, 1 in.	1477.0	1312.0	380.5	861.3	148.2	
Paper IV	3M 898, 0.71 in.	867.1	1108.0	743.1	875.7	55.9	973.0
Coating C	3M 610, 1 in.	767.9	785.0	543.0	616.2	66.0	
	3M 600, 1 in.	1111.0	1518.0	1009.0	1292.0	128.0	
	Permacel 99, 1 in.	1536.0	1651.0	499.4	1108.0	198.6	
Paper IV	3M 898, 0.71 in.	803.8	957.7	477.2	685.2	74.5	872.0
Coating D	3M 610, 1 in.	540.8	663.4	511.8	582.8	37.4	
	3M 600, 1 in.	1269.8	1354.5	1029.0	1197.0	69.1	
	Permacel 99, 1 in.	1251.0	1324.0	646.5	1021.0	126.8	

[A]The comparison of peel strength of four tapes applied to four coatings on four different papers. The peel strength was measured according to Practice F2226.