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STUDIES ON POTATO RESISTANCE TO MECHANICAL DAMAGE

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To conduct the constructional work leading to elaboration of new agricultural machines, a knowledge of the mechanical properties of treated farm products is required. These properties of agricultural materials can be defined, in general, as their behaviour under action of the forces exerted on them. According to this definition the relationship: stress--strain (deformation) is a distinctive feature of the mechanical properties. These relationships possess varied course for different materials.

Because plants similary as soil, are often deformated at high speeds, during the operation of agricultural machines, the stress-strain characteristics which define materials should be given not only for static or quasi-static strains but they should also be given for dynamic strains.

Basic features which condition the behaviour of bodies being under the influence of the applied forces are: elasticity, plasticity and viscosity. The ideal bodies representing above stated rheological features are as follows:

a) Hookean elastic body,
b) Saint-Venant plastic body,
c) Newtonian liquid.

In a Hookean elastic body the stress is directly proportional to the deformation. After the elimination of external forces (unloading), the elastic deformations entirely disapear, i.e. they are reversible. The return of the body to the initial state can occur in different ways, can be a linear elasticity (as in the case of steel) and nonlinear elasticity, e.g. for rubber (Figs. 1*a*,*b*). Compression tests of farm products (fruits, vegetables, grains) indicate [1] that the ideal elasticity does not occur in these products, even when the strains are very small. After complete removal of the stress some strain always remains (Fig. 1*c*).

The Saint-Venant body represents an ideal plastic behaviour. In this body, as long as the magnitude of the applied stress is below the criti-

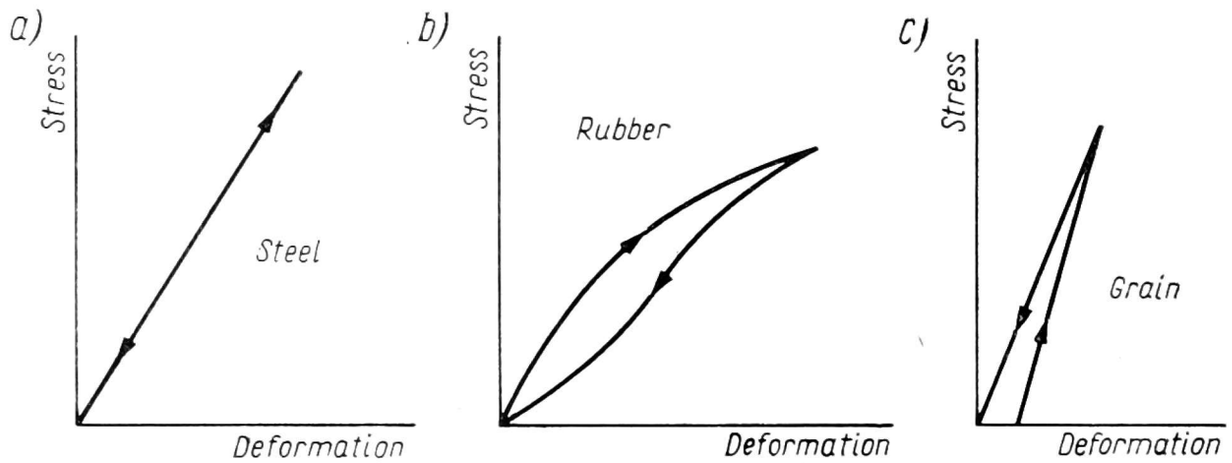

Fig. 1. The stress-deformation characteristics for different materials

cal value (yield point) material remains ideally rigid. Just as stress reaches a critical value a plastic flow also starts at constant stress.

In Newtonian liquid representing ideally viscous body the deformation and flow begins at the moment of application of the shearing stress. Elimination of stress like in a plastic body does not implicate the return to the initial state.

Because there is no real material of which behaviour would be similar to any of the ideal bodies, they can only serve for comparison with the behaviour of the real material. According to the postulates of rheology [2] each material possesses all features of the ideal bodies but to a various degree. The formation of models, being a combination of the elasticity, plasticity and viscosity, gives a certain approximation of the real material behaviour. Complex structure of farm products causes the description of their mechanical properties to require complex rheological models. Most of the authors [3, 4, 5] treated the agricultural products as viscoelastic bodies.

Research works which tend towards determining the mechanical properties of the agricultural products are mainly concentrated on the assignment of such properties as: modulus of elasticity, degree of elasticity, energy of destruction (e.g. for an apple — energy of skin rupture), specific energy of strain etc. Many authors have also studied the course of stress-strain curves at loading and unloading processes. That gives so called hysteresis loops for particular agricultural products. The magnitude of these hysteresis loops is a measure of the material elasticity as well as a measure of dissipation energy inside sample of studied material during the "loading-unloading" cycle. The smaller the hysteresis loop is, the more elastic is the tested material.

The studies of creep and relaxation of the farm products are very important and they also lead to the knowledge of their mechanical pro-

perties [6]. From the practical point of view they are particularly significant to determine the permissible conditions of transport and storage of the agricultural materials.

