ภาคผนวก

ภาคผนวก ก

การหาปริมาณค่าคลาดเคลื่อนจากการถดถอยเชิงเส้น

การหาปริมาณค่าคลาดเคลื่อนจากการถดทอยเชิงเส้น

จากสถิติพื้นฐาน (Simple statistics)

ค่าเฉลี่ยทางคณิตศาสตร์ $(\bar{y})$ $\bar{y} = \frac{\sum y_i}{n}$ i = 1,2,3,...,n

เมื่อ y_i คือค่าของข้อมูลที่จุดต่าง ๆ

n คือ จำนวนจุดของข้อมูล

ค่าเบี่ยงเบนมาตราฐาน (S_y) $S_y = \sqrt{\frac{S_t}{n-1}}$

Variance (S_y^2) $S_y^2 = \frac{S_t}{n-1}$

Coefficient of variation (c.v) $c.v. = \frac{S_y}{\bar{y}} \times 100\%$

เมื่อ S_t คือผลรวมของค่ากำลังสองของผลต่างระหว่างค่า y ที่จุดต่าง ๆกับค่าเฉลี่ย

$$S_t = \sum (y_i - \bar{y})^2$$

กำหนดให้ R^2 คือ Coefficient of determination, $R^2 = \frac{S_t - S_r}{S_t}$

โดยที่ S_r คือ Sum of squares of the residuals, $S_r = \sum_{i=1}^{n} (a + bx_i - y_i)^2$

เมื่อ a,b คือค่าคงที่ใด ๆ

X_i คือตัวแปรต้นของแต่ละจุดข้อมูล

ซึ่งถ้าทำการนำข้อมูลการทดลองที่ได้ไปเขียนกราฟโดยใช้โปรแกรม Excel ตัวโปรแกรมจะทำการหาค่า Coefficient of determination (R^2) ได้ โดยการเลือกคำสั่ง Add trend line และเลือกให้แสดงค่า R^2 ซึ่งค่า R^2 นี้จะเป็นตัวแสดงความถูกต้องของแบบจำลองทางคณิตศาสตร์ที่สร้างขึ้นกับข้อมูลการทดลองจริงที่ได้ ยิ่งค่า R^2 มีค่าใกล้ค่า 1 เท่าไร จะยิ่งมีความแม่นยำมากเท่านั้น

ภาคผนวก ข

การใช้ประโยชน์จากแบบจำลองทางคณิตศาสตร์

การใช้ประโยชน์จากแบบจำลองทางคณิตศาสตร์

โดยปกติแผ่นฟิล์มพลาสติกจะทำการซื้อขายเป็นหน่วยของน้ำหนักฟิล์ม โดยราคาของวัตถุดิบเป็นดังนี้เม็ดพลาสติกพอลิเอทิลีนราคากิโลกรัมละ 55 บาท และแคลเซียมคาร์บอเนตราคากิโลกรัมละ 5 บาท ดังนั้นหากฟิล์มพลาสติกที่ผลิตได้มีสัดส่วนของแคลเซียมคาร์บอเนตที่มาก ก็จะเป็นการช่วยประหยัดต้นทุนการผลิตลงได้ แต่การเพิ่มสัดส่วนของแคลเซียมคาร์บอเนตต้องคำนึงถึงสมบัติของฟิล์มพลาสติกที่ได้ด้วย โดยเทียบกับมาตราฐานสินค้านั้น ๆ ตัวอย่างเช่นต้องการผลิตฟิล์มหุ้มอาหารโดยต้องมีค่าตามมาตรฐานอุตสาหกรรม 1136-2536 ดังนี้ สมบัติความทนแรงดึงตามแนว MD ต้องมากกว่าหรือเท่ากับ 3.3 MPa และตามแนว TD ต้องมากกว่าหรือเท่ากับ 2.5 สมบัติการยืดตัวของแผ่นฟิล์มตามแนว MD ต้องมากกว่าหรือเท่ากับ 90% และตามแนว TD ต้องมากกว่าหรือเท่ากับ 190 % และต้องการอัตราการซึมผ่านของออกซิเจนอยู่ในช่วง 13,000 -14,000 cc/m^2.day และอัตราการซึมผ่านของไอน้ำอยู่ในช่วง 19.0 - 21.0 g/m^2.day

