TESTING OF MECHANICAL PROPERTIES IN FIBROUS PRODUCTS

Zoltán Müller

As a result of increased mechanization in agriculture and wider use of agricultural products in industry the importance of mechanical testing of agricultural products has greatly increased in recent years. The mechanical properties of plant materials, due to specific biological and physical factors, considerably differ from those of metallic materials, studied by classical mechanics. Therefore, the development of different methods of testing has become necessary.

In the Department of Mechanics of the Faculty of Farm Engineering of the Agricultural University research has been carried out to determine various mechanical properties (tensile strength, bending rigidity, rheological behaviour, cutting resistance) of plant materials, including fibrous products. The purpose of these tests was manifold; on the one hand, we sought to establish a relationship between the mechanical property of stalk structure (cotton, flax, etc.) and the mechanical property of industrial products. Further, the tests were designed to help plant scientists by predicting the mechanical properties that will be necessary for stalk stability. Furthermore, the tests were also intended to supply machine designers with criteria that can be of help in designing machines for harvesting and processing operations.

In the tests the stalk is regarded as homogenous and the changes in stalk cross section are neglected.

HOLDING THE STALK

In tensile tests the fixing of plant stalks is a difficult problem. Direct clamping of the stalk with a metal fixing device leads, in most cases, to damage to the stalk, and as a consequence, the stalk will break at the clamping device. Therefore, I have fixed plant stalks in a steel cylinder provided with a hole using plastic cement (e.g. UHU, Austrian-made, AR-51, Hungarian-made).

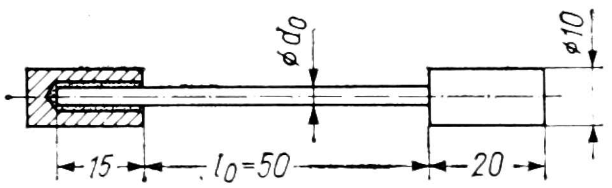


Fig. 1. Cementing plant stalk in steel cylinder

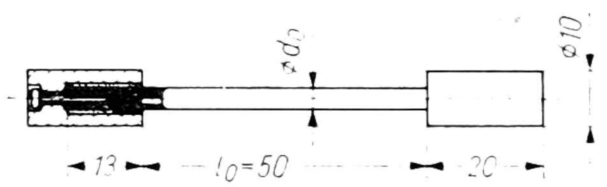


Fig. 2. Cementing plant stalk in steel cylinder with pinned inset

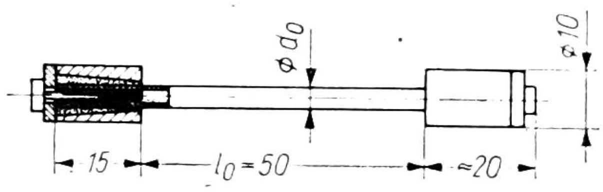


Fig. 3. Cementing plant stalk in cylinwith conical hole

In the case of stalks with a higher moisture content I have employed a plastic cement consolidating by the influence of moisture. The construction shown in Fig. 1 does not provide a sufficiently hard grip for all stalk types: e.g., it was suitable for lucerne, but allowed cereal stalks to slip out. Therefore, clamping of cereal stalks was modified to the from shown in Figures 2 and 3. In this design a steel pin reaches into the middle the metal cylinder, with its head being supported by the end of the metal cylinder. From the outside the cereal stalk was cemented into the hole of the cylinder, while from the inside it was cemented to the steel pin. The fastest grip was ensured by the design seen in Fig. 3., where the hole in the cylinder is conical which offers greater resistance to the stalk slipping out. For providing better adhesion to the cementing material it is advisable to roughen the clamping surface of the stalk

