Verification of prediction for bending rigidity of woven fabric laminated with interlining by adhesive bonding

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Abstract

The purpose of this study is to investigate the effect of pressing on bending rigidities of the face fabric, adhesive interlining and bonded composite fabric and verify the prediction method for bending rigidity of those. Predicting methods of bending rigidity for composite with face fabric and adhesive interlining based on laminated theory were verified with measured bending rigidities and thickness of samples. Bending rigidities and thicknesses of woven fabrics, adhesive interlinings and composites with those were measured by KES-FB system. Polytetrafluoroethylene (PTFE) film was used for measuring mechanical properties of pressed adhesive interlining. Bending rigidities of adhesive interlinings became larger and thicknesses of those became thinner than those of before pressing. Bending rigidities of face fabrics didn't change though the thicknesses became thinner than before pressing. It was found that the case of considering mechanical properties of pressed face fabric and pressed interlining was more efficient to predict bending rigidity of composite with laminated model.

Keyword: composite, adhesive interlining, mechanical properties, pressing, laminated theory, bending rigidity, woven fabric

Introduction

Interlining is a layer of fabric inserted between the face and the lining of a garment to give clothing a suitable appearance and stability. Interlining which uses a thermoplastic resin for attaching the face fabric is known as an adhesive or fusible interlining and it is usually used nowadays because of its convenience. Adhesive interlining generally gives a higher level of quality in a garment.

Because of the property changes, adhesive interlining is considered as an important material for clothing and the mechanical properties have been investigated. Several studies about the effects of adhesive interlining were conducted. In1979, Uruma et al. [1] investgated the relationships between the physical properties of textile composite fabric and those constituting face fabric and fusible interlinings experimentally and statistically. In 1987, Okamoto et al. [2] investigated the physical properties and fabric hand of wool blended fabrics interlined with fusible interlinings and compared them to blended fabrics without interlinings by measuring physical properties. In 2003, Matsunashi et al. [3, 4] studied about the behavior of needle penetration in blind stitch sewing and examined in the case where interlining is seemed together with other fabric. In 2007, Jing et al. [5] suggested predicting bond qualities of fabric composites after wash and dry wash based on a principal neural network model. In 1998, Kim et al. [6] investigated the suitability of nonwoven fusible interlinings to thin worsted fabrics with various fabric structural parameters. These studies mainly investigated mechanical properties of different face fabric and different adhesive interlining on the different situation statistically. However studies on pressing effects are still insufficient.

Adhesive interlining is bonded to face fabric by a pressing machine with high heat and pressure. Accordingly, the face fabric and adhesive interlining are pressed at the same time. Thus heat and pressure affect both adhesive interlining and face fabric. Therefore, it is necessary to study changes in mechanical properties of face fabric and adhesive interlining after pressing to understand the properties and effectiveness of adhesive interlining. Thus, the changes of mechanical properties on those, by pressing, were investigated in this study.

On the other hand, bending rigidity was considered as an important property for garment appearance when considering mechanical properties of interlinings. Therefore, it is necessary to predict the bending rigidity of the composite after bonding interlining and there have been some studies about this subject. Shishoo et al. [7] introduced regression equations and investigated the relationship of mechanical properties theoretically and experimentally. Fan et al. [8, 9 and 10] suggested a set of equations to predict low stress mechanical properties of fused composites from those of composed fabric and fusible interlining fabrics. Jeong et al. [11] reported on the construction of an integrated tool consisting of a neural network to predict mechanical properties. These methods and equations focused on experimental results. Therefore, the relationship between experimental results and theoretical ones still needed to be verified. Kanayama et al. [12, 13] proposed prediction methods about bending rigidity of a composite based on laminate theory for composite structure. These equations were considered useful to predict bending rigidity of that. However, there were still some differences between theoretical values and the predicted ones. Therefore it is more necessary to examine the calculation and measurement method of the parameters for the prediction equations. Furthermore, the studies were conducted in the 70s–80s and the making of the adhesive interlining technique was improved following progress of technical skill. Therefore, it is necessary to verify the efficiency of these methods for current adhesive interlining. Thus, Kanayama et al.'s prediction methods were verified and determination of the method for the parameter was supplemented with the measured results in this study.

Theoretical

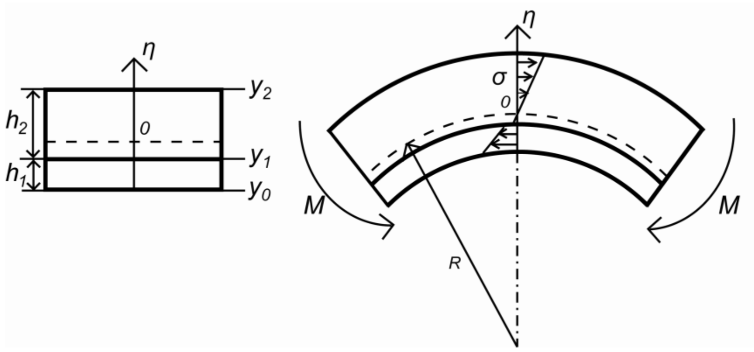

Figure 1 Structure of laminated composite and its bending.

