Microfocus X-ray seeds separator

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Abstract. In this paper the model of X-ray seeds separator is described. The main parameters of the seed separator are determined. The operating modes of the X-ray apparatus were determined; with these modes the greatest contrast of the image was achieved. For the research, seeds of almost 40 different plant species were selected. For each type of seed, the optimal parameters of the imaging were calculated; also during the experimental studies the parameters were checked.

The production of high quality seeds is an important task of developing agro-industrial complexes. Nowadays X-ray methods of nondestructive testing of seeds quality begin widely using. The main advantages of these methods are the high speed of analysis, the possibility of obtaining a large amount of information and the high probability of recognition of defects and pests.

Today there are two main methods of X-ray filming: the contact method and the method with a magnification of the image [1, 2]. To apply the first (contact) method the radiation source with the large focal spot (focal spot size more than 0.1 mm) is used. The filming object is located at a sufficiently large distance from the radiation source and as close as possible to the X-ray image detector. To apply the second (with magnification) method the microfocus radiation source (focal spot size less than 0.1 mm) is used. This method is called microfocus radiography. The filming object is located at the specified distance between the radiation source and the image detector and the ratio of this distance determines the image magnification of the object.

Microfocus radiography allows getting an enlarged image of the object. That is why this method is preferable for the radiography of seeds. This method allows getting sharp images of seeds with high magnification, which is not possible using contact method. Thus, the method of microfocus radiography can reliably detect the variety of seed defects, including the percentage of damage, empty seeds and pests [3].

For the separation of qualitative and substandard seeds, an X-ray seed separator model was proposed. In this model, X-ray radiation is used to obtain a shadow image of a group of seeds, after which digital processing of the image is performed. Based on the received data, the decision is made whether the seed is damaged or not, and, consequently, the damaged seeds are separated from the intact ones.

The model of the X-ray seed separator includes an X-ray protection chamber 1, a microfocus X-ray source 2, radiation source displacement system 3, X-ray detector 4, consisting of a scintillator 5 and a matrix of photosensitive transistors 6, seed displacement system 7, magnetic focusing system 8, processing and control unit 9. The processing and control unit is connected to the X-ray radiation detector, the X-ray radiation source and the magnetic focusing system. A schematic representation of
the model is shown in figure 1. The model is controlled by the operator, which loads the research objects into the seed displacement system, and also controls the operation of the separator.

![Figure 1. Schematic of the model of seeds separator.](image)

The coefficient of image magnification is determined when the operator selects the type of seeds to be examined. The coefficient is calculated on the basis of the minimum size of the defects that can be presented in these seeds, according to the following formulas:

\[
A = a \cdot \frac{f_1}{f_2}
\]

\[
H = d \cdot \frac{f_1 - f_2}{f_2}
\]

where \(a\) – size of the defect; \(A\) – size of the defect image; \(d\) – focal spot size of microfocus X-ray radiation source; \(f_1\) – distance from the focal spot to the seed; \(f_2\) – distance from the microfocus X-ray radiation source to X-ray detector. The separator works as follows: the operator sets the type of seeds to be examined; the voltage and current of the X-ray tube are automatically set, depending on the type of seeds. Also, depending on the type of seeds, the distance from the source of radiation to the object of research varies, thus changing the image magnification factor. The X-ray radiation, generated by the microfocus source passes through the seeds and is unevenly attenuated by the elements of seeds structure. X-ray image the image is recorded and converted into a digital electrical signal by an X-ray detector. The processing and control unit uses special software to process the digital image of each seed and determine the quality of all seeds.

To determine the quality of the seeds, a bank of standard X-ray images of seeds was collected, which were obtained earlier in the X-ray studies from different seeds cultures. During the development of the method, the operating modes of the X-ray apparatus were determined; with these modes the greatest contrast of the image was achieved. Samples of seeds for research were provided by the Botanical Garden of Peter the Great of the BIN RAS (St. Petersburg). For the research, seeds of almost 40 different plant species were selected. To carry out the research, a microfocus radiation source RAP50 is used, which having a range of variation of the anode voltage of the X-ray tube 5...50 kV and the range of the anode current variation of 20...200 \(\mu\)A.

For each type of seed, the optimal parameters of the imaging were calculated; also during the experimental studies the parameters were checked. At X-ray inspection of seeds research objects are
usually located on cards, in strict order. The card has a working field of X-ray transparent material with an area that allows the total number of seeds to be analyzed.

To obtain a bank of seed images, cardboard cards were also used. However, since when sorting the seeds with the help of a separator they will not be located separately from each other, in strict order, the experiments were carried out which made it possible to find out that all hidden defects are reliably recognized in chaotically located seeds.

As a result of the research, a bank of X-ray images of seeds of various plant species, representatives of different families was assembled. The main parameters of the developed X-ray seed separator are determined. It is shown that in the separator it should be possible to change the voltage of the X-ray tube from 14 to 30 kV, tube current from 60 to 200 μA over the operating voltage range. The image magnification ratio should vary from 3 to 20 times. For X-ray separation of seeds, microfocus sources of X-ray radiation should be used. The use of such radiation sources makes it possible to obtain images with high magnification. The proposed technique for automatic X-ray seed separation makes it possible to simplify the work and reduce labor costs for cleaning seeds to obtain results promptly and without seed quality testing by traditional methods.

References
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