METHOD AND RESULTS OF EXPERIMENTAL RESEARCHES OF AUTOMATED INSTALLATION FOR DEFINITION OF EGG GEOMETRICAL PARAMETERS BASED ON VISION SYSTEM

МЕТОДИКА И РЕЗУЛЬТАТЫ ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ АВТОМАТИЗИРОВАННОЙ УСТАНОВКИ ДЛЯ ОПРЕДЕЛЕНИЯ ГЕОМЕТРИЧЕСКИХ ПАРАМЕТРОВ ЯИЦ НА БАЗЕ СИСТЕМЫ ТЕХНИЧЕСКОГО ЗРЕНИЯ

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Abstract: A methodology and results of experimental researches of the automated installation for determination of geometric parameters of eggs, based on vision systems, using software LabVIEW and Vision Assistant, is considered in the paper. The installation provides improved performance and accuracy of the measurement of geometrical dimensions and determination of the form coefficients of the eggs. The principle of operation of the automated installation is based on non-contact method of measuring large and small diameter, area and perimeter of the eggs, as well as calculation of the values of form coefficients and comparing them with the fluctuation limits of the measured parameters. The basic technical parameters of the automated installation are accuracy of geometric parameters determination, image processing time and performance. Experimental researches were carried out by three stages: an estimation of geometrical parameters measurement accuracy; determination of measurement productivity of eggs geometrical parameters; determination of productivity of eggs division into two categories (relevant and irrelevant to the form requirements of the standard). The obtained experimental results give reason to consider that the measurement accuracy of the linear dimensions of eggs, using the automated installation, meets the technological requirements. Automated installation enhances 4.5 times the labour productivity, spent on measurement of parameters of eggs. The accuracy of separation of eggs into categories, based on the their form using the automated installation, depends on the time, which operator needs for the correct reaction on the signal of the virtual instrument indicator and is equal to 15% at productivity 1,800 eggs per hour and 5.0% at productivity 1200 eggs per hour.

KEY WORDS: AUTOMATED DEVICE, GEOMETRICAL PARAMETERS OF EGGS, VISION SYSTEM, LABVIEW

1. Introduction

The estimation of quality of eggs is the first necessary step for process control and successful incubation. Hatching eggs should be selected carefully, taking into account that any deviation from the norm adversely affected on the output and quality of young growth. Unsuitable for incubation by the external features of the whole eggs are considered eggs which have big and small masses, or irregular shape (completely round, excessively long, flattened) and defects of the shell. At present, the quality control of hatching eggs is carried out manually according to the analysis of the control sample batch of eggs. For definition of parameters of the control batch of eggs is used mechanical measuring devices (scales, calipers) and appliances (indeksomer, a device for determining the thickness of the shell). The measurement results are recorded manually or entered into the computer with the subsequent calculation of eggs parameters. With the purpose to increase the productivity of eggs geometrical parameters process measurement at the Kazakh National Agrarian University are developed an express method and automated installation for definition and the analysis of geometrical parameters of eggs within the framework of a research plan under target program MES "Target development of university science focused on innovative result" [1]. The automated installation consists of a chamber, a computer with specially developed software, a support and a working surface for placement of the object. The program for preparation and eggs image processing is developed in “LabVIEW” environment. The program includes a block diagram and a virtual instrument, which displays on the monitor the values of the measured geometrical parameters (large and small diameter, area, perimeter, and the coefficients of the form) of examined eggs. The installation automatically determines the eggs geometric parameters and compares the size and shape values with the given values of these parameters in accordance with standard and generates a signal of the correct size and shape. Studies have shown that the automatic device provides improved performance of eggs parameter evaluation and separation into categories, based on the size of eggs with simultaneous rejection of eggs with irregular shape.

