PACKAGING TECHNOLOGY AND SCIENCE VOL **6** 239–244 (1993)

Relationship between Seal Strength and Burst Pressure for Pouches

Kit L. Yam,* Jack Rossen† and Xuan-Fei Wu*

*Department of Food Science, Rutgers, The State University of New Jersey, New Brunswick, NJ 08903-0231, USA; †Center for Advanced Food Technology, Rutgers University, New Brunswick, NJ 08903-0231, USA

Based on force analysis, the seal strength obtained from the peel test is equivalent to the product of the burst pressure and half of the plate separation obtained from the burst test. To verify this relationship peel tests and burst tests were performed using MRE pouches. Good agreement between the observed and predicted values was observed when the peeling times of the two tests were the same. This relationship is useful for comparing the performance of the two tests, as well as for establishing criteria for destructive and non-destructive testing.

Keywords: Seal strength; burst pressure; peel test; internal burst test

INTRODUCTION

Assuring seal integrity is a critical step in quality assurance programs for retortable pouches. Two common causes of seal defects are weak seals and channel leaks: the former may lead to package failure, and the latter may allow the entrance of microorganisms into the packages.

The peel test and the burst test are commonly used to evaluate the seal integrity for retortable pouches.[1,2] The peel test is a form of tensile test that measures the maximum force, or seal strength, required to pull apart the seal of a 1-in. wide sample.[3] The test is simple to perform and can provide reproducible results; however, if many specimens from each pouch are to be examined, the test can be time consuming. In the burst test, a pouch is first restrained between two parallel metal plates and then pressurized by gas injection through a hypodermic needle inserted into the pouch. The pressure required to burst the pouch, or burst pressure, is known to vary with the plate separation and the rate of pressurization. The internal burst test is considered to be a good overall measure of the ability of a pouch to withstand transport and handling.[1]

The objective of this work was to define and verify a relationship between the seal strength and the burst pressure. Understanding this relationship is useful for comparing the performance of the two tests, as well as for establishing criteria for destructive and non-destructive testing.

THEORY

Figure 1 shows a pouch restrained by two parallel plates separated with a distance $2R$. When the pouch is inflated with air, the force acting on the upper body and bottom of the pouch is balanced by the reaction force exerted by the plates, while the force acting on the edges of the pouch is balanced by the reaction force exerted by the wall of the pouch around the seal area. Because the pouch is flexible, the air pressure exerts a tensile force on the seal to peel it apart and causes the edges of the pouch to take on an approximately circular shape, as illustrated in Fig. 1. Analysing the y-component of forces around the seal area (Figure 2), we obtain the equation

$$\mathrm{d}F_y = PR \sin\theta \,\mathrm{d}\theta \qquad (1)$$

0894–3214/050239–06$08.00

Received 21 September 1992
Revised 22 October 1992

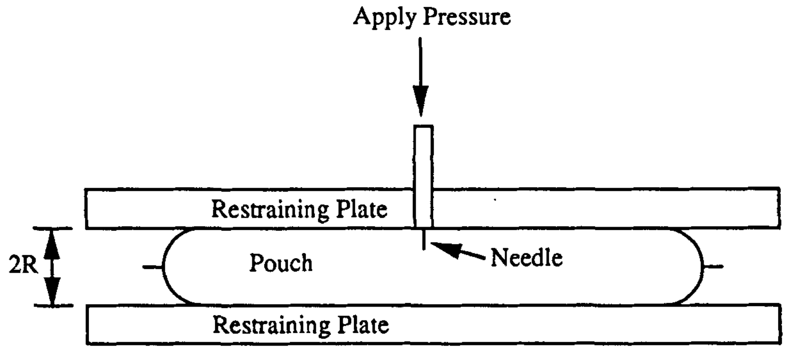

Figure 1. A schematic of the internal burst test for a flexible pouch

where F_y is the force peeling a 1-in. width of the seal, P is the internal pressure, R is the half-plate separation distance, and θ is the angle shown in Figure 2. Integrating Equation 1 yields

$$F_y = \int_0^{\pi/2} PR \sin \theta \, d\theta = PR \qquad (2)$$

At rupture, F_y and P can be substituted by the seal strength S (lbf/in.) and the burst pressure P_b (psi), respectively, yielding

$$S = P_b R \qquad (3)$$

MATERIALS AND METHODS

To verify Equation 3, experiments were performed using 4 ft. × 6 ft. preformed MRE pouches with three sealed sides. The pouch material was a polyethylene terephthalate (PET)/aluminium/polypropylene (PP) laminate.

