USE OF ROBOTS FOR QUALITY CONTROL OF PRECAST ELEMENTS

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SUMARRY

Testing of geometric quality of a precast unit is aimed at yielding reliable information on the features achieved in production. Therefore the authors present a measuring system consisting of a robot, the sensors and the coordinating computer. The main goal of this kind of measuring is to realize an objective low cost measuring procedure. The possibilities and the boundaries of this system are discussed. The authors show that this system is a first contribution in securing geometric shape with the help of automation of length-measuring process.

1. INTRODUCTION

Currently, data on precast units (product testing) are usually acquired by means of tape measure or vernier caliper. In view of technical and, hence, efficiency improvements being desirable, the problems involved are the comparatively large amount of manual work necessary (done by two or three labour) and the method of data acquisition. Referring to the latter, two parallel measurements, e.g. length and width, does not provide sufficiently accurate information on form (or shape) and position errors which, on large-size panels, are referred to as angle errors, wedge shape etc. The measuring accuracy can be substantially impaired by holding errors, reading errors, out-of-parallelism, and the like. Measuring results are preferably evaluated (product control) to document the quality level. This is necessary and, also, this is the correct approach. However, it is essential that the data be further evaluated with the aim of revealing in good time trends of variations on any mould of the production line.

Therefore, a typical approach is presented below to demonstrate acquisition, evaluation and communication of data within the framework of quality assurance for panel-shaped reinforced concrete units.

2. TEST FEATURES ON PANEL-SHAPED REINFORCED CONCRETE UNITS

Testing of geometric quality features of a precast unit is aimed at yielding reliable information on the features achieved in production which are critical to the erection process and use of the entire building. This implies that the measuring method be designed such as to rule out distortion of information. This is exemplified below for measuring the length and the height of a wall panel.

If the panel is parallelogram-shaped (Fig. 1) length measurement in two axes does not reveal whether or not a longer length would actually have a "critical" effect on the panel. Even when performed in combination with height measurement in two axes, no such information is obtained. Similarly, this is true of a trapezoidal shape as well as of all kinds of oblique-angled configurations.

Therefore, to obtain meaningful and accurate information on the test features it was reasonable to dig up the critical features by scanning the shape of the specimen and determining the ideal geometry of the panel (Fig. 2). This yielded the following requirements to be met by the measuring system:

- Scan the specimen geometry, i.e. both its outer edges and the cutouts (windows, doors) in the panel. At this stage, no demands are made as to the mode (continuous or incremental) and the method (optical, tactile, and the like) of scanning.

- Assign the determined shape, i.e. that found by measurement, to the ideal geometry in true-to-size terms and such that the panel is suited for installation.

- Calculate the deviations between the determined shape and ideal geometry to certify the geometric quality and assess the production. This may also be used as a starting test for the 'critical' features.

- Perform trend computations for the geometric quality on the basis of continual storage of measuring results by features and shape such that data on quality development of a particular type of precast component, individual features etc. can be fetched from the memory at any time.

- Feedback of trend computations to the production department.

In case of point-by-point scanning of the geometry of a wall panel including its openings (windows, doors), computerized evaluation can be adopted to obtain information on defined quality features. Typically, this is true of

- the maximum length of the precast unit which has a bearing on the fit ;

- determining the straightness of the edges of the precast unit by computing a fitted straight line and, thus,

- determining the angle errors of wall panels,

as well as a number of other features which, derived from the above and essential to comprehensive description of a wall panel, are required such that the quality of the product can be assessed and spheres in the production department where correction is necessary are revealed.

3. COMPONENTS OF THE MEASURING SYSTEM

Figure 3 illustrates the structure of the prototype of an automated measuring system which, developed at 'Otto von Guericke' Technical University of Magdeburg, is capable of accomplishing the measuring tasks outlined above. The CCD camera is carried by a robot with freely programmable control. Operation of robot and CCD camera is coordinated by an overriding computer which also functions to manage files, generate input references, evaluate and store measured data, and exchange data with a process management system as may exist. Moreover, its peripherals (monitor, keyboard) serve to control the overall system.