ตาราง ข เปรียบเทียบต้นทุนวัตถุดิบในการผลิตแผ่นฟิล์ม

Properties	Standard	#1 (%)		#2 (%)	
		$CaCO_3$	Stretch	$CaCO_3$	Stretch
		15	115	10	139
MD Tensile (MPa)	≥ 3.3	18.6		22.1	
TD Tensile (MPa)	≥ 2.5	17.6		21.5	
MD Elongation (%)	≥ 90	227		266	
TD Elongation (%)	≥ 190	310		305	
OTR (cc/m^2.day)	13,000-14,000	13990		13959	
WVTR (g/m^2.day)	19.0-21.0	20.2		20.2	
วัตถุดิบที่ใช้		$CaCO_3$	LDPE	$CaCO_3$	LDPE
ราคาต้นทุนวัตถุดิบ (บาท/กก.)		5.0	55.0	5.0	55.0
ปริมาณวัตถุดิบที่ใช้ต่อการผลิตฟิล์ม 100 กก.		15	85	10	90
ราคาวัตถุดิบที่ใช้ (บาท)		75	4675	50	4950
ราคาวัตถุดิบรวมทั้งสองชนิด (บาท)		4750		5000	

จากตาราง ข. จะเห็นได้ว่าการผลิตแผ่นฟิล์มเพื่อให้ได้ตรงตามมาตรฐานอุตหสาหกรรม สามารถใช้ปริมาณวัตถุดิบต่างกัน โดยปรับเปลี่ยนค่าแรงดึงฟิล์มขณะขึ้นรูป จากตาราง ข. สูตรการผลิตที่ 1 และ 2 ผ่านมาตรฐานอุตสาหกรรมทั้งสองสูตร แต่สูตรการผลิตที่ 1 มีค่าใช้จ่ายด้านวัตถุดิบที่ต่ำกว่า ดังนั้นจะเห็นได้ว่าแบบจำลองคณิตศาสตร์สามารถช่วยทำนายผลการผลิตที่จะเกิดขึ้น และสามารถช่วยให้เลือกสภาวะการผลิตที่มีต้นทุนด้านวุตถุดิบที่ต่ำได้

ภาคผนวก ค

มาตรฐานการทดสอบ

ASTM D3985: Standard Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Coulometric Sensor

1. Scope

1.1 This test method covers a procedure for determination of the steady-state rate of transmission of oxygen gas through plastics in the form of film, sheeting laminates, coextrusions, or plastic-coated papers of fabrics. It provides for the determination of (1) oxygen gas transmission rate (O_2GTR), (2) the permeance of the film to oxygen gas (PO_2), and (3) oxygen permeability coefficient ($P'O_2$) in the case of homogeneous materials.

1.2 This standard does not purport to address all of the safety problems, 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.

1.3 This test method does not purport to be the only method for measurement of O_2GTR. There may be other methods of O_2GTR determination that use other oxygen sensors and procedures.

2. Referenced Documents

2.1 ASTM Standards:

D1434 Test method for determining gas permeability characteristics of plastic film and sheeting

D1898 Practice for sampling of plastics

F1927 Test method for determination of oxygen gas transmission rate, permeability and permeance at controlled relative humidity through barrier materials using a coulometric detector

3. Test Specimens

3.1 Test specimens shall be representative of the material being tested and shall be free of defects, including wrinkles, creases, and pinholes, unless these are a characteristic of the material being tested.

3.2 Average thickness shall be determined to the nearest 2.5 μm (0.0001 in.), using a calibrated dial gage (or equivalent) at a minimum of five points distributed over the entire test area. Maximum, minimum, and average values shall be recorded.

3.3 If the test specimen is of an asymmetrical construction, the two surfaces shall be marked by appropriate distinguishing marks and the orientation of the test specimen in the diffusion cell shall be reported (for example, "side II was mounted facing the oxygen side of the diffusion cell").

4. Procedure

4.1 Preparation of Apparatus. If preceding test have exposed the apparatus to high moisture levels, it will be necessary to outgas the system. Particularly the catalyst bed, to desorb residual moisture. Water shall be removed from the nitrogen and test gas humidifiers. The system can then be dried by slowly purging overnight using dry carrier gas and with the sensor bypassed. Heating the apparatus will speed the drying and outgassing process.

