Study on Modeling of Fuser-generated Curled Sheets and a Prediction of Dog-Ear Defect in a Sheet-feeding Unit Using a Three-dimensional Sheet-feeding Simulation

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Abstract

Modeling of curled sheet for three-dimensional sheet feeding simulation was studied. Dimension and stiffness of curled sheet that affected by moisture content of sheet was studied experimentally. Curled sheet was modeled by using obtained sheet characteristics, and three-dimensional sheet feeding simulation was executed by using the model. It was confirmed that our model can simulate dog-eared defect of fuser-generated curled sheet in sheet feeding unit.

Introduction

Two of the main issues in the development of printers are to achieve sheet-feeding stability with various kinds of sheets and to shorten the development period. In recent years, studies on sheet handling have been performed [1][2] that enable us to develop a sheet-feeding path efficiently; however, defects resulting from sheet-feeding instability still occur because many three-dimensional defects cannot be analyzed with a two-dimensional simulation. Therefore, we focused on the three-dimensional behavior of sheets in sheet-feeding unit and started developing an analysis method [3][4].

The feeding of curled sheets (Fig.1) is a major problem because it induces many reliability problems, such as sheet jam and dog-ear defects. Sheet curl is caused mainly by thermal deformation as a sheet passes through a fuser unit. As this happens, the sheet is curled, and the moisture content of the sheet is decreased by heat and pressure. The sheet curl occurrence mechanism is difficult to analyze, and it is an obstacle to shortening the development period. Because the mechanism of this phenomenon is not fully understood, a sheet-feeding path is designed based on past experience and examination of prototypes.

As part of our efforts to design a stable sheet-feeding unit, we focused on the feeding of curled sheets and predicting the dog-ear defect.

In this study, we discussed a three-dimensional sheet-feeding simulation based on the characteristics of curled sheets to predict the dog-ear defect in sheets passing through sheet feeding unit.

Cause of Dog-ear defect

A dog-ear occurs when a sheet edge is caught and folded while the sheet is being fed through a sheet-feeding unit. Figure 2 shows causes of the dog-ear defect. Catching the edge of a sheet happens easily when a sheet is curled, and/or the sheet-feeding path has gaps, such as openings in sheet guide for rollers or sheet detectors. Folding occurs more easily with sheets that are less stiff.

The amount of curl and stiffness of a sheet are related to its moisture content, which is affected by the atmosphere. To stabilize sheet feeding, the feeding unit must be developed so that it matches the sheet characteristics.

Figure 1. Curled sheets

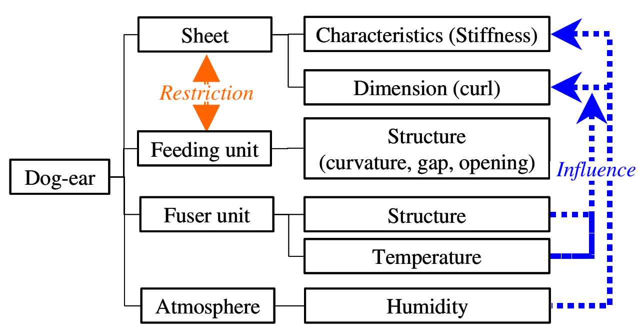


Figure 2. Cause of dog-ear defect

Experimental apparatus

To better understand the characteristics of curled sheets, continuous printing tests were conducted with printer equipment.

Figure 3 shows a cross-sectional view of the printer. A sheet is picked up with the pick-up roller, and a toned image is transferred electrically to it at the second-transfer unit. When the sheet is nipped at the fuser unit, the toner on the sheet is heated, and it is melted to fix the toned image. At the fuser unit, the sheet undergoes heat and pressure, which causes it to curl, and the dog-ear defect occurs occasionally at the feed roller with particular type of sheet.

We achieved 250-page continuous printing without toned images and measured the amount of sheet curl.

Figure 4 shows the definition of the amount of sheet curl. Stack heights of several types of sheets at their four corners and at the midpoints of their four edges were measured, and the difference between the maximum and minimum heights were used as the maximum amount of curl Δmax of the sheets. It was previously determined experimentally that the curl amount is affected by the moisture contents of a sheet. The moisture contents of the sheets were controlled and moisture contents of the used sheet were varied. The moisture contents and Young's modulus of the sheets were measured before and immediately after the continuous printing test. The moisture content was estimated as a ratio of the original weight to the dry weight, and Young's modulus E was measured by the vibration reed method.

