Image Monitoring and Analysis System for Glass Formation Process

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Abstract: The usable output of glassware formation production line depends, among other factors, on the weight and shape of a lump of hot molten glass called a gob. In this paper, an automated image processing system for monitoring gob weight and shape on a production line is proposed. Present techniques often rely on manual weighing of gobs on a sample basis by manually controlling the gob feeder. The proposed automated image monitoring system checks the weight and shape of every free-falling gob before it reaches the mould. In this system, the estimated weight of the gob is sufficiently close to its actual weight.

Keyword: gob, inspection, image processing, glass formation

1. INTRODUCTION

The process of feeding gobs of proper size and shape for the formation conditions is called gobbing. Gobs are most important in glass formation and must be made precisely and uniformly considering various factors. Nevertheless, while it is considered that the gobbing process in panel formation for high-precision glassware[1-2] products such as computer monitors is the most important stage for formation stability, the reality is that the gobbing process relies mainly on skilled operator know-how without the use of special measuring devices other than thermometers and gob weights. Accordingly, when the press is reactivated or the machine is replaced, a significant amount of time is required before production is stabilized quantitatively because of complicated setups and verification procedures.

Therefore, in order to resolve the problem of relying on operator experience during the gobbing process on the manufacturing line, this research has developed a new gob image monitoring and analysis system. It is a real-time image processing system, composed of a general zoom lens, CCD camera, and image processing board, that can analyze the gob shape and estimate the gob weight of a free-falling gob using image detection and acquisition algorithms. Now, on the manufacturing line[3], the Gob Image Monitoring and Analysis System (GIMAS) measures the variation in gob shapes, which used to be performed by skilled operators. Furthermore, a gob image processing system[4-7] using this type of automatic visual inspection[8] will be developed to quantify and standardize gob shapes. The system provides a gob tendency analysis following production line modifications, ensuring reproduction of gob formation and contributing to stable press operation.

2. FORMATION PROCESS AND GLASSWARE CONDITIONS

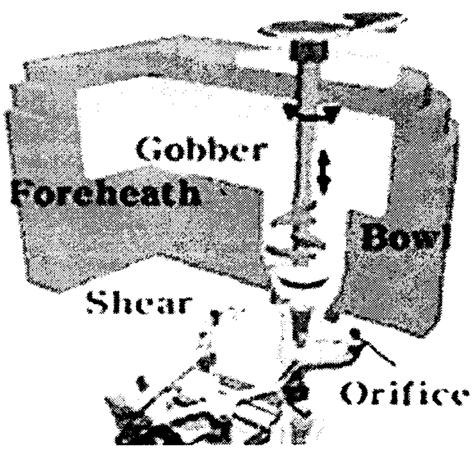

Fig. 1. The furnace for the gobbing process

Most important in panel forming are the shape of the gobs and a stable supply of free-falling gobs to the mould. As shown in Fig. 1, molten glass in the furnace is normally supplied through the forehearth. In the forehearth, hot molten glass flowing continuously from the furnace needs to be cooled down to a temperature of viscosity suitable for gob formation, and the heat difference inside the molten glass vertically from the entrance of the forehearth downwards must be minimized before it reaches the bowl because the glass must be homogeneous in the bowl, which is also very important in the gobbing process. In the bowl, the gobber moves up and down at a constant speed to discharge molten glass, which is cut by shears to become a gob. If the gobber does not move, molten glass will stream downward through the orifice ring due to gravity. So gobber movement also plays a role in preventing molten glass from streaming down during the gobbing process.

The gob has a variety of sizes and shapes depending on how it is formed. In general, the shape of a gob is described by L/D, the ratio of the maximum diameter D and the length L, and the gob weight and volume.