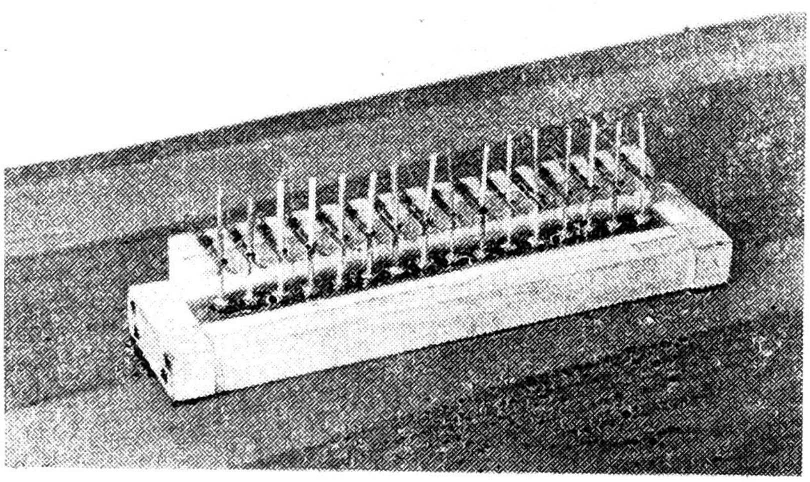


Fig. 4. Casting of plastic clamping head

by using emery paper. Cementing the stalk in a metal cylinder was mostly used in rheological tests where a close fit is necessary. The first stage of cementing cereal stalks in the metal cylinder is shown in the photo in Fig. 4, and the prepared specimens are shown in Fig. 5. Only for

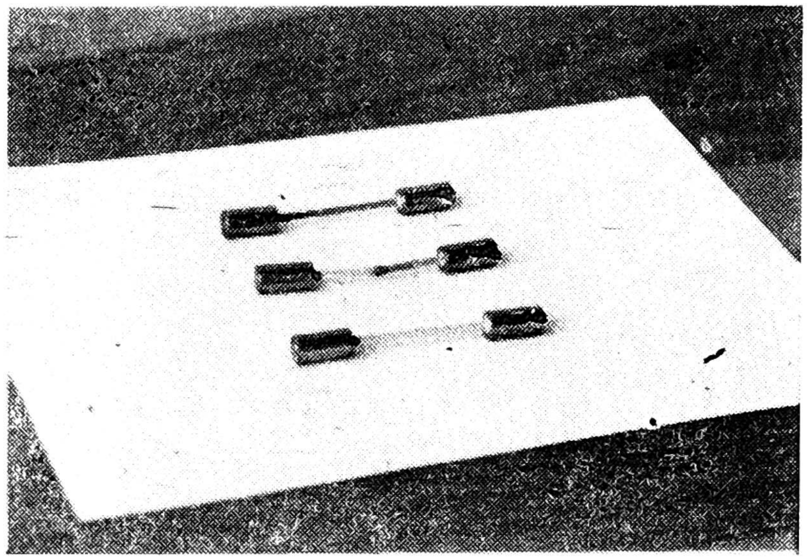


Fig. 5. Specimens prepared for testing

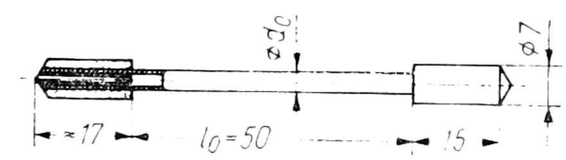


Fig. 6. Specimen designed with plastic clamping head

use in tensile tests were the cereal stalks provided with plastic heads as shown in Fig. 6. To prevent the stalks from being crushed between the clamping wedges of the tensile test machine, a steel pin was cemented into the hole of the stalk. The plastic head was made in blind holes drilled in paraffin.

RECORDING OF TENSILE TEST DIAGRAM

Tensile test of cereal and lucerne stalks was performed in the measuring range from 0 to 50 kg with the GDR-made RT250 tensile test machine. In this measuring range one scale division corresponds to 0,1 kp. For the test the machine was set at a 10 mm per minute traverse speed. Due to pendulum force measurement the upper clamping mechanism of the test machine was displanced by 12.5 mm by the influence of a force of 50 kp. Hence the rate of loading, if the strain of the specimen is also considered, (for cereal stalk, with a force of 15 kp strain is about 0,7 mm) is about 33.7 kp/mon. To ensure better precision in recording the tensile test diagram, the test machine was provided with inductive transducers as seen in Fig. 7. Strain, i.e. the displacement of clamping wedges in relation to each other, was measured with the help of the built-in fra-