For the peel test, 1-in. wide specimens were cut from the pouches according to the ASTM standard.[3] An Instron tensile testing machine equipped with a data acquisition system was used to measure their stress–strain behaviour. The distance between the two clamps of the tensile testing machine was set to be πR, so that the area of the specimen acted upon by the peel test was the same as the area acted upon by the burst test.

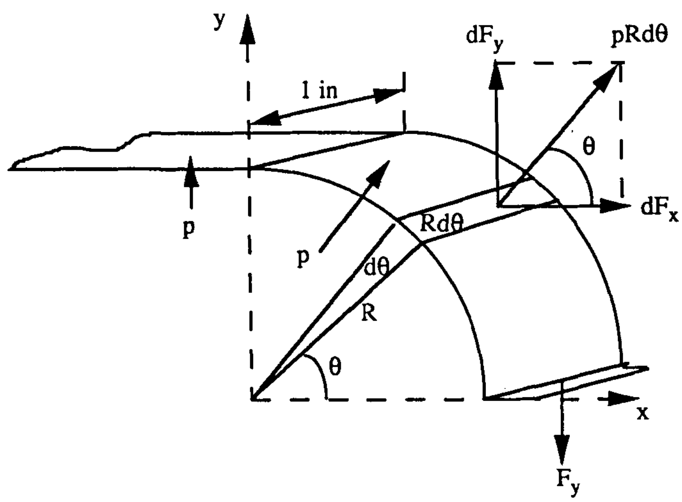

Figure 2. Analysis of force near the seal area

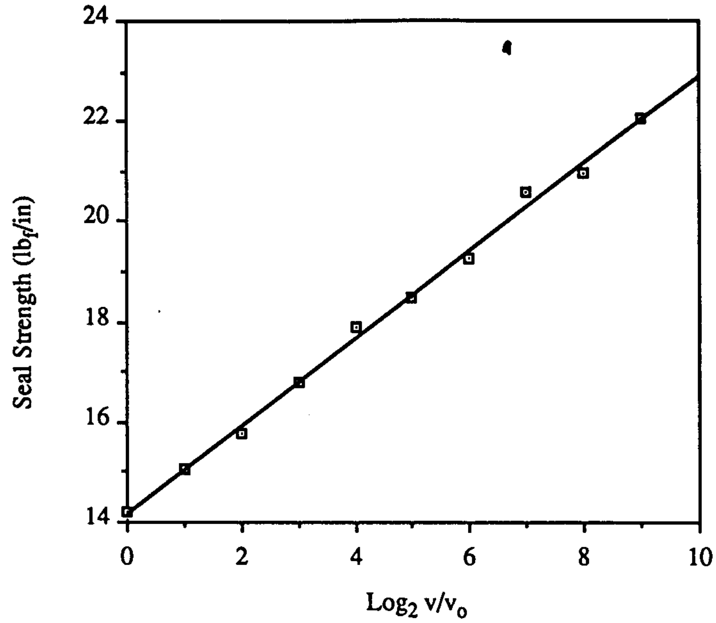

Figure 3. Effect of crosshead speed on the seal strength (v_0 = 1 in./min)

Several crosshead speeds ranging from 0.039 to 20 in./min were used. The seal strength from each specimen was obtained from the maximum peak of the stress–strain curve, and the tensile peeling time t_p (the time required to reach the seal strength) was calculated from

$$t_p = 60\Delta L/v \tag{4}$$

where ΔL was the elongation at seal strength (in.) and v was the crosshead speed (in./min).

