The change of the bending stiffness of handsheets during humidity cycle

습도에 따른 수초지의 휨강성 변화

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1. Introduction

Paper is a strong hygroscopic material that undergoes substantial dimensional changes with moisture content variation. Mechanical properties of paper also change with exposing to different humidity conditions. Since strength properties of paperboards are critical for their end use it is very important to understand the effect of moisture content of paperboard on strength properties. Furthermore, the lifetimes of corrugated paperboard boxes are greatly reduced when they are exposed to cyclic change in temperature and humidity in warehouses, it is of prime importance to understand the influence of cyclic changes of humidity on paperboard properties. The response of papers and paperboards under various relative humidity conditions has been explored experimentally by several researchers [1,2,3,4], but there is still many aspects that remained to be explored.

It is well known that high bending stiffness of paperboard is of importance to obtain rigidity and strength, and the bending stiffness is considerably dependent on macroscopic thickness and distribution of elastic modulus.

This study was intended to demonstrate the change of bending stiffness, elastic modulus and thickness under cyclic humidity conditions.

2. Experimental

Figure 1 illustrates the procedures to prepare long fibers fraction and fines fraction with UKP. The fractionation was carried out using Sweco® Vibro-Energy® separator. The average fiber length and width of long fiber fraction were 2.33 mm and 31.3 ㎛, respectively. To produce fines fraction, the original UKP stock was subjected to severe beating for a long time. It had the fiber length of 0.22 mm and the width of 23.1 ㎛.

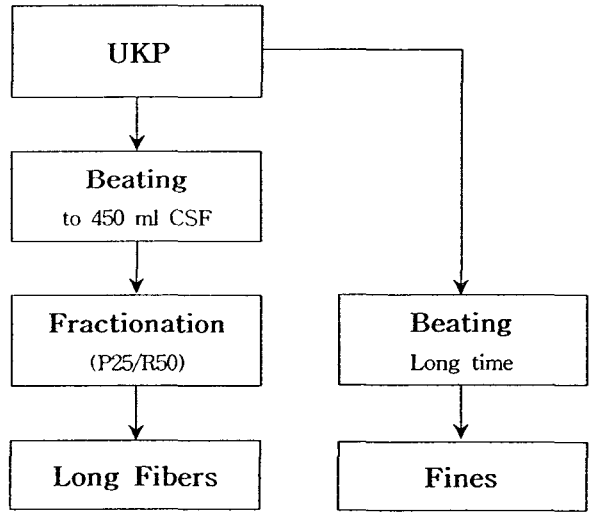

Figure 1. Procedures for the preparation of long fibers and fines fraction with UKP.

The handsheets were formed according to TAPPI Test Method T205 sp-02. Single-ply handsheets containing different amounts of fines were made to have oven dry weight of 100 g/m^2. Handsheets were cut into a suitable size for physical testing, and then preconditioned to reach equilibrium in a standard conditioning room (51% RH, 23 ℃) for more than 48 hours. After this preconditioning treatment in the standard humidity chamber, the

pre-cut testing specimen were exposed to different humidity conditions in sequence consisting of 74%, 94%, 51% and 32% RH. After conditioning under these conditions bending stiffness, elastic modulus and apparent thickness of the samples were measured according to TAPPI Test Methods. The relative humidity in the testing room was maintained to the same level as that employed when the samples were conditioned.

3. Results and discussion

Single-ply handsheets were made containing different amounts of fines in the sheet, ranging from 0% to 20% at 5% increments.

Fig. 2 shows RH vs. moisture content, and the bending stiffness, elastic modulus and thickness as a function of moisture content for single-ply handsheet with no fines. When the samples were exposed to high humidity condition in humidity cycling, they absorbed moisture. Exposure to lower humidity condition afterwards caused reduction in moisture content. Cyclic humidity conditioning of the samples clearly showed hysteresis effect. With increasing moisture content, bending stiffness and elastic modulus decreased and thickness increased. Bending stiffness and elastic modulus showed reversible change. However, as depicted in Fig. 3, single-ply handsheet with 10% of fines showed irreversibility in bending stiffness. It showed higher bending stiffness during de-hydration. None the less elastic modulus changed quite reversibly when subjected to a change in moisture content. Similar results were exhibited for handsheets containing 20% of fines as shown in Fig. 4. The difference in bending stiffness due to hysteresis in moisture content became greater as the fines content increases in the sheet.