The basic principle adopted to determine the actual shape of the precast unit can be described as follows:

The geometric shape and the desired dimensions of every specimen to be tested (precast unit) are stored in the coordinating computer. From these data the latter generates measuring points with the space coordinates (x, y, z) which are transmitted to the robot control, thereby causing the robot to be positioned to the desired coordinate where a point of the specimen to be measured is expected. Positioning completed, the CCD camera determines the deviation of the selected specimen edge relative to the assumed position. Presented below are the components of the overall system.

3.1 Robot

The prototype measuring system uses a four-axis joint robot with multi-processor industrial robot control. Power for the arm motions is transmitted through pre-tensioned roller chains. Drives and incremental angle measuring systems for each axis are arranged at the low end of the robot.
In view of findings obtained from investigations, the fol-

lowing is the preferred approach:

- Use of the robot control as an automatic position control system, with reference positions (reference increments) for the axes to be specified by a separate computer.

- Point-to-point specification of the coordinates to be assumed. Moving along a path (e.g. the edge of a panel) while using the integral path computer of the IRS robot control is not recommended.

Moreover, this approach is advantageous in that comfortable off-line programming of the robot is practical on a separate computer.

In this mode of operation, the robot can be used to carry the CCD measuring system; the maximum positioning error is less than 1 mm.

3.2 Sensors

An image recognition system with CCD-camera was used for non-contact measuring of the location of the significant panel edge relative to the reference point. The direct-light method was adopted, the specimen being illuminated by a halogen spotlamp at an angle of about 45° relative to the measuring plane. Thus, it was possible to select projecting edges by producing hard shadows (Fig. 4a).

The illuminated and the darkened areas scanned in the measuring range were imaged on the CCD array as pixel information. The image recognition unit converts the pixel information to a binary pattern which is stored in the run-length code in a condensed form. A serial input-output feature (V24) was provided to transfer data to the coordinating computer as needed. In this way it was possible to determine the distance *l* of an edge from the optical centreline of the CCD camera by evaluating the picture element address of the black-to-white or white-to-black transition according to the following equation (Fig. 4b)

$$BP_x = \frac{\Delta l}{h} \, \xi_k \qquad (3.1)$$

where ξ_k is a camera constant.

To this end, it is essential that the distance h (from camera to specimen) be known. This distance can be determined by the triangulation method: Once an image is made and stored, the camera is moved by the robot through a defined distance Δs normal to the edge to be measured, keeping in mind that the relevant edge must still be within the scanning range of the camera (Fig. 5). Another image is made and the desired distance results from the relation

$$h = \Big\} k \frac{\Delta s}{PE_{x1} - PE_{x2}} \qquad (3.2)$$

where PE_{x1} - Picture element address in measurement 1
PE_{x2} - Picture element address in measurement 2.

A number of investigations have been conducted [1] to study the imaging accuracy of the measuring system as a function of specimen illumination, measuring distance, lens system, and line integration time. For a mean distance h = 1 m, a scanning range δ = 390 mm and integration time T_I = 2 ms, the measuring error obtained was two picture elements (equivalent to approx. 0.7 mm).

3.3 Coordinating computer

Based on a personal computer, the coordinating computer was the master in the hierarchy of the overall multiprocessor system. It was connected to the image recognition unit through a serial V24 interface, and to the free programmable control through a parallel standard interface. Monitor and keyboard of the personal computer are also used for operator communication unless the measuring system is incorporated into an automated production line with process guidance system. Being very complex, the functions of the coordinating computer can be characterized as follows:/2/

- Edit and manage the specimens.
- Generate the robot control program.
- Store the data measured by the CCD camera.
- Compute the geometric dimensions.
- Control the entire system.
- Coordinate operations with the overriding management system.

4. MEASURING PROCEDURE AND EVALUATION OF DATA

For the robot configuration used, the precast unit was fixed to a reference point in vertical arrangement prior to the measuring procedure. In view of the scanning width of the camera, the tolerable deviation from the reference point is ± 100 mm in both X and Z. With the number of the precast unit specified, the geometric reference dimensions are taken from the precast-unit file and the measuring procedure is initiated. The time required to scan one point is about 1.5 sec; this includes a 1-sec dwell for the mechanical vibrations of the robot to die out. Once scanning is performed the actual geometric shape is computed. The result can be either immediately hardcopied as a quality certificate or stored in a file. Thus, material tracking control (process management system) being provided, statistical evaluation can be performed to draw conclusions as to sources of poor quality in the production line. Complete scanning, evaluation and printout are accomplished by the measuring system within 10 minutes and, hence, the measuring system can be incorporated into a cycle-timed production line.