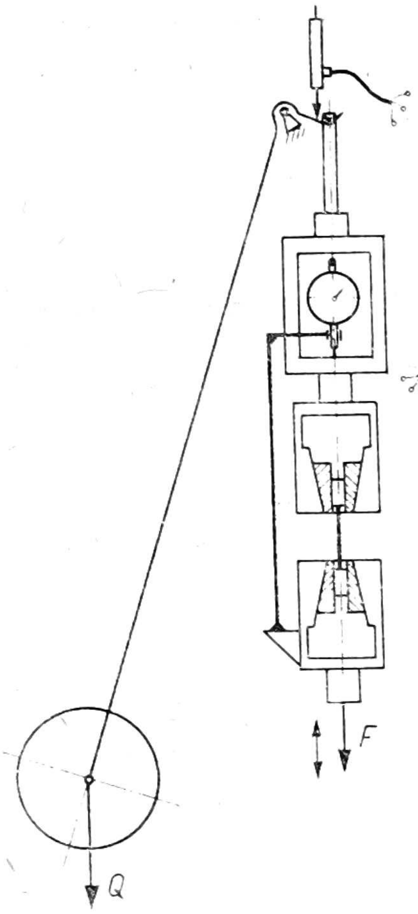


Fig. 7. Positioning of inductive transducers

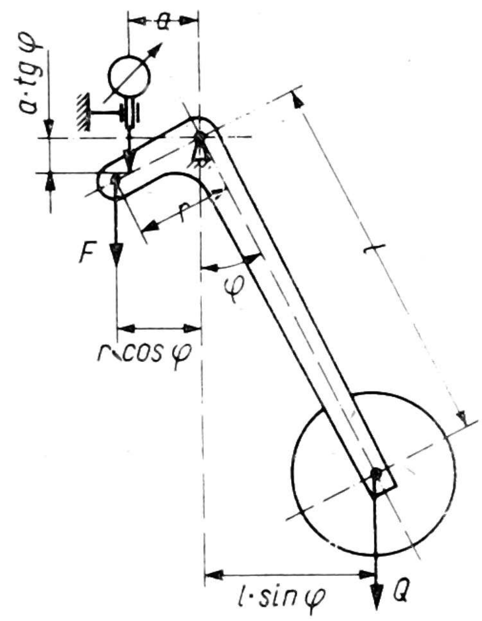


Fig. 8. Measurement of force magnitude

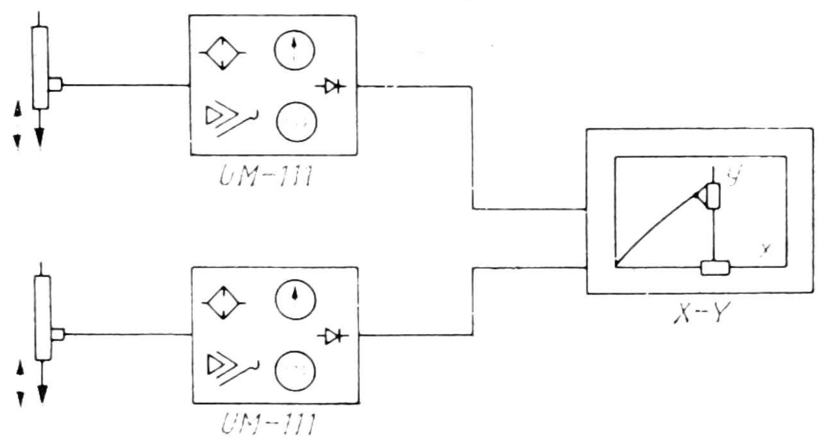


Fig. 9. Block drawing of measuring connection

me in the centreline of the specimen. Measurement of force was performed at a given distance from the fulcrum with a magnified, vertically positioned inductive transducer, as shown in Fig. 8. A linear relation exists between the displacement of the pointer of the inductive transducer and the tension force. The inductive transducers were connnected to UM-111 measuring amplifiers (GDR-made) and the electric signal obtained was fed to x-y recording instrument. The block drawing of connection is shown in Fig. 9. The photos taken from the equipment are shown in Fig. 10 and 11. By way of illustration, two tensile test diagrams recorded in this way are shown in Fig. 12.

