Air Filled Cushioning Material, Structures and Properties

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Abstract: Air inflated cushion using pre-sealed two-layer plastic films forms air filled structural cushion when compressed air is charged to pre-sealed airtight chambers during packaging operation. The plastic films are made by co-extrusion of polyethylene/polyamide/polyethylene (PE/PA/PE) to keep required strength, permeability of the cushioning materials and easy production of the cushion. The air filled cushion structure is designed into column chambers with five different selective widths which form five different–cushion thickness when regulated compressed air is charged into the chambers using controlled pressure gauge during packaging performance. Uniquely designed charge port to each chamber provides individual chamber with the ability to work independently, hence ensures the protective function of packaging and allows the air cushions to be easily manipulated to a given product to be packaged. Static cushioning performance tests to air filled cushion materials at desirable air pressures showed that minimum cushion factor was about 4, and appeared at compressive strain of the materials from 55-80%. Dynamic impact to the samples with dimension of 180 by 180cm at drop height of 76cm demonstrates relationship between impact mass and acceleration levels, indicating the suitability of the materials for a wide range of packaging application to electronic products and devices. Overall packaging properties of the material relating to co-extruded film strength, permeability, sealing strength of the plastic films were discussed.

Keywords: Airpaq; co-extrusion plastic film; cushion structure

1. Introduction

Environmental protection and sustainable use of natural resources are paid much more attention in recent years in packaging industry worldwide. New concepts, from broader prospects, based on efficiency of resources used for packaging from manufacturing, packing, transporting, and back to the waste stream provide market opportunities for Eco-friendly products to be developed. Air filled cushioning materials, by filling compressed air into pre-sealed airtight chambers with varied structures using plastic films during packaging operation, can minimize the impact of packaging on the environment by reducing waste packaging materials, shipping and storage spaces, thus developed rapidly in recent years. Handmade air filled cushion mats using polyvinyl chloride (PVC) film of 0.3mm thick was studied for its static compression properties [1], and its cushioning properties are superior to expanded polystyrene foam. Also air filled cushions by polyvinyl chloride plastic film in printer and microwave oven packaging showed better results in drop test [2].

The specified air filled cushioning materials and their properties in static compression affected by its structure and air pressure were reported and simulated using computer technology [3, 4].

An air filled cushioning materials using two-layer structure consisting of an airtight chamber filled with air and flexible, resilient urethane was studied for improved flexibility and reusability of the material in packaging application [5]. Due to the advantages of saving shipping space, reliable performance and environmentally friendly nature of the materials, the air filled cushions are expanding their applications for packaging protection of small home electronic appliance, and will widen the application window by improved structures and properties to contribute more to the environment protection.

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2. Materials and methods

Air filled cushion is made of two-layer plastic films pre-sealed and shaped into paralleled columns with inlet for charging compressed air to form required structure for different cushioning package applications. Polyethylene/polyamide/polyethylene (PE/PA/PE) coextruded plastic films of different thickness are used to form cushioning structures by thermally sealed into chambers of varied width with charge port individually to each chamber. When compressed air is charged into the chambers of the pre-sealed films, air filled cushion structure can be formed from inflated columns. The coextruded films, samples of pre-sealed films with different selective chamber widths are provided by Jiangyin Air-Paq Composite Material Co., Ltd.. Jiangsu Province, China.

2.1. Sample preparation

The pre-sealed cushion structures have film thickness of 0.08mm and different chamber width for forming air columns with different height (or cushion thickness). The pitch width of the chamber (seal width plus chamber

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width before inflating) is ranging from 20 to 60mm with seal width of 2.5mm. Unilateral valve are installed with each independent chamber that ensures pressurized air will constantly be held in the columns to possess air cushion function after designed air pressure is charged in. The air-filled cushion samples were prepared using chamber pitch width from 30 to 60mm in this evaluation and divided into 4 types marked as sample A to D to test their cushioning property.

