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GLASS QUALITY TESTER

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Abstract − The techniques for digital image acquisition and digital image processing used to identify defects in transparent elements are described in the paper. The block diagram of the test set-up, algorithm of the software developed for identifying geometrical parameters of defects are presented here. The set-up, presented in the paper is proposed for glass quality production control at final and intermediate production line of double glassed windows. The other applications are foreseen. One of the very important feature is calibration of the image with the use of reference glasses, light correction and adjusting parameters of the set-up according to requirements. Calibration is achieved with the of use patterns prepared ahead of time and also with a use of the same set-up. Glass can be categorised depending on number of defects and percentage of defected area or can be disqualified at production line if any permanent defect is found in observed element.

Keywords: image processing, glass tester, transparent material tester.

1. GLASS QUALITY PROBLEM

The quality of glass components influence the performance of doubled glazed windows. Huge sheets of glasses after cutting are face grinded as the first stage of glazing. The glass selection and elimination of defected sheets of glass play a very important role in achieving adequate quality of the final product. It is not an easy task to perform a control test to identify such defects as blobs of air, scratches, colorations, blemishes, surface deformations, removable and non-removable impurities.

The proper selection of glass sheets for further processing requires that only glass without any visible colouring with only removable impurities and small allowable defects passes this stage of production line.

It is not an easy task and it is also time consuming to differentiate removable and non-removable elements of defects. The other problems in proper selection of glass sheets are caused by the fact that the decision process should be conducted manually and can be supported by objective tools only to a small degree. Finally it is a subjective type of information and human experience plays the most important role in glass defect detection. It is obvious that the defected glass components of windows if not eliminated as early as possible at production line, waste time and money and other components of windows, so if at the end of production line it is revealed, that glass is faulty, the final ready product is destroyed or is marked with a lower quality. Such an event has financial consequences. Hence, it is important to develop a set-up such as one described in this paper and utilize it at the production line.

2. QUALITY CONTROL SET-UP CONFIGURATION

The developed system is a physical prototype, which consists of CCD standard monochrome camera, image acquisition PCI card and software written in a G- language.

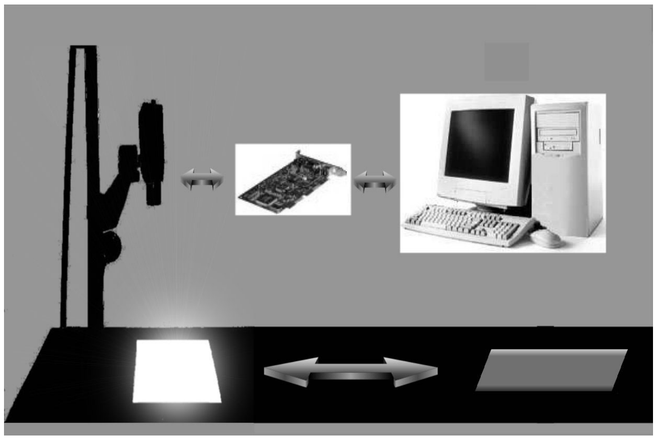

Fig.1. Hardware configuration of test set-up.

The software tailored to the application plays a key role in the system as it is responsible for identification and evaluation of defects, based on an image represented in the digital form. Image processing includes inversion, level of brightness, filtration and corrections of histogram threshold. The calibration process, which includes selection of the proper illumination, allows to achieve the most desirable lighting of the object under test, which is necessary for a correct evaluation of defects and roughness due an external noise caused mainly by false lighting.

The block diagram in Fig 1 depicts all functional elements of the set-up. The glass sheets are not smaller then 1 m^2 so an illuminated table with a stiff handler for the camera is used.

The size and shape of tested transparent elements depend on geometrical parameters of illuminated table, optical parameters of camera and CCD optical converter. The Eq. 1 defines a measure S_{MIN} of these parameters, which expresses the smallest possible amount of information acquired by Data Image Acquisition Module. It is a measure describing the minimal area possible to differentiate and interpret within one acquired image ("shot" and processed for analysis).

$$\mathbf{S_{MIN} = MIN(S_O, S_P, S_C)} \qquad (1)$$

where:

S_O – minimal object surface (minimal area of transparent element under test)

S_P – illuminated table surface

S_C – image conversion surface

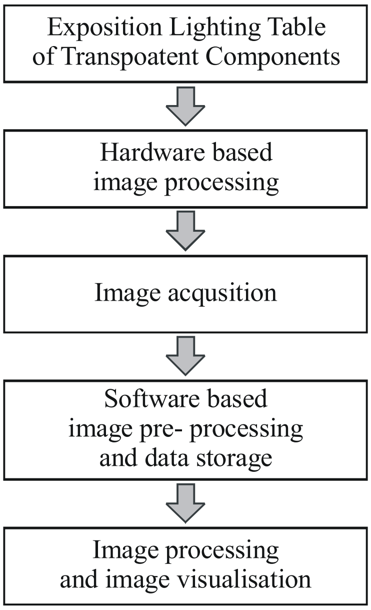

Fig.1. Block diagram of the glass control set-up.