2. Materials and methods of research of object using vision systems

2.1. The information on object of researches. Object of research is stationary installation for definition of geometrical parameters of eggs. The stationary automated installation allows determination of the following eggs parameters: large diameter (D), small diameter (d), perimeter (L), area of longitudinal section (S), an index of the form К1 (К1 = (d/D).100 %), shape factor К2 ($К2=L^2/S$) [1]. The basic technical parameters of the installation are accuracy of definition of geometrical parameters, image processing time and performance. Schema of the stationary installation is shown in Figure 1.

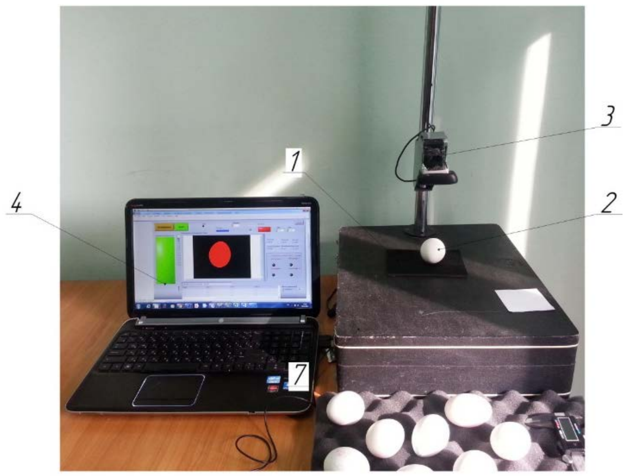

Fig. 1 *- Schema of the installation*
1- working surface; 2 - egg – the object of study; 3- image capturing device (camcorder, camera, webcam); 4 - personal computer with software.

2.2. Installation principle of operation. Egg is set on a work surface in the control zone gripping device that captures the object of study, and transmits the acquired digital images to a PC, where by means of the special software "STZ Egg" the eggs geometrical parameters are determined. Software "STZ Egg" provides photos capture of the working surface with egg, followed by extraction of the eggs image and determination of its parameters. In Microsoft Office Excel the egg data parameters are transformed in the form of a table by which the database is formed. The solution developed in LabView program, provides a comfortable working environment for an operator with initial computer skills. The following skills are required to work with the automated installation: Windows applications 7, 8, 8.1; MS OFFICE, OpenOffice, LibreOffice; LabView, Vision Builder, VisionAssistant and VisionDevelopment.

2.3 Preparation of installation for work. The stationary automated installation is mounted on a smooth, evenly lit surface (table). Webcam on a support is mounted in a vertical position perpendicular to the work surface at a height of 160 mm. In the control area on the working surface of the table is inserted matt black cover. PC is connected to the power supply network and after that it is connected to a video capture device via USB-3.0. The distributive software "STZ Egg" includes: a software environment Labview; NI VisionAssistant; NI VisionDevelopment; the client part of the Windows application. To start the system is required to pass a panel Start menu Windows (XP, 7) programs, find the folder "STZ Egg" and run the executable file STZ Egg.exe. The program interface "STZ Egg" is shown in Figure 2 and consists of the following operating and display windows:

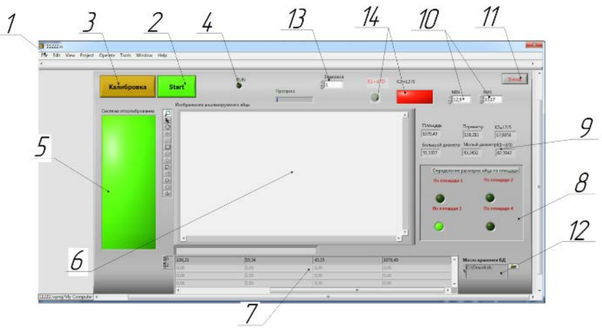

Fig. 2 *- The program interface "STZ Egg"*

1. Main menu - contains functions for program start-up and closure, window turning, as well as the help function;

2. Start Button - Starts the camera work and the program for identification and analysis of the geometric parameters of the studied eggs;

3. Start button calibration "Calibration" - starts calibration device; "Stop Calibration" - disables the calibration device;

4. Program (RUN) indicator and a progress indicator;

5. Indicator for calibration accuracy. Green color - designates that the system is calibrated; Red indicator - the system is not adjusted for measurements,

6. Image window of analyzed object - in this window the image of the analyzed eggs is displayed in black - red color.

7. Table with data - in the given table values of geometrical parameters of each analyzed object are entered.

8. Area indicators. Indicators of the area with green color show, each egg to what category on the size is concerned.

9. Indicators of geometrical parameters - The current values of the geometric parameters of the object are displayed: Large and small diameter, area, perimeter, shape index and shape factor.