Characteristics of sheet curl

In this section, the sheet curl characteristics are discussed based on the results of the continuous printing test. Four types of sheets, including sheet A, which is prone to dog-ear defects were used. Sheet B, C and D represent common sheet that can feed stably without dog-ear defect.

Figure 5 shows the relationship between the moisture content of a sheet and the maximum curl amount Δmax. It is clear from this figure that Δmax increases as the moisture content of the sheet increases, and the effect of the moisture content depends on the sheet type. In addition, sheet A exhibits a larger amount of curl than the other sheets.

From now on, discussion about sheet characteristics is focused on sheets A and B. Table 1 lists the basic properties of these sheets.

Figure 6 shows the relationship between the initial moisture content of a sheet and its Young's modulus E in the longitudinal (sheet feeding) direction.

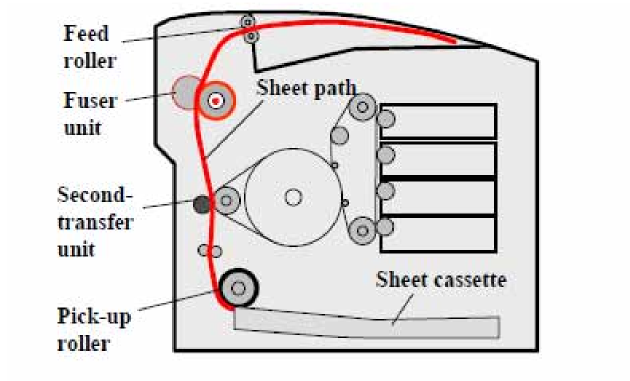
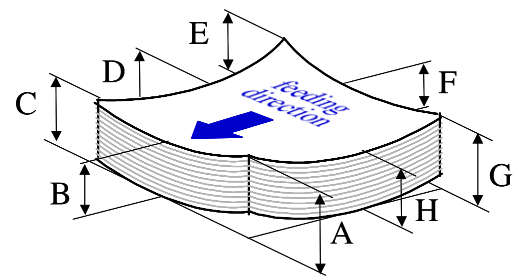


Figure 3. Cross-sectional view of printer



$$\Delta max = MAX(A\text{-}G)\text{-}MIN(A\text{-}G)$$

Figure 4. Measurement of amount of sheet curl

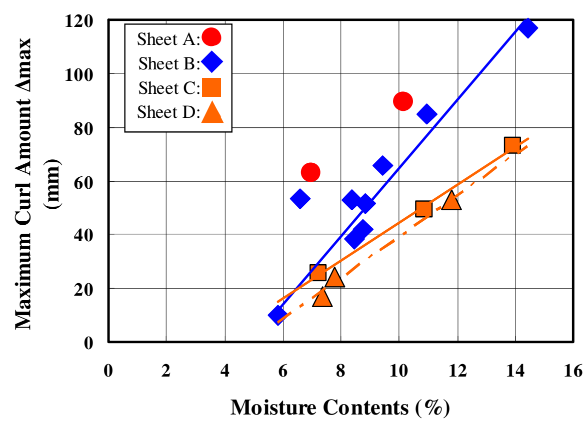


Figure 5. Relationship between moisture content and maximum curl amount

Table 1. Basic properties of sheets

Sheet	Size [mm] (Lateral x Longitudinal x thickness)	E [x10^9 Nm^{-2}]*
A	210 x 297 x 0.07	4.5
B	216 x 276 x 0.10	12.4

* room temperature / room humidity

In this figure, the moisture content of the sheet is represented by the initial moisture content. This figure shows that Young's modulus increases as the initial moisture content of the sheet decreases.

To describe the tendency for a sheet to have a dog-ear defect, the concept of bending stiffness was used.

Figure 7 shows the relationship between the moisture content of a sheet and its bending stiffness in the longitudinal direction. In this figure, the moisture content measured immediately after the printing test was used as the data for "after fusing." The bending stiffness Sb was calculated with equation (1).

$$Sb = Ebt^3/12, \qquad (1)$$

where b denotes the sampling width of the sheet and t is the thickness of the sheet.

