Studies on Particle Board (VII).
Studies on the pressing (3).
Effect of moisture content of wooden surface particle on board properties.

Mutsumi IWASHITA*

I Introduction

The influence of surface particle moisture content during hot pressing of three-layer particle board on the board properties has been investigated by many researchers. STRICKLER[7] has shown that density of the surface layer of board is increased by increase of the moisture content of the surface particles, at the same time the density in the core layer is decreased, and consequently the mechanical properties such as specific bending strength are improved. MAKU[5] has investigated the effect of particle moisture content on temperature rise in particle mattress and moisture distribution during hot pressing, and he has recognized the superiority of three-layer board. The authors[2] have also investigated the relationship between particle moisture content before hot presing and process of particle mattress during hot pressing, physical and mechanical properties of board. As such it has been recognized that the board properties are affected by not only surface particle moisture content, but also by core particle moisture content.

These researchers have also evidently asserted that board properties are lowered with excessive surface moisture causing inferior bonding beneath the surface layer.

With respect to this inferior bonding, it is considered that if the moisture content of surface layer is high during hot pressing, because too much vapor occurs at the surface layer and then proceeds to the inner layer, the urea resin adhesive at the surface layer may be washed away to the inner layer with the vapor.

From this viewpoint, to define the cause of decrease of board properties and to decide the upper limit of suitable surface moisture, this study was conducted. In addition, the objective of the study is to determine the behaviour of urea resin adhesive throughout the board thickness during hot pressing, by means of the quantitative analysis of nitrogen.

The author is indebted to Mr. K. FUJIWARA and Mr. A. ÔKURO for their assistance in the experimental work.

II The relationship between moisture content of surface particle and behaviour of urea resin adhesive.

It is impossible to measure directly the amount of urea resin adhesive in particle board after hot pressing. Therefore and generally its content can be assumed by the quantitative analysis of nitrogen content of urea resin adhesive within the board.[3] Consequently, in this experiment the behaviour of urea resin adhesive throughout the board thickness as affected by different surface particle moisture contents were investigated by means of Kjeldahl's process and also the relationship between the behaviour of urea resin and surface particle moisture content.

---

* Chief of Wood Improvement Lab., Wood Technology Div., Dr.

1. Experimental procedure

(1) Manufacture of particle board

Species of wooden particles was larch (*Larix Kaempferi* SARG.) and the sizes of particle were 0.2 by 1 to 3 by 20 mm for the surface layer, and 0.5 by 3 to 6 by 40 mm for the core.

The moisture contents of surface particle after glue spreading were at six levels, 10%, 15%, 20%, 25%, 30% and 35%, and that of core particle was at one level only, 10% throughout. The adhesive (urea resin, Plyamine TD 511, 49% solids) content was 11% for surface particle and 7% for core particle in oven-dry condition. The hardner, catalyst 376, was used at a rate of 3% of urea resin. Weighing ratio of surface to core particles was 1 : 2 in dry state. The particle after glue spraying were felted by hand in a 45 by 45 cm wooden deckle box. The temperature of hotpress platen was 140°C, and the pressing time was 10 min. The pressure was applied on a step-down system of 30 kg/cm², them 20 kg/cm² and finally 10 kg/cm² for every 5 min. Board thickness was 20 mm (the distance bars were used for thickness adjustment), and the specific gravity of board was about 0.65. Two replication of boards were made for each condition.

(2) Testing procedure for quantitative analysis of nitrogen

The specimens for quantitative analysis of nitrogen were cut 1 cm width from the center of board as shown in Fig. 1. Subsequently, the specimens were divided by fret saw into three layers, surface layer, core layer (1) and core layer (2), as shown in Fig. 2. Each of the specimens was crushed by hammer crusher and wiley mill until fine particle was produced below 20 mesh. Using these fine specimens, Kjeldahl's process[6] was used for quantitative analysis of nitrogen.