The relationship between bending stiffness and elastic modulus under cyclic humidity follows in Fig. 5. As expected, it could be comprehensible that

elastic modulus played a great role in the change of bending stiffness over the entire moisture cycle. Otherwise, as documented in Fig. 6, thickness increase accompanied by the increase of moisture content did not improve bending stiffness.

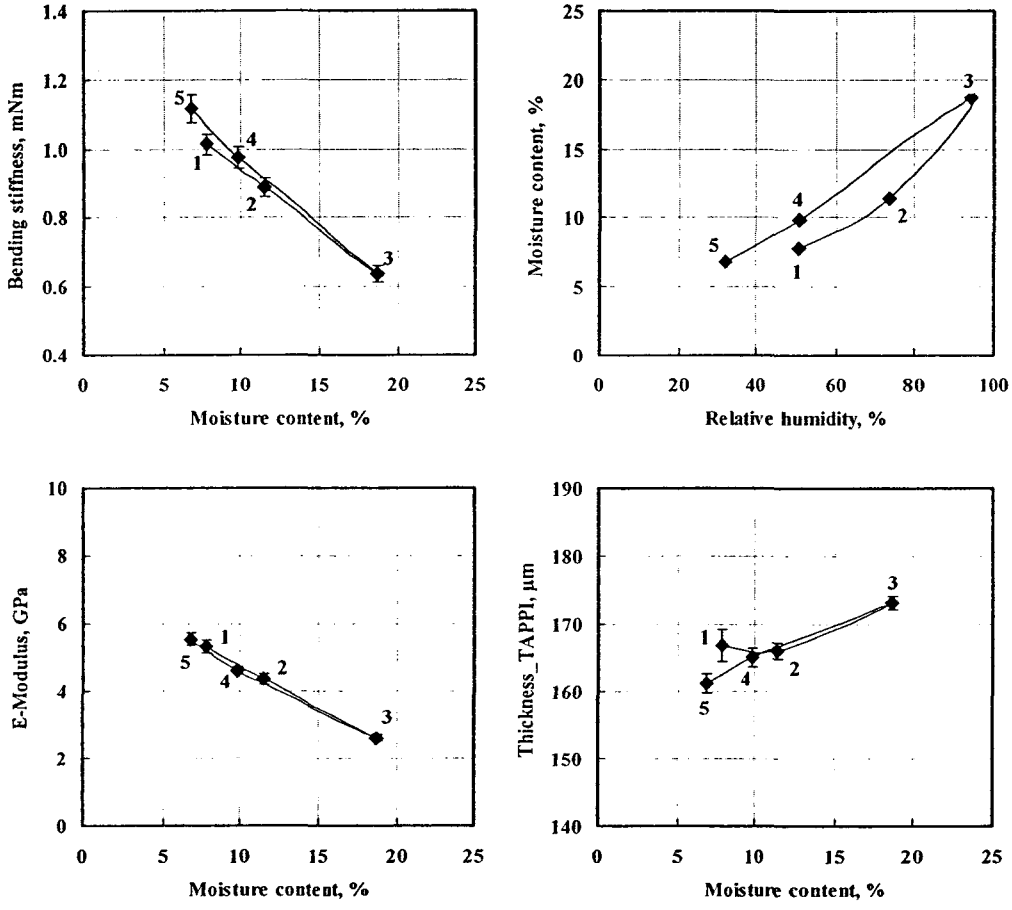

Figure 2. RH vs, moisture content and bending stiffness, elastic modulus and thickness of handsheet plotted as a function of moisture content. It was made of long fiber fraction of UKP.

