Analysis and Simulasion of Opened Stress Mechanism on Heat Sealing Surface

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Abstract: There is the history over the half century on the thermobonding of plastics packaging material by the heat sealing, and large contribution has be made to be packaging utilization of the plastic material. The basic important function of packaging for the consumer is easiness in opening."The difficulty openability" of the Cup, Tray and Film packaging are an important problem of the packaging mentioned in the primacy problem of UD of packaged goods. The ASTM F88-* (enactment in 1968) which becomes a worldwide standard of the heat sealing management is clarified with "It is the achievement of openability and closability which the ultimate problem of the heat sealing technique is a basic function of the packaging". However, rational measures are unfinished still. Openability and Closability have expectation function which is contrary in the equal mechanical characteristic each other. Tear opening method of "notch" system has been applied to many present goods. In this method, it becomes "refuse" on the table, potsherds such as broken bag scatter, and the packaging function after it opens the resealing by doing difficult, has been lost. It is a problem that the openability is made to reflect peeling seal function of heat sealing based on the stress analysis of the opening and operation. That is to say, it reaches lastly the control of melting surface temperature which qualifiedly demonstrates the design performance of packaging material of the control of the openability. In this paper, next item is discussed.
(1) The standardization of the stress mechanism of [The pluck opening] is attempted.
(2) It clarifies the mutual relationship of Six Elements [(a)Pluck line size, (b)Pluck distance, (c)Pluck force, (d)Heat sealing strength,(e) Peeling width, (f)Elongation of material] concerning the openability.
(3) Evaluation and improvement of the openability of the market goods are shown by this study.

Keywords: openability; closability; heat seal; heat seal strength; peel seal; tear seal; melting surface temperature; opened stress mechanism; simulation for opened stress; MTMS

1. Introduction

There is the history over the half century on the thermobonding of plastics packaging material by the heat sealing, and large contribution has be made to be packaging utilization of the plastic material. The basic important function of packaging for the consumer is easiness in opening. On the other hand, large tensile strength is demonstrated by the manufacturer in order to give priority to "Closability". Material thickness is increased in this reason. The increase of the tensile strength has not been connected in the improvement of the adhesion mechanism. Therefore, it does not become the radical improvement of "breaking bag" with the purpose. [1]
Not only the increase thickness countermeasure becomes cost increase, but also it has inhibited "Easy Opening" which is a demand of the consumer. The ASTM F88-* (enactment in 1968) which becomes a worldwide standard of the heat sealing management is clarified with "It is the achievement of openability and closability which the ultimate problem of the heat sealing technique is a basic function of the packaging". [2] However, rational measures are unfinished still. Openability and Closability have expectation function which is contrary in the equal mechanical characteristic each other. "The difficulty openability" of the Cup, Tray and Film packaging are an important problem of the packaging mentioned in the primacy problem of UD of packaged goods. Today, next method has been applied the opening of packaged goods. (a) Small cut like a notch, (b) utilization of peelness of the heat sealing plane, (c) open by scissors and cutter Tear opening method of "notch" system has been applied to many present goods. In this method, it becomes "refuse" on the table, potsherds such as broken bag scatter, and the packaging function after it opens the resealing by doing difficult, has been lost. It is a problem that the openability is made to reflect peeling seal function of heat sealing based on the stress analysis of the opening and operation. That is to say, it reaches lastly the control of melting surface temperature which qualifiedly demonstrates the design performance of packaging material of the control of the openability.
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(1) The standardization of the stress mechanism of [The pluck opening] is attempted.
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concerning the openability.

Table 1 Classification and order of the element which constitutes the Openability in the heat sealing

Basic function	Kind of Function	Expectation function	Execution content	Way	Note
The Openability	Guarantee of the closing	Mechanical adhesion	·Security of the mechanical strength ·Edge cutting is caused	Cohesion	·Tensile strength of materials ·Increase in the material thickness
		Air tightness	·Microorganism and Gas barrier property ·Defense of breaking and Pinhole ·Absorption of the impact load	Adhesion	·Prevention of the poly ball ·Utilization of the peeling energy
	Easy Open [Universal Design]	Easy peel	Both expression of Edge cutting and delamination	Control by same temperature for edge cut and delamination	·Control of the heating temperature for peel and tear sealing. ·Intercalation delamination of the heat sealing plane
			Peeling of the bonding surface	Adhesion	·Utilization of the interface peeling ·Temperature control of the peeling seal range · Utilization of the peeling energy ·Utilization of the peculiar performance of the packaging material
		Easy Open by tab and lip	·Easiness in opening from the outside ·Setting of the griping part	· Setting of the tab · Setting of the lip	·Easy peeling-ness from the outside ·Utilization of the interface peeling ·Intercalation delamination of the heat sealing plane
		Easy cut	·Addition of the notch ·Processing of the tear line	·Processing of the notch ·Processing of Laser beam ·Processing of Biaxial-Orientation	·Processing is the necessity ·Generation of the cut off fragment ·Control of the oblique cut
			·Perforation	·Processing of perforation	·Packaging inside and outside are penetrated. ·Hermetic of the packaging is not possible. ·Function coexistence of openability and Closing is not possible

