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Design and Control of Guide-wheel-type Paper Alignment Mechanism to Improve Production Reliability of Corrugated Paper Plants

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The manufacturing process for corrugated paper products is usually mass production and batch-by-batch production. Therefore, a high-speed mass production is required. Because the conveyer speed of the production line in a corrugated paper plant is very fast, unwanted material loss or even process interruption may occur during the cutting or clipping process if the corrugated paper on the conveyer is slanted. Hence, the paper alignment on a conveyer is important and necessary. In this study, we install photo-couples at both edges directly over the conveyer path to detect whether or not the corrugated paper is slanted from the number difference between non-activated photo-couples of the two edges. The deviated angle is calculated through a computer program using the detected information, and a servomotor-driven wheel aligns the paper in accordance with the calculated angle. This work reduces the material waste and promotes the production reliability and utility rate of the material for a corrugated paper plant.

Nomenclature

W	True width of the paper
L	Measured paper width
θ	Slant angle
φ	Rotation angle of the wheel
Θ	Alignment resolution
d	Shortest distance between the centers of two adjacent photo-sensors

1. Introduction

Manufacturing processes for a corrugated paper product are pasting, cutting, cohering, printing, and forming. Because the market requirement for corrugated paper products is increasing day by day, the manufacturing must be a mass production.(1) Before pasting, if the corrugated paper on the conveyer is slanted,(2) the paper will become waste material because of the followed cutting process and thus, investment loss is incurred.(3) The forward speed of a conveyer in a corrugated paper plant is about 100 to 200 meters per minute. A large amount of

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waste materials may be generated under such a fast conveyer speed. Therefore, paper material alignment on a conveyer is important and necessary for an efficient manufacturing process.

Nowadays, most paper plants use a guide plate mechanism to solve the slanted-paper problem. The schematic diagram of the mechanism is shown in Fig. 1. However, the paper material breaks frequently during practical operations owing to the mismatch between the conveyer speed and the open-and-close speed of the plates. Consequently, the manufacturing process must be stopped for readjustment, which is laborious and time-consuming.

In this study, we propose a guide wheel mechanism; Fig. 2 shows a schematic diagram of the guide wheel mechanism, which is composed of a set of photo-couples at each edge directly over the conveyer path,(4) a guide wheel that is used to align the deviation of the paper material, and an AC servomotor that drives the guide wheel to replace the traditional guide-plate-type alignment mechanism.(5)

2. Alignment Mechanism

2.1 Determination of slanted direction

According to the width of the conveyer and the required resolution of measurement, equal numbers of reflection-type photosensors should be installed directly over the conveyer path at both sides of the center line of the conveyer. The surface of the conveyer should be reflective, and thus be made of reflective material or with reflective paint. The sensitivity of the photosensors should be adjusted such that they cannot be activated by any disturbance other than by the reflected light of the conveyer.(6) The guide wheel is installed at the middle of the two rows of photo-couples and directly over the center line of the conveyer, and it presses down on the paper material with an adequate normal force. At the beginning of the manufacturing process, the paper material should be adjusted to a straight direction that is judged by receiving equal numbers of non-activated signals from the photo-couples on each side, as shown in Fig. 3. The paper on the conveyer may slant to either the left or the right during conveyance. The slanted direction must be known before alignment can be performed. The slanted direction can be

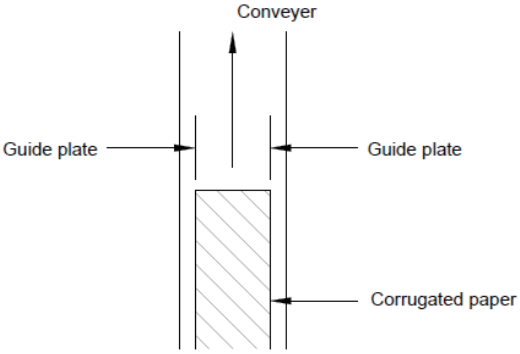

Fig. 1. Schematic diagram of the guide-plate mechanism.

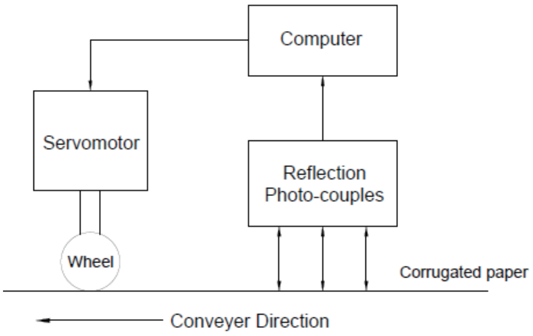

Fig. 2. Schematic diagram of the guide wheel mechanism.

