Fundamental study on developing wood powder as an additive of paperboard

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ABSTRACT: In this study, we investigated the applicability of wood powder to the manufacture of paperboard. Laboratory studies and mill trials were carried out to develop wood powder suitable for a functional additive of paperboard and to determine its ability to improve the sheet bulk and to reduce the drying steam. The wood powder was manufactured by grinding and screening. The maximum particle size was a critical factor affecting the applicability of the wood powder as an additive. In the laboratory studies, handsheets containing the wood powder were made, and their physical strength properties were analyzed. The wood powder increased the sheet bulk and decreased the physical strength of the sheets. The mill trials were performed in a white lined chipboard (duplex board) mill, and the wood powder was added to the middle ply of Sunny Coated (SC) 300 g/m^2 and 400 g/m^2, a commercial grade of duplex board that contains a back ply made of deinked pulp. As the level of the wood powder was increased, the bulk increased linearly, and the drying steam decreased significantly. We conclude that well-manufactured wood powder can be used as an additive for paperboard and is beneficial with respect to bulk improvement and drying steam reduction.

Application: Wood powder can be used as an additive to improve paper thickness and to decrease drying energy in a duplex-board mill. Because this material is added to the middle ply of paperboard, papermakers can achieve bulk improvement and steam reduction without the deterioration of paper strengths.

Paperboard is a thick paper product with a higher basis weight than that of printing and writing paper. There are many grades of paperboard, but most are multiply products [1]. The main advantage of multiply manufacture is the ability to utilize inexpensive low-grade waste material, such as old newspapers (ONP), recycled office paper, old corrugated containers (OCC), and old magazine (OMG), in the inner plies of the board [2]. As the recycled pulps usually deteriorate the strength and thickness of the paperboard and increase the drying energy consumption due to hornification and high fines content [3-5], reducing the use of recycled pulps in the manufacture of paperboard is the first step to decrease production costs and to increase paperboard qualities.

Many researchers have tried to develop alternatives to virgin pulps or recycled fibers [6-12], but paper mills have not adopted practical alternatives. This has occurred because research has focused only on the pulping of new material and not on other ways to incorporate new materials in the papermaking process. Thus, the industry must find a new paradigm to practically apply alternatives to cellulosic fibers in the papermaking process.

Paper bulk, which is defined as the inverse of paper density [13], has drawn increasing attention from both papermakers and paper customers. For papermakers, if the paper bulk can be increased, the stiffness and opacity of the paper can be enhanced by using less pulp fibers, thereby producing the same thickness paper with reduced paper weight, saving on costs of raw materials [14]. Therefore, a functional additive to increase paperboard bulk was explored based on the ability to increase paperboard bulk.

Many researchers reported that mechanical pulp fibers are stiff and do not collapse easily in papermaking because of high lignin content and that they help to improve the paper bulk [15-16]. Thus, we selected wood powder as a functional material because it is stiff and cheaper than mechanical pulps. Wood powder is finely pulverized wood and commonly utilized as filler in thermosetting resins and in linoleum floor coverings. It is also the main ingredient in wood/plastic composite building products.

In this study, we carried out laboratory and duplex board mill studies on the paper bulk, strength, and drying energy reduction to investigate the potential utility of this wood powder.

MATERIALS AND METHODS

Materials

Mixed woods, including softwoods and hardwoods, were used to prepare wood powder suitable for the manufacture of paperboard. Korean old corrugated containers (KOCC) were used to make handsheets in a laboratory. To retain the wood powder in the handsheets, Percol 175 supplied from BASF Schweiz AG (Basel, Switzerland) was used. Bleached kraft pulp (BKP) and various recycled pulps were used to manufacture the duplex boards in the mill tests.

Wood powder manufacture

Wood powder was manufactured by G-Biotech Co. Ltd. (Seoul, South Korea). After the mixed woods were pulverized to small particles, a screening process was performed to prepare many classes of wood powder according to maximum particle size. All the classes of powders that were manufactured were not utilized. Instead, the optimal class was selected by observing the surface roughness of handsheets containing wood powder with the naked eyes. When the surface test was carried out, handsheets with grammage 135 ± 4 g/m² were manufactured with KOCC and wood powder. The average particle size of the final wood powder was measured using a particle size analyzer (Mastersizer 2000, Malvern Instruments Ltd.; Malvern, UK).

