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EXPERIMENTAL EXAMINATION OF BOND STRENGTH AND ENERGY OF GRAIN ON THE EAR

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The strength and energy with which a grain is bound in the ear are important agrophysical characteristics of cereals. Experimental investigation of these has been the subject of papers by a number of authors. Some were led by the desire to established suitable harvest technology for a given variety and to reduce harvest losses. With others the work was associated with breeding new varieties. Some authors tried to estimate absolute values while others used their equipment for examining only relative values of bond strength and energy of grain on the ear in different varieties and in different biological conditions. Generally it can be said that the konwledge of values of these quantities may be utilized both in the field of agricultural engineering (questions of threshability, energy balance of threshing, harvest losses, suitable time of harvest) and in classifying and breeding varieties with necessary properties.

DEFINITIONS

In spite of a relatively wide extent of work done on this topic the bond strength and energy of grain on the ear, as an agrophysical quantity, has not been defined until recently. That results in inaccuracies and errors in interpreting experimental data. First of all it should be borne in mind that the release of a grain from the ear is a process which takes a certain time over which the grain slides out of the spikelet. During this period a force must be exerted on the grain so as to overcome the force originating during the release of the grain and due to the bond of the grain on the ear. This force shall be called the binding force. Its origin is mainly in the rigid attachment of the grain to the pedicel and in the constraint of the grain in the spikelet. The binding force is not constant throughout the release period. If the instantaneous value of the force is designated F, then, during the release, this force will be a function of the relative position r of the grain with respect to the spikelet, hence $F = f(r)$. For example, with wheat and rye, F reaches its maximum value after separation of the grain from the pedicel while for further release, during movement of the grain in the lemma and palea, less force is required, which drops to zero when approximately half of the grain has slid out of the spikelet. Thus the bond strength in the spikelet is to be considered as the maximum value F_v of the course of the force required for the release, i.e. the maximum value of the binding force. In addition, the direction of action of this force should be determined. It must be the direction of sliding out of the spikelet, i.e. the direction of the longitudinal axis position of the grain *in situ* which may be different for different parts of the ear, as well as for different varieties.

Let us then formulate the definitions: The bond strength of a grain in the ear is equal to the maximum value of the course of the binding force F required for keeping the grain in the ear during its release; its direction is identical with the possible direction of sliding out of the spikelet (i.e. along the longitudinal axis of the grain on the ear *in situ*). The work required for releasing the grain is $W = \int_0^l F\,dr$, where l is the path along which the binding force acts. The bond energy is defined by this work.

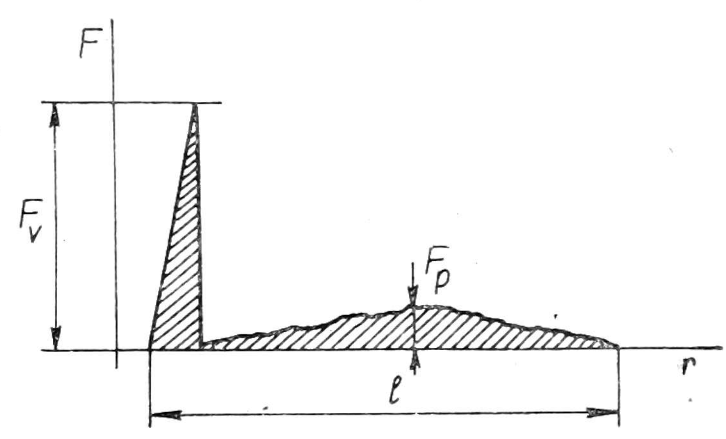

Fig. 1

The above mentioned quantities are demonstrated in Fig. 1, where F is the binding force, F_v the bond strength, F_p maximum value of the binding force due to the constraint of lemma and palea, the hatched area defined by the course of the binding force F and by the axis r corresponds to the bond energy W, l is the path along which the binding force acts — may be set equal to the length of the grain.

BRIEF SURVEY AND CRITICAL EVALUATION OF EXISTING METHODS

Grain bond strength has often been determined by an indirect method making use of the inertia force effects when the ear is moving at acceleration. Most often the movement is realized by fastening the ear to the centrifuge rotor and the revolutions or angular velocity of the rotor at which the grains fall are recorded. Provided we know the grain mass, rotation radius, and angular velocity we can calculate the inertia force at which the connection of the grain with the ear is broken, i.e. we determine the bond strength. Inaccuracies of this method occur mainly in estimating the mass of individual grains and the rotation radius, furthermore, in neglecting the fact that the possible direction of sliding out of the ear is different from that of inertia force action, a certain influence is exerted by vibrations of the centrifuge, as well.