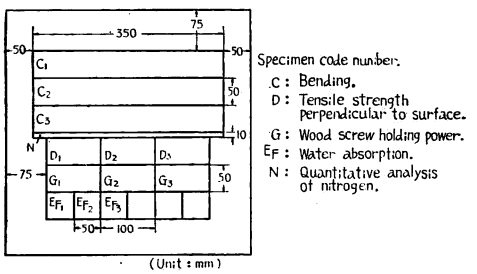

Fig. 1 Sampling of specimens.

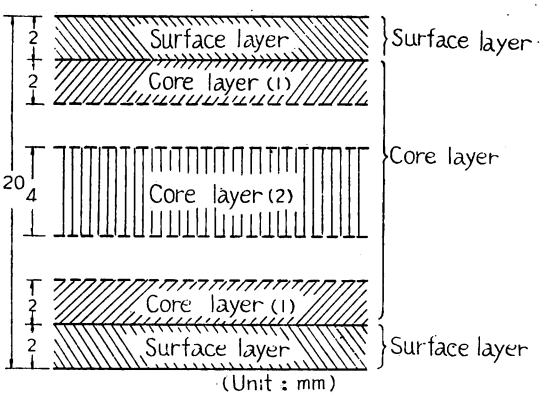

Fig. 2 Sampling of specimens.

2. Results

(1) The relationship between the quantity of urea resin in board and nitrogen content by measurement

The constituent of urea resin and hardner used in this study were not exactly known, because the resin and hardner came from the market. Therefore, the nitrogen content of urea resin adhesive used (49% solids, the hardner was used at a rate of 3% of urea resin) was measured.

Now, when the nitrogen content of e grams urea resin (d % solids) is n grams, the nitrogen content N_A (%) of resin solids is shown in the following equation :

$$N_A = \frac{n \cdot 10^4}{e \cdot d} \ (\%) \quad \cdots\cdots(1)$$

Actually, when the nitrogen content (n) of 0.557 g of urea resin mixed with hardner was measured, it was 0.0807 g.

Then, from Eq. (1)

$$N_A = 29.57\ (\%) \quad \cdots\cdots(1)'$$

Then, the nitrogen content N_P (%) of particle board coated by urea resin adhesive is shown in the following equation :

$$N_P = \frac{N_A \cdot c}{b+c} \ (\%) \quad \cdots\cdots(2)$$

where b = oven-dry weight of particle, c = quantity of resin solid.

When the resin content of board is x (%), the quantity of resin solid is

$$c = \frac{b \cdot x}{10^2} \quad \cdots\cdots(3)$$

Therefore, from Eq. (2) and Eq. (3)

$$N_P = \frac{N_A \cdot x/10^2}{1+x/10^2} = \frac{N_A \cdot x}{x+10^2} \quad \cdots\cdots(4)$$

Moreover, since the nitrogen content of wood (larch particle in this study) was very little (about 0.07% by measurement), it was canceled in Eq. (4).

Assuming, 11% and 7% urea resin contents for surface layer and core respectively, and using Eq. (4) and measurement (1)', the computed values of nitrogen contents in surface layer and core were 2.930% and 1.934% respectively. A very similar value appeared when compared with the measured nitrogen contents in the case of 10 to 15% of surface particle moisture content, as shown in Fig. 3. But the computed values of the nitrogen content did not coincide with measured value completely. It seems that the difference depends on the experimental error in manufacturing board, sampling error of specimens and rejection of nitrogen in wooden particles, etc.

From these results, it is considered that the contents of urea resin adhesive in board can be assumed by measuring the nitrogen content in board.

(2) The relationship between surface layer moisture content during hot pressing and nitrogen content of each layer.

Based on the result of the above section, if it can be considered that measured nitrogen content of board is proportional to the content of urea resin adhesive, it appears quite clearly in Fig. 3, that the contents of urea resin adhesive in board changed with change of moisture content in surface layer.