Above discussed studies were carried out using a small deformation speed. The increasing mechanisation of farming requires a knowledge of the mechanical properties of these products in the case of dynamic deformation, i.e. as the force acts at short time.

The purpose of this paper was to study the stres-strain characteristic in the "loading-unloading" cycle of potatoes which underwent a beating at speeds of 1.9 and 2.6 m/s. An apparatus for determination of the farm products resistance to mechanical damage was used in this study. In this apparatus (Fig. 2) a potato, placed on a special table, is impacted

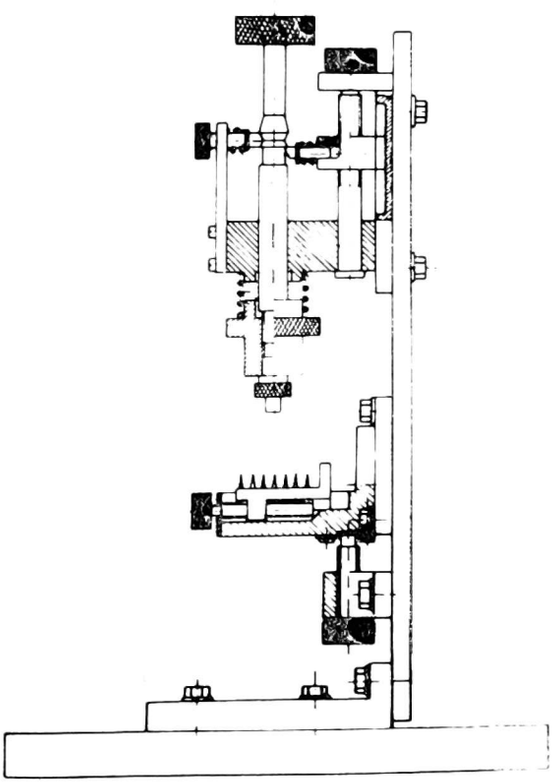

Fig. 2. An apparatus for the determinations of the farm products resistance to mechanical damage

from the top with a plunger which is a cylinder with a section of 0.5 sq.cm. The speed of the plunger is regulated by means of spring tension. The speeds of striking ranged from 1 to 3.5 m/s. In an original version this apparatus allowed the determination of the striking force and the final deformation.

It has been modified by working out a special assembly which changes nonelectric characteristic (force, deformation) to electric ones. It gave a possibility to record the changes of these properties on the two--flux oscillograph screen. The measurement of the force is done by means of the strain gauge system and the registration of deformation by

using an optimeter. The application of the two-flux oscillograph allows the study of the course of the force and deformation in function of time, or it enables the registration of the force in relation to the deformation. For studies presented in this paper the second possibility was applied and the graphs of the relationships force-deformation at speed: 1.9 and 2.6 m/s (Fig. 3*a*,*b*) were received after photographing the course of the oscillograph spot.

