EVALUATION OF CERAMIC TILES DEFECTS WITH THE USE OF IMAGE ANALYSIS TECHNIQUES

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Summary

In many cases ceramic tile manufacturing processes have been almost completely automated. Two stages of these process are exceptions. They are quality control and sorting at the end of the production line. These operations have been realized by the staff so identification of defects depends only on the human. Because of specific abilities of human sences, visual quality control of tiles is often not precise and reliable. Automatic visual inspection and estimation of tiles is a crucial problem in a ceramic industry. Inspection with the use of a vision stystem eliminates problems connected with the tiredness of human sences. Such systems are able to operate many hours without any breaks and are much faster and preciser. In the paper a concept of a method of the quality evaluation of the ceramic tiles, basing on digital image analysis, and the first results of the research have been presented. Three groups of defects have been distinguished, they are corner defects, edge defects and surface cracks that could be detected during the manufacturing process.

Keywords: ceramic tiles, quality evaluation, image analysis, vision system.

OCENA DEFEKTÓW PŁYTEK CERAMICZNYCH Z ZASTOSOWANIEM METOD ANALIZY OBRAZÓW

Streszczenie

Proces wytwarzania płytek ceramicznych w wielu przypadkach jest całkowicie zautomatyzowany, za wyjątkiem dwóch etapów - kontroli jakości podczas produkcji oraz sortowania płytek na końcu linii produkcyjnej. Czynności te są wciąż wykonywane przez ludzi, a kontrola jakości produktu jest zależna od zmysłów ludzkich. Z tego powodu kontrola wizualna, jest subiektywna, nie jest precyzyjna ani powtarzalna. Automatyczna kontrola jakości przeprowadzana przy użyciu systemów wizyjnych jest bardzo ważnym aspektem przemysłu ceramicznego. Automatyczna inspekcja z użyciem technik wizyjnych oraz metod przetwarzania i analizy obrazów eliminuje problemy wynikające z szybkiego męczenia się oka ludzkiego. Inspekcja taka zapewnia precyzyjną i szybką kontrolę, która dzięki temu, że system może działać bez przerw znacznie przyspiesza proces produkcji. W niniejszym referacie została przedstawiona koncepcja metody detekcji wad płytek ceramicznych bazującej na analizie obrazów cyfrowych. Wyróżniono trzy podstawowe grupy wad: wady krawędzi, naroży oraz pęknięcia płytek ceramicznych, które mogą być wykrywane już na etapie produkcyjnym.

Słowa kluczowe: detekcja wad, analiza obrazów, system wizyjny, płytki ceramiczne.

1. BACKGROUND OF THE RESEARCH

Nowadays, estimation of the ceramic tiles quality during their production has been still performed by the people usually only at the end of the production line [1, 4]. The quality of this evaluation relays only on the human sence capability, because of that such quality control is not precise and reliable. Specific features of human sences, cause fast tiredness, lack of attention, eye fatigue or even sickness of an inspector that results in low efficiency of inspection and in decrease of quality of the final product. Therefore automatic visual inspection and estimation of the quality of tiles is a crucial problem in a ceramic industry. Inspection with the use of a vision stystem eliminates problems connected with human sences. Such system can operate many hours without any breaks and is much faster and reliable.

Concerning the quality evaluation during the production process, tiles are usually inspected only when all expensive operations like glazing or pattern printing have been already performed. In such case the tile could not be easily recycled [2]. Defects of ceramic tiles could emerge on every stage of the process: during forming the biscuit on the press, during firing or pattern printing. The most important problem is to detect occuring defects as early as possible, e.g. before firing, when the demaged tile can still be recycled. In such case both material losses and production costs can be reduced. On the basis of bibliographic research [2, 5] and according to experts' opinions one can state that the most common defects of the ceramic tiles are: edge defects, corner defects and surface cracks.

In the paper, concept of a method of the defects evaluation of the ceramic tiles, based on digital image analysis has been presented.

2. OBJECT OF INVESTIGATION

In the presented experiments objects of investigations were square ceramic tiles, of dimensions 350 x 350mm. As it was stated, three groups of defects have been distinguished as the most common. Therefore these defects have been taken into consideration in the presented research.

On the basis of experts' opinions, the area of the specimen that should be observed can be reduced to the border of the ceramic tile. The reason of such reduction is based of the specification of the considered defects. Parts of the tile that are most exposed on demages are edges and corners. In the case of surface cracks, it was stated that this kind of demage usually have its begining at the edges, from where the damage propagates. Therefore the analysed area has been also reduced only into the border region.