It is found that the bending stiffness increases as the moisture content of the sheet decreased. Tendency of reduced moisture content and increased bending stiffness after fusing are also observed. Furthermore, plots of before and after fusing exhibit the same pattern. The effect of moisture content on the bending stiffness is different depending on the sheet varieties, and the trend can be measured as a unique characteristic of the sheet. In this test, change of sheet thickness was less than 3%, it can be interpreted that structural properties of a sheet do not change before and after fusing but only the influence of the moisture content changes. From this, it is determined that considering the change of bending stiffness is important to estimate the sheet-feeding behavior as the sheets pass through the sheet-fusing unit.

Three-dimensional sheet-feeding simulation

The obtained sheet characteristics immediately after the sheets passed through the sheet-fusing unit was used to simulate three-dimensional sheet feeding. The curl dimension was measured using three-dimensional shape-measurement equipment and generated coordinates for the model.

Figure 8 shows the dimensions of an actual curled sheet and its model. In this simulation, a pre-curled sheet with properties of after fusing was inserted into the fuser unit and fed through the feeding unit, and the moisture content of the sheets was determined for sheet A was dog-eared.

Figure 9 shows the model of sheet feeding unit. In this model, sheet-feeding pass is curved and the sheet is guided by upper and under sheet guide after ejected from the fuser unit. Openings are formed on upper and under sheet guide, and upper and under rollers are arranged to contact each other through them. The curled sheet is flatten at the nip area of fuser unit, and change back into the curled form as the sheet is ejected from the fuser unit. In this simulation, every sheet was fed into the curled sheet-feeding pass

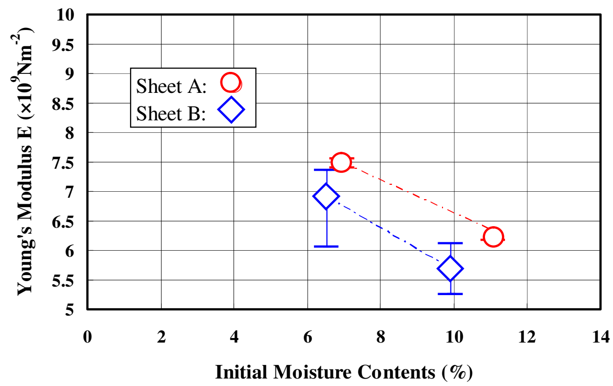


Figure 6. Relationship between initial moisture content and Young's modulus

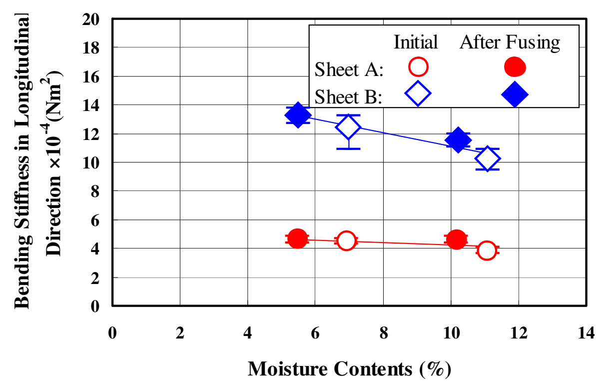
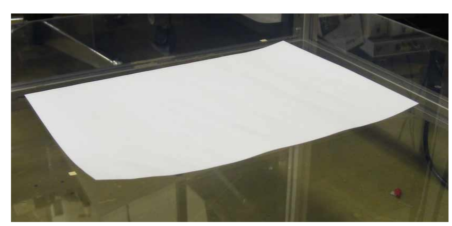
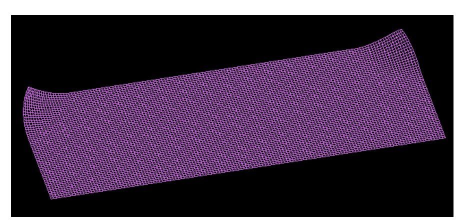


Figure 7. Relationship between moisture content and bending stiffness in longitudinal direction