The resin contents of surface layer decreased with increase of moisture contents of surface layer, particularly above 30% moisture content of the surface layer, while the resin contents of core layer (1) increased with

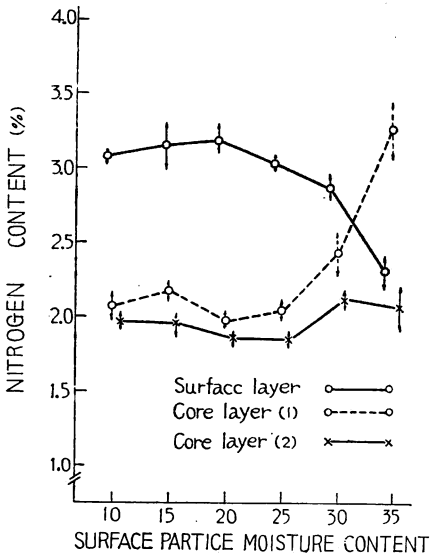

Fig. 3. The relationship between surface particle moisture contents and nitrogen contents of each layers.

increase of moisture content of surface layer particulary above 30% moisture content. The resin contents of core layer (2) were slightly affected by the change of moisture content in surface layer, that is above 30% moisture content only.

Generally, during hot pressing of the particle mattress, the steam of moisture vaporizes from the surface layer and then goes through the inner layer of board and finally evaporates from board edge. From the results mentioned above, therefore, the adhesive at the surface layer would transfer to the core layer (1) with steam flow. Consequently, the adhesive at the surface layer is decreased, while on the other hand, the adhesive at the core is increased.

According to the analysis of variance, the nitrogen contents of surface, core (1) and also core (2) between the moisture contents of surface layer are significant at the 1% level of probability. According to the estimation of population mean between each level, however, the nitrogen contents at surface layer between 10% to 20% moisture content of surface layer are not significant at the 5% level; but between these moisture content group and other moisture content group (from 25% to 35%), they are significant at the 1% level of probability. The nitrogen contents at core layer (1) between 10% and 25% as well as between 20% and 25% moisture content of surface layer are not significant at the 5% level; but between other moisture contents of surface layer are significant respectively at the 1% level of probability. And the nitrogen contents at core layer (2) between 10% and 15%, between 20% and 25%, and between 30% and 35% moisture content of surface layer are not significant at the 5% level, but between each gruup of moisture content of surface layer are significant at the 1% level of probability.

In the case of 15% to 20% moisture content of surface layer, the nitrogen contents at core layer (1) and (2) showed slight fluctuation. It seems that this depends on the experimental error during manufacturing board, not on the measurement error of nitrogen.

III The relationships between moisture content of surface particle and board properties.

STRICKLER[7], KOLLMANN[4] and the authors[2] have reported that if the moisture content of surface particles during hot pressing of the particle mattress is increased more than a certain quantity of moisture content, the mechanical properties of board decrease. Based on the results mentioned in chapter II, the study in this chapter was conducted for the purpose of investigating the cause of depression of board properties as affected by moisture change at the surface particle during hot pressing.

1. Experimental procedure

Board specimens for testing physical and mechanical properties were identical with the specimen used for measuring nitrogen content as mentioned above. After hot pressing, the specimens for testing physical and mechanical properties as well as for measuring nitrogen content were cut at the same time as shown in Fig. 1. After conditioning at 20°C temperature and 65% relative humidity until constant weight have been attained, the specimens were tested according to JIS A 5908 (1961), except water absorption test. Water absorption was tested according to JIS A 5907 (1961) (25°C, 24 hrs.). Thickness swelling was also measured at the center of water absorption specimens (size : 5 by 5 cm). Six replication were used for each condition.