The value of S_{MI} never exceeds 60000mm^2. This parameter seems to be optimal from the economical point of view subject to technical restrictions for assumed size of tested components; the increase of the parameter S_{MI} requires better technical resources to keep the same quality of the identification of tested transparent components. It is more reasonable to increase resources for surface fragmentation, use higher resolution or pre-select regions of interest.

The next step is image acquiring, for which optical elements DSC and 1/3" 768x494, C/CS/back-focus of ULTRAK KC6500MN were applied, then the image was digitalised and acquired, as is represented by Acquisition module in Fig .1. The module contains also frame-grabber PCI 1409 type of National Instruments with 8-bit monochromatic A/D converter.

Point Spread Function, **PSF** given by Eq.2., which represents density of image intensity of the whole acquired over the area of whole image under observation.

$$\iint_{a,b} PSF(x,y)\,dxdy \qquad (2)$$

This definition is based on the results of experimental pattern recognition of a single recognizable point. It means that PSF represents modulus of two dimensional Fourier transposition called: Modulation Transfer Function, MSF, given by Eq.3.

$$MTF(f_X, f_Y) = \left|\Im\left[PSF(x,y)\right]\right| \qquad (3)$$

The parameters like resolution and the ability of the conversion module to defecate are related directly to Modulation Transfer Function, MTF.

Finally, the digital representation of an image carries certain amount of structural information about object under test as given by Eq.4. ,

$$N_O = 4\int_0^a dx \int_0^b dy \int_0^\infty df_X \int_0^\infty df_Y \cdot MTF(f_X, f_Y) \qquad (4)$$

The measure of structural information transferred and recorded in the measurement system is denoted by N_0. N_0 is expressed in pixels for observed surface and is expressed by $S_{MIN} \cong a \cdot b$ [mm^2] and $a \cdot b \in (S_{MIN})$,

Product a·b belongs to the range of values, which are characterising spatial surface of the image, and may be expressed by S_{MIN}, in which N_0=307200 (640x480). N_0 relates to the observed surface, which is not smaller then 60000mm^2.

Image acquisition and processing before final recording in the form of file includes several online elementary operations, which modify the images in such a way, that image becomes more convenient for further processing with the use of techniques typical for data image processing.

These elementary operations include so-called Look-up Table, LUT, which is available in hardware of the image acquisition systems.

Next, the off-line processing of a file in BMP format is performed. Processing covers: filtration, inversion, histogram correction, and operation of closing of recognized curves, which seems to form a closuring loop elements. These operations are aimed to improve the effectiveness of identification, localization and measure of interesting elements of investigated defects. Element locations are expressed by their coordinates. Geometrical mean of the located defects and square area of the defect are measured based on patters defined in the calibration process.

Finally the recognized and localized permanent defects are displayed on Video Display Unit (monitored).

3. ALGORITHM OF IMAGE PROCESSING FOR DEFECTS IDENTIFICATION

Acquired image of the object under test is recorded as 8-bit grey scale (256 levels) pixel map. At the very first step image is corrected by elementary image correction such as: gamma, brightness and contrast, according to values reached at the calibration process. The next step is filtration, histogram correction, closuring operation and finally threshold and inversion.

The stages of image processing performed to obtain the best possible defect detection are as follows:

1. snap of image
2. look-up table operation to get the best possible image for processing – logarithmic or linear
3. gamma, brightness and contrast correction
4. low pass filtering,
5. histogram correction,

6. threshold,
7. colour transformation,
8. colour inversion
9. closuring up defects
10. calculation process: numbering the defects and total area of defects

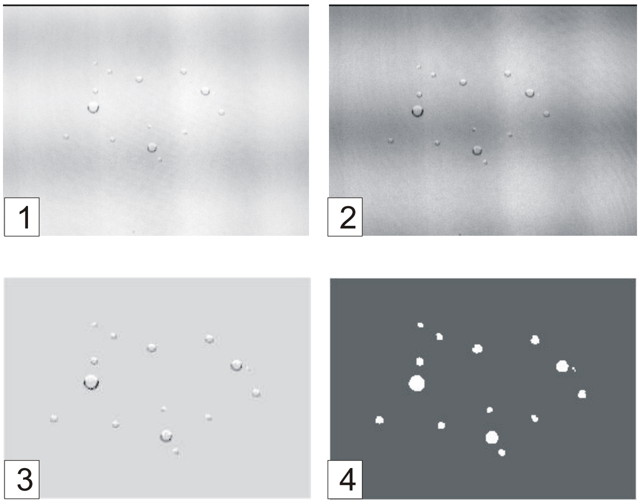

Fig 2. Different stages of image digital correction: (1) snap image; (2) logarithmic Look Up Table, LUT; (3) low pass filtering, histogram correction, (4) threshold and colour transformation inversion

Such processed image is a base for localisation of defects, their numbers, coordinates and area of defects.