5. RANGE OF APPLICATION OF MEASURING SYSTEMS USING MEASURING ROBOTS

The measuring systems presented in this paper are intended to be a first contribution towards automation of length-measuring processes in prefabrication in the construction industry. The basic principle of measuring and evaluating is comparatively independent of the type of robot design. It is reasonable to assume that, depending on the demands made on measuring accuracy, size of working area and compactness of the robot, portal-type robots just as joint robots may be used for this job and, using the components presented here, can be combined into a measuring system. Similarly, the mode of data acquisition may be varied in that, typically, the image recognition system is replaced by tactile scanning of the edges of a precast unit. Also, it should be pointed out that the automatic measuring system for precast units is an initial approach towards outgoing inspection which is certainly necessary for the product.

References

[1] Mewes, S.: Untersuchungen zur Meßgenauigkeit einer CCD-Kamera zur Betonelementevermessung. Großer Beleg 6.5/89, Technische Universität, Magdeburg, 1989.

[2] Westphal, M.: Entwicklung eines Plattengeometrierechners für Meßrobotersysteme mit CCD-Kamera. Diplomarbeit 6.5/88, Technische Universität, Magdeburg, 1989.

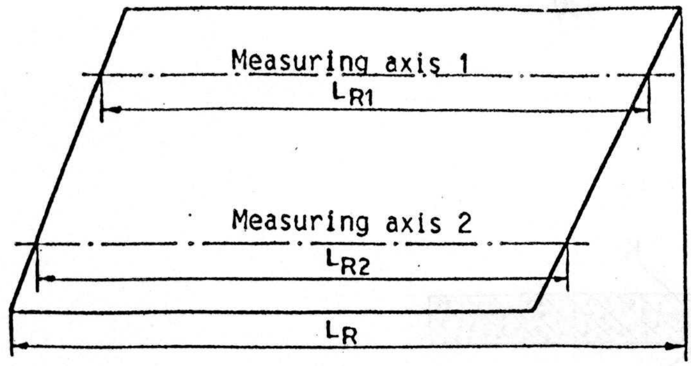

Fig. 1: Paralleogram-like shape of a wall panel.
L_{R1} and L_{R2} serve to determine the length of the wall panel. L_R is the actually effective length.

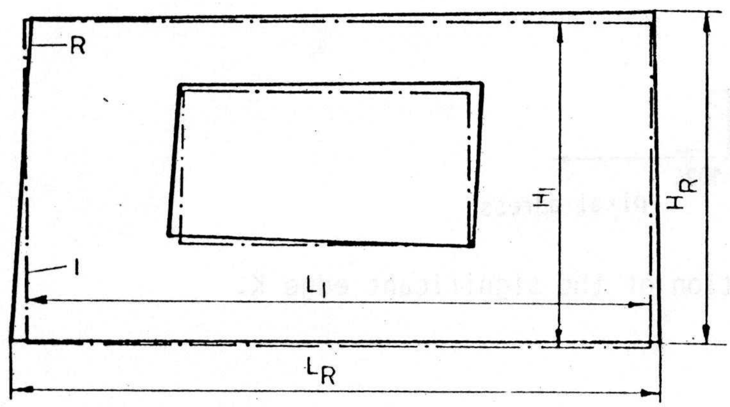

Fig. 2: Ideal (I) and determined (R) geometric shape for an orthogonal wall panel.
Examples of critical features:
H_I, H_R Ideal and effektive panel height
L_I, L_R Ideal and effektive panel length