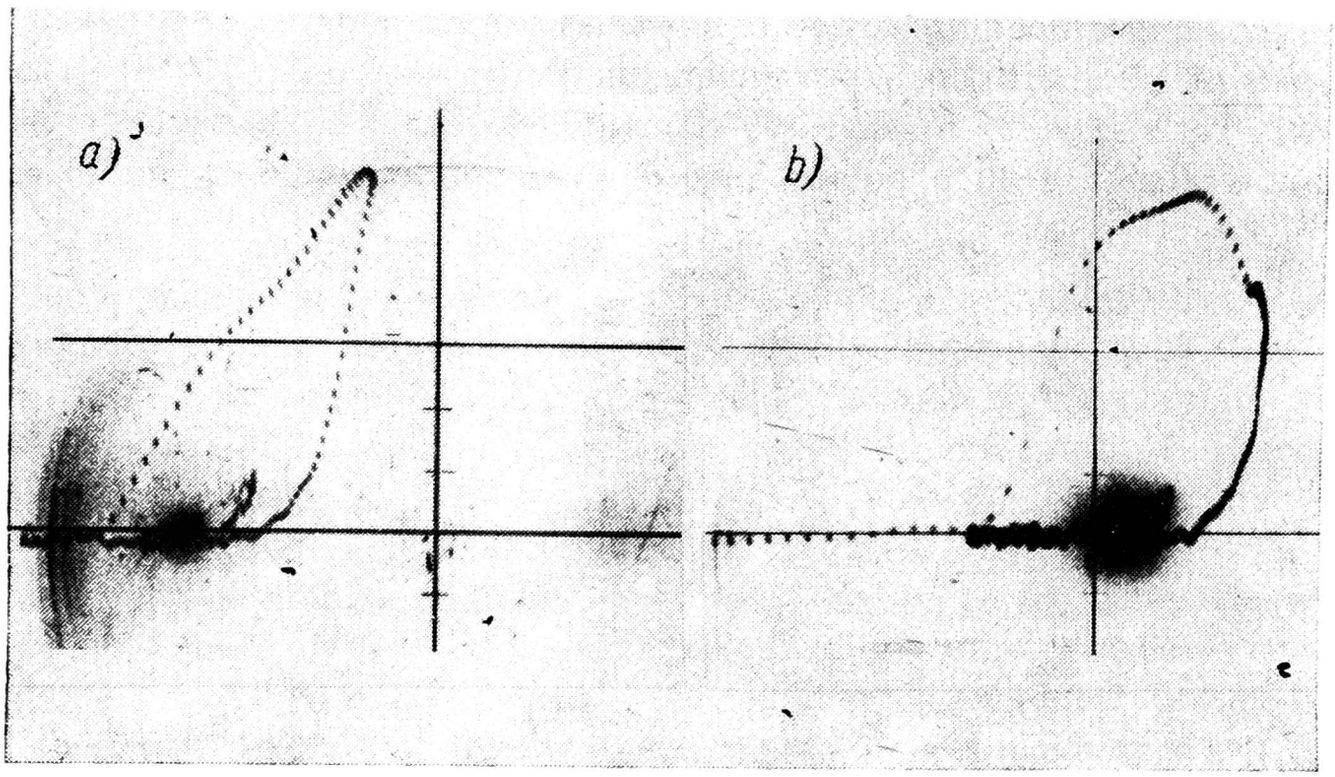

Fig. 3. Examples of the force-deformation oscilographs

Before measurements, the apparatus was calibrated so that the graphs, beside the characteristic changes of course, also give the possibility to determine the value of the force and deformation.

Three varieties of potatoes were tested, namely: Noteć, Nysa and Prosna. From the integrated area of the curves the total deformation energy was determined, and dividing its by volume deformation the specific energy was also defined. Energy was expressed in joules (J), deformation volume in cubic centimeter (c.cm), and specific energy in joules per c.cm (J/cm^3).

The specific energy ranged, depending upon varieties and fertilization methods, from 0.93 to 1.23 J/cm^3. Results of this study pointed out that the specific energy of deformation depends on the beating speed. At higher speeds, in all varieties, this energy is greater. Similar results were also obtained by other authors [3, 7]. The magnitude of the specific energy of deformation is a characteristic feature for the particular variety. The Noteć variety appeared to be most resistance, i.e. it possessed

the highest specific energy. Less value was shown in Nysa, and the least in the Prosna variety. There is no significant relationship between the specific energy of the potato deformation and the soil fertilization method.

Knowledge of the value of specific energy at a given speed may be applied as a criterion to evaluate the utility of different potato varieties for their mechanical harvesting.

The method which has been presented in this paper, beside the study of relationship "force-deformation", can also be used more widely to determine other parameters characterizing mechanical properties of potatoes, e.g. degree of its elasticity, and dynamic modulus of elasticity.

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BADANIA ODPORNOŚCI ZIEMNIAKA NA USZKODZENIA MECHANICZNE

Streszczenie

Postępująca mechanizacja prac rolniczych wymaga znajomości własności mechanicznych płodów rolnych. Przeprowadzone badania mają na celu określenie własności mechanicznych ziemniaków, które poddawane były uderzeniom bijaka z prędkością ok. 2 m/s, co odpowiada prędkości uderzenia ziemniaka elementem roboczym kopaczki ziemniaczanej.

Badania przeprowadzono mierząc odkształcenie i zmianę siły z jaką oddziałuje na powierzchnię ziemniaka bijak o określonej prędkości początkowej uderzenia.

Wykres „siła—odkształcenie" był fotografowany z ekranu katodowego oscyloskopu impulsowego. Ze scałkowanej powierzchni wykresu określano energię całkowitą odkształcenia (J) oraz energię właściwą (J/cm³) dla różnych odmian ziemniaków. Sprawdzona metodyka pozwala badać zależność energii właściwej odkształcenia od prędkości bijaka.

Określenie energii właściwej w zależności od prędkości uderzenia może znaleźć zastosowanie przy określeniu przydatności różnych odmian ziemniaków, bądź uprawianych różnymi metodami, dla ich zbioru mechanicznego i transportu.

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ИССЛЕДОВАНИЯ СОПРОТИВЛЕНИЯ КАРТОФЕЛЯ МЕХАНИЧЕСКИМ ПОВРЕЖДЕНИЯМ

Резюме

Развивающаяся механизация сельскохозяйственных работ требует ознакомления с механическими свойствами сельскохозяйственных продуктов. Проведенные исследования имели целью определение механических свойств картофеля, подвергаемого ударам стержня со скоростью ок. 2 м/сек., что соответствует скорости удара картофеля рабочим элементом картофелекопателя. Исследования велись путем измерения деформации и изменения силы воздействия стержня с определенной начальной скоростью удара на поверхность картофеля.

График „сила-деформация" фотографировался с экрана катодного осциллографа. Из проинтегрированной площади графика определялась полная энергия (дж) и удельная энергия (дж/см³) для различных сортов картофеля. Проверенная методика позволяет исследовать зависимость удельной энергии деформации от скорости стержня.

Определение удельной энергии в зависимости от скорости удара важно для установления пригодности различных сортов картофеля, выращиваемых различными методами, для их механического сбора и транспорта.

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