10. Shape Factor variation range controller. It designates the allowable boundary value of the shape factor, depending on the requirements and chickens breed.

11. Exit button - sets the overall output of the system software.

12. Way of storage databases (DB) - specifies the place where analyzed objects data will be stored.

13. The delay controller. The period of time, in seconds, required to determine the parameters of one egg. The time can be set from 1.0 to 30.0 seconds depending on the task.

14. Indicators of aspect ratios - show compliance with the standard form of eggs from the values of the two coefficients characterizing the shape of eggs. Shape index, equal to the ratio of small to large-diameter as a percentage (the permissible limits for hatching eggs provides the industry standard) and the value of the shape factor equal to the ratio of the square perimeter of the area, which is recommended by the results of research as informative.

2.4 Installation operating procedure. After checking the working capacity of the program, it is necessary to calibrate the system for determination of the geometric parameters. The calibration procedure provides, translation of values of geometrical parameters from the digital form, specified in pixels, in metric system (millimeters). The sizes of the special standard are included in a database (a square of white color in the sizes 70x70 mm). In order to calibrate the system it is necessary to run a calibration program by press button "Calibration" on the panel.

Further it is necessary to adjust height of installation webcam using a support to the moment when the green color indicator "System is calibrated" is turned on. The next step is as follow: press the button "Stop Calibration" and enter the value of the allowable range of changes in the shape factor of the controller range. Minimum and maximum value of the shape factor is equal to the ratio of the square perimeter of the image eggs to its area, determined in accordance with the requirements of the standard and with the researches results. The time required to determine the parameters of one egg in seconds, taking into account the time it takes to install and remove the eggs from the working surface is entered in the delay area. The time necessary for determination the parameters of a single egg on the automated installation is 960 milliseconds. The delay time can be varied from 1.0 to 30.0 seconds. In the storage database (DB), by pressing the function button to open (as a folder) opens conductor. Select a local drive "C" and save the data in the format Excel. Next, set the following egg and again using the Start button starts the system. If the egg has an irregular shape, the shape factor indicator lights up in red that indicates that the egg misses in a predetermined allowable range of the shape factor and the egg shape is unusual. At the same time the area indicators irrespective of the eggs shape factor determines egg category by the size (weight). Figure 3 shows relevant indicators.