The bending laminated composite of two plates, of which each modulus is different, was considered in this study. The structure of laminated composite is shown in Figure 1. The elastic modulus of each plate is E_1 and E_2, and the thickness of each plate is h_1 and h_2.

When the laminated composite is bent, the strain distribution in the cross-section is continuous. However the stress distribution is discontinuous at boundary. The neutral surface is not consistent to the symmetry axis of the cross section. In considering bending deformation, strain, ε, is given by

$$\varepsilon = \frac{\eta}{R} \qquad (1)$$

where R is the radius of curvature for the neutral surface of the composite after bending and η is the distance from the neutral surface in a composite. Assuming the Bernoulli-Euler law, the bending moment, M, is given by

$$M = \frac{\overline{EI}}{R} \qquad (2)$$

where $\overline{EI}$ is the equivalent bending rigidity of the composite. From the laminated composite theory of elastic plates, $\overline{EI}$ is given by

$$\overline{EI} = \frac{b}{3}\left(E_1\left[y_1^3 - y_0^3\right] + E_2\left[y_2^3 - y_1^3\right]\right) \qquad (3)$$

where y_0, y_1 and y_2, are the coordinates of surface and boundaries from the neutral surface in the cross-section of the laminated plate as shown in Figure 1 and b is the breadth of plates.

In this case, the neutral surface of the composite can be determined by the following relationship.

$$N = \int_A \sigma dA = 0 \qquad (4)$$

in which N is the resultant force in axial direction of the composite and σ is stress.

From Equation 4, we obtain

$$y_1 = \frac{h_1^2 E_1 - h_2^2 E_2}{2(E_1 h_1 + E_2 h_2)} \qquad (5)$$

By substituting $y_0 = y_1 - h_1$ and $y_2 = h_2 + y_1$ into the Equation 3, we obtain

$$\overline{EI} = \frac{b}{3}\left(E_1\left[h_1^3 + 3y_1h_1(y_1 - h_1)\right] + E_2\left[h_2^3 + 3y_1h_2(y_1 + h_2)\right]\right) \qquad (6)$$

Introducing the moment of inertias, I, of each plate,

$$I_1 = \frac{bh_1^3}{12}, \quad I_2 = \frac{bh_2^3}{12} \qquad (7)$$

then

$$\overline{EI} = E_1\left[I_1 + bh_1\left(\frac{h_1}{2} - y_1\right)^2\right] + E_2\left[I_2 + bh_2\left(\frac{h_2}{2} + y_1\right)^2\right] \qquad (8)$$

Then substituting Equation 5 into Equation 8, after some reductions

$$\overline{EI} = E_1I_1 + E_2I_2 + 3E_1I_1E_2I_2\frac{(h_1 + h_2)^2}{(E_1I_1h_2^2 + E_2I_2h_1^2)} \qquad (9)$$

In this study, the bending rigidity per unit width of the composite calculated from Equation 9 is denoted by B_1.

$$B_1 = \frac{\overline{EI}}{b} \qquad (10)$$

E_1I_1 and E_2I_2 are the bending rigidity of each plate. They can be measured by a pure bending tester.

The bending rigidity of the composite can be calculated from the bending rigidities and thicknesses for the each plate by using Equation 10. Kanayama et al.[13] used Equation 10 for the prediction of bending rigidity of composites.

Kanayama et al. [14] also proposed an equation considered the effect of adhesive agent with B_1 as follows.

$$B_2 = (1 + \frac{l_h}{l_s})B_1 \qquad (11)$$

where l_h and l_s are each widths of adhesive agent area and no adhesive resin area of interlining (See Figure 2). They assumed that the shape of adhesive agent area was a rectangle and the adhesive agents were put on regularly following a pattern.

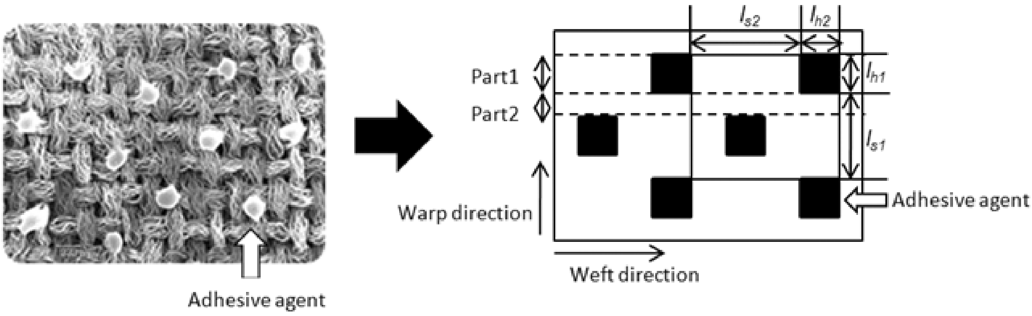

Figure 2 SEM pictures of adhesive interlining (left) and structure model of adhesive interlining from Kanayama et al.(right)

Experimental

The prediction of the bending rigidity of composite with adhesive interlining with equations 10 and 11 was verified. Face fabrics, adhesive interlinings and the composites were prepared as samples and their bending rigidities and thicknesses were measured and used to verify the equations. The mechanical properties of the face fabric and adhesive interlining may change after the pressing process. Therefore, it was also considered necessary to use the mechanical properties changed by pressing to verify the equations. To measure the mechanical properties changed by pressing, face fabric and adhesive interlining were pressed and the bending rigidity and thickness of each sample was measured and used to verify the equations as well.