4.2 Inserting the specimen. With the sensor bypassed, unclamp the diffusion cell and open it. Apply a thin layer of sealing grease around the raised rim of the lower half of the diffusion cell. Remove the test specimen from the desiccator and place it upon the greased surface, talking care to avoid wrinkles or creases. Set the movable half of the diffusion cell into place and clamp both halves tightly together.

4.3 Purging the system. Place the system in the CARRIER PURGE mode and purge air from the upper and lower diffusion cell chambers, using a flow rate of 50 to 60 mL. After 3 or 4 min, reduce the flow rate to the desired value between 5 and 15 mL/min, Maintain this configuration for 30 min.

4.4 Establish E_0. After the system has been flushed with nitrogen for 30 min, INSERT THE SENSOR so that the carrier gas which has passed through both sides of the diffusion cell is diverted into the sensor.

At this time, the sensor output will usually increase abruptly, indicating that oxygen is entering the sensor with the carrier gas. The most likely sources of this oxygen are (1) outgassing of the sample, (2) leaks in the system, or (3) a combination of (1) and (2). The operator shall observe the recorder trace until the sensor output current stabilizes at a constant value with no significant trend in either direction. Trick samples may require a purge of several hours, or even overnight, before a steady low value of sensor current is

obtained. On older systems, the sensor should be bypassed except for brief periods when the zero level is being checked. Once a steady low value of sensor current has been obtained, the sensor may be inserted to monitor the zero level and left there until a stable zero level is obtained. At this time, the zero level is recorded and labelled E_0. It has been found helpful to periodically test the O_2GTR of a piece of brass shim stock in order to ascertain that no leaks or contamination of the carrier gas have developrd.

4.5 Once E_0 has been established, switch OXYGEN into the test-gas side of the diffusion cell. This action will be automated on newer systems.

4.6 The sensor output current should increase gradually, ultimately stabilizing at a constant value. While some thin films with high diffusion coefficients may reach equilibrium in 30 to 60 min, thicker or more complex structures may require a number of reach a steady state of gas transmission. The steady-state voltage value of the oxygen transmission rate shall be record and labeled E_c.

4.7 Temperature shall be obtained by monitoring the temperature as close as possible to the specimen.

4.8 Standby and Shutoff Procedures. Follow the manufacturer's instructions in the instrument manual for putting the instrument into standby mode when the system will not be used for an extended period.

4.9 Tests in Moist Environment. This test method is for dry (O RH) condition only. Specific procedures for testing in a controlled RH environment are covered by Test Method F1927.

4.10 The O_2GTR at temperature other than ambient may be determined by thermostatically controlling the diffusion cell provided that the temperature of the gas does not adversely affect the operation of the sensor. Experience has shown that the unit can be operated satisfactorily in the range from 4 to 65°C.

4.11 Testing Poor Barriers. Films having transmission rate in excess of 200 cm^3 (STP)/(m.d) when tested with an oxygen partial pressure difference of one atmosphere are defined as poor barriers. Examples of such materials, depending on thickness, include polyethylene, polycarbonate, and polystyrene. High oxygen concentrations in the carrier gas, from the testing of poor barriers, will tend to produce detector saturation. One way to avoid this problem is to use a test gas that is a mixture with a known concentration of oxygen in nitrogen. The permeance of the film should be calculated using the known value of oxygen partial pressure, and then a transmission rate should be calculates for the

appropriate partial pressure difference from the permeance and the desired partial pressure difference. Another way to reduce the oxygen concentration in the carrier gas when testing poor barriers is to mask off most of the area of the test specimen using a mask of thin metal or aluminum foil on both sides of the test specimen by use of a suitable adhesive such as contact cement or epoxy. The specimen area then becomes equal to the open area of the mask. The effect of varying the area of the open hole in the mask should be tested to ensure thet the mask is performing properly.

ASTM E398: Standard Test Method for Water Vapor Transmission Rate of Sheet Materials Using Dynamic Relative Humidity Measurement

1. Scope

1.1 This test method covers dynamics evaluation of the rate of transfer of water vapor through a flexible barrier material and allows conversion to the generally recognized units of water vapor transmission (WVT) as obtained by various other test methods including the gravimetric method described in test methods E96.

1.2 Limitations. This test method is limited to flexible barrier sheet materials composed of either completely hydrophobic materials, or combinations of hydrophobic and hydrophilic materials having at least one surface that is hydrophobic.