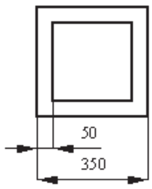


Fig. 1. Representation of the border region

In the presented experiments the border region has been limited to area of width from 20mm to 50mm. Border region has been presented in the Fig. 1.

3. VISION SYSTEM

For the research purposes, the laboratory stand consisting of a camera, illuminator and PC computer has been prepared. A schema of the laboratory stand has been presented in Fig. 3.

On that early stage of the research the specimen and the camera were stationary. However, in order to simulate the environment of the production line, the laboratory stand will be equipped with the conveyor belt and the tile will move under the stationary camera. Because of that concepts of two methods of tile observation and image acquisition have been proposed. The first method consists in observation of the whole specimen with the use of one camera. Such method allows us to acquire one image for every specimen and analysis can be performed for all border areas simultaneously. However some limitations of the minimal defect size occur. This restriction came from bigger field of view (FOV) of the camera what results in a smaller number of pixels composing the visible detail.

The second concept is based on the observation of the tile with the use of two different cameras. In this case the vision system should consist of two synchronized cameras observing parallel areas. In this case, the field of view (FOV) of the camera should be equal to half of the width of the tile and observation of border area is similar to the scanning process. Thanks to limited FOV of the camera it is possible to identify smaller defects. The schemas of two concepts have been presented in Fig. 2.

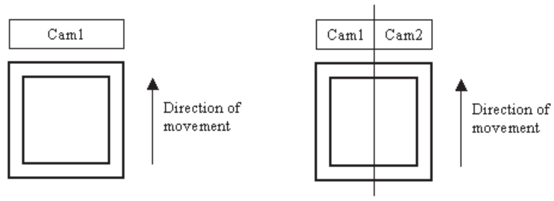


Fig. 2. The concepts of image acquisition method

Because of the possibility of limitation of the area of observation to the maximum 50 mm width of the border, the size of the acquired data can be also minimized by a region of interest (ROI), wchich is chosen before the acquisition. Concepts presented above are to be developped in the further research.

3.1. Laboratory stand configuration

In order to simplify the research at this stage of the investigation, the second presented concept of laboratory stand has been applied, but camera and the specimen were fixed. Positions of an illuminator were being changed during the experiment by changing the ditances d_1 and d_2. Such experiments have been performed in order to verify the influence of the position of the illuminator on the visibility of defects. Exemplary results have been presented in paragraph 2.1.

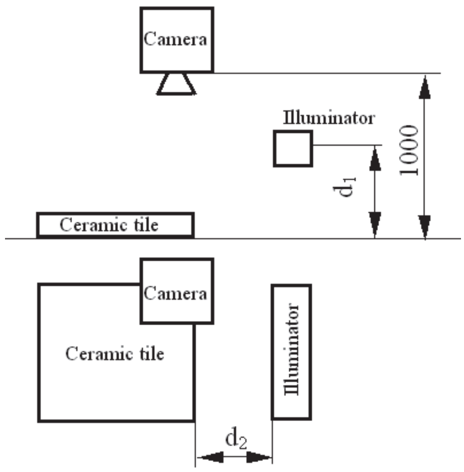


Fig. 3. Laboratory stand configuration

Parameters of the camera used in the experiment and information about the measurements precision have been presented in tab. 1.

Tab. 1. Parameters of the camera used in the investigations

Camera	Imaging Source Mono DMK 31BF03 CCD 1/3''
Resolution	1024 x 768 pixels
Pixel size	4,6 μm x 4,6 μm
Focal length	f=50mm
Specimen - camera distance	1m
Field of view	91 x 68 mm
Measurement precision	approx.0,15 mm

Exemplary images representing ROIs with the most common defects have been presented in Fig 3-7.

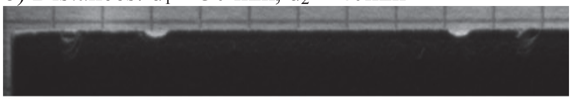
3.1. Methods of specimen illumination

A very important role in the image acquisition as well as analysis plays an appopriate illumination of a scene. The illumination well matched to the task enables that all information, and characteristic features of the surface are visible. It is emphasized in many references that the suitable illumination is the 70% of sucess in vision system applications [3]. In the presented reasearch, a fluorescent lamp has been used as the illuminator. Such kind of the illuminator is a source of diffused light. In order to investigate the influence of the position of the illuminator in regard to the specimen several different configurations have been tested. Changes of the illuminator possitions have been realized by changing distances between the specimen and the illuminator. Distances d_1 and d_2 pointed out in Fig. 3. were equal from 5 mm to 100 mm. Depending on the illumnator – specimen configuration one can obtain images in which defects are clearly visible, or in contrary, where defects are barely recognizable. In the paper images acquired under configuratons which reflected the biggest differences in the image quality and visibity of the defects have been presented in Fig. 4.