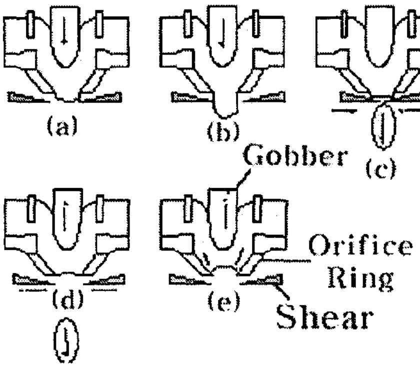

Fig. 2. Five steps for the gobbing process

The gobbing process consists of five steps as shown in Fig. 2:
(1) The gobber starts moving downward.
(2) Molten glass is discharged through the orifice ring by the gobber downward movement.
(3) Shears cut the molten glass.
(4) The shears move back and the gobber starts moving upward.
(5) Molten glass stops streaming downward due to upward movement of the gobber.

3. IMAGE MONITORING ALGORITHMS

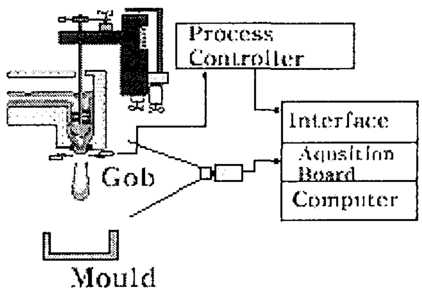

Fig. 3. Proposed system configurations

3.1 Gob Image Monitoring and Analysis System (GIMAS)

As shown in Fig. 3, the gob discharged from the furnace through the orifice ring by the downward movement of the gobber is cut by shears and falls due to gravity into a mould placed underneath. When the computer detects the movement signal of the shears, the camera takes pictures at a speed of 30 frames per second using the image monitoring board, and the GIMAS interprets the data of the captured images and calculates gob information. Currently available cameras cannot capture the free-falling gob to measure the shape of the gob, because their frames consist of even and odd fields with different times. In order to overcome this problem, this research adopted a progressive scan camera mode. As the camera in this mode allows us to get one frame of image at the same time, it is possible to obtain the contour data of a moving object in a system that can be implemented at a relatively low cost.

3.2 Camera Calibration

Since most panel factories were designed for conventional production processes, they are not suitable for installing a CCD camera. Therefore, the camera position may differ in every manufacturing process, and this was taken into account from the early stage of development. In order to measure the gob shapes quantitatively, the camera must be calibrated after installation. Also, as the camera must be calibrated in a high heat environment for ensuring easy use by ordinary workers, the calibration is much more difficult than in normal camera calibration work. Therefore, this study adopted the method of measuring the shape of an object of known size with the camera. As an example of calibration, as we already know the exact diameter of the orifice ring from the specifications of line installation or system replacement, we obtained the actual length of a pixel from the number of image pixels corresponding to the diameter of the orifice ring. To be more specific, the procedure is as follows:

(1) Choose the center of the orifice ring roughly while the gob is not flowing through the orifice ring.

(2) Read the pixel brightness of the center and create a new image by increasing regular brightness.

(3) Calculate the number of orifice ring distance pixels, P_orifice, from the new binary image.

(4) Compare the number of the orifice ring pixels, D_orifice, that we already know with the number of the pixels calculated in (3), to calculate the actual length per pixel, C_dpo.

3.3 Extraction Algorithm of the Gob Region

At the work site, a bright region is found not only on hot glass but also on surroundings that reflect strong light from the hot glass, rendering irregular shaped bright regions. To extract the bright region of a gob, image monitoring is generally performed using additional processing such as binary image, region extraction, and position or size of the extracted region. However, since it is impossible for an ordinary low-priced image monitoring board to monitor the free-falling gob image, we introduced the following image monitoring process in consideration of the peculiarity of the process.

When the gob is placed in the mould by gravity after being cut by the shears at the entrance of the orifice ring, the shape and the weight of the gob have a great influence on the panel quality after glass formation. Therefore, if we can control the shape and the weight of the gob quantitatively, we can produce quality panels. To extract the gob region from the captured image is easy if done with normal region-extraction techniques. However, for high-speed image monitoring, we introduced the following image monitoring technique based on the molten glass development point at the orifice ring.