To estimate the bond energy Pustygin and Levin designed an apparatus where the ear is fastened on a lever which is set to motion by means of springs. At the moment of collision with an obstacle the grains are pulled out from the ear by inertia force action. The kinetic energy of the released grain immediately before collision is considered by authors as bond energy. Inaccuracy of this method is caused both by inaccuracies in determining the velocity immediately before collision and by the fact that grain retains a part of kinetic energy after release.

DIRECT METHOD

The use of the direct method [1, 2] follows the above definitions. The ear or only one spikelet is firmly fastened, the grain seized with fine jaws through the slit between the lemma and the palea. (Sometimes they must be pried open gently. If this is performed carefully, the bond strength F_v is not influenced, on the contrary, it may exert an effect on the force F_p. A special verifying measurement with aid of centrifuge showed, however, that this influence on F_p was negligible [3]). The jaws are equipped with tips which are impaled into the grain. We then make a force act on the jaws in the direction of the longitudinal axis of the grain and record either its course during the release of grain or only measure its maximum value F_v, i.e. the bond strength.

AVAILABLE EQUIPMENTS

To realize this method it is possible to use a precise testing apparatus, for example Instron. This equipment, however, is very expensive. Furthermore, at detailed investigation of the course of the binding force there is a disadvantage of a low velocity of the recording instrument. That is why a fine testing apparatus, suitable also for investigating other mechanical properties of agricultural materials, was constructed in the Department of Physics of the University of Agriculture in Prague (see Fig. 2). The dynamometric ring of this apparatus is equipped with a differential transformer. In connection with electronic measuring apparatus