Handsheet preparation at laboratory scale and measurement of physical properties

The KOCC was soaked for 18 h and then disintegrated at 10% consistency for 30 min using a standard disintegrator according to TAPPI Standard Method T 205 sp-06 "Forming handsheets for physical tests of pulp." The disintegration time was determined by the separation of the individual fibers. After disintegration, the KOCC was diluted to 0.5% consistency for the handsheet preparation. Handsheets with grammage of 135 ± 4 g/m² were produced by adding wood powder according to TAPPI Standard Method T 205 sp-06. After the wood powder was added to the pulp suspension and mixed for 1 min, 0.1 % of Percol 175 was added and mixed for 1 min at 600 rpm. Then, handsheets with grammage of 135 g/m² were produced. The handsheets were wet-pressed at 3.5 kgf/cm² for 5 min and dried at 120°C using a laboratory wet press and a cylinder dryer, respectively. The dried handsheets were conditioned at 23°C and 50% relative humidity (RH) to control the moisture content of the handsheets at 8%. They were then calendered using a supercalender (45FC-200EI, Kumagai Riki Kogyo Co. Ltd.; Tokyo, Japan) at 500 psi and 25°C. The physical properties and the strength of the sheets were measured, including their bulk (TAPPI Standard Method T 411 om-10 "Thickness [caliper] of paper, paperboard, and combined board"), breaking length (TAPPI Standard Method T 494 om-06 "Tensile properties of paper and paperboard [using constant rate of elongation apparatus]"), burst index (TAPPI Standard Method T 403 om-10 "Bursting strength of paper"), and compressive strength (TAPPI Standard Method T 818 cm-07 "Ring crush of paperboard [flexible beam method]"). The location of wood powder particles in Z-direction of the handsheet was identified using a scanning electron microscope (JSM-6701F, JEOL Ltd.; Tokyo, Japan).

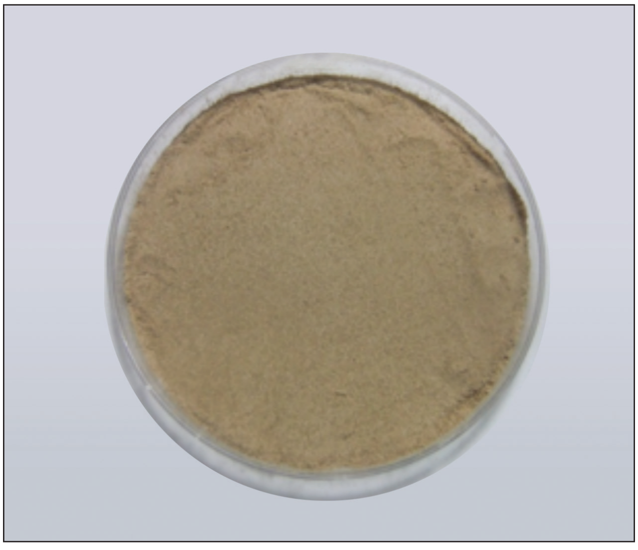
Mill trials

Mill trials were carried out at Hansol paper mill in Daejun to identify the effect of the wood powder on the bulk and the amount of drying steam of the duplex boards simultaneously. The mill trials were performed separately according to the grammage of Sunny Coated (SC) duplex board (a commercial grade of white lined chipboard with a back ply made of deinked pulp), 300 g/m² (SC 300) and 400 g/m² (SC 400), respectively. The wood powder was supplied by G-Biotech Co. Ltd. and added to a pulper with OCC directly, without any dilution. The addition levels of the wood powder were controlled to 4%, 6%, and 8% on o.d. OCC fibers, and retention aid was added to improve wood powder retention. The bulk and drying steam reduction of the samples of duplex boards were analyzed before and after the addition of the wood powder.