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Figure 1 The easily openable expectation

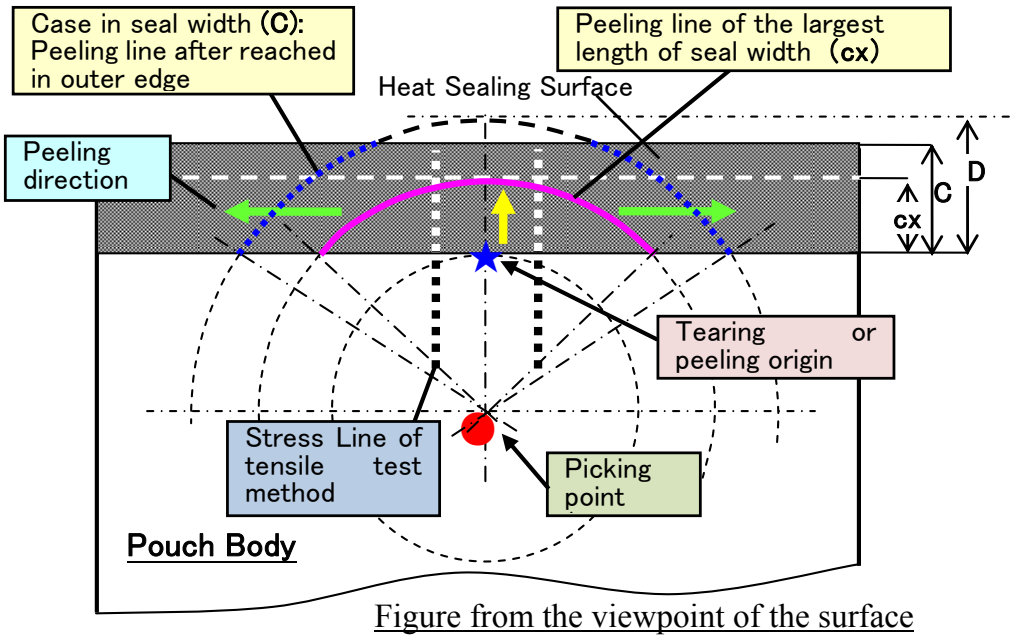

Figure 2 Analysis of opening mechanism of the opening operation

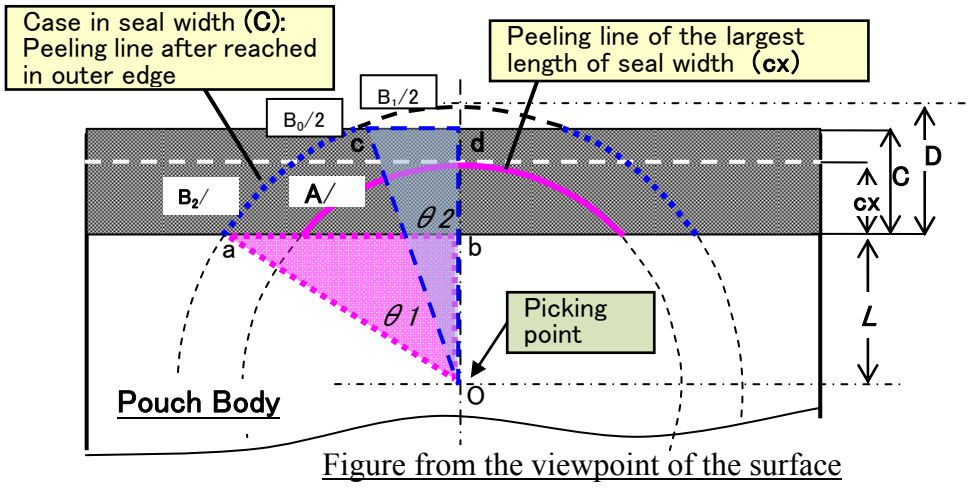

Figure 3 Calculation method of peeling circular arc Length of the simulation model