3.4 Estimation of Gob Weight

It is an indirect way to estimate the gob weight from the binary image, but it still has significant meaning in that, despite some discrepancy from the actual weight, it continuously monitors the changes in weight without measuring the weight of the hot molten glass directly. In this paper, we measured the volume V_{gob}, area S_{gob}, and weight W_{gob} of the gob by calculating the width of the gob and assuming a disk with a thickness of one pixel in Fig. 4 as follows:

$$V_{gob} = \sum_{x=0}^{L} \pi d_x^2 / 4,$$

$$S_{gob} = \sum_{x=0}^{L} \pi d_x,$$

and

$$W_{gob} = \rho V_{gob}$$

where d_x is the diameter of the gob at the position x and ρ is the density of the gob.

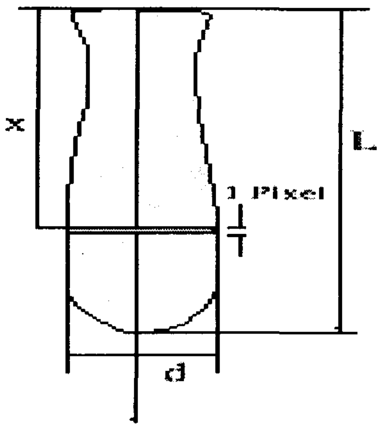

Fig. 4. The weight estimation of the gob

4. EXPERIMENTAL RESULTS

The field test was performed using the Gob Image Monitoring and Analysis System (GIMAS).

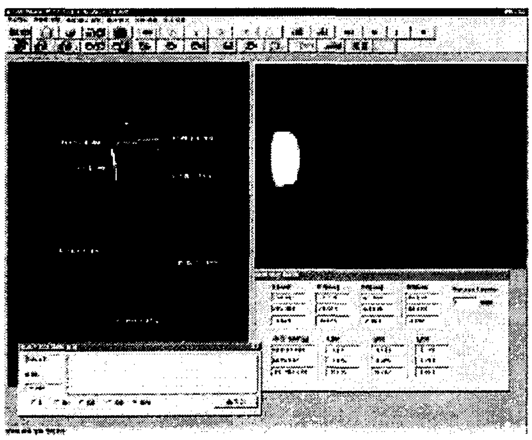

Fig. 5. An example of the parameter estimation of the gob

As shown in Fig. 5, an example of the main window is shown in the Windows application of the GUI environment. The program displays shape data for every gob generated, and by adding a function for comparing the shape data with the reference gob shape during manufacturing, allows the workers to easily monitor changes in gob shape resulting from process variables and to minimize the time and effort required to restore the system in the event a problem occurs. The gob weight estimated from the gob region is compared with the actual weight. As you will notice from the result in Fig. 6, the estimation is very close to the actual value.

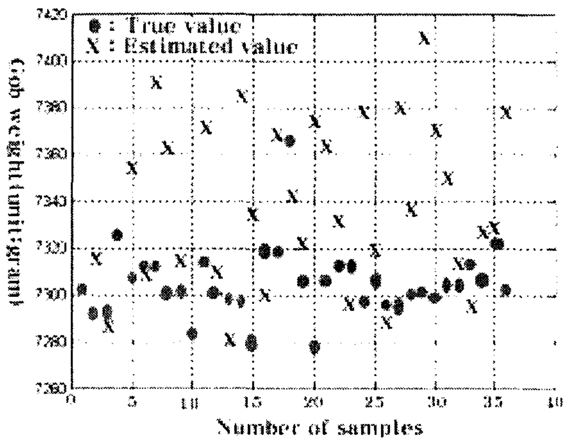

Fig. 6. Comparison with true and estimated value of gob weight

5. CONCLUSION

In forming glassware, consistent weight and stable supply of gobs to the mould is one of the most important factors for producing quality products. Nevertheless, it is true that the control of gob shape and weight has relied on intuition and experience of skilled operators. Now, quantitative management has become available with the image monitoring system developed from this research. Also, as it has become possible to determine any distortion at the earliest stage, faster process feedback and accurate corrective measures have become available, reducing the chances of errors previously made on the basis of skilled operator know-how.

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