4. HUMAN MACHINE OPERATING PANEL

The Panel of Glass Quality Tester is presented in Fig.3. The up-right corner of Fig.3 depicts the image after operations from (1) to (5) mentioned in previous section. The down left corner shows the image after operations from (6) to (10). The glass tester operator can change such pre-processing parameters as: brightness, contrast, gamma, threshold settings by means of virtual knobs or push up-down controls as these parameters depend on external parameters of environment like day-time lighting. The operator, while making these changes observes the histogram and intermediate images on the right part of the panel, which help him to achieve the best possible parameters. The rest of the operations are not influenced by the operator and are performed automatically, no variable parameters are needed.

Calibration of pixels (do not confuse with calibration of the system which uses of reference material – glass plates) is used to define a number of pixels per one square millimetre. It is used when the camera is set for the first time or the distance between the camera and the object was changed.
The quality criteria are: calibration of the quality control system to define maximum number of defects, cumulative size and maximum size of the biggest defect. It can be done based on a reference material, glass plate in this case, or may be set manually by an operator.

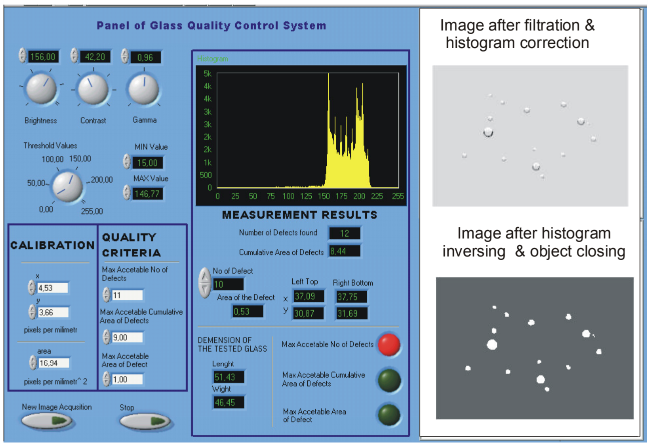

Fig2. Operating panel of the glass tester

The part of the panel with the measurement results shows: number of defects found after applying threshold and cumulative area of defects. Compliance with the quality criteria, or lack thereof, is signalled on green or red LED controls (middle right of control panel). Regardless of the final decision, the operator may examine each defect by selecting them from upper-middle-left control, the co-ordinates of a square that contains the defect and its area.
The dimensions of tested glass are displayed on indicators located at middle-down-left of panel.
New Image Acquisition button is used to make a new shot for next test. The stop button is used to stop the application.

5. CALIBRATION

Calibration of the elaborated tester is in this case a process, which covers all preparatory work for proper identification of objects, and classification whether a unit under test is carrying acceptable on non-acceptable defects. Calibration must be performed as a routine daily procedure or even more frequently depending of the external daylight influence. It is a process similar to instrument calibration, but the result is very much operator dependent, as set-up operator must categorise defects, and chooses filtration using his experience. The reference materials which are patterns of defected transparent materials help the operator, but his abilities to identify defects play the key role. The process of calibration is very operator dependent and very subjective. The patterns – reference materials are also a result of previously gained experience by set-up operator on how to identify air bubbles, scratches, and colorizations in transparent material. The calibration process consists of light intensity adjustment by positing the lamps, front and back. Daylight must be taken into consideration and if it changes the next calibration may be necessary. Several of reference materials support light intensity adjustment. Uniform distribution of light intensity might be not the best for achieving the adequate air bubbles exposition. Scratches and removable and non-removable impurity exposition also depend on lighting.
The second stage of so-called calibration consists of lens configuration and setting the lens distances that significantly affect the sharpness and brightness of the examined image.

The set of patterns used to calibrate the tester plays a very important role. The reference materials can be set only by people very well experienced in glass quality and defect identification. Once the reference materials are prepared, they can be used for every day checking of the tester.

6. CONCLUSIONS

The physical model of the tester was used at the laboratory and at the production site. The experience gained is used to develop a new version more advanced quality assurance system.

The set-up is only extending human abilities to identify defects in transparent material. The objective information only supports the decision process of a man. His experience plays a key role in the classification of transparent tested element. The illumination of the material under test plays very important role in gaining the objective information about the number of defects and the affected area.

The set-up configuration is typical for vision systems, although the software used for closuring gives the glass tester a unique character.

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