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The Effect of Atmospheric Conditions on the Physical and Mechanical Properties of Linerboard

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ABSTRACT

The physical and mechanical properties of linerboard were shown to be affected by changing atmospheric conditions. Two atmospheric conditions were measured in order to investigate how they were affected by different atmospheric conditions on the physical and mechanical properties of domestic linerboard. The basis data set for the standardization research was provided in this study. It is confirmed that the relative humidity seemed to be a major factor on the quality deterioration of a linerboard. Experimental results have shown that the short span compression test (SCT) could be used to evaluate the quality characteristics of linerboardat different moisture content and relative humidity.

Keywords : linerboard, atmospheric condition, compression strength, burst Index, basis weight

1. Introduction

Recently the consumption of the corrugated box, an environment friendly packaging material, has been greatly increased due to the facts that a new purchase pattern has been developed in the e-commerce industry including internet and home shopping, the demand for unit packaging has been increased, and the international environmental law against packaging material inducing environmental contaminations in the process of disposal and recycling has been tightened. The demand for high quality of corrugated box has been also increased in these days. It is well known that the characteristics of linerboard can affect significantly the final quality of corrugated box. It is also known that linerboard and corrugated medium occupy the large portion of production cost, about over 50 % out of the total production cost. Linerboard requires having the strength property that could endure a compressive load during the carrying and stacking in various environmental conditions, and the printing property that could provide a smooth surface for the printing processes (1-7). It has shown that the physical and mechanical properties of linerboard can be significantly affected by atmospheric

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conditions. Byrd *et al.* reported that the creep speed of linerboard at circulating humidity condition was 2-9 times faster than would be the case at constant humidity condition (8). Unpublished data has shown that strength properties of some domestic corrugated box exposed to harsh environmental condition were only 20 ~ 30% of original corrugated box strength properties (8). It is assumed that the strength properties of the domestic corrugated box are also very sensitive to temperature and relative humidity. In view of facts that globalization has matured in every aspectthese days and the competitive power of domestic corrugated box in the world distribution industry should be increased, it becomes very important to evaluate and compare results of a conventional test with those of International Standard Organization (ISO) (9).

This study was carried out in order to evaluate the physical and mechanical properties of domestic linerboard, provide the basis data set for the standardization research, and investigate the relationship between environmental preconditions and physical and mechanical properties of linerboard in a process of changing the atmospheric condition.

2. Materials and Methods

2.1 Materials

Three grades of domestic linerboards, KK, KA, and KC were used in this study. Linerboards made by seven different paper companies in Korea were employed to evaluate physical and mechanical properties at two different atmospheric conditions. KK grade had three different basis weights, 175, 225, and 300 g/m^2. KA and KC grade had 210 and 180 g/m^2, respectively.

2.2 Evaluation of physical and mechanical properties

2.2.1 Atmospheric conditions

Table 1 shows two atmospheric conditions applied for this study. At least 64 hours of preconditioning was taken for eachtest. When the condition of preconditioning was changed, 48 hours of interval was kept for next test. In order to set up the precise temperature and relative humidity, a digital wet and dry thermometer along with bulb hygrometer was used.

Table 1. Atmospheric condition

	Temperature (℃)	Relative Humidity (%)
Condition I	20 ± 2	65 ± 2
Condition II	23 ± 2	50 ± 2

2.2.2 Evaluations of physical properties

On the basis of ISO Standards, basis weight, moisture content, compressive strength, and burst strength were measured. Short-span compression strength, tensile strength, stretch, tear strength, and thickness were also measured. Over 20 times of measurement have been done for each test. Mean value and standard deviation were obtained for each sample. T-test has been done to obtain a test of significance.

3. Results and Discussion

3.1 Effects of atmospheric conditions on the specific burst strength

Generally burst strength has been used to evaluate the quality characteristics of linerboard

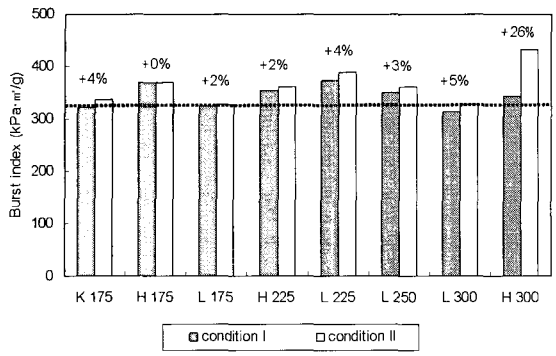

Fig. 1. The effect of different preconditioning on burst index of KK grades liners.