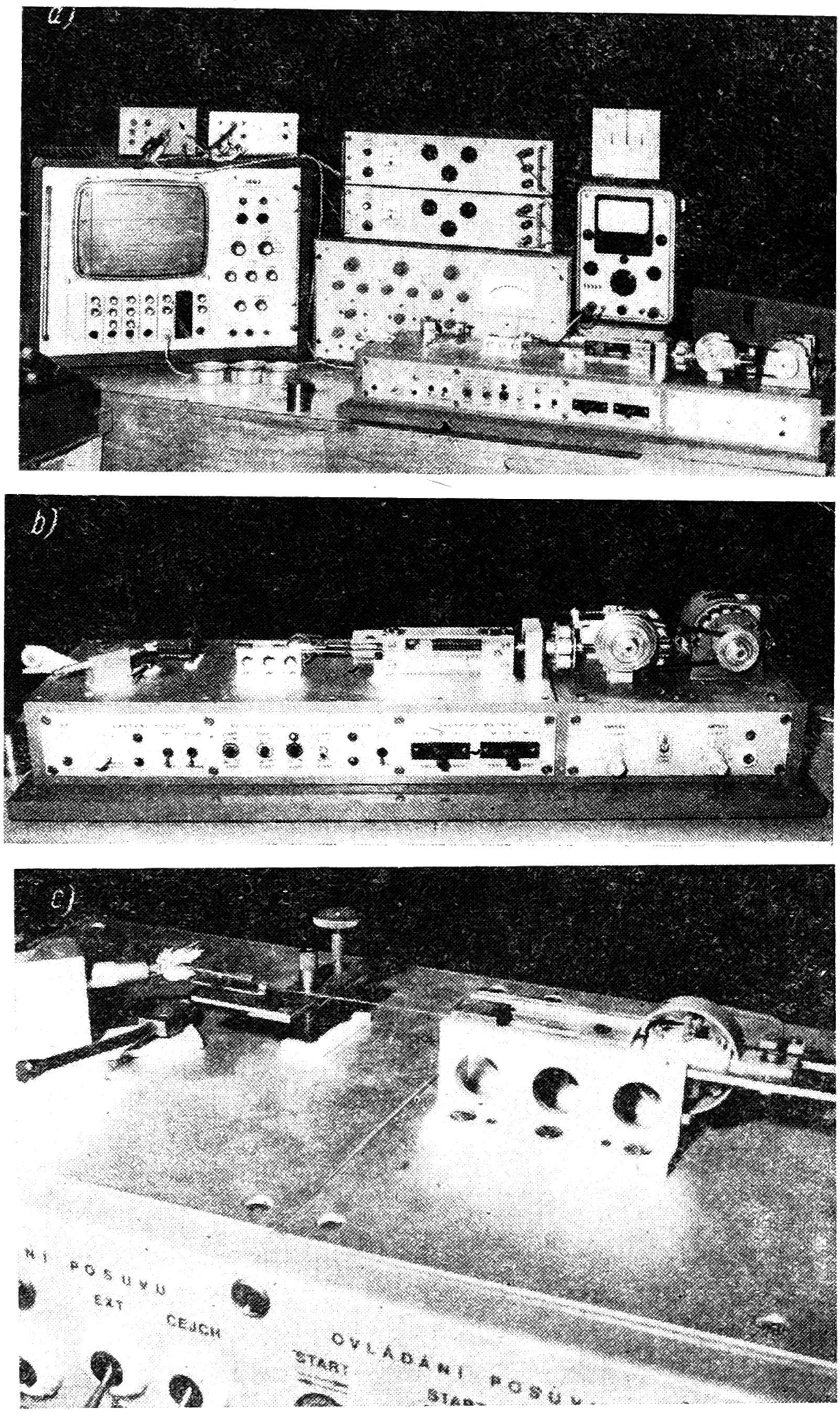

Fig. 2

there is discrimination limit 0.5 mN (~ 0.05 p) and the range up to 100 N. The course of the measured force is recorded with the aid of a loop oscillograph. The velocity of deformation, i.e. the velocity of the sliding of the grain out of the ear is given by the revolutions of the motion screw and may be adjusted in the range from 0.4 to 3 mm/s. By means of this device and its precursor of an older type [1] hundreds of records of the course of the binding force have been obtained in various wheat and rye varieties. With all the character of the course of the binding force was similar to that in Fig. 1. The coefficient k [3] characterizing the pattern of this course has been determined, too, for different varieties: $k = W/W^{+} = \int_{0}^{l} F\,dr/F_{v}l$. If the grain length is known we are able, provided we know the bond energy, by means of this coefficient to determine the bond strength and vice versa.

This device is also relatively complicated and, with all necessary equipment, expensive, as well. The studies performed with the aid of this device were aimed both at understanding the processes connected with the release of grain from the ear and at getting bases for constructing new, simpler devices. First it was the tensometric dynamometer which, in combination with electronic memory of maximum, makes it possible to measure the bond strength and, in connection with integrator, the bond energy. The force is impacted here by manual traction and higher velocities of release can be achieved (Fig. 3). This device appears to be rather complicated, too. It requires the use a tensometric apparatus and other electronic instruments. In an attempt at gaining a very simple and less expensive equipment a spring dynamometer with the pointer of maximum force — bond strength — was constructed. The bond energy can be determined with the aid of the coefficient k and the grain length (Fig. 4). The scale range with 50 sections is up to 50 N (500 p). Another simple device is the apparatus designed on the principle of Sharpy's pendulum (Fig. 5). The grain is clasped by jaws fixed on the frame of equipment. A thread loop attached to the pedicel of the spikelet is bound to the aid lever. The pendulum is dropped alway from the same hegiht, collides with the aid lever, severs the spikelet from the grain, and makes an over-swing. A lesser swing corresponds to greater bond energy. The magnitude of the swing is recorded by a pointer carried by pendulum. The bond energy can be read directly on the scale, corrected with regard to inertia effects of the aid lever, pointer, and severed palea, and to the friction in the bearing of the pendulum and of the pointer. With the aid of the coefficient k and the grain length it is possible to determine the bond strength.