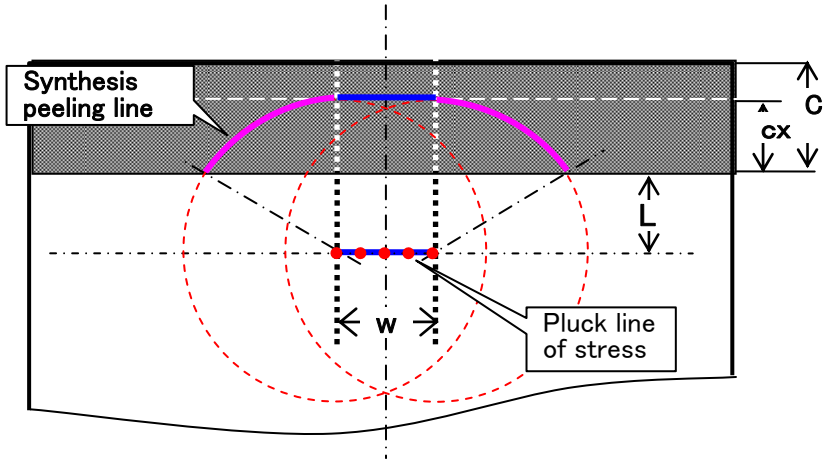

Figure 4 Description of the addition correction for opening force of stress length of the pluck line.

(3) Evaluation and improvement of the openability of the market goods are shown by this study.

2. Theory

2.1. Order of the elements which controls "Openability" and "Closability"

There is the mechanics which controls "Openability" and "Closability" for the relationship between the inside and outside, and it is necessary to discuss both by the equal table. Taking "Openability" as cardinal point, the mutual relationship of the relation element of “Easy Open” and "Closability" was shown in **Table1**. In this paper, [Easy peel] and [Easy Open by Tab and Lip] which conducted the hatch is mainly discussed. Execution means which **Table1** showed becomes the selection of aggregation adhesion or cohesion. Using the stress analysis of the opening, how the peeling seal function is used, has taken the analysis of the openability. That is to say, it reaches lastly the control of melting surface temperature which qualifiedly demonstrates the design performance of packaging material of the control of the openability.

2.2 The basic modeling of the stress mechanism of "picking openability" [3]

The achievement example of the open-easiness of the sealing surface as an object of this paper was shown in **Fig.1**. Shortest distance of pick point and adhesion line is affected, and the opening load arcuately diffuses. Opening force which increases in proportion to the circular arc length of the peeling linearly by fixing load point in this paper is analyzed. The analytical model of opening mechanism which made the picking point of such peeling opening to be cardinal point was shown at **Fig.2**. The peeling line becomes a circular arc of the radius which made load point central, when adhesive

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surface is Peel sealing. The circular arc length is proportional to the peeling width. Circular arc length is expanded, if the seal width increases (cx to C in the figure). The opening force rapidly decreases, after the peeling reaches it in (C), because the opening line becomes only circular arc minute on the seal width. Picking point can be optionally chosen, and there is the constraint set at the position where the sealing surface opened with Picking point is the closest.
Operation method of the simulation of the circular arc length was shown at **Fig.3**.

Distance of Picking point and original point of peeling ; L
Peeling width ; cx (variable)
Sealing width ; C

As a above mention, It is possible that the circular arc length shows by the following equation to which be decided according to above-mentioned three elements.

Case of (cx ≦ C)

Circular arc length (A/2) is obtained by requiring circular arc angle θ_1 from triangular oab.

$$\cos\theta_1 = L/(L+cx) \rightarrow \theta_1 \text{ (rad)} \quad (L>0) \qquad (1)$$

$$A = 2\pi(L+cx)\times 2\theta_1 / 2\pi = (L+cx)\times 2\theta_1 \qquad (2)$$

case of (cx>C)
range of (cx≦C) becomes [A]

Part of the circular arc is lacking on the range of (cx>C).
Whole of the circular arc length is $B_0/2$, Chip part is $B_1/2$, peeling part is made to be $B_2/2$
Whole B_0 of the circular arc length similarly requires circular arc angle θ_1 here from triangular oab with the equation (1) . B_1 requires the θ_2 circular arc angle from triangular ocd in the following equation.

$$\cos\theta_2 = (L+C)/(L+cx) \rightarrow \theta_2 \quad (L>0) \qquad (3)$$

Circular arc length in the peeling division is obtained from them in the following equation.

$$B_2 = B_0 - B_1 = (L+cx)\times 2(\theta_1 - \theta_2) \qquad (4)$$

In giving the numerical value in parameter and variable, it is operated. In this report, the heat sealing intensity was made to be [N/15mm].
It is made to change like; L=0, 10, 20, 30mm,
C=5, 10, 15, 20mm、cx=0, 1, 2･･･30(mm)
Unit of heat sealing intensity always used is reflected, it is come off, and the length is indexed. The peeling is also required on not only discussion of the intensity exactly but also discussion of the work (the peeling energy) of the peeling, because the peeled area increases. In this paper, it is discussed mainly on the intensity.