Bending properties of each sample were measured by KES-FB2 pure bending tester [14] and the *B* values of cases where the face fabrics are outside were used. The thickness of each sample was measured by KES-FB3 compression tester at 0.5gf/cm^2 load. Bonding interlining to face fabric was treated by a press machine (KOBE DENKI KOGYOSYO, BP-V4812D) and the bonding conditions were at 150℃, under 0.3kgf/cm^2 load and for 10s pressing time. Every test was carried out under standard conditions (a temperature of 20±1℃ and a relative humidity of 65±5%). All samples were treated under standard conditions for 24 hours. Every test was conducted for five samples and the average was used as a result. Changes in cross-section for adhesive interlinings before and after pressing were observed by taking a SEM picture.

Four types of woven fabric made with different yarn count and weave for women's jackets were prepared as face fabrics. Specification of face fabrics and their weave are shown in Table 1. Ten kinds of adhesive interlinings were prepared as samples. Specifications of adhesive interlinings are shown in Table 2. They were polyester plain fabrics and the adhesive agent was polyamide. The adhesive was double dot which means a structure of the superimposed adhesive dots. Five were controlling density of cloth on weft direction and another five types had a different adhesive agent pattern by controlling the number of adhesive agent dots per area. When the adhesive agent was put on cloth, a screen, which has a thin plate and holes for the adhesive agent, was used. Composites of face fabrics and adhesive interlinings were also prepared as shown in Table 3.

Furthermore, to investigate the pressing effects on the mechanical properties of each sample, bending rigidities and thicknesses of the adhesive interlinings, face fabrics and interlining cloth without adhesive were measured after being pressed individually. Face fabric samples were pressed with the same conditions of bonding interlining and those samples were named as 'pressed face fabric'. The pressing process of adhesive interlining sample was difficult to carry out because the adhesive on adhesive interlining melted when pressed and the adhesive interlining was adhered to the base after pressing. Therefore, polytetrafluoroethylene (PTFE) film (NITTO, No. 900, 0.05 mm) was used as a base for pressing the adhesive interlining. Adhesive interlining was bonded to PTFE film by pressing then the PTFE film was removed from the composites as shown in Figure 3. By this process, the adhesive agent can be fixed on the cloths for interlining by pressing to a fabric because the PTFE film is infusible and has a flat surface. Consequently, it was possible to investigate the behavior of the adhesive after pressing. These samples were named as '*pressed interlining*'. The properties of cloth for adhesive interlining and the changes of these by pressing were important to understand mechanical properties of adhesive interlining. Therefore, CE-3-NA, which was interlining cloth of CE-3, was prepared as a sample. Those were also pressed and called P-CE-3-NA and P-CE-3 respectively.

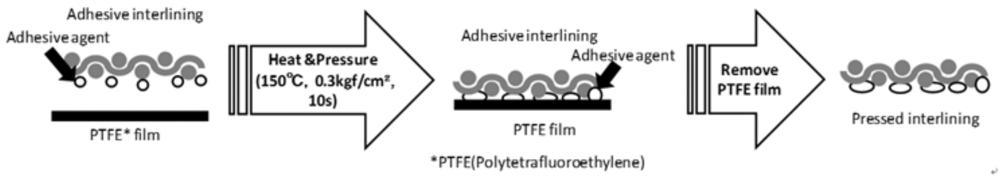

Figure 3 Processing of making *pressed interlining*.

Table 1 Specification of face fabrics

Sample name	Yarn Count(Nm)	Weave	Width(cm)	Density(/inch) (Warp × Weft)	Material	*Pressed face fabric*
A	2/60 × 2/60	Twill	148	72×56	Wool 100%	P-A
B	2/72 × 2/72	Twill	148	74×62	Wool 100%	P-B
C	2/72 × 2/72	Satin	148	110×74	Wool 85%, Angora15%	P-C
D	2/120 ×2/120	Satin	148	132×90	Polyester 80%, Wool 15%, Cashmere 5%	P-D