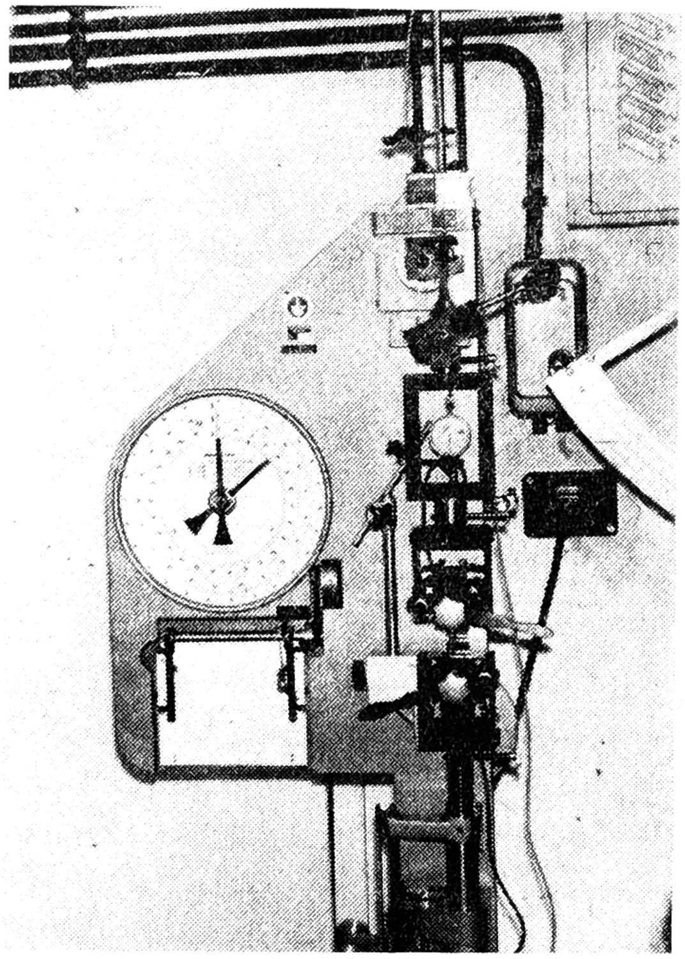


Fig. 10. Measurement on the tensile test machine

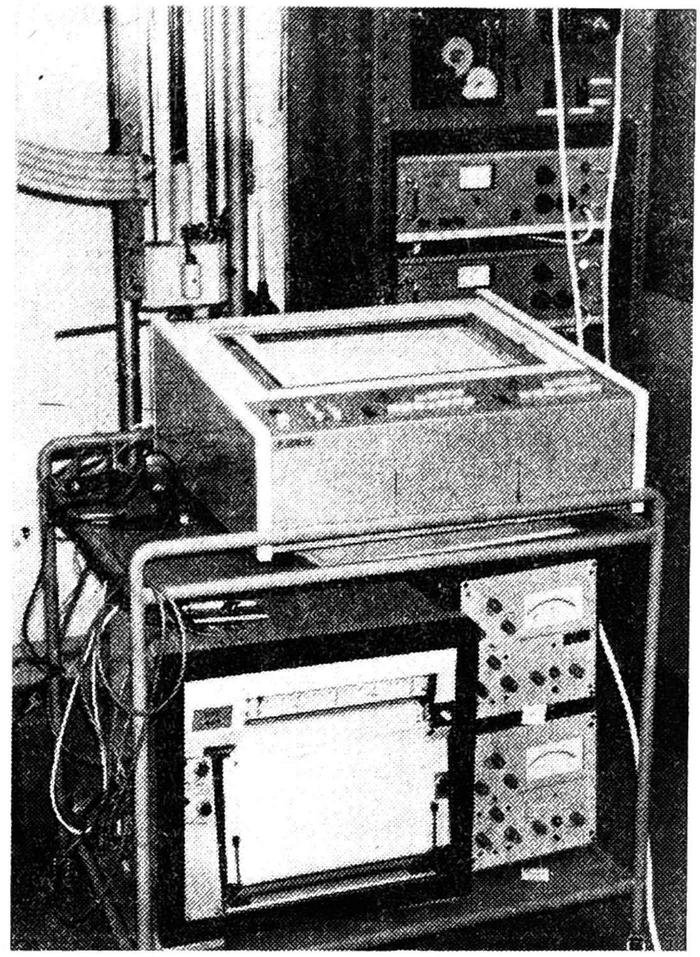


Fig. 11. Measurement amplifiers and x-y recording instrument

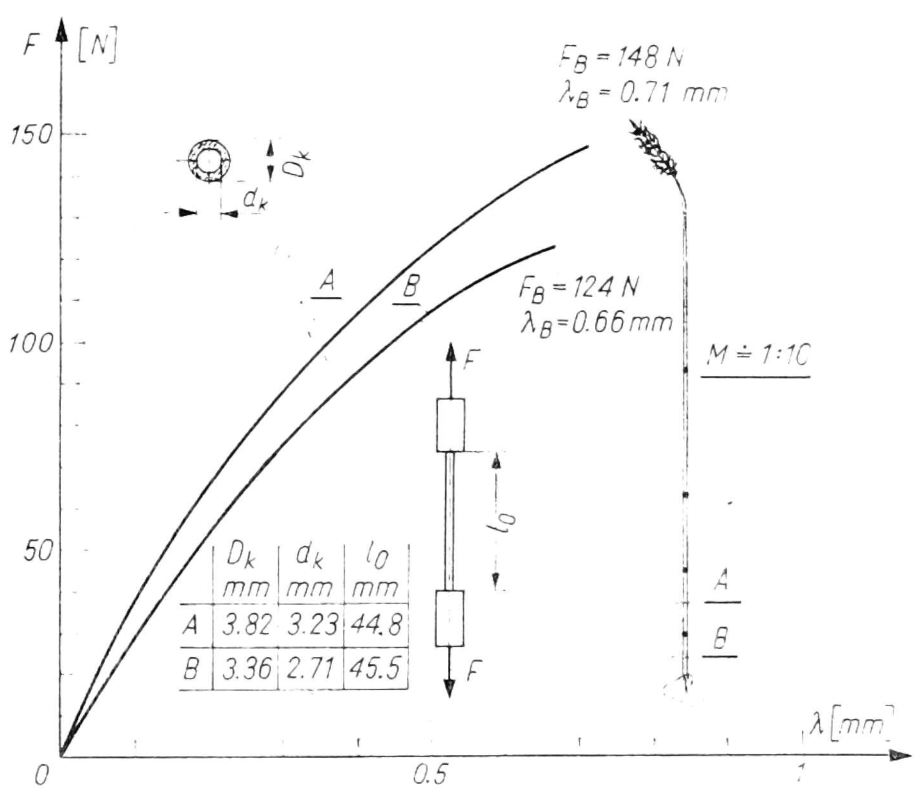


Fig. 12. Tensile test diagram of wheat stalk

RHEOLOGICAL TESTING

For a creep test the measuring equipment seen in Fig. 13 was constructed. At the start of measurement weight 10 is positioned on frame *1.* If water is allowed to flow into vessel 7 at a constant rate the loading on the specimen will increase lineary up to the point where weight *10* detaches from frame *1.* From this moment on the constant load on the speci-