2.3. Correction of the basic stress model considering "pluck size"

In the basic stress model, the opening load was handled as ≪ point ≫. The material has the restriction of the strength, and in the point load, the damage is generated in the easiness and is not practical. Calibration method of basic stress model considering the line stress was shown in **Fig.4**. The opening force is distributed linearly in development line in the grip generation. In the opening in the pluck generation, opening force which corresponds to the development width is biased. The equation (2) will be transformed as following, if peeling length of line is made to be [A_C].

$$A_C = A + (\text{pluck size}) = (L+cx)\times 2\theta_1 + W \qquad (5)$$

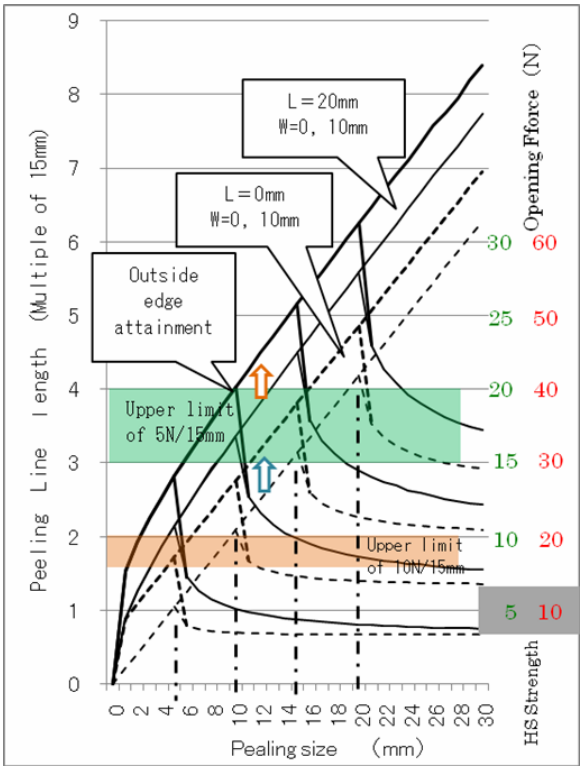

Fig.5 Correction result of the opening force pattern considering he pluck line of stress length
[comparison of L=20mm and 0mm]

Table 2 Relationship between opening force and peeling size (W=10mm)

L	Peeling size (mm)	Peeling line length (Multiple of 15mm)	Opening force (N)	
			5N/15mm	10N/15mm

20	5	2.81	14	28
	10	4.03	20	40
	15	5.16	27	53
	20	6.25	31	63
10	5	2.38	12	24
	10	3.46	17	35
	15	4.53	23	45
	20	5.59	28	56
0	5	1.71	9	17
	10	2.76	14	28
	15	3.81	19	38
	20	4.86	24	49

This zone are difficult opening

Example of standard simulation model and simulation result of correction model was shown in **Fig.5**. The detailed calculation result of the representative parameter was shown at **Tables 2**. The inhibition relation between openability and each parameter is proven from this table. **The six elements** which are related to the openability from this analysis can be exposed.

(a) Pluck length
(b) Distance to pluck line and heat sealing edge
(c) Pluck intensity
(d) Heat sealing strength
(e) Peeling width (Fin size)
(f) Elongation intensity of the packaging material.

3. Experiment and individual consideration of the experimental result

3.1.Operation of the simulation model

The parameter setting of [L=0, 10, 20, 30㎜] is made to be operation equation (2) and (4) which was modeled, and the variable is made to change in C=5, 10, 15, 20㎜]. It came off as [15mm], and the multiple calculation of [15mm] was done in respect of measurement width of the heat sealing strength in respect of the length, and the relationship between the heat sealing strength was standardized. The real opening force in being 5N/15mm and 10N/15mm at the heat sealing intensity in the right vertical line was heaped in the scale. The hatch was appended to the zone with the difficult opening in **Table 2**.

3.2. Measurement of the opening force which the consumer can put out

The other of packaged goods was grasped in the load indicator, and other side was picked in thumb and forefinger, and the generation intensity of the slip was measured. (a) Primary school child underclassman (male) 10～15N. (b**)** Primary school child upper grade (male) 15～18N. (c)The adult man : 20～25N. (d)The adult woman : 15～20N. In this paper, by setting 15～20N at the restriction range, the verification was done

3.3. Experiment and individual consideration of the experimental result

The openability of the on-market product was verified by the application of the simulation model of this paper. By integrating these test result in **Fig.6**, it was shown. Initial peeling seal has exceeded 30N commercial product, and the human pluck opening is difficult. It was able to be improved at 20N or less in the proper heating.
The proper-ness of the design of the packaging material was confirmed from this opening and test. It is proven that there is a problem on the failure of this case for heat management of the manufacturing process.

