Development of Software for Finding Cutting and Creasing Lines on a Corrugated Cardboard Web

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***Abstract*—the article discusses the issue of determining the actual positions of cutting and creasing lines on a corrugated cardboard web. which is very important for minimizing the losses. An approach is proposed to use photos of the cardboard web taken periodically during its continuous flow on the corrugator. A measurement complex was developed including a set of cameras mounted on a frame across the cardboard web coming out of the slitting machine. Multifunctional library EmguCV was used to design algorithms for identifying the lines on the image. Laboratory experiments with the measurement complex were made, and it is now ready for testing in production environment.**

I. Introduction

The competition among corrugated cardboard producers is growing with the arrival of new players, and in order to maintain the acceptable level of profitability there is an acute need to reduce production losses. One of the clear ways for that is to reduce the volume of defective products.

Quite often defects occur when the blades of the slitting machine get displaced during operation due to wear and tear, which disrupts the accuracy of cutting. Nowadays, the actual position of the blades is measured manually only at the very end of the production line, and until the incorrect position is noticed, the corrugator produces defective products. Similar situation is with the creasing lines on the cardboard web, which provide for controlled bending of the board (a creasing line is illustrated on Fig. 1)

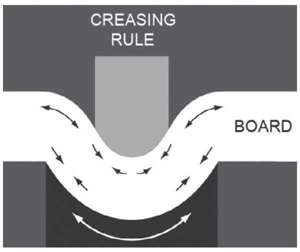

Fig. 1. A creasing line

Automated measurement of cutting and creasing accuracy will allow to dramatically shorten the time required to detect the deviation and thus reduce the volume of defective products, because maximum inside dimensions tolerance and crease spacing tolerance is ±2 mm, while typical speed of a corrugator is >300 m/min [1].

The article discusses one of the steps towards automating the measurement of position accuracy of cutting blades and creasing rules – automated identification of cutting and creasing lines on the cardboard web, and calculation of the distance between them. To reach this target, we propose to obtain a panoramic image of the web from a set of cameras, and identify on it cutting and creasing lines by image-processing algorithms.

II. Review of existing solutions

The main equipment for corrugated board production is the corrugator. Detailed information about corrugators can be found e.g. in [2].

The corrugated board quality and productivity of many corrugators is still largely dependent on the performance of operators, because it is very challenging to produce constant, high-quality corrugated board, and achieve a high level of productivity from the corrugator. The solution to this situation is automation of the corrugated board production process.

There exist a number of systems for automatic adjustment of important production parameters, including among others, ELCorruMatic TCCM [3]. With the maximum version of the system, the temperature, the web-tension and the moisture are measured and controlled optimally at all important places on the corrugator, permitting manual interventions from touch screen units, if necessary. However, the settings of blades are outside of the scope of this system.

Fosber's patented Constant System Rotary Shear allows a true gap-less order change [4]. It unifies the old and new orders so that a continuous flow of board runs through the web at all times.

However, the software tools of these systems are strictly tied to the equipment manufacturer and their installation on production lines of other manufacturers is impossible. Also, analysis shows that in Russia the use of such equipment in the production of corrugated board is very rare.

Another major problem is that although the Order Change System sets the blades to required positions, it doesn't monitor their actual positions afterwards. Due to the normal wear and tear of the equipment, cutting blades and creasing rules get displaced, which leads to incorrect sizes of the products, i.e. losses.

Currently, in the market there are no solutions for automated measurement of the actual distance between the cutting and creasing lines on the corrugated board web, so the distances are measured manually by operators every 5 to 10 minutes. Therefore, the required end-to-end automation of the corrugated board production process leads to the need also in automated measurement of the actual distances between the cutting and creasing lines

III. The measurement complex

The authors propose to use images of the corrugated board web to measure distances between the cutting and creasing lines. Due to the notable width of the web (up to 2200 mm) an array of cameras should be used to collect the images. The cameras are mounted on a frame positioned across the continuously moving web, which comes out of the slitting machine (Fig. 2). The number of cameras, their specifications, mounting height and location must be determined during laboratory tests prior to assembling the complex on a mill.

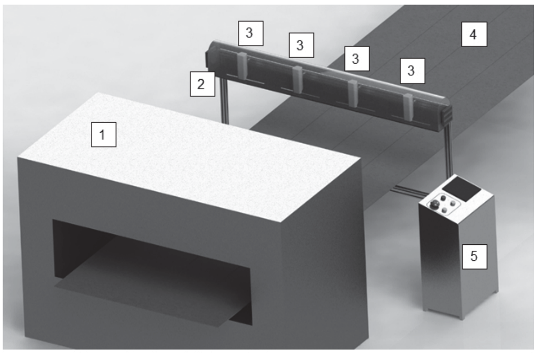

Fig. 2. Arrangement of the complex on the production line, where: 1 - slitting machine, 2 - bearing frame, 3 - cameras, 4 - corrugated board web with cuts, 5 - operator station

Upon a signal from the image processing station (at regular intervals or upon a command of the operator) the cameras synchronously take several photos of their dedicated areas of the web. The photos are then sent via router to the operator station for further processing. Special software tool then analyzes the photos, joins them into a panoramic picture of the whole corrugated board web, determines the actual distances between the cutting and creasing lines on it, and displays the results on the operator monitor. If some of distances differ from required values, an alarm is triggered to attract operator's attention immediately.