1.3 The minimum test value obtained by this test method is limited by the leakage of water vapor past the clamping seals of the test instrument. A reasonable value may approximately 0.01 g/24 h.m^2 for any WVTR method including the desiccant procedure of test methods E96 at 37.8°C (100°F) and 90% relative humidity. This limit can be checked for each instrument with an impervious specimen such as aluminum foil. Calibration procedures can compensate for the leakage rate if so stated.

1.4 This test method is not suitable for referee testing at this time, but is suitable for control testing and material comparison.

1.5 The values stated in SI units are to be regarded as standard. The values gives in parentheses are provided for information purposes only.

1.6 Several other ASTM test methods are available to test a property. This test method is unique in that it closely duplicates typical product storage where a transfer of proceed without constantly sweeping the environmental side with dry gas. Methods with constantly swept dry sides include test methods F1249, ASTM F372 and ASTM F1770.

1.7 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:

C168 Terminology Relating to Thermal Insulation

C677 Practice for use of a polyethylene terephthalate reference film for the measurement of the time averaged vapor pressure in a controlled humidity space E96 test methods for water vapor transmission of materials

F17 Terminology relating to flexible barrier materials

F372 Test methods for water vapor transmission rate of flexible barrier materials using an infrared detection technique.

F1249 Test Method for water vapor transmission rate through plastic film and sheeting using a modulated infrared sensor.

F1770 Test method for evaluation of solubility. Diffusivity, and permeability of flexible barrier materials to water vapor.

3. Test Specimens

3.1 Test specimens shall be representative of the sample.

3.2 Where the test specimen is completely hydrophobic, no special conditioning procedure is required except that the surface exposed in the dry cell must not have visible free water present.

3.3 For specimens containing a hydrophilic layer, consideration must be given to its orientation. If the hydrophilic layer, such as paper, is facing the dry side of the test apparatus, false reading may result.

4. Procedure

4.1 Cut the specimen to the proper size for the test cell being used.

4.2 Orient the specimen appropriately. In dynamic test procedures, the presence of a water sensitive surface in the dry chamber may result in a reproducible but false reading due in part to edge effects. Tests in this orientation cannot reliably be made by this procedure.

4.3 Purge the dry chamber with the dried, purge air until the cell and exposed specimen surface are at equilibrium at a lower humidity condition than that employed for the test cycle.

4.4 Shut off the purge air and isolate the sensor containing chamber from the surrounding atmosphere. Allow the cell and specimen to begin to return to balance as moisture permeates through the film under test until the initial humidity desired to start the test is reached.

4.5 Measure and record the time for the relative humidity within the dry chamber changes from 0.1±0.05% below the nominal dry condition to 0.1±0.05% above the nominal condition. Conditions for the test samples must be the same as fro the calibration sample.

4.6 Repeat steps 4.3-3.5 without removing the specimen until successive reading of the time to transverse the humidity range are uniform. The resulting value is taken as the test result for that specimen.

4.7 The WVTR for the sample under test is calculated by comparing its time to the time required for the calibration film.

$$WVTR_T = WVTR_C * T_C/T_r$$

Where:

$WVTR_T$ = WVTR of sample under test.

$WVTR_C$ = WVTR determined gravimetrically.

T_C = Time to move through humidity rang for sample under test.

T_r = Time to move through humidity range for calibration film.

ASTM D882: Standard Test Method for Tensile properties of thin plastic sheeting

1. Scope

1.1 This test method covers the determination of tensile properties of plastics in the form of thin sheeting, including film (less than 1.0 mm. in thickness)

1.2 This test method may be used to test all plastics within the thickness range described and the capacity of the machine employed. Static Weighing, Constant-Rate-of-Grip Separation Test-This test method employs a constant rate of separation of the grips holding the ends of the test specimen.

1.3 Specimen extension may be measured in these test methods by grip separation, extension indicators, or displacement of gage marks.

