# *Image processing methods used in automated quality control of fiberplates*

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## *1. Introduction*

From constructional point of view the fiberplate is an optical device made of a bundle of light pipes, in which fibers are assembled in an arranged way, on the beginning and on the end of the device.

Fiberplates can be used as input or output optical elements e.g., for exact restoration of flat image projected on a spherical surface in some types of image intensifiers, for image transformation, including its rotating by selected angle and dimensions magnifying or reduction, or in diagnostics and medical therapy, etc. Thus, the arrangement of fibers in a fiberplate as well as their mutual positions and dimensions determine if fiberplate works correctly and if it may be succesfully used for particular purposes.

Evaluation of fiberplate quality is based on analysis of microscopic images of lightened fiberplate and their different parameters. The following of them are taken into consideration: diameter of light pipe fiber, distance between the centers of fibers lying near to each other on the fiberplate, density of fiber packing within a determined area, image distortion during its transmission from input to output of fiberplate, defects distorting transmission, (i.e., surface defects and defects inside of light pipe fibers, of which fiberplate is made).

The measurement of above mentioned parameters, and resulting quality control based on analysis of microscopic image, is quite arduous and time-consuming without proper equipment. In this case using computer image analysis and recognition techniques enables improvement of fiberplate quality control process, and maintain high repeatability of measurement conditions.

## *2. Description of the method*

This section presents problems connected with the microscopic image registration in an image acquisition system, the way of their solving and the image preprocessing. The block scheme of a site for described tests, with automated controlling elements, is shown in Fig. 1.

For proper image registration with the use of a microscope, the following features are most important: the type of used microscope, the way of controlling microscope stage as well as the character of used light.

Choice of microscopic objective is made according to following criteria:

- a character of observed objects,
- a kind of light used for their observation.

In the case of evaluated fiberplate image, the image registration was done using penetrating light. Thus, parameters of used light source should fulfil at least following conditions: it has to provide some minimum amount of radiation energy, spectral dispersion of radiation energy should be qualitatively matched with microscopic test method and image registering devices. The light source also has to have the timely invariant characteristics of emitted radiation. The stage of the microscope used for evaluation should have a possibility of micro-controlling with three axes *x*, *y* and *z* with sufficient resolution.

The image was recorded with CCD camera of increased sensitivity and then sent to an image acquisition card, registering images with resolution of $512 \times 512 \times 256$ gray levels. Obtained digital image has correct spatial resolution and number of gray levels in this case.

Image acquisition card, with which the station was provided, performed only the role of image digitizer. Thus, it is very cheap and is simply an extension card for IBM/PC computer.

Registered digital image is then subjected to area segmentation through thresholding, which may be replaced by use of a spatial median filtration.

Because of the character of observed objects (properly attached light pipe fibers), there are obtained the dark background (material separating and linking individual light pipe fibers) with bright objects (light pipe fiber core which is transmitting an image). Usually, such an image has bimodal histogram. Profiting from this fact, the area segmentation by thresholding is correct for use. The threshold intensity value is derived from histogram analysis, and in the case of bimodal one, it is equal to the gray level which probability of appearance in the image is the lowest in the interval from the maximum (corresponding to the background gray level) to maximum (corresponding to the objects gray level). As the result of this operation, the binary image is obtained.

As registered, with use of image discretisation system, fiberplate lighted structure microscopic image is characterised with high number of distortions of small dimensions and low gray level. The algorithms mentioned above used for image quality improvement as well as for area segmentation process, do not eliminate all of these distortions. For this reason an additional correction of obtained binary image is required because some algorithms used for evaluation of fiberplate quality are sensible for these distortions.

It was stated during experiments that use of morphological operations, especially dilation, removes the distortions. Regarding the size and shape of the local operator, it was stated that for this type of image and distortions the best results are obtained for the $5 \times 5$ operator of octagonal shape.

The individually written software enables also use of three other operations being a part of morphological operations, i.e., erosion, dilation and closing with different structure and dimensions of local operators. The result of use of these operations is elimination of distortions having the shape of spots with the background gray level from analysed area representing active image transmitting elements, i.e., cores of light pipe fibers.