Before compressed air is filled into the chambers, specifications of the flat, pre-sealed plastic films designed for making cushions are listed in Table 1 with chamber length of 180 mm. When each pre-sealed film chambers are inflated by compressed air, the cushioning material is formed. Dimension of a cushion sample made from the films relates to the chamber pitch width, amount of the columns and their length.

The chamber width decides the height (thickness) of the cushion, as wider pitch of the chamber makes larger column diameter. Air pressure variation in the column within a limited range was used. Dimensions of cushion samples with varied column widths, column heights after inflating and air pressure variation are shown in table 2. Length of the cushion samples after inflation is about 175mm long with difference within 5mm.

Table 1. Specifications of air filled cushioning structres before inflating

Sample ID	Chamber pitch (mm)	Seal width between chamber (mm)	Chamber width before inflating (mm)	Chamber number
A	30	2.5	27.5	8
B	40	2.5	37.5	6
C	50	2.5	47.5	5
D	60	2.5	57.5	4

Table 2. Air filled cushioning samples after controlled compressed air charging

Sample ID	Air pressure (MPa)	Average column width (mm)	Average column height (mm)	Sample width (mm)
A	0.07	17.77	17.7	159.45
B	0.06	24.38	23.53	158.76
C	0.06	31.56	31.95	167.8
D	0.06	38.25	35.17	160.91

2.2. Test methods

The cushion samples were tested by static compression under speed of 12mm/min, using FRLY Universila tester, (Changchun, Jilihn province ,China), complying with GB-T 8168-1987 and dynamic compression for package cushioning materials, GB 8176-87, using lansmont tester, (Monterey CA, USA).

The coextruded plastic films were cut into 15mm wide and 150mm long along two directions for tensile strength test according to standard GB 13022-91 using RG T-3 universile tester (Shenzhen, China). Permibility tests To the film samples of 110 by 110mm were carried out by permeation tester, GDP-C (Brugger Feinmechanik GmbH, Germany), according to standard GB/T 1038-2000.

3. Results and discussions

3.1. Static compression and cushion curves

Static compression tests showed that number of column and width of the cushion chamber of the samples affect loading ability at the same compression strain shown in Figure 1. Within a certain width of a cushion, there are more columns distributed with narrow chamber width and more columns bear higher loading. However, the narrow column in a cushion has limited space of deformation in the compression as height of the cushion is restrained.

Unlike foam cushioning material, the air-filled cushioning material is of structural cushion functioned by filled compressed air, contacting area for stress calculation to this type of cushion during compression is changing and increasing with strain. The contacting area at different compression strain was obtained by ink marked area in a series tests. Printing ink was applied to a compressing surface, from which the ink was transferred to the surface of the cushion samples during compression to manifest the contacting area at different strain. The marked area to the sample surfaces calculated is very close to a linear relationship to compression strain shown in Figure 2. Calculation of stress and cushion factor of the samples is based upon the linear relationship of area test results. Cushion factor to each type of the cushions is shown in Figure 3. The cushion factors of the samples are within a narrow band between 4 and 5 between the compression strains from 40% to 80%. The type and amount of the columns in the cushions of the given length reflect loading ability and cushioning properties, and provide different thickness of cushioning materials for required packaging application. A series of tests to cushions with given length and the same column width indicate that loading ability of the cushions is proportional to the amount of the column.

Slightly higher loading ability of type A cushion samples after compression strain of 60% is caused by higher number of columns in the cushion and higher compressed air pressure inside the columns. The compression stress value to each sample is very close though thickness of each type of the cushion is varied.