In the configuration where the illuminator has been remoted from the specimen (Fig. 4a) defects of the edges have been barely visible. In such case the analysis of the image was very difficult and identification of the defect were not possible. One can observe that the best results have been obtained under the configuration where the illuminator was placed on the height equal to the position of the specmen surface and very close to its edges (Fig. 4d.) In this case defects have been clearly visible and image processing and analysis were less complicated and the defects have been easily identified.

a) Distances: d_1 = 100 mm, d_2 = 100mm

b) Distances: d_1 = 30 mm, d_2 = 40mm



c) Distances: d_1 = 10 mm, d_2 = 20mm

d) Distances: d_1 = 5 mm, d_2 = 5mm

Fig. 4. Influence of illuminator position on the defects visibility

4. METHOD OF DEFECTS IDENTIFICATION

According to the assumption made at the beginning of the experiment, images have been acquired with the use of one camera placed 1m above the specimen. Methods based on image processing techniques have been applied in order to distinguish damages from the proper surface. The algorithm of image processing consisted in image enchancement by median filtering and normalizaton. In the next step of the algorithm, in order to limit the volume / size of processed data, regions of interest have been choosen and after that ROIs have been analysed. The operation of image analysis used in the computations were edge/line detection procedures, and morfological operations. With the use of the elaborated procedures three groups of defects were possible to be detected and sizes of edge defects were estimated.

An examplary image representing the ROI (9 x 56 mm) with proper edge has been shown in Fig. 5. It is visible that the edge is straight and can be acknowledged as ideal. An example of ROI with edge and corner defects has been presented in Fig 6.

Fig. 5. Exemplary results for tile with proper edge

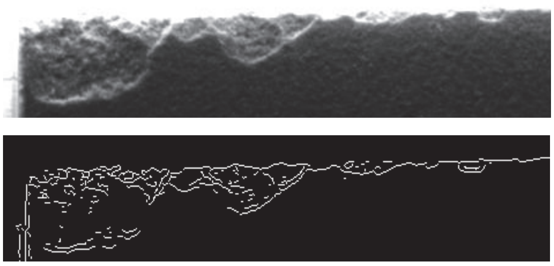


Fig. 6. Exemplary results for tile with corner defect

In this case chosen ROI is bigger than in previous case (14 x 56mm) because of sizes of damages.

The third group of defects of the tiles are scrathces and cracks. An example of the original image and image after analysis have been presented in Fig. 7.

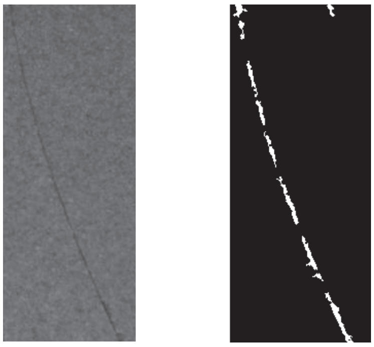


Fig. 7. Exemplary results for tile with crack

In this case morphological operations were very useful. Some kinds of filtration caused removal of the crack line from the tile surface, because of the presence of a huge number of pixels with the same gray level.

5. EVALUATION OF DEFECT SIZE

The main goal of the research, except the defect detection, was an estimation of the defect size. In Fig. 8 an example of a damaged edge has been presented. In the selected ROI four different damages are visible. For the purpose of the size evaluation, some procedures have been elaborated. Procedures were based on the searching for the stright horizontal line in a binary image, in the next step, black pixels below the line are counted. The procedure is simple but has given acceptable results.

Fig. 8. Exemplary results for tile with damaged edge.

Results of the operation of the defects size estimation procedures have been presented in Tab. 2.

Tab 2 Results of the defects size estimation

Defect number	Number of pixels of defect	Defect size [mm^2]
1	202	4,2
2	199	4,2
3	166	3,84
4	256	4,78

On this stage of the research, it is possible to estimate only the size of the defects. In further research it is planned to make possible the evaluation of the shape and mutual orientation of the defects as well.

6. CONCLUSIONS

Automatic detection of the defects of ceramic tiles is an essential task in ceramic industry. Therefore experiments of the application of image analysis methods has been undertaken, and the first obtained results have been very promising. Detection of the demaged tile and its elimination from the production process before very expensive operation such as glazing and pattern printing may keep to the minimum losses incured by the manufacturers.

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