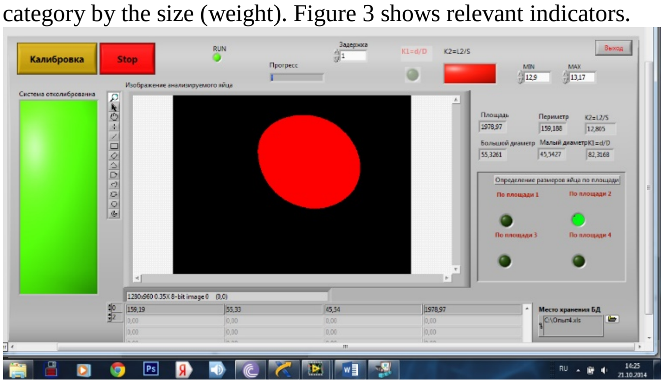

Fig. 3 *- Egg has an irregular shape*

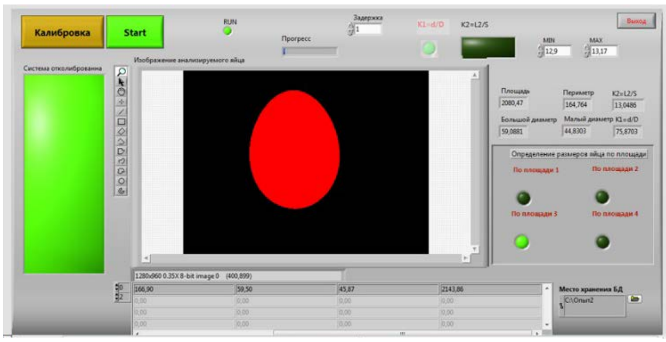

Fig. 4 *- Egg has correct form*

If the egg has the correct form, the shape factor indicator remains green that indicates that the egg is in the acceptable range of values of the form factor and its shape corresponds to the standard (Fig. 4).

After the research it is necessary to shut down the system by pressing the "Stop" button, wait for the RUN indicator to turn off, and then click Exit and confirm the output (YES) or cancel (No).

3. Methodology and results of experimental researches

The basic technical parameters of the automated installation are accuracy of geometric parameters determination, image processing time and performance. Experimental researches were carried out by three stages.

1. An estimation of geometrical parameters measurement accuracy;
2. Determination of measurement productivity of eggs geometrical parameters;
3. Determination of productivity of eggs division into two categories (relevant and irrelevant to the form requirements of the standard).

3.1. Estimation of geometrical parameters measurement accuracy. The geometrical parameters measurement accuracy depends on the following factors: resolution of the camera; calibration accuracy (procedure of converting a digital image in pixels, in the metric system in millimeters); location of the object on the working surface toward to the camera. Selected webcam has three variants of CCD resolution. High resolution - 1280 x 960 pixels, average - 960 x 720 pixels and low – 640 x 480 pixels. Analysis of the image quality on the screen showed that the clear contour lines are obtained at high and medium resolution setting. Therefore, for the experimental setup "STZ Egg" high resolution (1280x960) is chosen.

To verify the effect of the object location on the eggs geometrical parameters measurement accuracy series of tests were performed with eggs located at different angles toward the camera.

1 position. Egg is disposed horizontally toward webcam, the large diameter is located at the abscissa axis, and the small diameter along the vertical axis. Such egg arrangement is standard in determining of eggs parameters. However, during operation the operator can place the egg with some deviations from strict predetermined position, whereby, during the measurement some additional random errors can be appeared. Eggs location for this first position is shown in Figure 5.

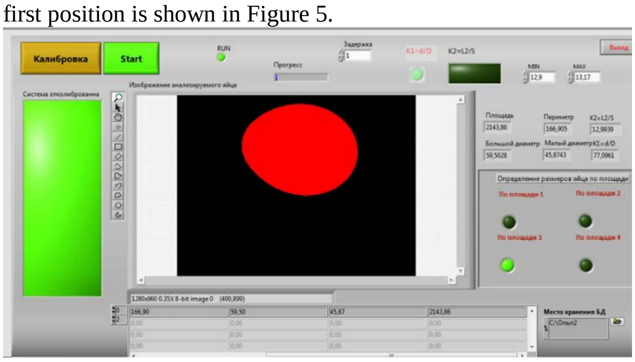

Fig. 5 *- Horizontal position of the object*

2 position. Egg is located approximately 45 degrees toward the web camera; **3 position**. Egg is located approximately 90 degrees toward the web camera and **4 position** - Egg is located approximately 135 degrees toward the web camera.

For each of the above considered positions, geometrical parameters of one and those eggs were measured with tenfold frequency. After each parameters measurement, the egg is removed from the working surface and for the next measurement is reset again. This approach simulates the actual measurement process, taking into account the random errors caused by arbitrary egg location toward the camera during operation of the operator.

4. Experimental results and discussion

The large and small diameters, the perimeter, the area and the values of the index form K1 and the form factor K2 were repeatedly evaluated ten times using the experimental installation. The generalized values of the mathematical expectation value and the standard deviation of the geometric parameters and coefficients of the form are presented in Table 1.