1.4 A procedure for determining the tensile modulus of elasticity in included at one strain rate.

1.5 Test data obtained by this test method is relevant and appropriate for use in engineering design.

1.6 The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information only.

1.7 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:

D618 Practice for conditioning plastics for testing

D638 Test method for tensile properties of plastics

D4000 Classification system for specifying plastic materials

D5947 Test Methods for physical dimensions of solid plastic specimens

D6287 Practice for cutting film and sheeting test specimens

E4 Practices for force verification of testing machines

E691 Practice for conducting an interlaboratory study to determine the precision of a test method

2.2 ISO Standard:

ISO527-3 Plastics-determination of tensile properties part 3: test condition for films and sheets

3. Test Specimens

3.1 The test specimens shall consist of strips of uniform width and thickness at least 50 mm. (2 in.) longer than the grip separation used.

3.2 The nominal width of the specimens shall be not less than 5.0 mm. (0.2 in.) or greater than 25.4 mm. (1.0 in.).

3.3 A width-thickness ratio of at least eight shall be used. Narrow specimens magnify effects of edge strains or flaws, or both.

3.4 The utmost care shall be exercised in cutting specimens to prevent nicks and tears which are likely to cause premature failures. The edges shall be parallel to within 5% of the width over the length of the specimen between the grips.

3.5 Wherever possible, the test specimens shall be selected so that thickness is uniform to within 10% of the thickness over the length of the specimen between the grips in the case of materials 0.25 mm. (0.010 in.) or less in thickness and to within 5% in the case of materials greater than 0.25 mm. (0.010 in.) in thickness but less than 1.00 mm. (0.040 in.) in thickness.

3.6 If the material is suspected of being anisotropic, two sets of test specimens shall be prepares having their long axes respectively parallel with and normal to the suspected direction of anisotropy.

3.7 For tensile modulus of elasticity determinations, a specimen gage length of 250 mm. (10 in.) shall be considered as standard. This length is used in order to minimize the effects of grip slippage on test results. When this length is not feasible, test sections as short as 100 mm. (4 in.) may be used if it has been shown that result are not appreciably affected. However, the 250 mm. gage length shall be used for referee purposes. The speed of testing of shorter specimens must be adjusted in order for the strain rate to be equivalent to that of the standard specimen.

4. Procedure

4.1 Select a load range such that specimen failure occurs within its upper two thirds. A few trial runs may be necessary to select a proper combination of load range and specimen width.

4.2 Measure the cross-sectional area of the specimen at several points along its length. Measure the width to an accuracy of 0.25 mm. (0.010 in.) or better. Measure the thickness to an accuracy of 0.0025 mm. (0.0001 in.) or better for films less than 0.25 mm. (0.010 in.) in thickness and to an accuracy of 1% or better for films greater than 0.25 mm. (0.010 in.) but less than 1.0 mm. (0.040 in.) in thickness.

4.3 Set the initial grip separation.

4.4 Set the rate of grip separation to give the desired strain rate, base on initial distance between the grips. Zero the calibrated load weighing system, extension indicator(s) and recording system.

4.5 In case where it is desired to measure a test section other than the total length between the grips, mark the ends of the desired test section with a soft, fine wax crayon or with ink. Do not scratch these marks onto the surface since such scratches may act as stress raisers and cause premature specimen failure. Extensometers may be used if available; in this case, the test section will be defined by the contact points of the extensometer.

4.6 Place the test specimen in the grips of the testing machine, taking care to align the long axis of the specimen with an imaginary line joining the points of points of attachment of the grips to the machine. Tighten the grips evenly and firmly to the degree necessary to minimize slipping of the specimen during test.

4.7 Start the machine and record load versus extension.

4.7.1 When the total length between the grips is used as the test area, record load versus grip separation.

4.7.2 When a specific test area has been marked on the specimen, follow the displacement of the edge boundary lines with respect to each other with dividers or some other suitable device. If a load-extension curve is desires, plot various extensions versus corresponding loads sustained, as measured by the load indicator.

4.7.3 When an extensometer is used, record load versus extension of the test area measured by the extensometer.

4.8 If modulus values are being determined, select a load range and chart rate to produce a load-extension curve of between 30 and 60° to the X axis. For maximum

accuracy, use the most sensitive load scale for which this condition can be met. The test may be discontinued when the load-extension curve deviates from linearity.

4.9 In the case of materials being evaluated for secant modulus, the test may be discontinued when the specified extension has been reached.

4.10 If tensile energy to break is being determined some provision must be made for integration of the stress-strain curve. The may be either an electronic integration during the test or a subsequent determination from the area of the finished stress-strain curve.