Table 2 Specification of interlining

Sample name	Density (/inch)	Adhesive dot number (/inch)(warp×weft)	Adhesive dot size (mm)	Mass per unit area (g/m^2)	Adhesive Mass without Interlining(g/m^2)	Screen thickness (µm)	*Pressed interlining*
CE-1	96.5×55.0	26×26	0.17	36.2	8.6	200	P-CE-1
CE-2	96.0×59.0	26×26	0.17	35.6	8.0	200	P-CE-2
CE-3	95.5×64.0	26×26	0.17	36.5	8.3	200	P-CE-3
CE-4	95.0×66.0	26×26	0.17	36.5	8.1	200	P-CE-4
CE-5	95.0×67.0	26×26	0.17	35.7	7.7	200	P-CE-5
DP-1	98.0×62.0	23×23	0.25	38.5	8.7	200	P-DP-1
DP-2	98.0×62.0	26×26	0.23	39.9	10.0	150	P-DP-2
DP-3	98.0×62.0	26×26	0.30	41.8	11.6	200	P-DP-3
DP-4	98.0×62.0	28×28	0.20	37.5	8.7	200	P-DP-4
DP-5	98.0×62.0	30×30	0.10	39.3	10.1	150	P-DP-5

Table 3 Specification of composite

Face fabric \ Adhesive interlining	CE-1	CE-2	CE-3	CE-4	CE-5	DP-1	DP-2	DP-3	DP-4	DP-5
A	A-CE-1	A-CE-2	A-CE-3	A-CE-4	A-CE-5	A-DP-1	A-DP-2	A-DP-3	A-DP-4	A-DP-5
B	B-CE-1	B-CE-2	B-CE-3	B-CE-4	B-CE-5	B-DP-1	B-DP-2	B-DP-3	B-DP-4	B-DP-5
C	C-CE-1	C-CE-2	C-CE-3	C-CE-4	C-CE-5	C-DP-1	C-DP-2	C-DP-3	C-DP-4	C-DP-5
D	D-CE-1	D-CE-2	D-CE-3	D-CE-4	D-CE-5	D-DP-1	D-DP-2	D-DP-3	D-DP-4	D-DP-5

Results and Discussion

Changes of bending property and thickness for woven fabric and adhesive interlining by pressing

The pressing effects were investigated by comparing the properties of each sample before and after pressing. The thicknesses of face fabrics changed after pressing as shown in Figure 4. However the effects were different for the different weaves. The thicknesses of twill and satin fabric increased and that of plain fabric decreased. It was conceivably due to the effects from heat and pressure during pressing. Therefore, it was found that thicknesses of face fabrics were affected by pressing while bonding adhesive interlining. However, it is necessary to study more about the pressing effects on woven fabric of different weaving.

Even though, the thicknesses of face fabrics were changed by pressing, bending rigidities of *pressed face fabric* were almost the same as before pressing as shown in Figure 5. Therefore, it was determined that bending rigidities of face fabrics were not affected by pressing.

Thicknesses of *pressed interlining* were lower than that before pressing as shown in Figure 6. In addition, some changes in the adhesive agent shape were observed after taking SEM pictures as shown in Figure 8. The round shape of the adhesive was flattened and the shape changed. Adhesive agent permeation into space between warp and weft yarns as shown in Figure 9. These changes were also found in all composites. Furthermore, the thicknesses changes of adhesive interlinings and interlining cloth by pressing are shown in Figure 10. Comparing CE-3 to P-CE-3, the thickness of P-CE-3 was lower than that of CE-3. The thicknesses of the adhesive interlinings became clearly thin by pressing. The thickness of CE-3 was lower than the sum of thickness for CE-3-NA and adhesive screen, 200µm. The reason was that adhesive agent was permeated into cloth surface during the manufacturing process.

Comparing P-CE-3-NA to CE-3-NA, the thickness of P-CE-3-NA was higher than that of CE-3-NA. With these results, it was conceivable that shrinkage and extension of cloth for adhesive interlining were occurred on adhesive interlining cloth by pressing so the thickness of adhesive interlining changed. Therefore, it is clear that pressing is affected not only adhesive agent but also cloth respectably.

Bending rigidity of pressed interlining increased compared with that before pressing as shown in Figure 7. In addition, bending rigidity of P-CE-3-NA was slightly smaller than that ofCE-3-NA whereas bending rigidity of P-CE-3 increases in comparison with that of CE-3 as shown in Figure 11. Therefore, it is conceivable that the most of pressing process did not affect the bending rigidity of cloth for adhesive interlining and this was similar results with *pressed face fabric*. With these result, it was concluded that the adhesive agent permeation made adhesive interlining stiffer than before.

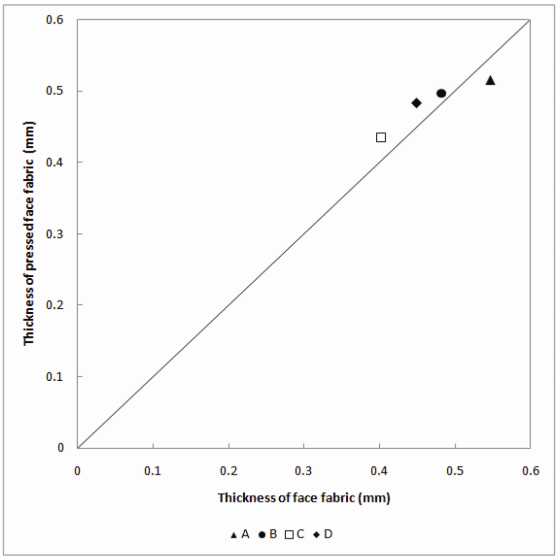

Figure 4 Relationship between thicknesses of *pressed face fabrics* thickness of face fabrics.