For the burst test, the open side of each empty pouch was first heat sealed at 250°C and 60 psi for 1 s. The pouch was then restrained in a fixture consisting of two adjustable parallel metal plates separated by a distance of $2R$ (Figure 1). A needle pierced the pouch through a small opening at the centre of the upper plate, and nitrogen was injected into the pouch through the needle. The burst peeling time t_b was defined as the elapsed time between initial pressurization and pouch bursting, which decreased with increasing gas flow rate. A valve was used to control the gas flow rate so that specific burst peeling times could be obtained. Several plate separations were used in the experiment. All the pouches tested were found to rupture at the seals, indicating that the seals were the weakest part.

All the experiments were conducted at room temperature, and each datum reported here was the average of eight replicates.

RESULTS AND DISCUSSION

Figure 3 shows that seal strength (S) increases linearly with the logarithm of crosshead speed (v). Since tensile peeling time (t_p) is inversely proportional to v as described in Equation 4, S decreases as t_p increases (Figure 4), and the smaller the t_p, the stronger its influence on S. Similarly, burst pressure P_b is also a function of burst peeling time t_b, decreasing with increasing t_b (Figure 5), and a logarithmic relationship between P_b and t_b was also found (not shown).

Table 1 presents the data of tensile peeling time, burst peeling time, predicted burst pressure using Equation 3 and observed burst pressure, for a plate separation of 0.5 in. To test the validity of Equation 3, the predicted burst pressure was plotted against the observed burst pressure (Figure 6). Within experimental error, all the data were found to be near the 45° line, indicating that the predicted and observed burst pressures are in