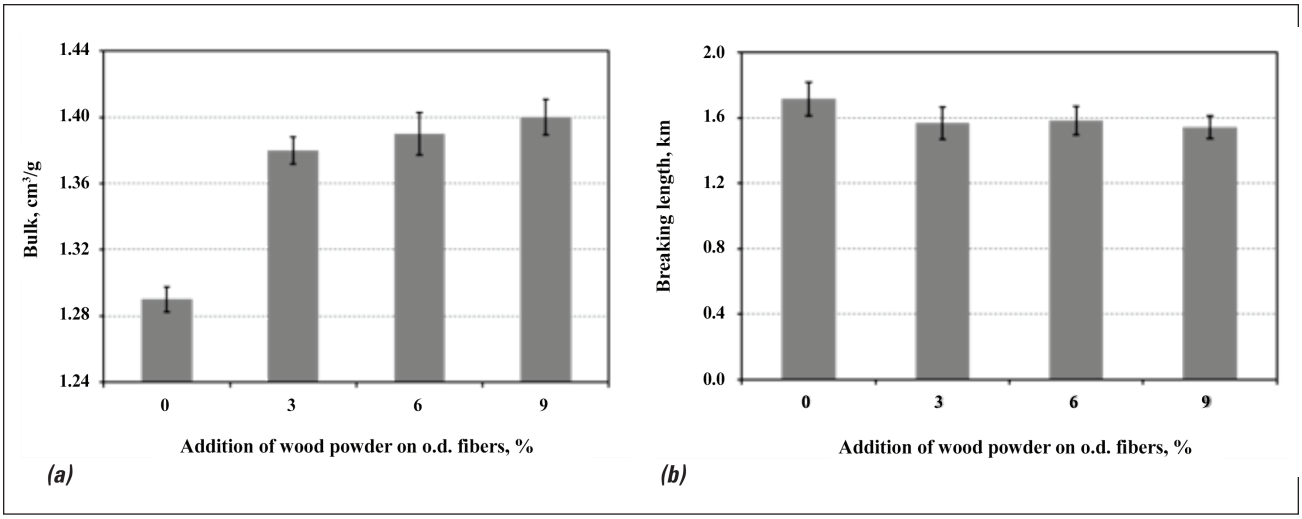
RESULTS AND DISCUSSION

Wood powder properties

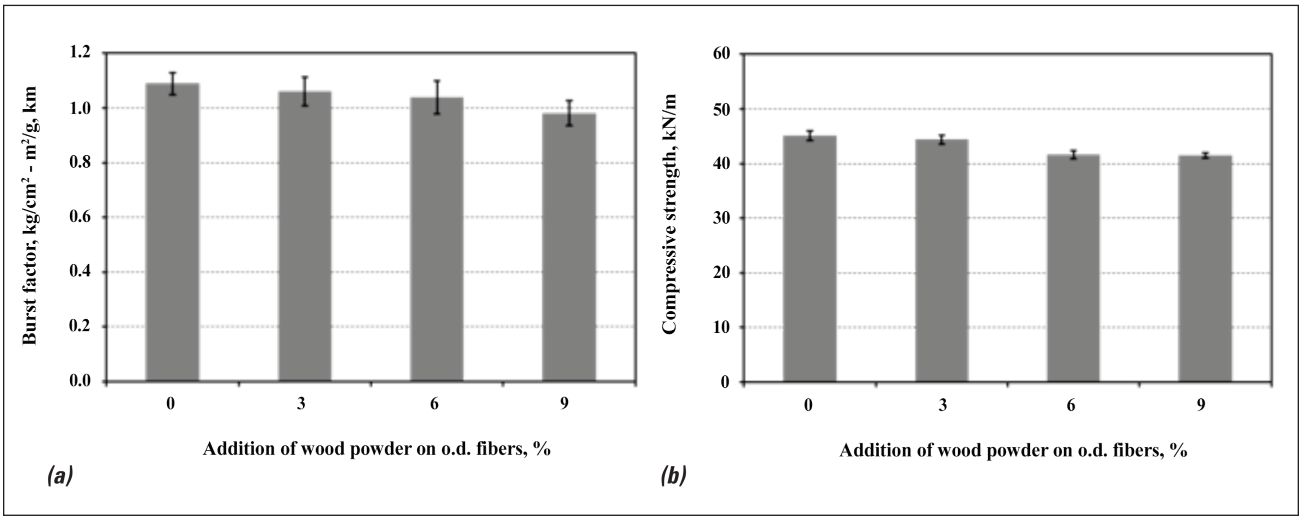
Various classes of wood powder were manufactured, and the applicability of the wood powder as an additive suitable for paperboards was estimated by observing the surface property of sheets containing the wood powder. As commercial wood powder used in industry commonly shows larger average particle size than cellulosic fibers or paperboard thickness, it cannot be used as an additive for paperboards because of surface extrusion. Thus, the first task was to determine the critical factors affecting surface extrusion. We observed the surface extrusion caused by the wood powder without any instrument analysis because the extrusion occurred irregularly in sheets. The average particle size, particle size distribution, particle shape, and maximum particle size of the wood powder were controlled, and the relationship between these parameters and the surface extrusion were analyzed. We found that the maximum particle size was the most critical