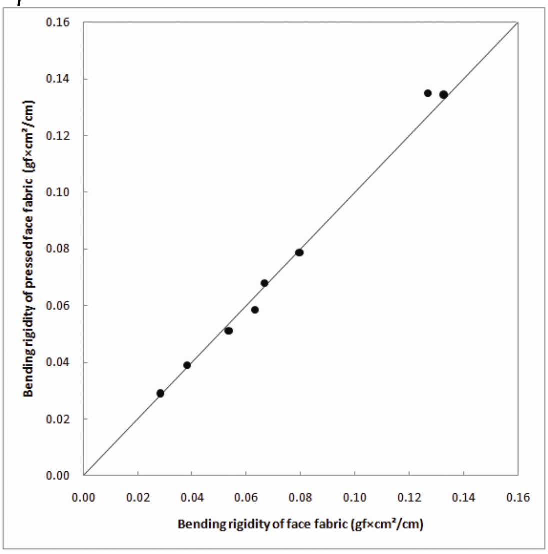

Figure 5 Relationship between bending rigidity of *pressed face fabrics* and bending rigidity of face fabrics.

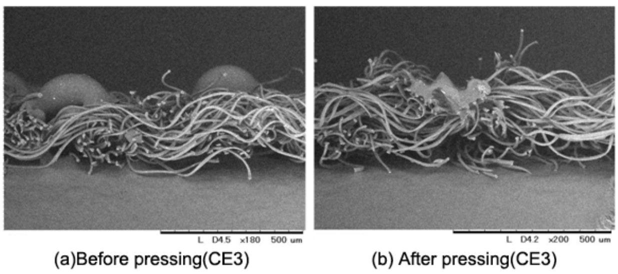

Figure 8 SEM pictures of Cross section for adhesive interlining: (a) Before pressing and (b) After pressing.

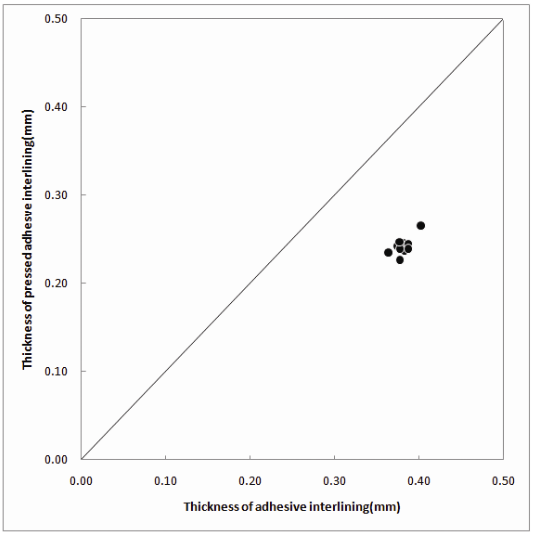

Figure 6 Relationship between thicknesses of *pressed interlining* and thickness of adhesive interlining before pressing.

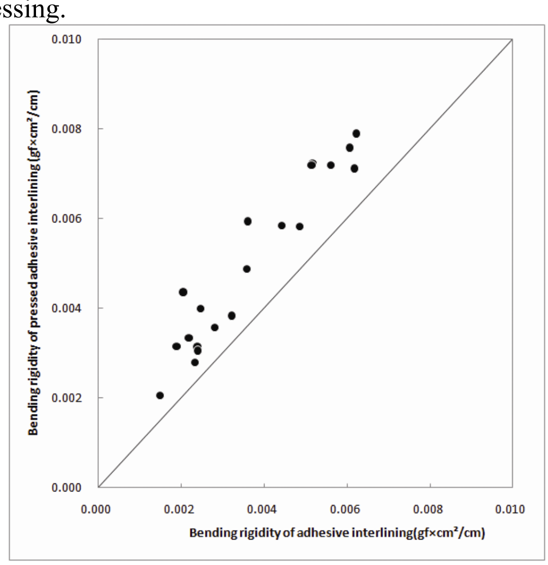

Figure 7 Relationship between bending rigidity of *pressed interlining* and bending rigidity of adhesive interlining before pressing.

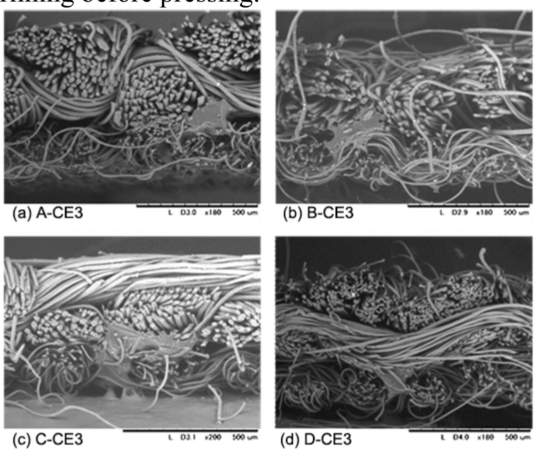

Figure 9 SEM pictures of Cross section for composites: (a) A-CE-3, (b) B-CE-3, (c) C-CE-3, (d) D-CE-3.