Recently we have studied the influence of vibrations on the bond

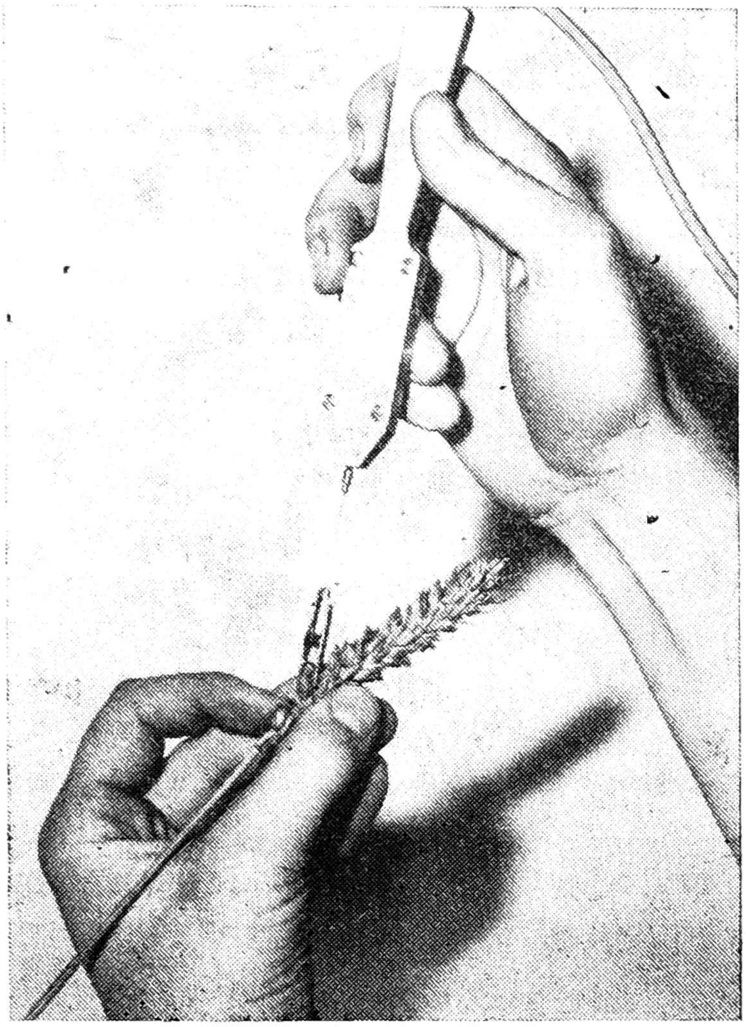

Fig. 3

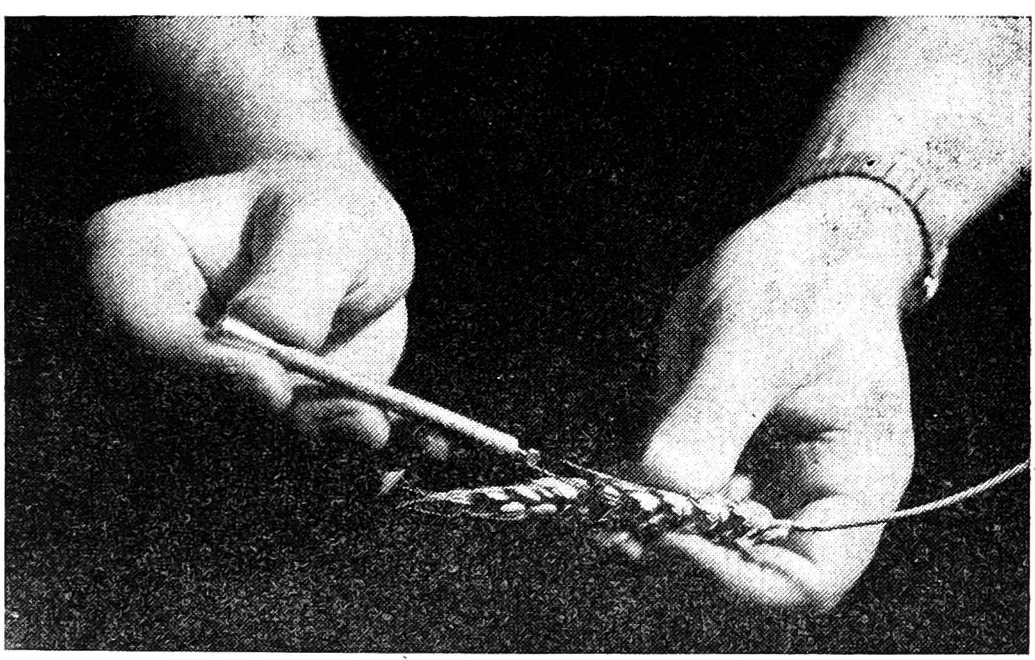

Fig. 4

strength. The force acting on the grain changed harmonically round the constant value set before. The variable force was achieved by means of an electromagnetic exciter. Measurements made up to now in the frequency range from 50 to 200 Hz have proved that this way of force