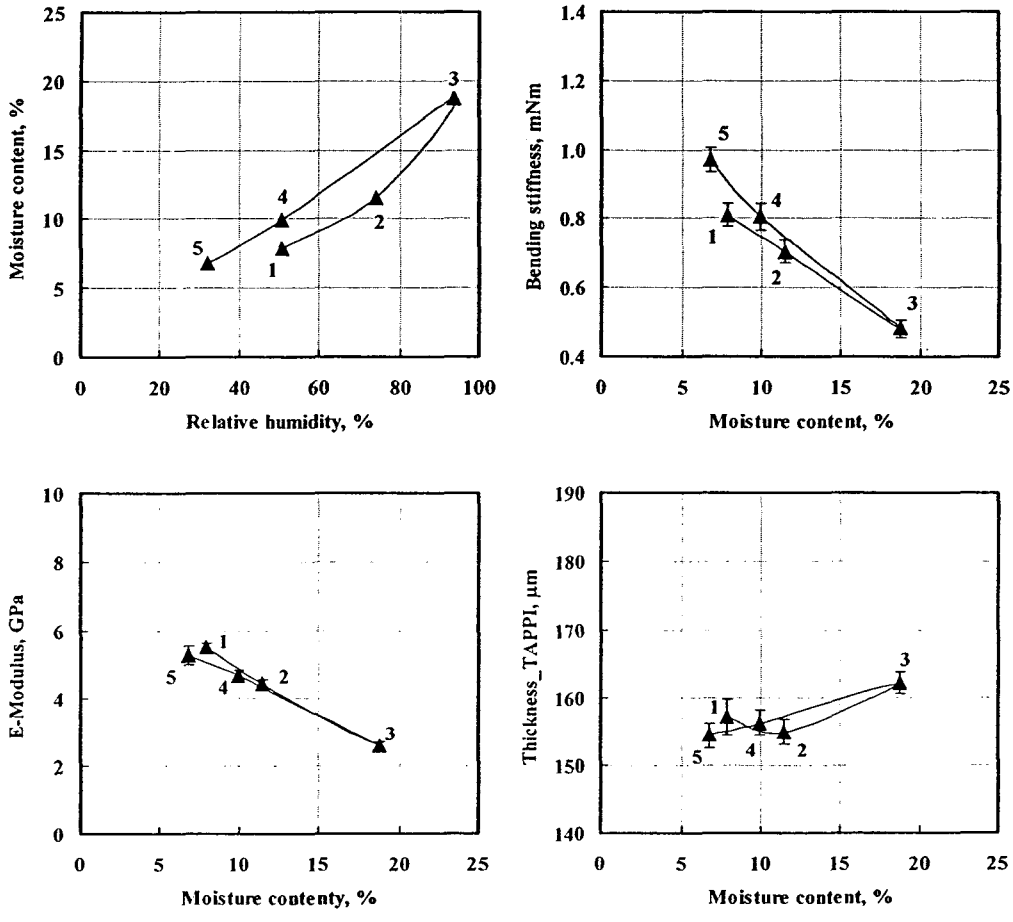

Figure 3. RH vs. moisture content and bending stiffness, elastic modulus and thickness of handsheet plotted as a function of moisture content. It was made of UKP with 10% fines.