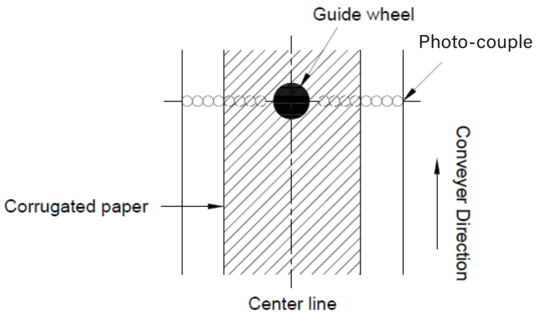

Fig. 3. Initial position of the paper material for the guide wheel mechanism.

judged from the variation in the numbers of non-activated signals of photosensors. As shown in Fig. 4, once the paper slants to the right during conveyance, the number of non-activated signals from the right side will increase whereas that from the other side decreases. Similarly, the number of left-side signals increases if the paper slants to the left. Figure 5 depicts the left-slant situation. If the numbers of non-activated signals from the two sides are the same, then the paper material is moving in a straight direction, as shown in Fig. 3.

2.2 Determination of slant angle

If the paper material is slanted, the numbers of non-activated photo-couples on the two sides will be different. As shown in Fig. 6, the measured paper width L is obtained by summing up the distributed distance of all non-activated sensors. Accordingly, the slant angle θ is derived as

$$\theta = \cos^{-1}\frac{W}{L} . \tag{1}$$

The guide wheel rotates θ but in reverse direction so as to align the slanted paper material to the straight direction. Therefore, the rotation angle of the wheel φ is written as

$$\varphi = -\theta . \tag{2}$$

It is seen that the rotation angle is zero if the paper is already moving in the straight direction and the guide wheel need not be operated.

2.3 Determination of shortest distance between centers of two adjacent photosensors

The alignment resolution Θ represents the smallest slant angle that this mechanism can detect and align. The required shortest distance between the centers of two adjacent photosensors, d, in accordance with the required alignment resolution Θ is calculated as

$$d = L - W . \tag{3}$$

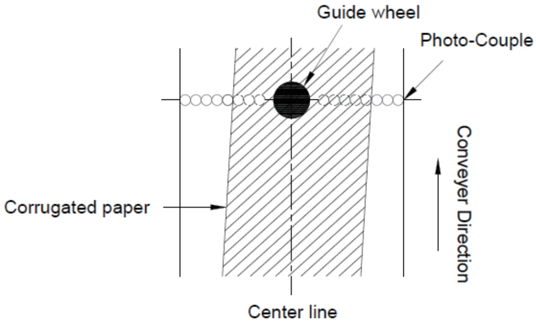

Fig. 4. Paper slants to the right.

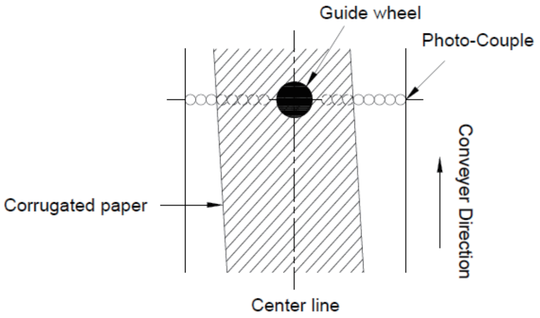

Fig. 5. Paper slants to the left.

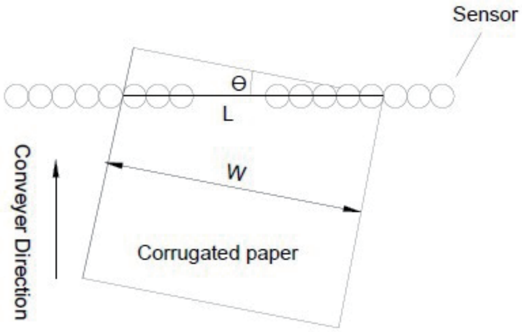

Fig. 6. Determination of slant angle.

For a given W and a measured L together with the required Θ, d is determined as

$$d = L - W = \frac{W}{\cos\Theta} - W = W\left(\frac{1}{\cos\Theta} - 1\right). \tag{4}$$

Accordingly, the alignment resolution is written as

$$\Theta = \cos^{-1}\left(\frac{W}{d+W}\right). \tag{5}$$

3. Experimental Setup

3.1 Sensors

In this study, we use reflection-type photocouples as sensors in the paper alignment mechanism. As depicted in Fig. 7, the sensor is composed of an LED, a phototransistor, and an optical filter lens. The lens is used to filter out light other than the light emitted by the LED so as to avoid the light interference problem. When the light of the LED is reflected to the photosensor,

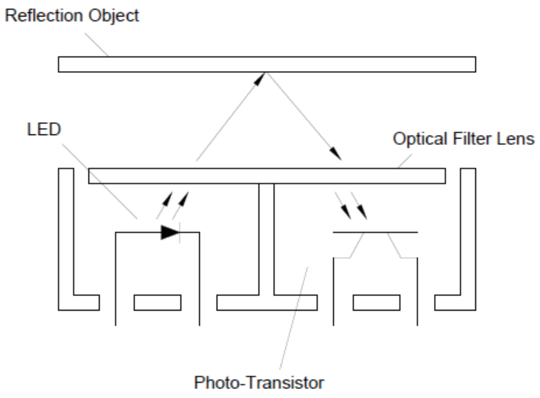

Fig. 7. Structure of the reflection-type photosensor.

the normal-open contact point of the photoswitch is closed such that the computer reads a logic-high signal. Otherwise, the computer reads a logic-low signal.(4)

3.2 Driving motor for the wheel

In this study, we adopt an HC-HKF43 universal AC servomotor that is manufactured by Mitsubishi Company, Japan.(7) This is a brushless and electronically controlled AC motor. The controller is a Mitsubishi universal AC servo controller.(8)

The servo system has the following features.