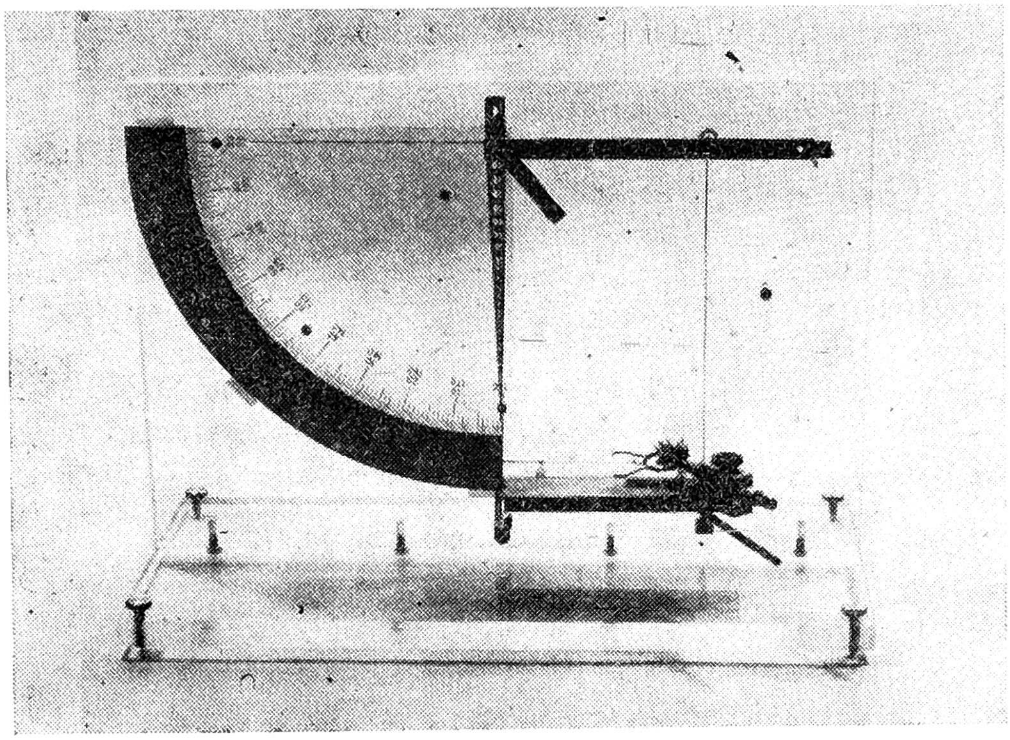

Fig. 5

action does not influence essentially the strength of the connection of grain with pedicel (Fig. 6).

All the methods an devices mentioned until now imitated the actual process of threshing. The procedure of releasing the grain out of the ear may be considered as ideal threshing. (Then the ratio W/W_r, where

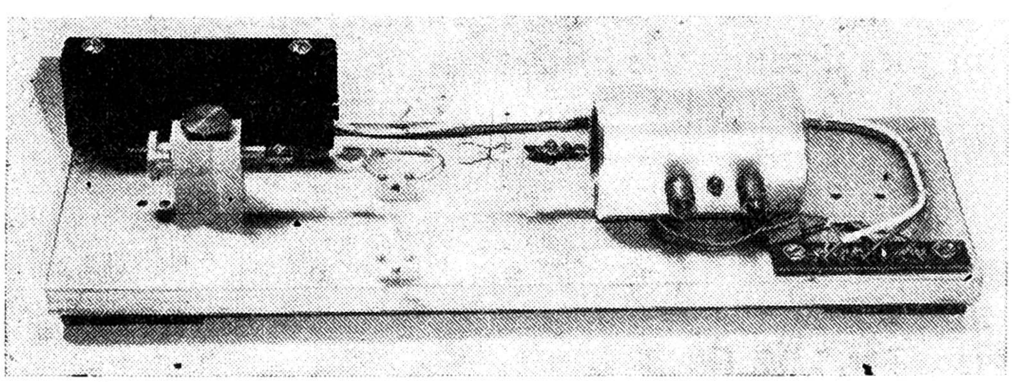

Fig. 6

W_r is the energy required for releasing one grain during real threshing, represents the energetic efficiency of threshing. On the basis of our measurements the value of this efficiency is less than 0.5% for average values W and W_2). For the purpose to elaborate the method for measuring average energy required for releasing the grain from the ear in the process similar to real threshing a device was constructed on the principle of Sharpy's pendulum. The pendulum energy is utilized for pulling the whole ear through a slit or hole. From the decrease of

