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PROBLEMS IN THE MECHANICS OF PLANT MATERIALS

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Crops in their natural state may be fibrous, tuberous and grain materials. There are, however, artificial forms, such as chopped, milled, pressed, baled, etc.

In the practice of agricultural engineering both categories are regularly met with either during cultivation and harvesting, or in processing and storing. Consequently, it is desirable to obtain as perfect a knowledge as possible of all the physical properties of these materials.

In the past few decades plant materials have been studied in more and more places, and a great number of publications relating to research and practical application are available. It is to be regretted that so far neither unified theory nor unified measuring techniques have been established, although efforts in this direction have recently been made. A further problem is that a great part of theoretical considerations and research work cannot be directly translated into practice. As a result, practice is sometimes obliged to work only with empirical relationships for solving the given restricted task. This means that a great part of data from measurements and tests is not utilized in scientific research.

In accordance with what has been said above, the basic objective must be the development of a unified theory, which would promote, through certain simplifications, the solution of practical problems. At the same time uniform measuring and testing procedures must be developed and accepted internationally, which would ensure the comparability of published data. Finally, empirical relationships have to be connected to theoretical fundations so that they may be made full use of.

In the following a single restricted area of plant physics is dealt with, that of the mechanics of plant materials.

From the mechanical point of view the primary job is to study the properties of the material, which can only be performed by measurements. In doing so, it is advisable to make use of applied mechanics, because it is rather well worked out for a wide range of practical engineering problems and besides it has uniform measuring and testing techniques. A particular part of the plant, that can be regarded as homogenous, must be tested either statically or dynamically with traditional methods (compressive, tensile, bending, torsion tests). In this way material constants can be given.

In the first approximation the materials can be regarded as linearly elastico-plastic. More precisely, it is always possible to mark out a stress limit up to which the relationship between deformation and loading is linear and reversible, and beyond which it is linear but irreversible.

This approximation can be successfully used especially with small loadings. In this case the initial — usually curvilinear — phose of the stress-strain curve is replaced by a straight line tangent or secant. The approximation essentially means that the given crop is regarded as a linear elastic body, that is, a Hooke body. In this case, the vast body of knowledge accumulated by elasticity theory may be taken advantage of, because in many cases direct solutions are found to the problems in such literature.

Regarding the material as plastic in the case of heavily loadings means that the usually arched section of the stress-strain curve is regarded as straight. In this case the results of plasticity theory can be made use of in solving the respective problems.

As experience shows, conditions are also time-dependent, therefore in the second approximation the law of the material is considered to be elastic-viscous. This, in a certain approximation, is characterized by a first-degree relation between stress-strain and the velocity of these. In such cases rheology can be brought to bear on the problems to be solved. Considering the more complicated nature of the relationsip, the solving of such problems is more difficult, and less suport is found in literature, too.

The object of research is twofold. On the one hand, the validity of the assumed linear law of material is studied on various plant materials, and on the other, the materials constants are determined. It should be noted that the properties of plant materials are very much dependent on biological factors, such as stage of maturity, moisture content, etc. For this reason the introduction of other material characteristics may occasionally be justified. Naturally, these objectives necessitate the use of the correct experimental equipment, suitable measuring techniques and reliable evaluation.

Research of this kind is presented in assistant professor Dr Müller's paper on the "Investigation of mechanical properties in fibrous crops". His primary objective was to develop a measuring technique and measuring equipment for the mechanical testing of various fibrous crops.

Then, after proper evaluation of the data from the measurements, he sought to establish the law of the material tested and to determine the constants included. After prolonged efforts he developed an ingenious equipment for clamping the plant stalk in such a way that in case tensile load is applied, it holds fast where fixed and failure occurs in the central section of the stalk, similarly to metal specimens. Measuring of the force was carried out with spring dynamometer, while that of elongation with inductive indicator. Recording of both quentities was achieved electrically throughout the duration of breaking. Traditional break tests were made, on the one hand, for wheat and lucerne materials, and on the other, creep test were also made for studying time-dependent phenomena. The latter were made on the assumption that plant materials follow the Poynting-Thomson law. A detailed system of evaluation was elaborated, which from the set of measurement data yields the material constants belonging to the above law of material by means of computer, i.e. the coefficients of elasticity, creep and relaxation.

The measurement are very promising. However, many more measurements are needed to test fibers of various states and kinds. We intend to perform similar measurements for several other crops.

In reality plant materials are of complex composition and of inhomogenous structure. Generally speaking, on the basis of geometrical shape they must be regarded as structures in the mechanical sens, and considering various biological layers, they must be regarded complex structures as well. Therefore the material constants of individual layers and the structure must be known before a complete mechanical testing can be performed which enables deformations arising by the influence of various loads to be calculated.

It is only this attitude that can make it possible to utilize the vast amount of knowledge accumulated in applied mechanics for the solution of practical tasks. The latter refers to such problems as the behaviour of the plant in natural conditions when subjected to such influences as wind load, own weight, leaning against each other, load caused by foreign bodies, processing, drop, impact, rolling, etc. A similar situation arises when human intervention causes the plant to come into contact with foreign bodies, such as equipment, machinery, conveying mechanisms, storage installations, etc.