2. Results

The results of test are shown in Fig. 4 to Fig. 6. According to the analysis of variance, bending strength, Youngs' modulus, and water absorption between the moisture contents are significant at the 1% level of probability, while thickness swelling in water absorption between the

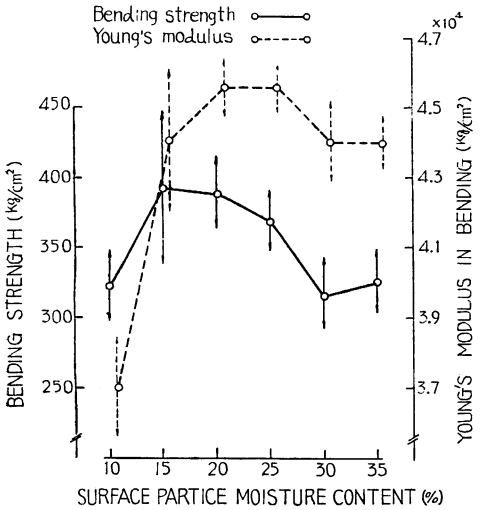

Fig. 4. The relationship between surface particle moisture contents and bending properties of board.

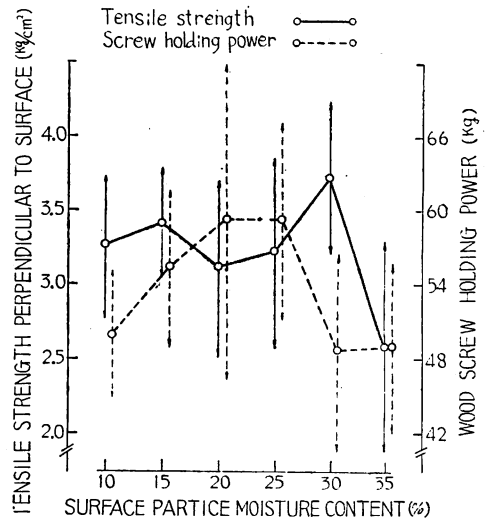

Fig. 5. The relationship between surface particle moisture contents and tensile strength, wood screw holding power of board.

moisture contents was significant at the 5% level. Other properties, tensile strength perpendicular to surface and wood screw holding power, are not significant at the 5% level. According to the estimation of population mean between each level, however, bending strength between 10% and 15%, 20% moisture content of surface layer, between 15% and 30%, 35%, between 20% and 30%, 35%, and between 25% and 30% are significant at the 1% level of probability, and also between 10% and 25%, and between 25% and 35% are significant at the 5% level. Young's modulus and water absorption between 10% and other moisture contents of surface layer are significant at the 1% level of probability. Thickness swelling in water absorption between 10% and 35% moisture content is significant at the 1% level, and between 10% and other moisture contents is significant at the 5% level.

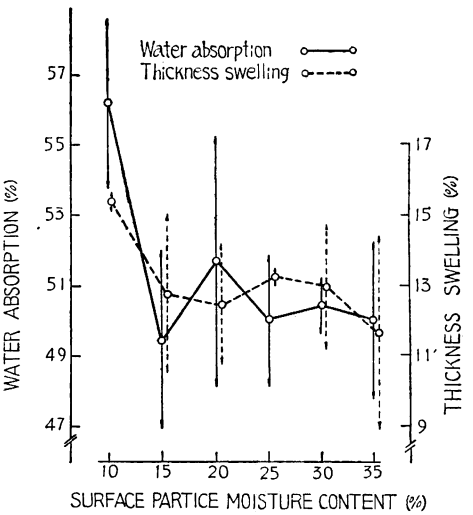

Fig. 6. The relationship between surface particle moisture contents and water resistant properties of board.

As shown in Fig. 4, the bending properties decreased remarkably, especially in 10% moisture content of surface layer. This depends on decreasing plasticity or compressibility of the surface particles and therefore the depression of specific gravity at the surface layer, due to low moisture content of the surface particles. However, the bending properties again decreased in 30% and 35% moisture content. This is due to the decreased adhesive at the surface layer as cited in the previous chapter. In other words, when the moisture content of surface layer is

increased above 30% during hot pressing, the steam is vaporized excessively at the surface layer, and when the excess vapor steam goes to the inner layer and evaporates from the board edge, the adhesive at the surface layer is diluted and transferred also by steam flow to the inner layer. Consequently, it is concluded that bonding failures occur between each of the particles near the surface and then bending properties decrease above 30% moisture content of surface layer.