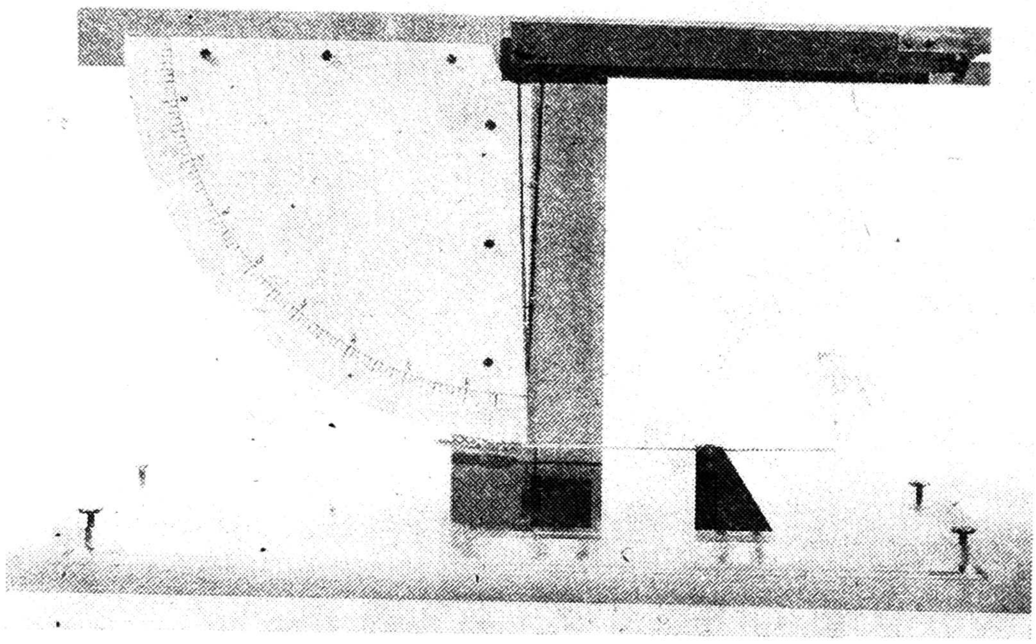

Fig. 7

pendulum energy and the number of released grains the average energy per one grain may be computed. Though the relative velocity of the movement of the ear through the slit is lower by an order than during real threshing, this process appears to be similar enough to that of releasing grains out of the ear in the threshing mechanism. Photograph of the device is to be seen in Fig. 7. The ear is fastened by the pedicel on the frame of the instrument. To the pendulum are attached two plates forming the slit which drives out the grains from the ear at the moment the pendulum goes through the lowest position.

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METODA POMIARU SIŁY I ENERGII ZWIĄZANIA ZIARNA Z KŁOSEM

Streszczenie

Energia i siła związania ziarna w kłosie — to charakterystyczne wielkości agrofizyczne, stosowane w dziedzinie techniki rolniczej i w dziedzinie klasyfikacji i selekcji odmian.

Energia związania ziarna jest to praca niezbędna do usunięcia ziarna z kłosa w kierunku podłużnej osi ziarna.

W pracy celem zmierzenia energii i siły związania ziarna z kłosem została zastosowana metoda bezpośrednia.

Р. Жезничек

МЕТОД ИЗМЕРЕНИЯ ПРОЧНОСТИ И ЭНЕРГИИ СВЯЗЫВАНИЯ ЗЕРНА В КОЛОСЕ

Резюме

Энергия и прочность связывания зерна в колосе — это характерные агрофизические величины, применяемые в области сельскохозяйственной техники и в области классификации и селекции сортов.

Энергия связывания зерна — это работа, необходимая для изъятия зерна из колоса в направлении продольной оси зерна. В настоящей работе для измерения энергии и прочности связывания зерна с колосом применяли прямой метод.

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