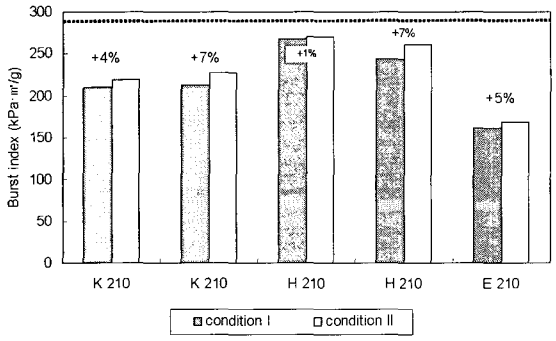

Fig. 2. The effect of different preconditioning on burst index of KA grades liners.

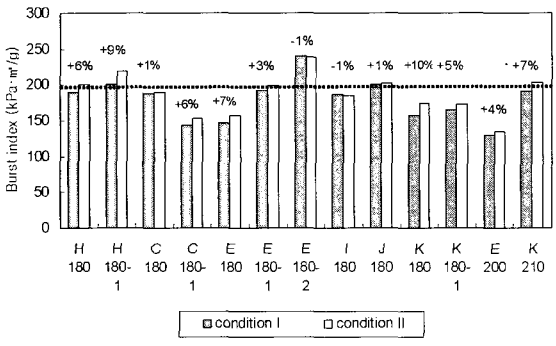

Fig. 3. The effect of different preconditioning on burst index of KC grades liners.

in the corrugated box industry and has been an important factor for the control of manufacturing process. Burst strength value was, then, converted to specific burst strength index based on basis weight. Figs. 1 ~ 3 show the results of burst strength test obtained from each sample. Dot line represents the standard value set by KS M 0000. All KK grade samples except one sample exceeded a certain Korean Standard value. However, all KA grade samples were less than the mark value. In case of KC grade, only three samples met the permissible burst strength criterion.

When compared with the preconditioning results by atmospheric condition I, the preconditioning results by atmospheric condition II seemed to have greater mean variation rate than the results by atmospheric condition I. It appeared that KA and KC grades were less than the mark value prescribed by Korean Standard as a result of fiber's hornification caused by repetitive recycle treatment. In case of KK grade, usually made by the mixed high quality of waste paper, met the permissible burst strength criterion prescribed in previous version of Korean Standard.

3.2 Effects of atmospheric condition on the ring crush strength

Compressive strength, usually measured by using ring crush test (RCT), is one of major factors in evaluating the characteristics of the liner paperboard. The compressive strength along with burst strength has a significant effect on the performance of the corrugated box. Previous version of Korean Standard prescribed different permissible ranges of specific compressive strength with different grades and basis weights for liner paperboard. After preconditioning, RCT was carried out. The results of the ring crush test

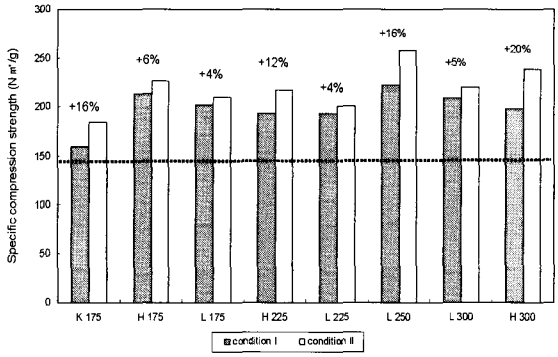

Fig. 4. The effect of different preconditioning on specific compression strength of KK grades liners.