Table 1 *– Generalized values of the geometric parameters.*

		D	d	L	S	K1	K2
0	M	59,50	44,88	165,55	2097,12	75,43	13,07
	σ	0,012	0,007	0,008	0,312	0,079	0,003
45	M	59,42	44,88	165,42	2094,51	75,54	13,06
	σ	0,0482	0,035	0,04	0,293	0,119	0,005
90	M	59,15	44,78	164,82	2080,87	75,71	13,05
	σ	0,055	0,042	0,042	0,201	0,142	0,006
135	M	59,43	45,69	166,53	2132,87	76,87	13,02
	σ	0,012	0,006	0,007	0,311	0,079	0,004

For comparative assessment of the accuracy of determination the geometric dimensions by the experimental installation, large and small diameters of the same eggs were identified using an electronic caliper with an accuracy of 0.01 mm. ten times repeatedly. Fig. 6 shows the procedure for measuring large and small diameters using an electronic caliper.

Fig. 6 *Measuring large and small diameters*

As a result of statistical processing of the measurement of the large and small diameters the following results were obtained. The average value of a large diameter (D) is equal to 58.53 mm. The standard deviation (σ) is equal to 0.23 mm. The average value of a small diameter (d) is equal to 44.45 mm. The standard deviation (σ) is equal to 0.19 mm. The shape index (K1) is equal to 75.85% respectively. The values of the area and perimeter were not measured by an alternative method of measurement due to the absence of appropriate certified measuring tool.

The comparison between values of the large and small diameters measured by the automated installation and the same values measured by the caliper shows that the absolute value of differences for a large diameter is not more than 0.97 mm., while for the small diameter it is not more than 0.45 mm. The relative value of differences when measuring large diameter is 1.66% and it is 1.01% of small diameter. The obtained values of differences between the certified method of determining the size of the eggs and the values obtained from the automated installation gives a reason to believe that the accuracy of determination the linear dimensions of eggs on the automated installation meets the technological requirements for determining the size of the eggs.

3.2. Comparative assessment of the automated installation performance. The purpose of this experiment is a comparative evaluation of the performance of the two methods of determination the geometric parameters of the eggs, the manual method for measuring large and small diameter using electronic calipers and entering data into the computer and the evaluation of large and small diameter, area and perimeter as well as the values of the index and the shape factor using automated experimental installation. The experiment was conducted in a research laboratory in KazNAU. To determine the performance of a manual method of measuring large and small diameter of eggs using an electronic caliper, it was performed timekeeping of the time spent by three different operators to measure and to enter the results obtained in prepared in advance table in the computer. The process of measuring the size of the eggs using an electronic caliper is shown in Fig. 7.

Fig. 7 *- Measuring the size of the eggs using a caliper*

Figure 8 shows the procedure for measuring large and small diameter, area and perimeter as well as the values of the index and the shape factor on the automated installation. It can measure parameters of both white and brown eggs.

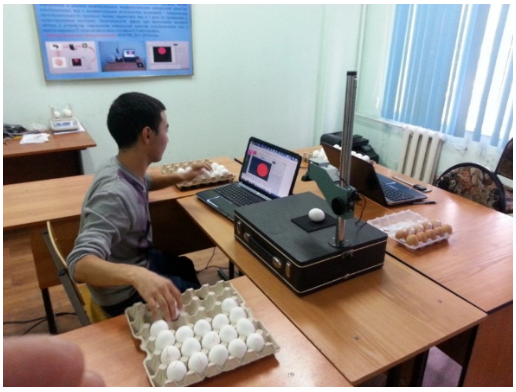

Fig. 8 *– Measurement of egg parameters on the automated installation*

Investigations were carried out in 3 stages:

10 eggs, the average time spent for the measurement – 122 seconds; 30 eggs, the average time spent for the measurement – 426 seconds and 60 eggs, the average time spent for the measurement – 865 seconds.