To obtain a panoramic picture of the whole web width, the cameras are located on the frame in such a way that photos taken by adjacent cameras share a common area of the web (the overlap area). To enable correct joining of photos into a panoramic picture of the web laser pointers are mounted on the frame between the cameras above the overlap area of adjacent cameras. The mounting of cameras and laser pointers is shown on Fig. 3.

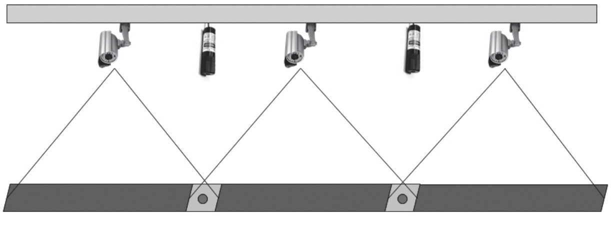

Fig. 3. The mounting of cameras and laser pointers on the frame

IV. The image processing software tool

The quality of photos taken by cameras is often aggravated by optical distortions, such as barrel distortion, pincushion distortion, and mustache distortion. Other distortions are in principle possible, but do not generally occur in practical lenses, or are small relatively to these [5].

Therefore, additional image processing is necessary for determining distortion coefficients and removing the distortions for a particular setup of the measurement complex. This procedure is called calibration and requires a reference set of images. For calibration we propose to make a series of 15-20 photos of printed black and white chessboard in different positions, with slope and offset. Next, the pictures are processed by a calibration algorithm, and distortion coefficients are determined.

Initially, images are obtained from the cameras in the RGB color model, which is simple in terms of hardware implementation, but is somewhat inconvenient for use by humans. HSV color model is more convenient in practice as it operates with such concepts as hue, saturation and brightness, where "hue" generally speaking indicates the color tone, "saturation" indicates how the color is diluted with white, and "brightness" or "value" is the intensity of the light. HSV model allows to search objects in the image by their color and brightness, and can be used to identity laser marks and cutting and creasing lines.

The laser marks are used to obtain panoramic picture of the cardboard web. After identifying the laser marks in the images from two adjacent cameras (by their distinctive bright red color), the images from these cameras are joined together so that these marks are aligned.

To identify the cutting and creasing lines the panoramic image is first preprocessed by a set of filters and transforms to distinguish the main corrugated board web from an "anomaly", which can be either a cutting, or a creasing line. These areas are then studied further.

By experimenting with actual board sheets the width of a cutting line was empirically identified as approximately 5 pixels. However, after cutting adjacent parts of the web may separate wider, as the web is often subject to defects such as warping (warped board does not lie flat on the level surface), vibrations, and "waves" in machine and cross directions, and other. Therefore, the actual width of a cut must be measured exactly in every case.

The classical approach to identifying lines on an image is the Hough Transform and its modifications [6]. Our experiments with actual board sheets have shown that it works acceptably well for identification of cutting lines. However, it fails to provide required precision, which is ±0.5 mm, when identifying creasing lines – U-shaped "gutters" on the cardboard web. Therefore, a proprietary algorithm was developed.

For development of image-processing algorithms we used EmguCV [7] – a cross-platform .Net wrapper to the OpenCV image processing library [8]. OpenCV (Open Source Computer Vision) is a popular library of programming functions, mainly aimed at real-time computer vision, which contains many modules, including detection and description of planar primitives, camera calibration, etc.

The measurement complex was assembled in laboratory environment of IT-park of PetrSU and >200 experiments were conducted with real sheets of cardboard taken from industrial sites. Based on experimental results, the hardware setup, algorithms, and their parameters had been improved. The final series of experiments have shown that the complex can successfully identify >95% of cutting and creasing lines (in laboratory environment).

Therefore, the measurement complex operation should be tested on production site, where the web is subject to defects – warping, vibrations, "waves" in machine and cross directions, and other. Results of these practical tests will require further elaboration of the hardware and software.

V. Conclusion

Testing of the hardware and software components of the measurement complex in laboratory environment have shown that we can proceed to testing its operation in real production environment. Required arrangements have been made with one of the mills in Russia.

The hardware and software will be further elaborated and tuned according to results of these practical experiments.

Acknowledgement

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