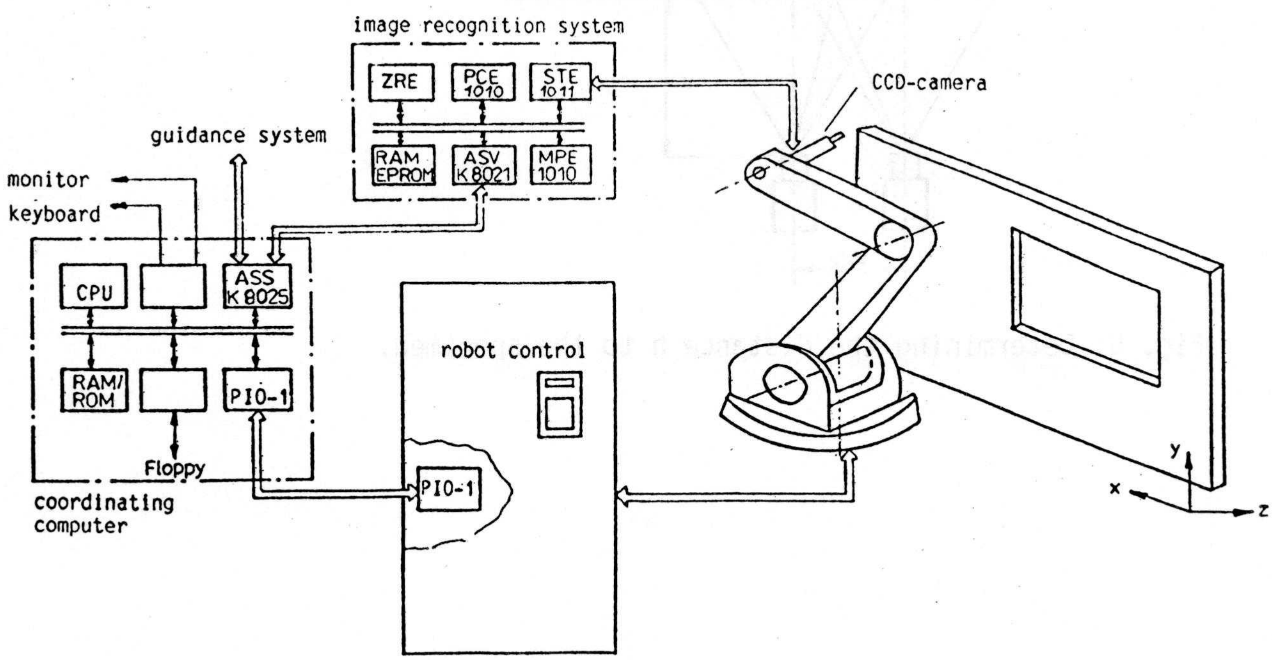

Fig. 3: Structure of the measuring system.

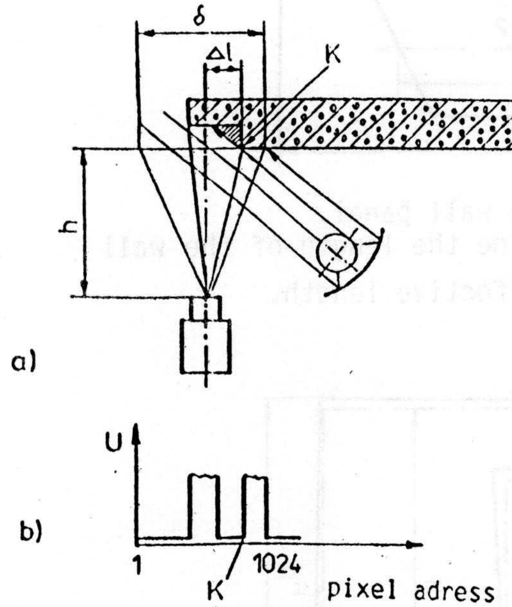

Fig. 4: Determining the location of the significant edge K.
a) Measuring setup
b) Bit pattern

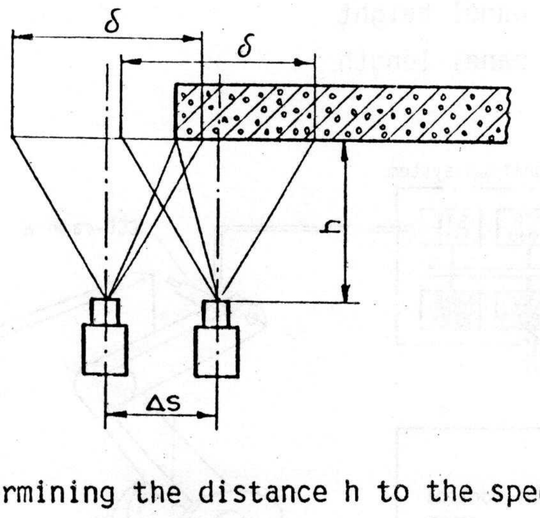

Fig. 5: Determining the distance h to the specimen.