1. Image of the developed wood powder for manufacture of the paperboards.



2. Effect of wood powder on bulk (left) and breaking length (right) of sheets.



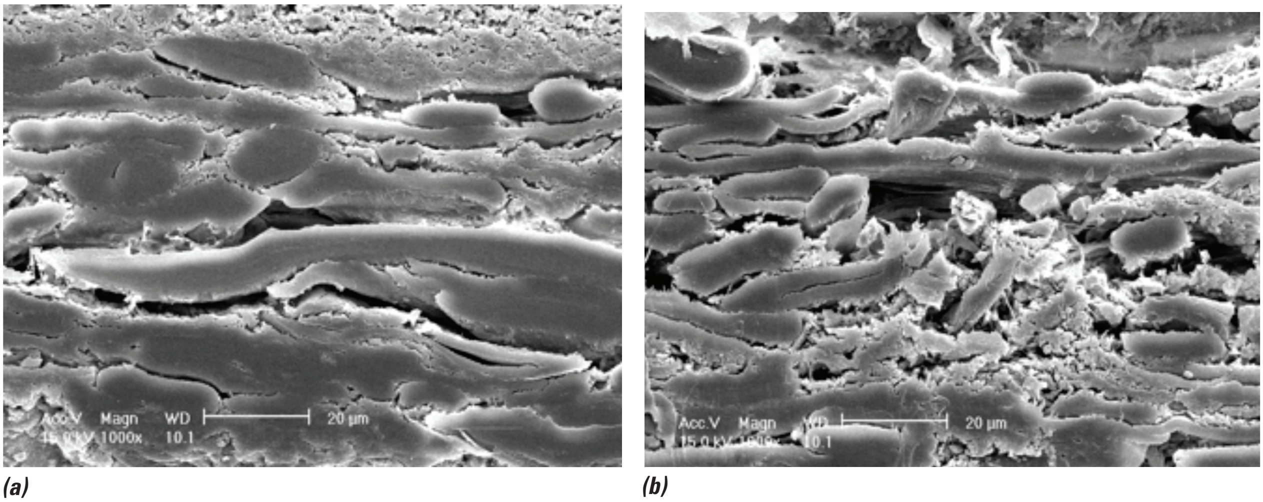
3. Effect of wood powder on burst factor (left) and compressive strength (right) of sheets.

property of the wood powder for surface extrusion. Therefore, surface extrusion was investigated as a function of the maximum particle size of the wood powder in a surface test of sheets containing the wood powder. We found that the maximum particle size must be less than 0.3 mm to remove surface extrusion. The final average particle size was 48-50 µm. The wood powder used in the manufacture of the paperboards is shown in **Fig. 1**.