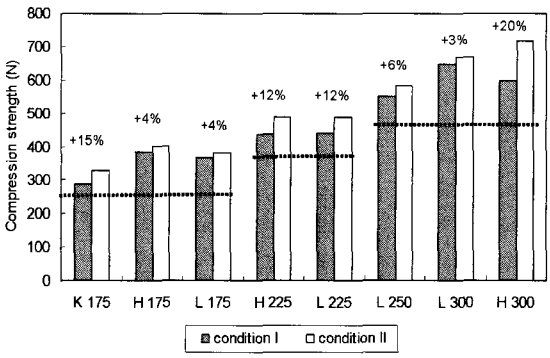

Fig. 7. The effect of different preconditioning on compression strength of KK grades liners.

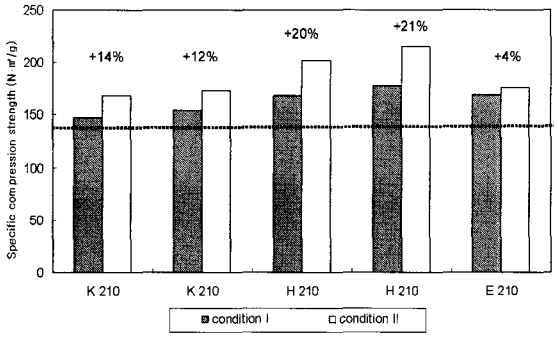

Fig. 5. The effect of different preconditioning on specific compression strength of KA grades liners.

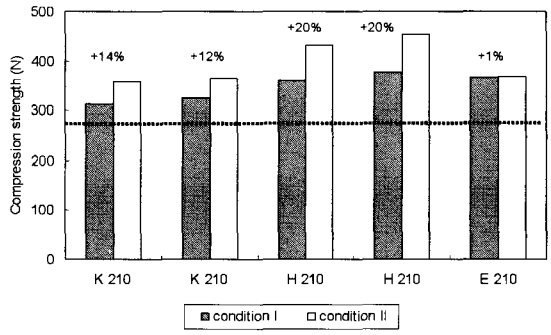

Fig. 8. The effect of different preconditioning on compression strength of KA grades liners.

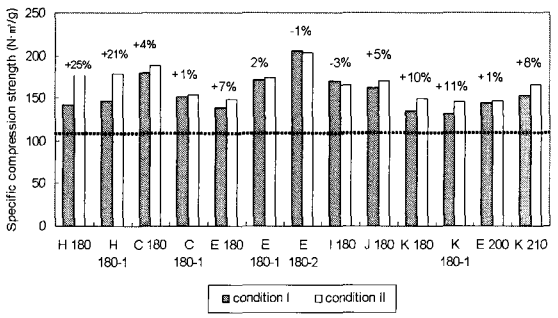

Fig. 6. The effect of different preconditioning on specific compression strength of KC grades liners.

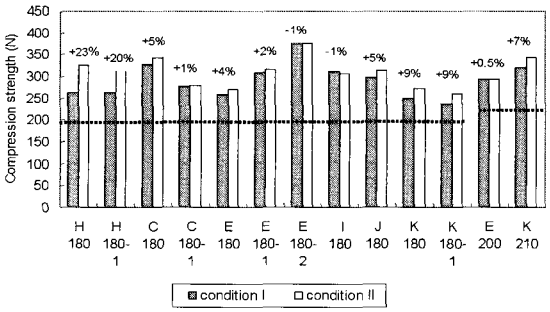

Fig. 9. The effect of different preconditioning on compression strength of KC grades liners.

Table 2. Average SCT(Short-span Compression Test) strength measured at two different atmospheric conditions **(Unit: kNm/kg)**

	Condition I Average	Condition II Average	Variation ratio	Condition I Permissible error
KK Grades 175 g/m^2	27.91	31.49	12.88	-
KK Grades 225 g/m^2	26.77	31.21	16.61	-
KK Grades 250 g/m^2	27.90	33.81	21.16	-
KK Grades 300 g/m^2	25.31	29.25	15.48	-
KA Grades 210 g/m^2	23.07	26.43	15.01	-
KC Grades 180g/m^2	23.22	25.82	11.42	-
KC Grades 200g/m^2	20.40	23.68	16.10	-

met the permissible burst strength criterion prescribed in previous version of Korean Standard, as in Figs. 4~9.