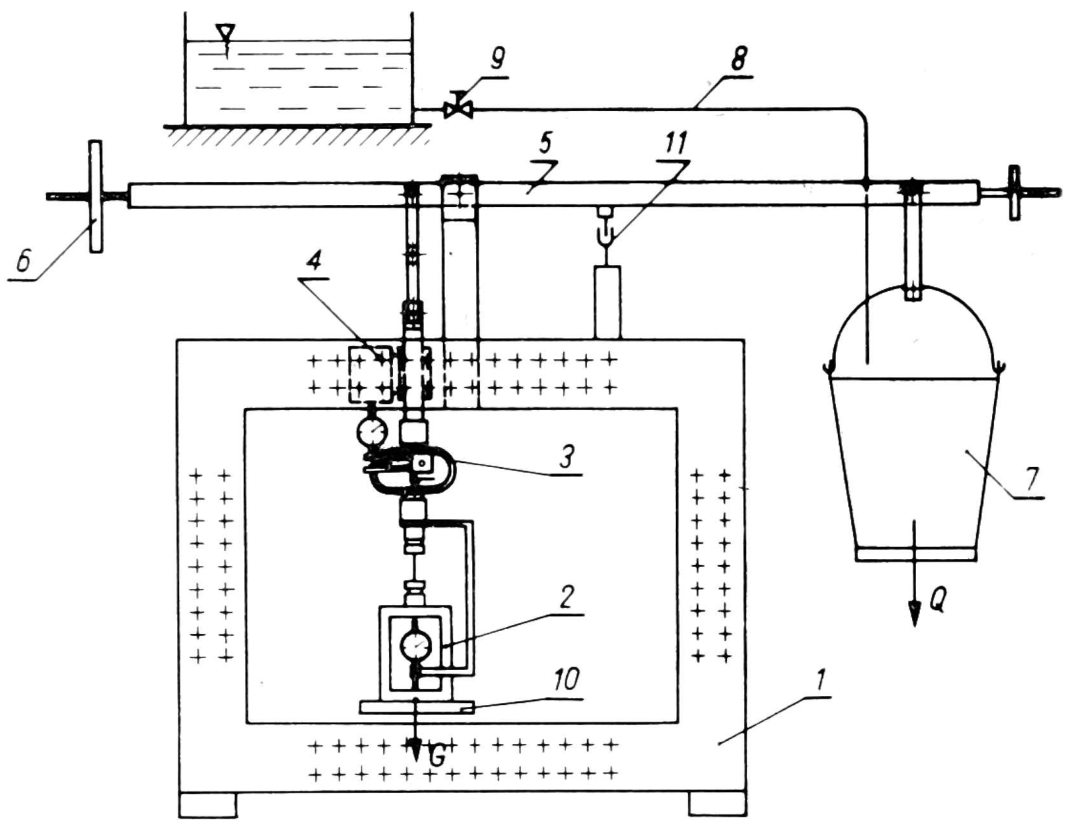
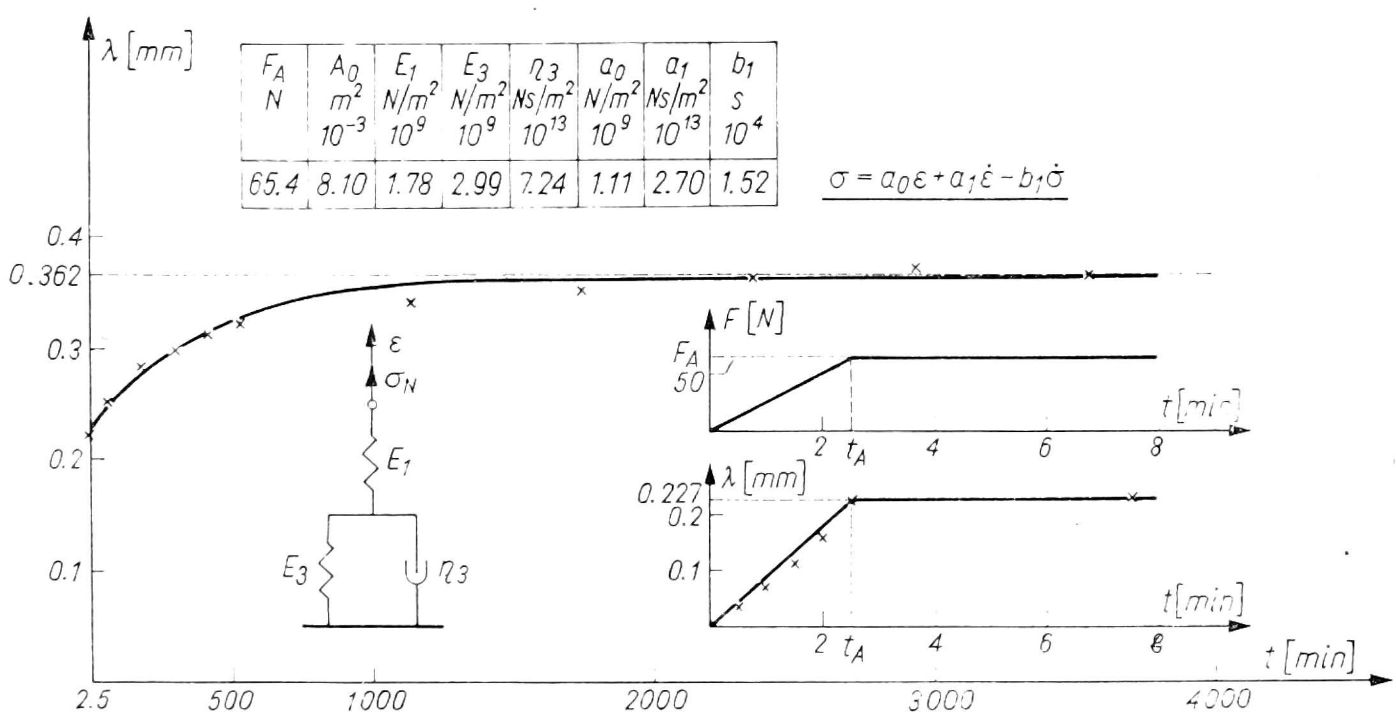