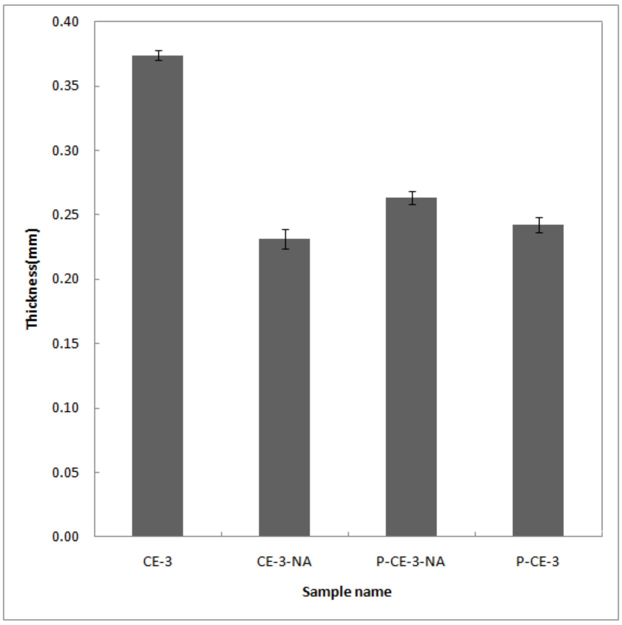

Figure 10 Thickness of adhesive interlining and its cloth without adhesive, before and after pressing.

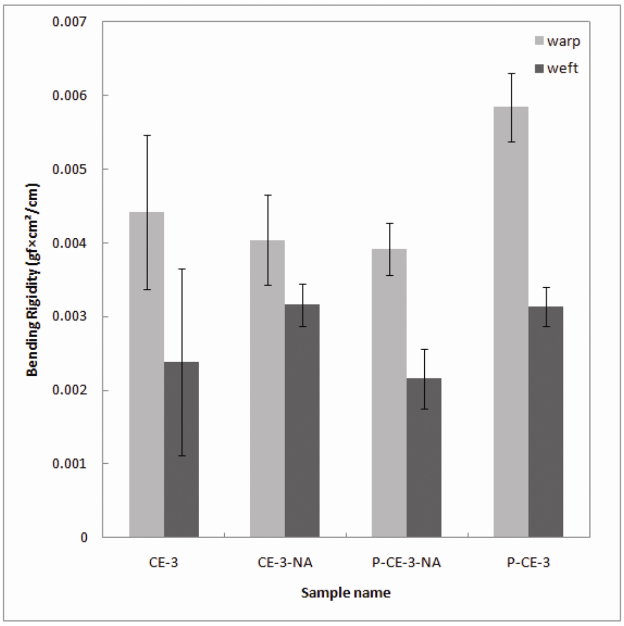

Figure 11 Bending rigidities of adhesive interlining and its cloth without adhesive, before and after pressing.

Prediction of bending rigidity for composite with adhesive interlining

The Equation 10 and 11 were used to verify with the measured mechanical properties. Bending rigidity and thickness of adhesive interlining before pressing was used to verify Equation 10 and 11 and this case was named as *A.I.* As previously mentioned, it was found that the pressing process affected the mechanical properties of each sample. Therefore, it was necessary to consider the mechanical properties changes due to pressing. Bending rigidity and thickness of *pressed interlining* used to verify those equations and that was named as *P.I.* Furthermore, it was also found that the pressing process affected the mechanical properties of face fabric. Therefore, bending rigidity and thickness of *pressed interlining* and thickness of *pressed fabric* was used to verify those equations and named as *F.P.I.* The list of parameters used for calculation and nomenclature of the result is shown in Table 4.

Comparison of the experimental and calculated bending rigidities with B_1 (*A.I.*) and B_2 (*A.I.*) equations is shown in Figure 12. Comparing results of equation B_1 (*A.I.*) to B_2 (*A.I.*), B_2 (*A.I.*) was slightly closer to the experimental results as a whole. It was because equation B_2 was considered the adhesive agent effects on B_1. Comparing the bending rigidity of warp and of weft direction, the lower values of weft direction were agreed with the experimental values better than warp direction. This tendency was also shown in Kanayama's results [12, 13].