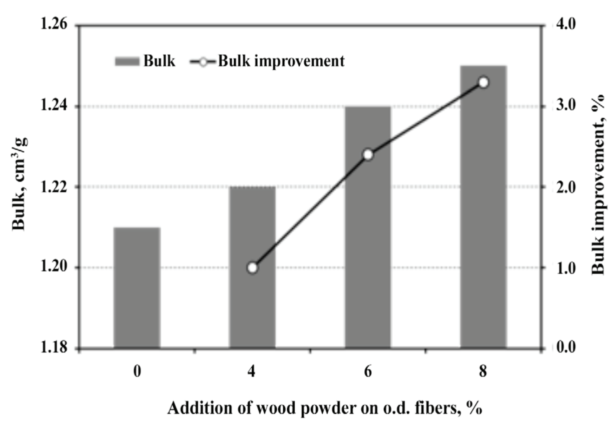
Laboratory handsheet properties

Wood powder was added to KOCC, and handsheets were manufactured. **Figure 2** shows the effect of the wood powder on the bulk and the breaking length of the handsheets. The bulk of the handsheets increased significantly in accordance with an increase in the amount of wood powder added. The bulk improvement was greatest with the addition of 3% wood powder. When the addition of the wood powder increased from 3% to 9%, the bulk increased linearly. This indicates that wood powder increases the bulk significantly and that the paper bulk improves proportionally in accordance with an increase in the amount of powder added. As the bulk of the sheets increased, the breaking length decreased. As shown in **Fig. 3**, the burst factor and the compressive strength of the sheets also decreased as the amount of wood powder added was increased. Researchers have reported that materials that increase the paper thickness decrease the area of fiber bonds and paper strengths [17-20]. These phenomena can be explained by the location of wood powder particles in the Z-direction of a paper. As shown **Fig. 4**, the wood powder particles were embedded as an expander, which increased paper thickness and loss of strength [17]. The decrease in the strength cannot be avoided, but the strength level can be controlled by adjusting the addition level of the wood powder.

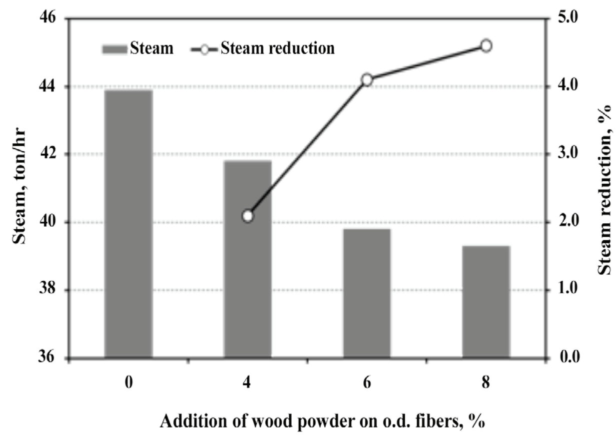
The wood powder can also be utilized to improve the bulk of the paperboard. To achieve desired bulk and physical



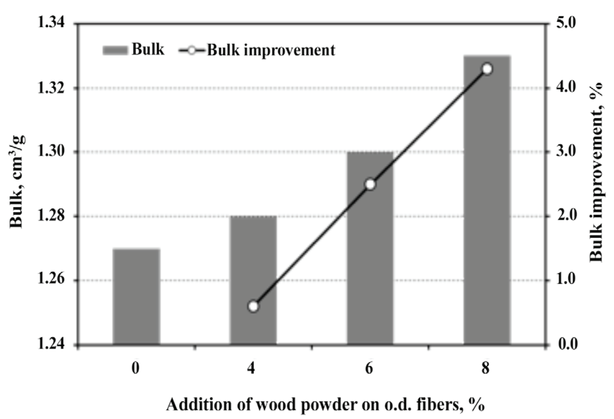
4. Scanning electron micrographs of Z-direction of handsheets without wood powder (left) and 9% wood powder (right).



5. Effect of wood powder on the bulk improvement of Sunny Coated (SC) 300 g/m² grade of duplex board in mill trial.



7. Effect of wood powder on the drying steam reduction of Sunny Coated (SC) 300 g/m² grade of duplex board in mill trial.

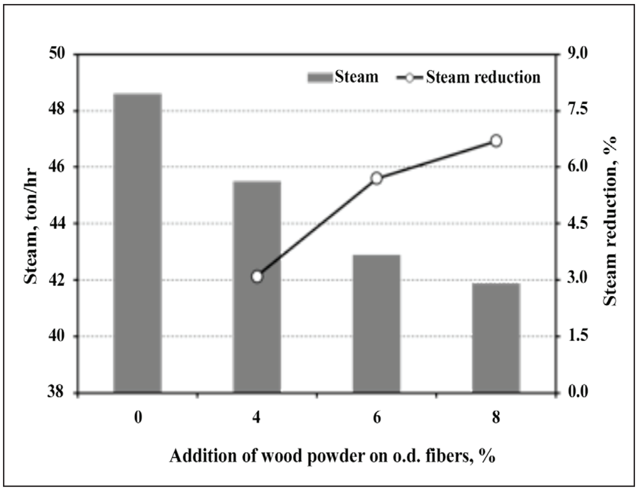


6. Effect of wood powder on the bulk improvement of Sunny Coated (SC) 400 g/m² grade of duplex board in mill trial.

strengths simultaneously, the amount of wood powder that can be added has to be controlled.