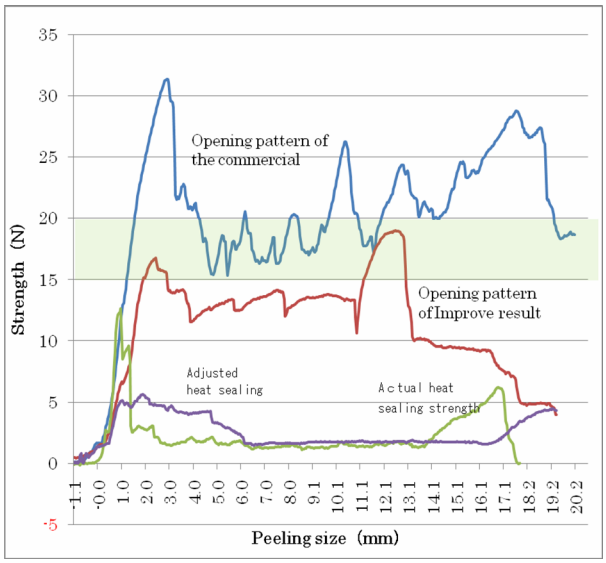

Figure 6 Verification and improvement case of the openability of commercial product of pillow packaging

3.4 Verification of the easily openable contrivance of the consumer

The consumer intends to barely open bag and cup packaging and has trouble. Main contrivance brings the picking point to the heat sealing line. These are the operations which make L to small of simulation, and this is reasonable. Next method is done.
(a) It puts on the opening load in the intersection point between principal rafter applying of the pillow packaging and opening heat sealing plane.
(b) It brings the pluck point if possible and close to the opening plane.
(c) The pluck point is shifted and is moved for the opening plane, when the opening also happens on coming out a little.
These operations are simulation, and it is reasonable.
It was shown the simulation of shifted the operation in

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Fig. 7. This example showed (5mm×3 time) or change example of the opening operation of 2 times of (10mm+5mm) in the load point of (L=20mm) in respect of 15mm heat sealing width (Fin width). 26N is required for the opening of 15mm, when if no shifted.
It is proven that it shifts that is carry out the opening is effective.

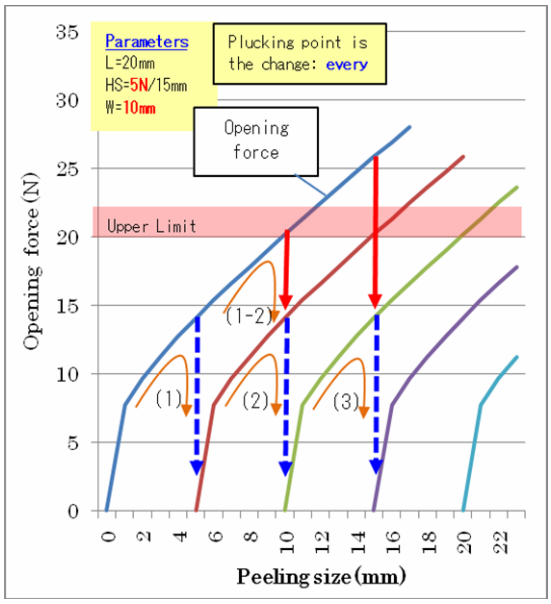

Figure 7 Verification of the wisdom of the opening of the consumer according to the simulation model

8. Conclusion

(1) It succeeded in the analysis of opening stress mechanism of the heat sealing plane.
(2) "Six elements" which controlled the openability was determined.
(3) Opening force is decided at heat sealing strength and pluck width initial stage in picking system.
(4) It is necessary to design the opening force at 20N or less.
(5) Upper limit of the heat sealing strength was able to find 10N/15mm.
(6) It is necessary to greatly design the material elongation force from the opening force of the setting.
(7) The experimental rule of the consumer is reasonable which brings the pluck point to the opening edge and durability spare in the opening .
(8) The openability of many commercial products was not good.
(9)The completion of this logic is an important position of the function achievement of the heat sealing.
Refer to **Oral session [015-06].**
It is possible to guide all the items which I presented.
I will do the support which is equal in the countries.
I am waiting for your demand.
You send e-mail to me ! Thank you.

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