The specific amount of time for measurement of large and small diameters and to input data to a computer was, respectively, 12.2; 14.2; 14.4 seconds. It is assumed that the average duration of the manual method of determining the size of the eggs using an electronic caliper equal to 13.6 seconds. Thus, the performance of the parameter measurement of eggs using an electronic caliper is an average of 265 eggs per hour.

It is known that the time for determining the size of the eggs on the automated installation can be set from one to 30 seconds per egg. Before the experiment, it was checked how long it takes for an untrained operator to measure parameters of eggs on the automated installation. The program developer spent no more than two seconds to define the parameters of one egg, and the students involved as operators spent three seconds.

The experiment on an automated installation was also carried out in 3 stages: using 10 eggs, the elapsed time of 30 sec.; 30 eggs, the elapsed time of 150 sec.; and 60 eggs, the elapsed time of 180 seconds.

3.3. Determination of the performance of the separation of eggs into two categories. To evaluate the performance and accuracy of the selection of eggs for incubation, experiment was conducted in the following manner. The experiment used 60 eggs which were preliminary divided by the value of the shape factor into two categories: 1 - egg with shape corresponding to the requirements of the standard; 2 - irregularly shaped eggs. 14 out of 60 eggs had non-standard for incubation shape (23.3%). Then eggs were mixed and three experts independently and manually separated the eggs into two categories by its shape. The same procedure was carried out on the experimental installation. The operator set the egg on the work surface and following the shape factor indicator signal (14 in Fig.2) divided the eggs into two categories by its shape. If the indicator is green, the egg shape conforms to the standard, if it is red – it is irregularly shaped egg. This investigation produced the following results. During the manual selection, average time spent on the separation of 60 eggs was 196 seconds or 3.26 seconds per egg. The performance of sorting is 1100 eggs per hour. However, 8 irregularly shaped eggs were incorrectly assigned to the group of standard eggs and 13 eggs of standard form were separated to the category of non-standard eggs. The total number of incorrectly classified eggs was 21. The relative accuracy of the selection of eggs by its form using the manual method is 35%.

When separating eggs into categories based on the form on the automated installation two options selection were investigated. The first option includes a delay between the measurements of two seconds. The second option includes three seconds delay. In the first option of sorting time was 120 seconds, the number of operator errors was 9 eggs. Mistakes were made as a result of improper mechanical movement of eggs, when under operators own momentum an egg with regular shape was shifted into the container with non-standard eggs, or in opposite case. The separation accuracy of eggs by shape in that case is 15%. In the second option of sorting time was 180 seconds, the number of operator errors was 3 eggs. The separation accuracy of eggs by shape in that case is 5%.

5. Conclusion

As a result of the experimental investigation, the following results were obtained.

1. The values of large and small diameter of eggs, which are measured on an automated installation, do not differ from those, measured by electronic caliper. The absolute value of the differences is, for large diameter not more than 0.97 mm., and for the small diameter not more than 0.45 mm., thus giving reason to believe that the accuracy of the determination of linear dimensions of eggs on the automated installation meets the technological requirements and can be used to determine the eggs size.

2. The analysis of the results from the timekeeping show that the time for manual measurement of one egg is 13.6 seconds, while the same time on the automated installation is three seconds, thus the productivity of manual measurement is an average 256 eggs per hour, while the productivity of the automated installation – 1200 eggs per hour. Automated installation provides increased productivity spent on measurement of the eggs in 4.5 times. The installation also provides quantitative information for the size (area and perimeter) and shape (form factor) of eggs, which is not available for manual measurement.

3. The time required to determine the parameters of a single egg on the automated installation is 960 milliseconds. The technological capabilities of the automated installation allow bringing the performance of the process of determining the parameters of the eggs up to 3,600 eggs per hour.

4. The accuracy of the manual separation of eggs into categories by its form is about 35%, while the accuracy of the automated installation depends from the time needed for the operator's correct reaction on the signal of the virtual instrument indicator and is equal to 15% at productivity 1,800 eggs per hour and 5.0% at productivity 1200 eggs per hour.

6. Literature

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