Wood screw holding power characterized the surface property of board as well as bending properties, and showed almost the same tendency as bending properties (Fig. 5), but the deviation of the measurements was rather large and there was no significance between moisture contents of surface layer.

Tensile strength perpendicular to surface showed a large deviation of the measurements and was not significant at the 5% level of probability, but this strength tended to decrease in 35% moisture content of surface layer (Fig. 5). In this case, owing to excessive moisture of surface layer during hot pressing, the moisture content of inner layer increased. Therefore, it seems that the inner bonding was not completed during hot pressing.

Water resistant properties such as water absorption and thickness swelling were extremely inferior, especially in 10% moisture content of surface layer (Fig. 6). These phenomena are caused by low specific gravity at the surface layer of board in response to low moisture content at the surface layer during hot pressing, and low moisture content at the initial stage of water absorption test on account of a shortage of conditioning after hot pressing. The effect of excessive moisture at the surface layer during hot pressing was not recognized in spite of decrease of adhesive at the surface layer. It seems that this was affected by high specific gravity at the surface layer of board.

IV Conclusion

As far as these experimental conditions apply if the moisture content at surface layer is increased more than the required amount, the steam vaporized at the surface layer during hot pressing increases excessively and transfers the adhesive to the inner layer. Therefore, the effect of hardening the surface layer, which is a characteristic of three-layer board, is lost, and the mechanical properties are rather decreased.

Consequently, it is quite unnecessary to increase the moisture at surface layer excessively for the purpose of only accelerating the temperature rise of inner layer at the initial stage of hot pressing. When the weighing ratio of surface to core particles is 1 : 2 and the moisture content of core layer is 10%, it is not necessary to increase the moisture content of surface layer to more than 30%.

V Summary

The purpose of the work herein reported was to investigate the effect of moisture content of the surface particle during hot pressing of three-layer particle board, on the board properties, by means of clarifying the behaviour of urea resin adhesive, particularly by measurement of nitrogen content throughout the board thickness.

The results obtained in this study are summarized as follows :

(1) Since it was confirmed by the quantitative analysis of nitrogen content that the amount of urea resin adhesive can be assumed throughout the board thickness, from the viewpoint of the relationship between moisture content of the surface layer and nitrogen content of each layers, the behaviour of urea resin adhesive throughout the board thickness during hot pressing was assumed to be as follows :

(a) When the moisture content of surface layer is increased, the steam vapor increases during hot pressing and the adhesive at the surface layer is washed away to the inner layer with the vapor; then the amount of urea resin adhesive at the surface layer decreases.

(b) At the same time, the amount of urea resin adhesive at the core layer, immediately beneath surface layer, is increaased by transfer of the adhesive from the surface layer, while the amount of urea resin adhesive at the center layer is not affected by the moisture content of surface layer.

(2) It was confirmed by investigating the relationship between moisture content of surface layer and board properties, that the board properties are significantly affected by the behaviour of urea resin adhesive within the board :

(a) If the moisture content of surface layer lowers, the bending properties are decreased remarkably by shortage of plasticity or compressibility of the surface particles, while if the moisture content of surface layer increases, the bending properties are decreased again, because the amount of urea resin at the surface layer decreases and the bonding failure occurs at the surface layer.

(b) Since wood screw holding power is affected by the property of surface layer, it shows almost the same tendency as bending properties.

(c) Water resistant properties are not affected by excessive moisture at surface layer.

(3) In short, when three-layer particle board is manufactured, in which the weighing ratio of surface to core particles is 1 : 2 and the moisture content of core layer is 10%, it is quite unnecessary to increase the moisture content of surface layer to more than 30%.