3.2. Dynamic impact and cushioning properties

Identical cushion samples were tested by dynamic impact at drop height of 760mm with mass weighing from 2.96

to 8.65kg. Higher mass weight causes some columns of the cushions burst, which cannot reflect the cushioning properties constantly. The dynamic test results shown in Figure 4 uses acceleration versus mass weight instead of using acceleration versus static stress normally used in dynamic tests, as actual area for calculating static stress

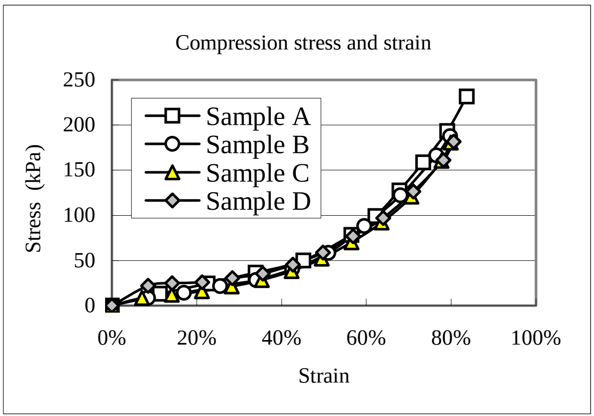

Figure 1. Compression stress and strain of four types of cushion samples.

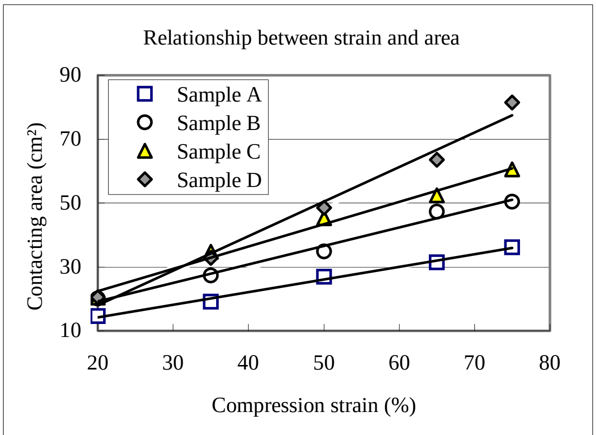

Figure 2. Linear relationship between contacting area of the cushion samples and compression strains.

changes to variety of drop masses in the impact tests. To the given samples, dimension of the sample are about 160 by 160mm after inflation, the column height equated with thickness of the sample reflects energy absorption during impact. Large column width has more deformation space in the impact and absorbs more energy, thus lower acceleration recorded compared with that of small column width samples with mass from 5 to 8 kg when the air pressure to the air-filled chambers is the same in sample B to D.

3.3. Properties of the coextruded films and influence to the cushions

The coextruded films construct the air-filled cushion structures. Strength of the films and seals supporting the compressed air pressure relates to the loading ability and cushioning properties of the columns, permeability of the