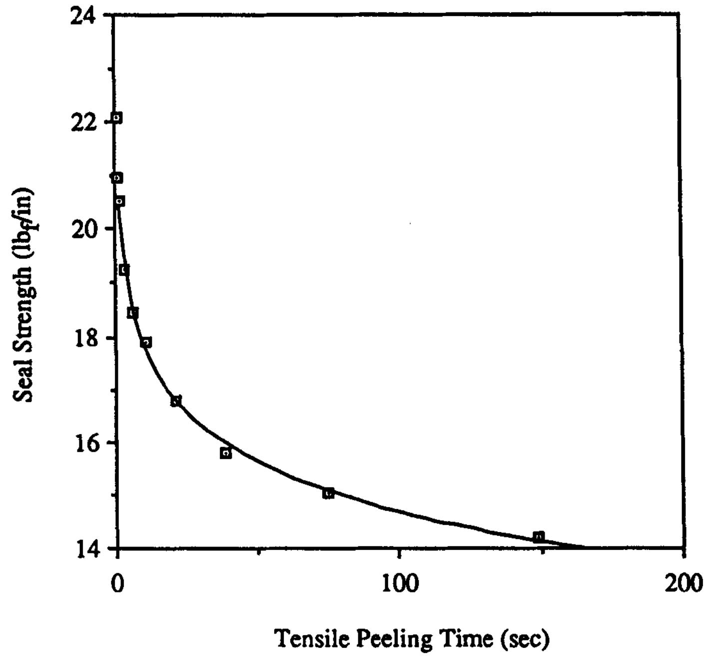

Figure 4. Effect of tensile peeling time on seal strength

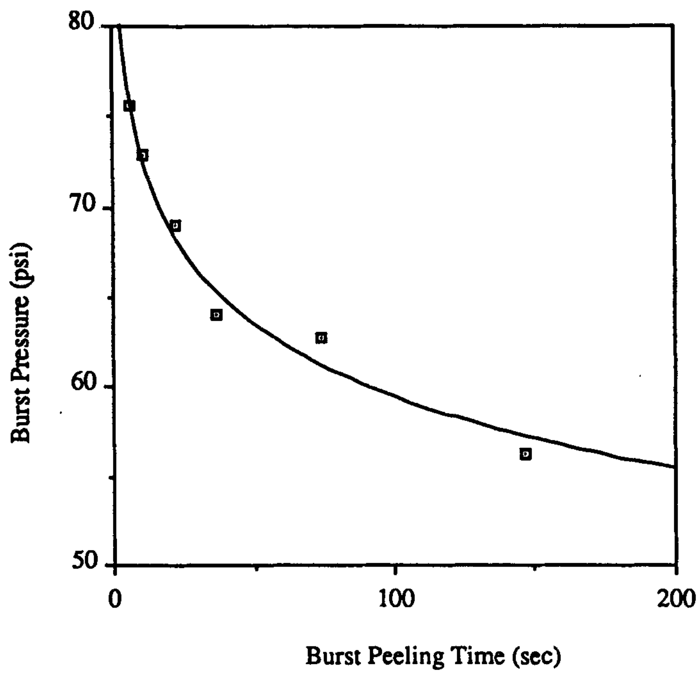

Figure 5. Effect of burst peeling time on burst pressure (plate separation of 0.5 in.)

Table 1. Relationship between peeling time and burst pressure

Tensile peeling time t_p (s)	Burst peeling time t_p (s)	Predicted burst pressure (psi)	Observed burst pressure (psi)
148.5 ± 24.4	146.6 ± 13.6	56.8 ± 1.3	56.3 ± 1.8
74.6 ± 5.9	73.9 ± 7.8	60.2 ± 1.9	62.8 ± 2.1
38.8 ± 5.2	36.9 ± 5.5	63.2 ± 2.0	64.1 ± 2.4
21.3 ± 2.9	22.1 ± 2.9	67.2 ± 1.9	69.0 ± 2.1
10.8 ± 0.9	10.4 ± 1.0	71.6 ± 2.0	72.9 ± 2.6
6.0 ± 0.6	5.8 ± 0.3	73.9 ± 1.2	75.6 ± 3.1

*The predicted burst pressures are calculated using Equation 3. Each datum is the average of at least eight replicates, and the value after the ± sign is the sample standard deviation.

good agreement. Note that for each data point it was necessary to match closely the tensile peeling time with the bursting peeling time, otherwise the predicted and observed burst pressures might significantly differ from each other.

Equation 3 was further tested with various plate separations. Figure 7 shows that the observed and predicted burst pressures are again in good agreement. Note that the pouches can withstand very high pressure without bursting when they are restrained with small plate separations. When the plate separation is small, the surface area that the pressure can act on is also small, and as a result, at constant pressure, the tensile force acting on the seal is smaller when the plate separation is decreased.

It is important to emphasize that the validity of Equation 3 is based on the assumption that the peeling times for the peel test and the burst test are the same. Figures 4 and 5 indicate clearly that small peeling times (say, below 20 s) affect the seal strength and burst pressure greatly. The tensile peeling time is a complicated function of gauge length, crosshead speed and stress–strain properties of the pouch material and the seal. Similarly, the burst peeling time is a complicated function of plate separation, rate of pressurization and stress–strain properties of the pouch material and the seal. Thus it is necessary to consider the testing conditions when comparing results obtained from the peel test and the burst test.

Equation 2 states that the tensile peeling force exerted on the seal (F_y) is equal to the product of the internal pressure (p) and the half-plate separation distance (R). Therefore, it is possible to maintain F_y unchanged, even if P is increased, by choosing a smaller R. This flexibility of varying R is particularly useful for designing non-destructive