The reason why the results from equation B_1 were not close to experimental ones could be as follows. Firstly, thickness changes of face fabric and adhesive interlining after pressing. Secondly, changes of bending rigidity for adhesive interlining after pressing. In equation B_1 and B_2, thicknesses and bending rigidities of samples after bonding were assumed to be the same as that before bonding. However after bonding an adhesive interlining to face fabric, the thickness of the composite after bonding interlinings, become lower than the sum of thickness for face fabric and interlining before bonding. It occurred due to the change of adhesive agent shape and mechanical properties changes of cloth by pressing as mentioned previously. Furthermore, bending rigidity of the adhesive interlining became larger than that before pressing. Therefore it will be necessary to consider those changes to predict the bending rigidity of the composite. In equation B_2, the percentage of adhesive agent was incorporated to enable the effects of the adhesive agent on bending rigidity to be considered. However, the increasing tendency of bending rigidity with increasing percentage of adhesive agent did not show in the results of B_2 *(A.I.)* in Figure 12. This was because the mass of adhesive agent was not considered in equation B_2. Some adhesive interlinings had different mass of adhesive agent even though the percentage of those was similar. Therefore not only the percentage of diameter but also the mass will need to be considered when calculating the effect of adhesive agent on bending rigidity of composite.

To consider the changes of mechanical properties for adhesive interlining by pressing, *P.I.* was used to predict the bending rigidity of the composite. Results of B_1 *(P.I.)* and results of B_2 *(P.I.)* are shown in Figure 13. Using bending rigidity values and thickness of *pressed interlining*, B_1 *(P.I.)* was introduced as a simple way to predict bending rigidity by Kanayama et al. However it was necessary to investigate the reason of using the method. In this study, it was found that thickness and bending rigidity of adhesive interlining were changed by pressing.

Therefore, using *P.I.* meant that the changes in adhesive interlining by pressing were already considered in the equation. Consequently the results of B_1 *(P.I.)* were closer to experimental ones than B_1 *(A.I.)* and B_2 *(A.I.)*. The results of B_2 *(P.I.)* were higher than the experimental ones than the results from B_1 *(P.I.)*. It was not useful to use these properties in B_2 because the changes from pressing were already considered in the results of *P.I.* Therefore, equation B_1 with *P.I.* would be better to predict a more accurate bending rigidity than B_2 *(P.I.)*.

However, the face fabric changes by pressing were not considered in the case of *P.I.* The equations were mainly affected by thickness and bending rigidity changes and also, in this study, it was found that the mechanical properties of face fabric were changed by pressing. Therefore, the thickness change on face fabric by pressing must be considered for predicting the bending rigidity of the composite. To consider the changes of adhesive interlining and face fabric by pressing, *F.P.I.* was used to predict bending rigidity of composite. The results of B_1 *(F.P.I.)* and results of B_2 *(F.P.I.)* are shown in Figure 14. Root mean square of errors (RMSE) and coefficient of determination of experimental results and those of each condition are shown in Table 5. RMSE of B_1 *(F.P.I.)* was lower than that of B_1 *(P.I.)*. Therefore, it was found that the results considered thickness changes after pressing face fabric gave a more exact prediction of experimental ones. Consequently, it will be possible to predict bending rigidity of the composite with adhesive interlining with equation B_1 under *F.P.I.* conditions more precisely.

Furthermore, Kanayama et al. [12, 13] calculated 3 types of face fabric (warp knit, plain woven and nonwoven). In their results, results of nonwoven agreed with experimental ones. The results from the plain woven showed larger values than the experimental ones. However, the results of the woven fabric, which was used in this study, showed closer values to the experimental ones. This could be because of the technical improvement in manufacturing the adhesive interlining. The interlining cloth was getting thinner and adhesive agent mass was getting smaller than the samples from Kanayama et al. Efficiency improvement of the adhesive interlining reduced the space between face fabric and adhesive interlining after bonding. It made the error decrease so that it was possible to predict the bending rigidity of composites.

Table 4 Parameters used for calculation and nomenclature

Symbol	Condition
A.I.	Used bending rigidity and thickness of adhesive interlining before pressing
P.I.	Used bending rigidity and thickness of *pressed interlining*
F.P.I.	Used bending rigidity and thickness of *pressed interlining* and thickness of *pressed fabric*

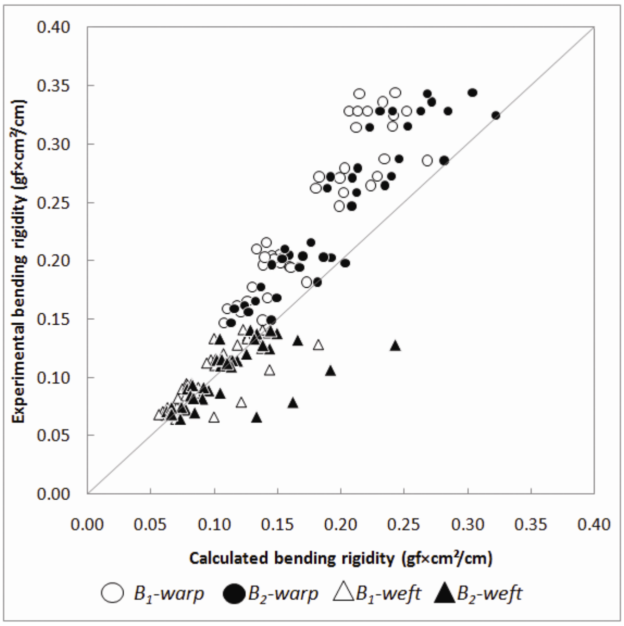

Figure 12 Comparison between experimental bending rigidities and theoretical bending rigidities using B_1 *(A.I.)* and B_2 *(A.I.)*