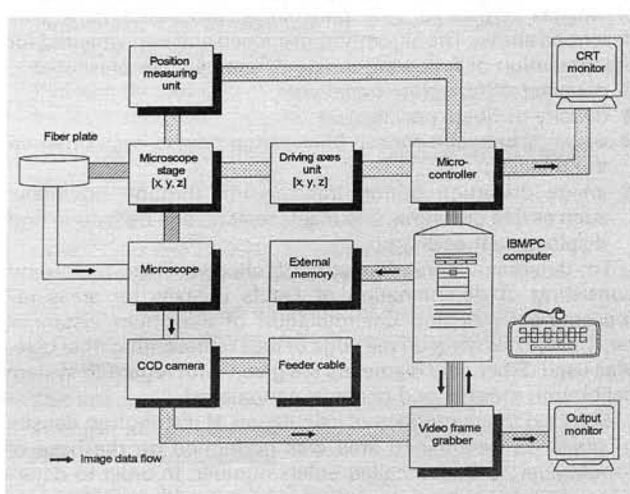
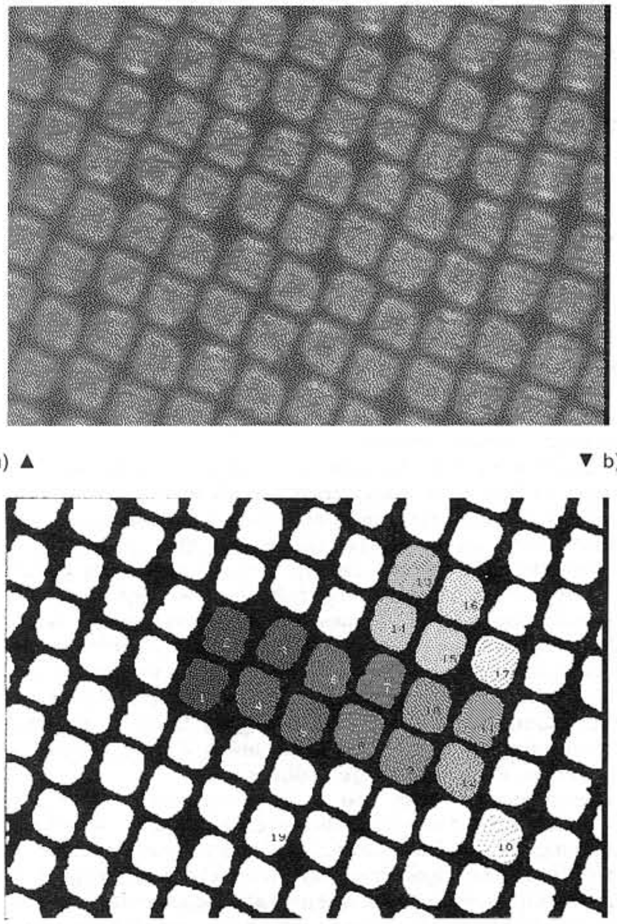



Fig. 1. Block scheme of the station with automated control elements



a) ▲ ▼ b)

Fig. 2. The original input digital image (a) and example of results of automated determination of fiber core diameters (b). Diameters of the fiber cores are from 6 to 7 μm and they are comparable with distances between fibers

Because the aim of the work was to determine of some fiberplate parameters (especially fiber core diameter, distance between cores of light pipe fibers and density of fibers), the calibration of image acquisition system had to be done, so that determined parameters, i.e., distances were given not as multiple of sampling step on the digital image, but as the values easily interpreted by the system user.

Calibration of the station is performed on the base of precise model, i.e., the area with determined exactly width and known accuracy, remembering the fact that the shape of quantization cell is rectangular.

This part includes description of algorithms used for analysis of images registered and preliminary processed in a way described above. The algorithms proposed and implemented for determination of following image parameters are presented:

- diameter of fiberplate fibers core,
- density of fibers packing,
- distance between chosen fibers, lying next to each other on the plate,
- image distortion during transmission through fiberplate, such as line deviation, line displacement, line deflection and displacement of image.

To determine core diameter of chosen fiber, a method consisting of determination of Ferets indexes for areas representing fibers and determination of maximum distances between pixels lying on the edge of area representing fiber core, was used. Fiber core diameters are given with regard to system calibration indexes and given in nanometers.

Solution to the problem of calculation of distribution density of fibers on determined area was performed on the base of topological parameter called Eulers number. In order to determine this parameter, eight-compactness was assumed for areas representing background and four-compactness for areas representing objects of interests of system user, assuming that image comprises only such objects and neutral background. This assumption is in this case fulfilled due to elimination of distortion like areas with background gray level, by the use of morphological operations, as well as by original procedure of eliminating area fragments representing parts of fibers in the determined area by giving them the background gray level.

Eulers number $E$ is calculated from the following expression:

$$E = C - H \tag{1}$$

where $C$ is the number of compact components of the object and $H$ is the number of holes in the object.

Packing density of fibers is calculated on the base of determination of area plane and number of fibers in this area.

For determination of distance between chosen fibers lying next to each other on the plate, a method consisting of determination of gravity centers of areas representing fibers with use of moment methods and especially, calculating area moments of the first order $m_{10}$, $m_{01}$ and zero order $m_{00}$ for chosen areas, and subsequent calculating the gravity centers $(x,y)$ of the areas, according to following expression, was used:

$$x = \frac{m_{10}}{m_{00}}, \quad y = \frac{m_{01}}{m_{00}} \tag{2}$$

In the case of continuos function of gray levels $f(x,y)$ the area moment of $pq$ order is described by the expression:

$$m_{pq} = \iint_S x^p y^q f(x,y)\,dx dy \tag{3}$$

Knowing calibration indexes, the distance between areas representing chosen fibers is obtained.

Modifying a way of image registration, it is possible to determine image distortions during its transmission through the fiberplate from input to output, with use of the software.

Example of results of processing and analysis of microscopic images of lightened fiberplate structure in order from registration to recognition, consisting of determination of fiberplate parameters, are presented on the Fig. 2.

## 3. Conclusions

The tests and observations performed during system exploitation show high usefulness of imaging digital system for automated control of fiberplate quality. Methods of digital analysis of properly registered microscopic images enable eliminating of traditional testing methods (time-consuming and arduous) maintaining high accuracy of measurements and repeatability of conditions of their performance, as well as making measurements more simple. Such measurement is also less time-consuming, which has great importance during technological process where control of produced material quality is one of the most important problems.

Presented method together with described hardware makes universal tool for automated quality evaluation of all fiberplates and fiberscopes structures.

Especially written software has simple and convenient user interface, including management of system errors. It may also be easily modified due to the procedures compiled to the library in Microsoft C and ANSI C languages.

### References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