Fig. 13



F_A N	A_0 m^2 10^{-3}	E_1 N/m^2 10^9	E_3 N/m^2 10^9	η_3 Ns/m^2 10^{13}	a_0 N/m^2 10^9	a_1 Ns/m^2 10^{13}	b_1 s 10^4
65.4	8.10	1.78	2.99	7.24	1.11	2.70	1.52

$\sigma = a_0\varepsilon + a_1\dot{\varepsilon} - b_1\dot{\sigma}$

Fig. 14

men will be weight G. By this method the influence of frictional force is eliminated. The dial indicator at place *2* was used to measure strain, while dynamometer *3* served to measure force changes during loading.

In the creep tests it was found that the rheological behaviour of cereal grain and lucerne stalks may be adequately represented by linear models composed of springs and dampers. For this purpose the models in the first model class [3] are suitable. The general form of the differential equation relating to them.:

$$\sigma + \sum_{k=1}^{n} b_k \frac{d^k}{dt^k} = a_o \varepsilon + \sum_{k=1}^{n} a_k \frac{d^k}{dt^k} .$$

It was found that a close approximation is obtained for the description of the phenomenon even by using the simplest form, $n = 1$, of the differential equation. Fig. 14 and b show the creep test results for lucerne stalks. By compensation computation the three-element Poynting--Thomson model ($n = 1$ in the differential equation) was fitted to the measuring points.

The results of measurement are considered valid only for the materials tested. Conclusions of general application could only be made on the basis of a great number of studies covering all conditions (variety, maturity, growing season, weather effects, fertilization, etc.). The purpose of our investigations is to collect measurement data for a variety of agricultural products.

REFERENCES

1. Dunca J., Duris M., Volek V.: Vyskum trenia, ohyber a rezu stebiel ozimnej psenice odród Diana I. a kosutska. Acta Operativo-oeconomica Universitatis Agriculturae-Nitra-Czechoslovakia — XII, 1966.
2. Horky P., Hacker F.: Mechanickě vlastnosti stébel obilninmez pevnosti v talm. Studentská vedecká prace. Vysoká Skola Zemedelská v Praze, 1974.
3. Müller Z.: Classification of rheological models composed of springs and dampers. Lecture. Colloqium on Agricultural Soil Mechanics, Gödöllö, 1974.
4. Pollhamer E.: Complex testing of barley stalk stability Növěnytermelés (Plant Cultivation), 1971, Vol. 20. No. 3, 193—198.
5. Simon T., Wolcsánszky Erzsěbet, Császár J.: Fiber length conditions in wheat varieties with stable stalks and inclined to lodging respectively. Publications of ATE (University of Agriculture, Gödöllö) 1963, 407—417.