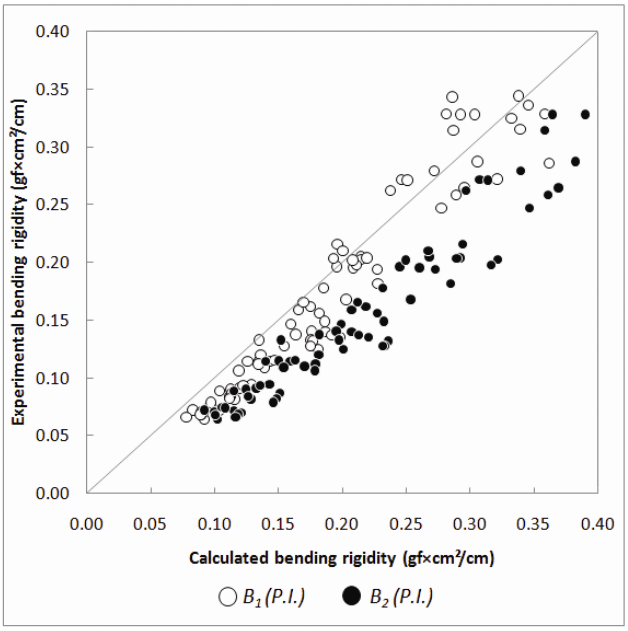

Figure 13 Comparison between experimental bending rigidities and theoretical bending rigidities using B_1 *(P.I.)* and B_2 *(P.I.)*.

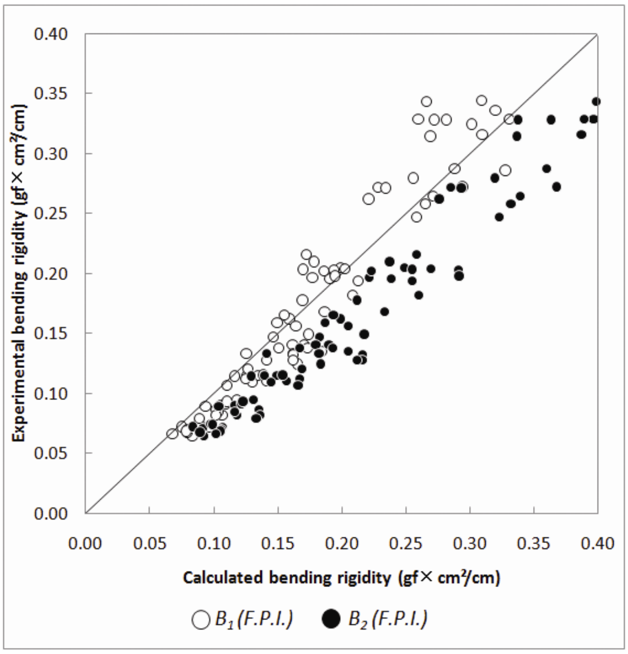

Figure 14 Comparison between experimental bending rigidities and theoretical bending rigidities using B_1 *(F.P.I.)* and B_2 *(F.P.I.)*.

Table 5 Root mean square of errors (RMSE) and coefficient of determination (R^2) between experimental results and those of each condition

Conditions	RMSE	R^2
B_1 *(A.I.)* results and experimental results	0.0056	0.8817
B_2 *(A.I.)* results and experimental results	0.0046	0.8325
B_1 *(P.I.)* results and experimental results	0.0039	0.9263
B_2 *(P.I.)* results and experimental results	0.0085	0.9355
B_1 *(F.P.I.)* results and experimental results	0.0029	0.9264
B_2 *(F.P.I.)* results and experimental results	0.0062	0.9405

Conclusions

The changes of mechanical properties, for adhesive interlining, face fabric and composites of these, by pressing were investigated and the predicting methods were verified with measured data. It was found that not only the properties of adhesive interlining but also the properties of face fabric changed in the pressing process. It was also found that the pressing process had also effects on cloth for adhesive interlining. The predicting methods for bending rigidity of composite with adhesive interlining and face fabric suggested by Kanayama et al. based on laminate theory for the laminated composite were verified. Comparing results of B_1 and those of B_2, those of B_2 which considered the adhesive agent area were closer to experimental results in the case of using mechanical properties of samples before pressing. However B_1 was closer to the experimental results in the case of results considering the pressing effects, which used bending rigidity and thickness of *pressed interlining* with B_1. Furthermore, the case of considering thickness of the *pressed face fabric* was more efficient at predicting bending rigidity of composite with B_1. With these results, it was concluded that the Equation 10 was useful to predict bending rigidity of composites with adhesive interlining, with mechanical properties, the pressing effects on adhesive interlining and face fabric were considered.

The entire predicted results for bending rigidities from this method agreed with experimental ones. For the prediction having higher accuracy, improvement of the further model will be necessary. Therefore, future studies will need to address this.

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