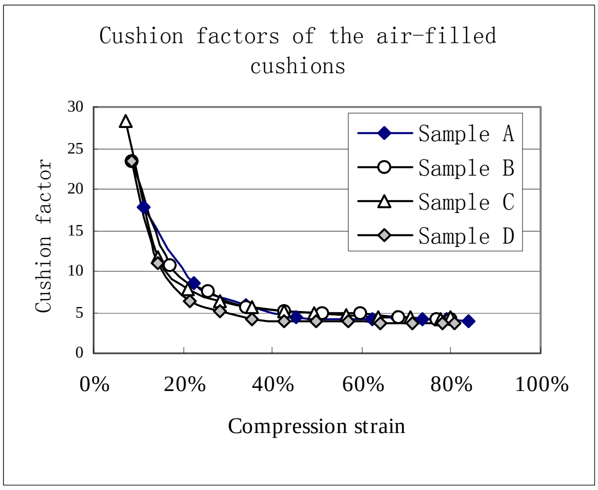

Figure 3. Cushion factors vs. strain of four types of cushion samples

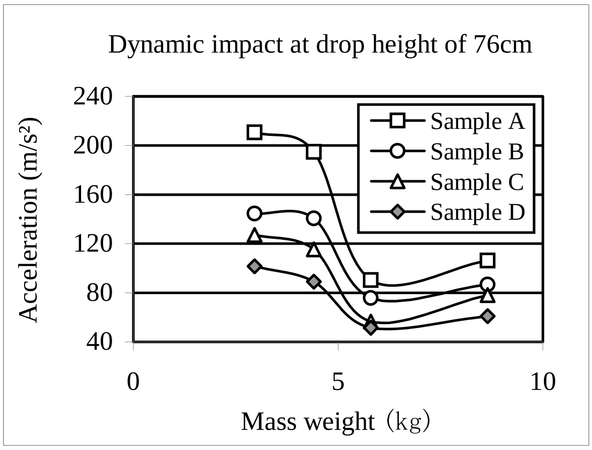

Figure 4. Dynamic test curves of the samples with different column width.

films maintains cushion functions during storage and transportation of packaged products. Tensile strength were tested to the films of 0.08mm thick and compared with that of 0.1mm thick, and it showed limited difference between two thickness in two testing speeds, one was 10 millimeter per minute and the other was 500 millimeter per minute respectively, which is shown in Figure 5. The tests were in perpendicular directions to the films, and X, Y denotes two testing directions. These test results coincide with loading ability of the cushion samples in the static compression, which showed the same stress-strain relationship to the same column structure made of two different film thicknesses. It indicates that when strength of the films is sufficient for the air pressure in the cushions under compression, loading ability and cushioning properties are more closely related to air-filled column structure with the same prefilled air pressure.

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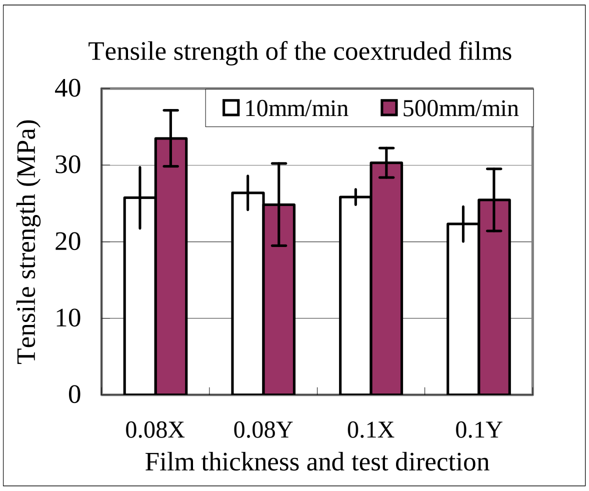

Figure 5. Tensile strength of two coextruded films with 0.08mm and 0.10mm thick at two different test speeds in perpendicular directions.

The average seal strength of the films is 20Mpa, which is less than the tensile strength of the films. Failure happened along the seals of the cushion chamber when the cushions under exceeded impact from which inner pressure goes beyond ultimate seal strength. It can be avoid by selecting relevant cushion type and contacting area to the weight of the product in the design.

Another factor keeping cushioning properties of the air-filled columns during functioning period (from packing to consuming) is permeability of the coextruded films. Polyamide has superior barrier properties to that of polyethylene in addition to its strength. Average permeation of the films is 72 cm^3/m^2 d bar. A test similar to creep test using 20kg weight load to the samples show that stain variation of the cushion from 90 minutes to 5400 minutes is between 1.85% and 1.91% at 24°C.

4. Conclusion

The air-filled cushion materials made of coextruded polyethylene/polyamide/polyethylene films with varied chamber width possess cushioning properties for packaging application.

Column width of the cushions defines the thickness of the cushions, and has varied loading ability. Static compression tests to the cushion samples show that high cushion efficiency occurs at strain from 40% to 80%. Dynamic impact at height of 76cm to the samples indicates that sample types relating to the column width correspond with required protection for certain range of fragilities of the products to be packaged. The cushioning properties of the samples by given dimension in the tests demonstrate essentials for cushion design, and can be exploited to cushions with other dimensions accordingly.

The coextruded films for the cushion structures need necessary tensile strength, seal strength and certain barrier properties to maintain loading ability, inner pressure of the cushion column, thus to keep stability of their cushioning properties during storage and transportation stages.

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