Mill trial

In the mill trials, the paper machine speed and the press pressures during duplex board manufacture were not changed, because other independent variables were removed to try to replicate the effect of the developed wood powder on paperboard properties and drying steam reduction under normal conditions. SC 300 and SC 400 grades were selected to identify the effect of grammage on the bulk and the drying steam reduction when the wood powder was added. When the thickness of the duplex board changed, the stock flow from the OCC storage tank was controlled to maintain the thickness of the duplex board to the range of product specifications. Samples with physical properties in the range of product specifications were selected for the analysis of



8. Effect of wood powder on the drying steam reduction of Sunny Coated (SC) 400 g/m² grade of duplex board in mill trial.

bulk measurement and determination of the drying steam.

When the wood powder was added to the process, the thickness increased, and the strengths did not decrease significantly compared to control samples because the wood powder was added only to the middle ply of the duplex board. Also, the addition level was not high enough to decrease the strength significantly. **Figures 5** and **6** show the bulk improvement of the SC 300 and SC 400 grades as a function of the addition level of the wood powder. These data show that the wood powder linearly increased the bulk of the duplex board and that a high grammage is more effective than a low one. **Figures 7** and **8** show the trend of drying steam as a function of the addition of the wood powder. As the addition level of the wood powder increased, the drying steam decreased linearly. The steam reduction with SC 400 was higher than with SC 300, showing that the wood powder is more effective in terms of steam reduction when duplex board with a relatively high grammage is used.

We concluded that the wood powder can replace OCC fibers, which are detrimental to the efficiencies of dewatering and drying and that well-manufactured wood powder can result in bulk improvement and drying steam reduction.

ABOUT THE AUTHORS

The Korean paper industry faces many difficulties related to virgin pulp and recycled fibers because of the lack of natural biomass. Many researchers have tried to develop alternatives to the pulps, but paper mills have not adopted practical alternatives because most of the research has focused only on pulping new materials and not on other ways to incorporate new materials in the papermaking process. In this study, we investigated the suitability of wood powder for use in the manufacture of paperboard. Our work was the first such attempt in Korean paper industry.

The most difficult aspect of this research was that conventional wood powder used in many industries was not appropriate as an additive for paperboard because its particle size was larger than both the particle size of OCC fibers and the thickness of the sheets. Thus, a variety of wood powder classes was manufactured according to the particle size, and laboratory studies were carried out to develop a wood powder suitable for paperboard production.

We discovered that the maximum particle size of the wood powder was the most important factor in determining its potential use. It was determined that the maximum particle size should not be over 0.3 mm.

Wood powder is considered an important additive and is widely used to reduce production costs in Korean duplex board mills. After this work, we will research the most effective technology to acquire improved physical strength with the greatest bulk for paperboard containing wood powder.

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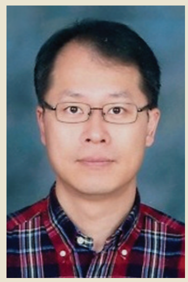

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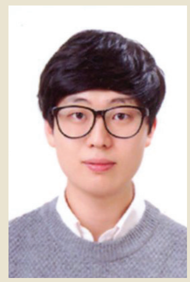

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CONCLUSIONS

Wood powder as an additive for paperboard manufacture was developed and tested in laboratory studies and mill trials. The wood powder was made from mixed woods, including hardwoods and softwoods, by grinding and screening, and its maximum particle size was controlled under 0.3 mm. To evaluate the effect of the wood powder on the physical properties of paperboard, handsheets containing wood powder were prepared, and the physical properties of the sheets were analyzed. Wood powder increased the bulk and decreased the strength of the sheets. The strength was not a critical issue because the bulk improvement was the most important property. Moreover, the strength could be controlled by adjusting the addition level of the wood powder. Mill trials were carried out in a duplex board mill, and the manufactured wood powder was applied to the middle ply of SC 300 g/m^2 and 400 g/m^2 to identify the functionality of the wood powder in actual paperboard. The wood powder was added to a pulper with OCC, and the addition levels were controlled to 4%, 6%, and 8% on o.d. OCC fibers. As the addition level of the wood powder increased, the bulk increased linearly, and the drying steam decreased significantly. The strength did not decrease significantly because the wood powder was added only to the middle ply of duplex board, and the addition level was not high enough to decrease the strength significantly. We conclude that well-manufactured wood powder can be used as an additive for paperboard and that it is beneficial to the bulk improvement and drying steam reduction. **TJ**

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