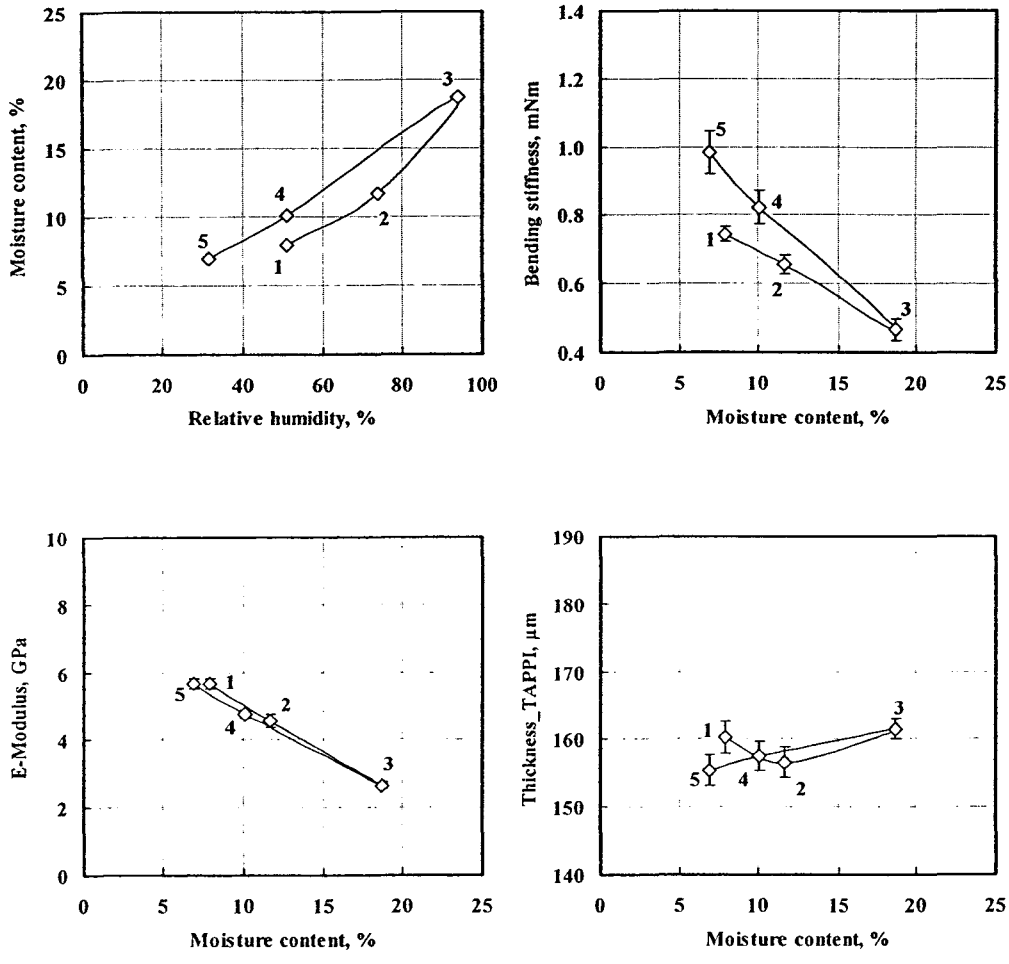

Figure 4. RH vs. moisture content and bending stiffness, elastic modulus and thickness of handsheet plotted as a function of moisture content. It was made of UKP with 20% of fines.

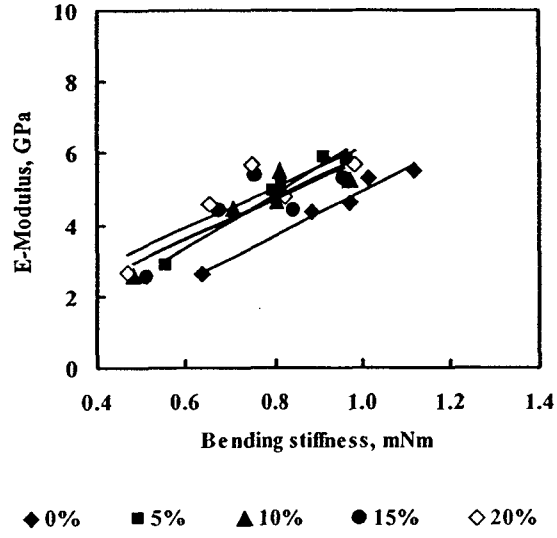

Figure 5. Relationship between bending stiffness and elastic modulus of single-ply handsheets made of UKP with different amounts of fines.

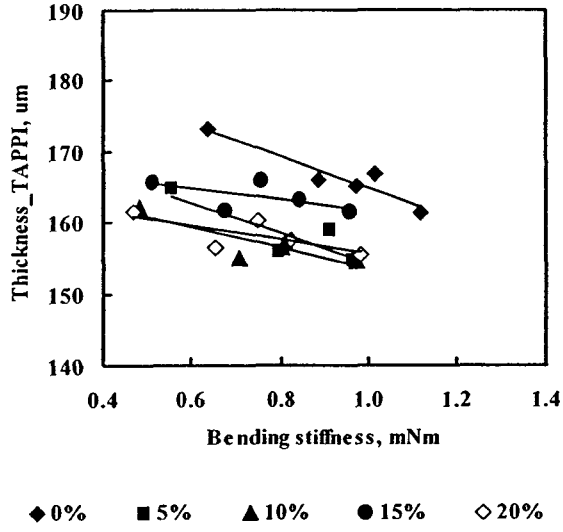

Figure 6. Relationship between bending stiffness and thickness of single-ply handsheets made of UKP with different amounts of fines.

4. Conclusions

Bending stiffness, elastic modulus and thickness of handsheets under humidity cycling conditions were evaluated. Bending stiffness of handsheets with low fines content changed reversibly, while that with high fines content showed irreversible change. Results for elastic modulus showed quite reversible change. It appeared that elastic modulus was a definite factor for increase or decrease of bending stiffness by moisture changes.

References

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