There is the measurement necessary in such cases, too. They are necessary partly to check the above-mentioned calculation, and inversely, for the determination of material characteristics. It is to be noted, that research of this nature is often reported without the actual technical realization being indicated. I should like to point out that many authors are wrong when proposing to directly determine the constants characteristic of the plant from these — otherwise simple — measurements. These measurements are undoubtedly useful, and what is more, even directly applicable, but they are to be regarded as empiricism.

This topic is dealt with in Dr Kaifás's paper, entitled "A mechanical model of failure". This paper is concerned with the very important problem of crop determination caused by mechanical influences. Tubers are regarded as near-ellipsoid in form, a structure consisting of two parts, outer skin and inner flesh. These are materials with differing mechanical properties, and the inner part is often more of a liquid than a solid. As a basic principle it is assumed that biological damage is directly related to mechanical effect, which first causes only local deformation, then extending to a greater volume.

The ellipsoid body is regarded as a mechanical model where the deformation arising under an applied load is separable. First the flesh takes on the part of the loading which causes failure, and the rest is taken on by the skin. Finally these two states are summarized. Otherwise, on the basis of experiences, a law of material is used where specific elongation is quadratic, while the behaviour of the body in relation to time enables it to be handled as a Kelvin body. Relationships are derived for the calculation of the above model at a given load. In conclusion, experiments are reported proving the correctness of the above model in the case of hydrostatic pressure.

When there is a large amount of plant material to be handled, it can be regarded as a continuum from the mechanical point of view. This is the case when the crop in question is put in storage places of large dimensions and research is aimed at the investigation of the whole bulk. Obviously, particular elements cannot be dealt with in such investigation. The bulk itself is regarded as homogenous. Here, too, measurement is of great importance, particularly because there is some uncertainty about the assumption of the continuum. Research along these lines is reported in associate professor Dr. Szabó's paper, entitled "Stress state in grain sets", dealing with grain materials.

The objective of this study is to investigate time-dependent deformation properties of grain in bulk in tower silos. It is assumed that the bulk is elastic viscous and the Poynting-Thompson law is considered valid for the description of mechanical conditions. The experimental equipment designed is, essentially, a cylindrical vessel, in which an axial compressive force was created. Force was measured both axially and riadially, as well as the values of axial compression. After evalution of the creep diagrams obtained with the axial force held constant it was found that the law of material can be considered, with approximation, corresponding to the assumption in the case of wheat. As a matter of course, the problem must be studied for each grain type separately.

The ultimate objective of mechanical investigations is practical application. A great number of complex problems are to be found in this field. Three categories may be established: states from sowing to harvesting, during harvesting and during processing after harvesting.

Basically, all questions arising in these states may be solved in the way suggested by the above investigations, i.e. after exploring material characteristics and structure. Here are a few problems. Until the harvest crops are subject to influences of own weight, wind, adhering moisture, insects, etc. These influences lead to deformation, which may be harmful. The evaluation and comparison of individual varieties, and thereby the work of plant breeders could be greatly assisted by knowing the objective mechanical characteristics, that is, by a reliable judgement of the resistance of the plant. During harvesting the plant comes into contact with foreign bodies and with mechanical equipment which also expert power impulses. The purpose of the latter is to create a deformation of exactly such a degree which ensures the breaking and separation of a particular part of the plant. Precise knowledge of the mechanical behaviour of the plant may render great assistance in designing the working parts of the machine to give optimum performance. This is just the foundation of ensuring the lowest power consumption. After harvest, crops are exposed to power impulses when transported or processed (pressing, bending, milling, etc.). In the case of some states mentioned care must be taken to observe allowable deformations, while in some other states it is just a certain deformation limit that must be exceeded. Some aspects of these problems are presented in Mr. Horváth's paper, entitled "Investigation of crop failure caused by impact". It is pointed out in the paper that there exists a threshold value, below which biological damage to the crop due to impact does not occur. In this field, too, considerable difficulties are encountered because of the lack of an internationally accepted definition and measuring method for failure. The paper presents a measuring technique. The immediate cause of failure is considered to be the power belonging to plastic deformation, which is greatly influenced by the force and duration of impact. The testing equipment corresponds to Charpy's impact testing machine, to which equipment for measuring force and time were connected.

From the point of view of failure a decrease or cessation in germinative ability is again of importance. Tests were made for the study of the latter, too. The crops tested included apples, tomatoes and some grain crops. It is suggested, in conclusion, that for reducing impact effects the machine elements making contact with the crop should be provided with a suitable protective coat to ensure edequate damping.

Research engineer Dr Irene Komándi's paper, entitled "Development of methods of investigation for plant physics in the mechanization programme of vegetable production" is concerned with farm machinery development. The development of a machine is preceded by systematic investigations. This is supplemented by research into problems in sowing, cultivations and harvesting. The position of the crop is very important for cultivation and harvesting. It is important to know the geometrical arrangement and sizes of the crop. The stage of maturity must be taken account of. Mechanical tests enable the separating force to be determined. Some empirical testing methods of failure, such as field tests of strength, are indicated. The paper presents problems in the mechanics of agricultural products starting from the practical side.

The brief summary marks out the basic objectives of our department in the investigation of plant mechanics. It is our endeavour to develop a uniform method and mechanical concept, based on the use of mechanical calculations relating to the law of material and material characteristics. Naturally, the latter should always go together with proper control measurements and tests.

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