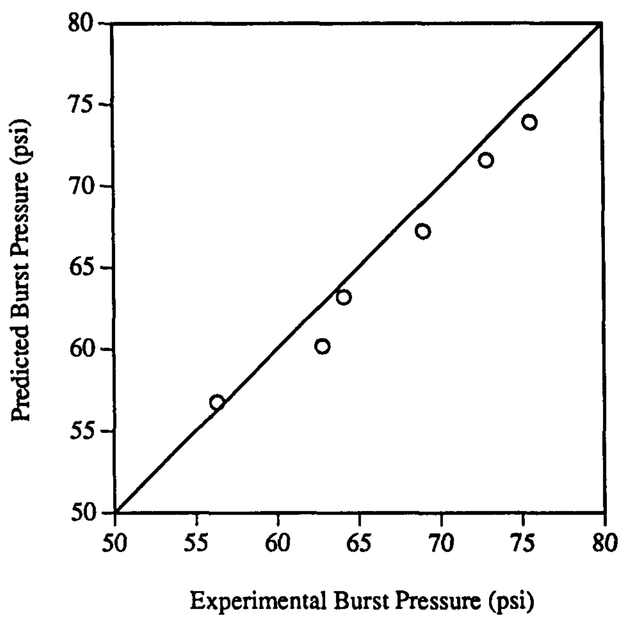

Figure 6. *Predicted versus observed burst pressures (plate separation of 0.5 in.)*

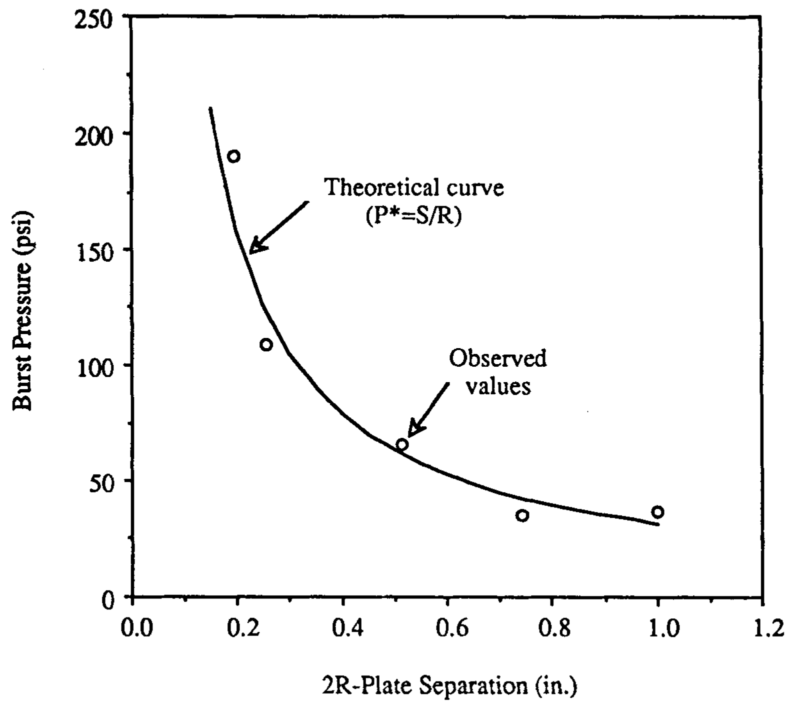

Figure 7. Comparison of predicted and observed burst pressures at various plate separations

tests that use the technique of applying external pressure to the seals of packages.[4] The response times of these tests can be greatly reduced by applying high external pressure. However, the high pressure may also cause the seals to rupture prematurely. The occurrence of these ruptures can be avoided by restraining the seal with a small plate separation, and Equation 2 may serve as a design equation for this purpose.

Acknowledgements

Paper number D10117-92-6 of the Journal Series, New Jersey Agricultural Experiment Station, Cook College, Department of Food Science, Rutgers, The State University of New Jersey, New Brunswick, NJ 08903. This work is funded by the Defense Logistics Agency through the Center for Advanced Food Technology at Rutgers University.

REFERENCES

1. Lampi, R. A., Schulz, G. L., Ciavarini, T. and Burke, P. T. *Food Technol.* **30,** 38 (1976).
2. Lampi, R. A. *Adv. Food Res.* **23,** 306 (1977).
3. ASTM Standard F88-85. *Seal Strength of Flexible Barrier Materials.*
4. Stauffer, T. *J. Packag. Technol.* **2,** 147 (1988).