When the preconditioning was changed from atmospheric condition I to atmospheric condition II, the mean value of specific compressive strength was increased by 10.55%. KS M 7502 prescribes the mark value of specific compressive strength determined by RCT for each individual specimen on the basis of grade and basis weight. Compressive strength and specific compressive strength show the same trend and all samples exceeded a certain Korean Standard value. Compressive strength was increased when the preconditioning was changed from atmospheric condition I to atmospheric condition II.

3.3 Effects of atmospheric condition on the SCT of the liner paperboard

It is known that the SCT of the linerboard is closely correlated with compressive strengths of corrugated medium and corrugated box. There are no prescribing mark values of compressive strength determined by SCT. Table 2 shows the average SCT strength values measured at both atmospheric condition I to atmospheric condition II.

It is shown that compressive strength values obtained by using SCT were increased when the preconditioning was changed from atmospheric condition I to atmospheric condition II. All of samples, regardless of grade appeared to be very sensitive to the atmospheric condition (Figs. 10~12). It appears that the SCT can be used to

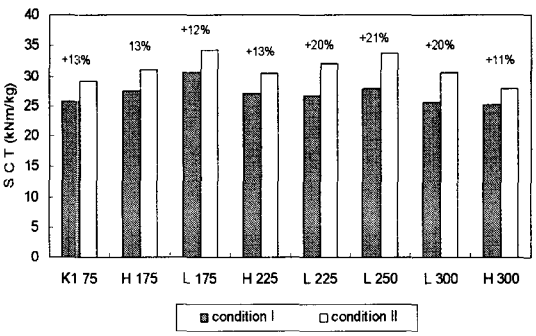

Fig. 10. The effect of different atmospheric condition on SCT strength of KK grades liners.

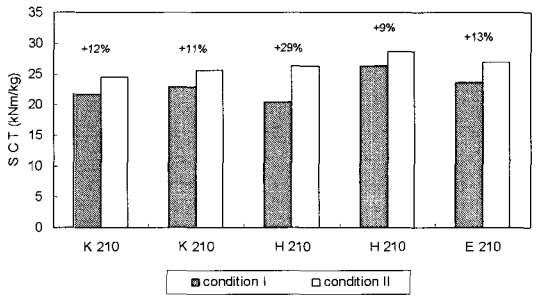

Fig. 11. The effect of different atmospheric condition on SCT strength of KA grades liners.

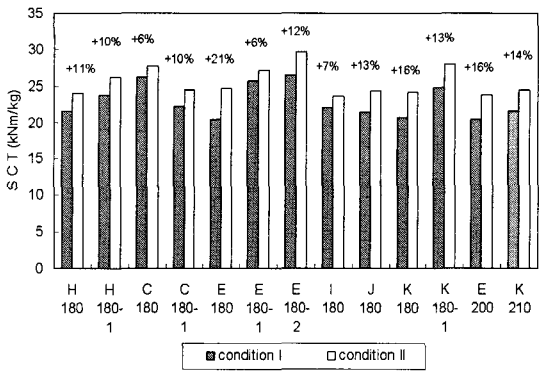

Fig.e 12. The effect of different atmospheric condition on SCT strength of KC grades liners.

evaluate the performance of linerboard in a sense that SCT is efficient test method for measuring the compressive strength of a slender corrugated linerboard with buckling of the specimen constrained.

4. Conclusions

This study was carried out in order to evaluate physical and mechanical properties of domestic liner paperboard under two different atmospheric conditions and finally to provide the basis data set for the standardization research, and investigate the relationship between environmental preconditions and physical and mechanical properties of linerboard. There was about 10% increase in the specific compressive strength of linerboard when atmospheric condition was changed from environmental preconditions I to environmental preconditions II. However the specific burst strength of the liner paperboard showed slight increase when preconditioning was changed from atmospheric condition I to atmospheric condition II. While the basis weight of the liner paperboard showed a little difference when atmospheric condition was changed, the moisture content of linerboard showed big difference when atmospheric condition was changed from environmental preconditions I to environmental preconditions II. It is suggested that the short span compression test (SCT) can be used to evaluate the performance of liner paperboard at different moisture content and relative humidity.

Acknowledgement

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