References

1) FAHRNI, F. : Das Verpressen von Spanplatten bei gefeuchten der feuchten Deckspänen, Holz als Roh- und Werkstoff, **14**, 1, pp. 8～10, (1956)

2) IWASHITA, M., MATSUDA. T. and S. ISHIHARA : Studies on Particle Board (Ⅲ), Studies on the pressing (1), On the curing cundition, especially moisture content of wooden particles, Bulletin of the Government Forest Experiment Station, 126, pp. 63～89, (1960)

3) KLAUDITZ, W. and K. MEISER : Zur Bestimmung des Harnstoff- und melaminharzgehaltes von Holzspanplatten, Holz als Roh- und Werkstoff, **18**, 5, pp. 163～166, (1960)

4) KOLLMANN, F. : Über den Einfluss von Feuchtigkeitsunterschieden in Spangut von dem Verpressen auf die Eigenschaften von Holzspanplatten, Holz als Roh- und werkstoff, **15**, 1, pp. 35～44, (1957)

5) MAKU, T., HAMADA, R. and H. SASAKI : Studies on the Particle Board (Report 4), Temperature and Moisture Distribution in Particle Board during Hot-pressing, Wood Research, 21, pp. 34～46, (1959)

6) NIINA, K. : A Comparative study of Four Kjeldahl Methods. Application to Soils and Plant Materials, Bulletin of the Government Forest Experiment Station, 53, pp. 127～134, (1952)

7) STRICKLAR, H. S. : Effect of Press cycles and Moisture content on Properties of Douglas-Fir Flake-Board, F.P.J., **9**, 7, pp. 203～215, (1959)

パーティクルボードに関する研究（Ⅶ）

パーティクルボードの熱圧に関する研究（第3報）

表層小片含水率の影響

岩　下　　睦(1)

概　　要

この研究の目的は，3層パーティクルボード製造時の熱圧における表層小片含水率の影響，特に窒素定量によって尿素樹脂接着剤のボード厚さ方向における挙動を明らかにし，それがボードの材質に及ぼす影響について検討したものである。

この研究で得られた結果を総括すればつぎのとおりである。

（1） ボード中の窒素含有量を定量することにより尿素樹脂接着剤量を推定しうることを確め，表層小片含水率と，各層別の窒素含有量の関係から，熱圧時のボード中の尿素樹脂接着剤の挙動について，つぎのごとく推論した。

a）表層小片含水率が30，35%のように高くなると，熱圧時に表層において生ずる水蒸気が多くなり，その水蒸気が接着剤を内層へ押し流し，表層の尿素樹脂接着剤含有量は減少する（Fig．3)。

b）表層に近い内層部分（内層1）の尿素樹脂含有量は，表層小片含水率が30%以上の高含水率になると，前述のように接着剤が表層から押し流されてくるため増加する。しかし，中心層の尿素樹脂接着剤含有量は，表層小片含水率にほとんど影響されない。

（2） 表層小片含水率とボード材質との関係を求めることにより，尿素樹脂接着剤の挙動が，ボード材質にきわめて大きな影響を及ぼしていることを確めた。

a）表層小片含水率が低い場合は表層小片の可塑性が少なく，圧縮性が悪いため，曲げ性能は低下するが，30%以上の高含水率になると，表層中の接着剤含有量が減少し，表層に接着不良を生じるため，曲げ性能はふたたび低下する（Fig．4)。

b）木ねじ保持力は，表層の性質に影響されるため，曲げ強さと傾向は同じである（Fig．5)。

c）耐水性能においては，過度の表層小片含水率の影響は認められなかった。

（3） 以上の結果，3層パーティクルボード製造時の熱圧における表層小片含水率は，表層，内層構成比1：2，内層小片含水率10%の場合，30%以上に増加させることは望ましくない。

(1)　木材部材質改良科材質改良研究室長・農学博士