1. Three basic control modes and combinations among modes.

(1) Velocity control

The highest pulse rate is 500k pps. The pulse rate can be set by external analog instruction to perform a highly precise and smooth start/stop revolution or rotation direction change.

(2) Position control

The highest pulse rate can be resolved to 131072 pulses/rev to obtain highly precise positioning with an absolute position encoder.

(3) Torque control

The output torque can also be set by external analog instruction, and this function can provide no-load burst protection.

2. RS-232C and RS-422 serial communication interfaces are used to set parameters.

3.3 8255A interface card

A dual 8255A interface card, which is a programmable peripheral interface, is used between the microcomputer and the servomotor.(9,10) The assembled setup is shown in Fig. 8.

4. Results and Discussion

The slanted paper material being transported on a conveyer belt can be aligned to the straight direction by the setup depicted in Sect. 3. However, the following situations require extraprocessing.

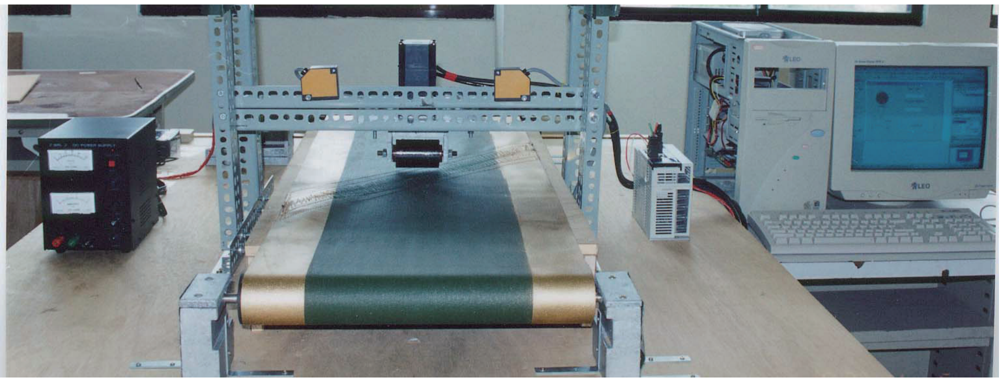

Fig. 8. (Color online) The assembled setup.

(1) The setup can only process a slanted situation, whereas a transverse shift, where the center-line of the paper material deviates from the center line of the conveyer belt, cannot be corrected by this setup. Therefore, the adjustment at the beginning of the manufacturing process is necessary and important. The execution time for this adjustment depends on the size of the corrugated paper. Normally, it takes 1–5 min.

(2) After the initial adjustment is properly performed, the forward speed of the conveyer should be accelerated gradually to the normal speed of the conveyer until the process becomes stable. According to experience, the acceleration time is approximate 60 s.

(3) In this study, W = 100 cm and Θ is prescribed as 10 deg. According to Eq. (3), d is calculated as

$$d = 100\left(\frac{1}{\cos 10^{\circ}} - 1\right) = 1.54\,(\mathrm{cm}). \tag{6}$$

Since Θ is decided by d, the size and layout of photosensors should be arranged according to the prescribed Θ.

(4) Because of the initial adjustment, the slant angle is usually small during the manufacturing process such that the paper material can be kept at a straight direction with only slight rotation of the wheel.

(5) The computing speed of the setup is fast enough to drive the guide wheel to correct slant situations under the normal forward speed of the conveyer. If the conveyer is faster than 200 meters per minute, as learned from the results of experiments, extra considerations and skills will be needed.

5. Conclusions

In this study, we set up a guide wheel mechanism to perform the alignment of slanted paper material on a conveyer in a corrugated paper plant. The traditional guide-plate mechanism may interrupt the manufacturing process and cause investment loss since the guide plate breaks the paper material under the fast forward speed of the conveyer. The proposed mechanism is composed of a guide wheel, photo-couples, a driving motor, and a control computer with its necessary peripheral devices. This mechanism provides better choice to avoid manufacturing interruption and material waste due to the paper slanting in the cutting process, and hence the production reliability is improved.(11)

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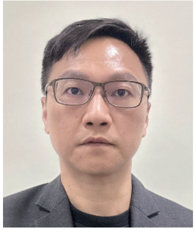

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