(a) Actual curled sheet



(b) Model

Figure 8. Model of curled sheet

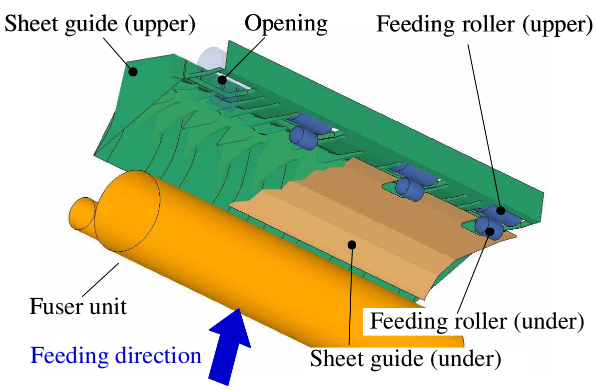


Figure 9. Model of sheet feeding unit

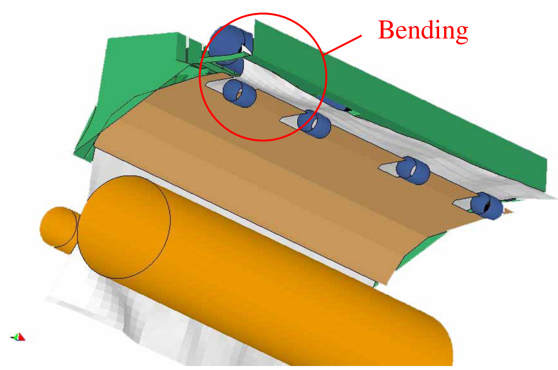


Figure 10. Result of three-dimensional sheet-feeding simulation (Sheet A)

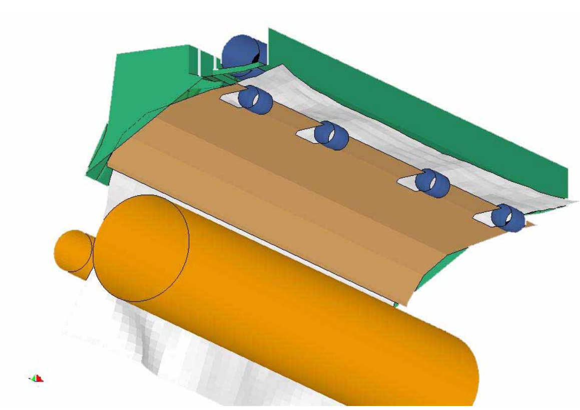


Figure 11. Result of three-dimensional sheet feeding simulation (Sheet B)

without problems in spite of their curled form.

Figure 10 shows the result of the simulation with sheet A in which the sheet got caught on an opening in the sheet guide for the feeding roller. In this simulation, the bending continued until sheet edge came out of the feeding unit but did not progress to the point of sheet folding.

Figure 11 shows result of the simulation with sheet B in which the sheet did not get caught at the opening in the sheet guide for the feeding roller.

From these results, it is determined that our model can simulate the dog-ear defect of fuser-generated curled sheets in a sheet-feeding unit. Using this analysis method, stable sheet-feeding unit can be designed.

Conclusion

Modeling of curled sheets for a three-dimensional sheet-feeding simulation was studied. The effect of moisture content on the stiffness and dimensions of curled sheets was studied experimentally, and following results were obtained.

(1) After fusing, moisture content is reduced and bending stiffness is increased. The effect of moisture content on the bending stiffness is different depending on the sheet varieties, and the trend can be measured as a unique characteristic of the sheet.

(2) Curled sheet was modeled using obtained sheet characteristics, and three-dimensional sheet feeding simulation was executed by using the model. It was confirmed that our model can simulate dog-eared defect of fuser-generated curled sheet in sheet feeding unit.

References

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Author Biography

Shogo Matsumoto received a Master's degree in Mechanical Engineering from the Science University of Tokyo in 1988 and joined the Mechanical Engineering Research Laboratory of Hitachi, Ltd. in the same year. In 2005, he transferred to the Research & Development Center of Ricoh Printing Systems, Ltd. He has been engaged in the development of non-impact printing systems. He is a member of IS & T, ISJ and JSME.