Z. Müller

BADANIE WŁAŚCIWOŚCI MECHANICZNYCH ROŚLIN WŁÓKNISTYCH

Streszczenie

Rośliny włókniste są poddawane różnym wpływom mechanicznym w czasie uprawy, zbioru i przerobu. Ważność badania ich własności mechanicznych stale wzrasta z uwagi na rozwój mechanizacji produkcji rolnej i bardziej intensywnego wykorzystania przemysłowego produktów rolnych.

Celem pracy jest zbadanie cech mechanicznych roślin włóknistych (wytrzymałość na rozciąganie, próby na skręcanie i zginanie, odporność na ścinanie, własności reologiczne itd.).

Dla uzyskania wglądu we własności wytrzymałościowe roślin włóknistych, próby jednoosiowe, a w ich obrębie próby rozciągania, są pierwszorzędnej wagi.

Zbadano łodygi przy różnych zawartościach wilgoci i zmierzono ich wytrzymałość na rozciąganie. Dla zapewnienia pewnego uchwycenia badanej próbki zastosowano dwuskładnikowy cement plastikowy do wklejenia w cylindry metalowe.

Wyznaczono krzywą histerezy dla łodyg niektórych roślin. Zastosowano obciążenia wzrastające liniowo do pewnej wartości po czym zmniejszające się liniowo do zera. Tę procedurę powtórzono kilkakrotnie.

Zbadano reologiczne zachowanie łodygi za pomocą prób odkształceń i relaksacji i ustalono, że proces ten może być opisany za pomocą reologicznych modeli liniowych składających się ze sprężyn i elementów tłumiących. Dla opisania tego zjawiska zastosowano model Poyntinga-Thomsona.

Opracowano specjalny aparat pomiarowy do badań reologicznych, oraz programy komputerowe do oceny wyników badań. Wykazano. że moduł sprężystości roślin włóknistych leży pomiędzy dwoma określonymi wartościami w obrębie, których może on być opisany za pomocą modelu liniowego. Te dwie wartości modułu mogą być wyznaczone zarówno z diagramu naprężeń stałych modelu reologicznego, jak i ze stałych równania różniczkowego.

З. Мюллер

МЕХАНИЧЕСКОЕ ИССЛЕДОВАНИЕ ТРАВЯНЫХ РАСТЕНИЙ

Резюме

Травяные растения подвергаются при уборке, обработке и промышленном использовании многим механическим воздействиям. Значение исследования их механических свойств постоянно возрастает вследствие интенсивной механизации сельского хозяйства и более значительного промышленного использования сельскохозяйственных продуктов.

Целью наших исследований было изучение механических свойств травяных растений (прочность на разрыв, кручение, изгиб; сопротивление сдвигу, срезу; реологическое поведение и т.д.). В моем докладе я излагаю нашу работу в этой области и привожу полученные результаты.

Для ознакомления со свойствами прочности травяных материалов мы счи-

таем первостепенно важными одноосные исследования и среди них — исследование прочности на разрыв.

Мы исследовали люцерновые стебли различной степени влажности и измеряли изменение их прочности на разрыв как функцию влажности. Для осуществления защемления, необходимого для исследования прочности на разрыв, мы успешно применяли двухкомпонентные пластмассовые клеи, которыми мы приклеивали стебель либо внутри металлического цилиндра, либо образовали на стебле пластмассовый зажимающий цилиндр.

Мы установили гистерезисную кривую люцерновых и зерновых стеблей (мы увеличивали нагрузку линейно до определенного значения, а потом уменьшили ее линейно до нуля, повторяя этот процесс несколько раз).

Мы изучали реологическое поведение растительного стебля (исследуя ползучесть и релаксацию) и установили, что это поведение хорошо описывается линейными реологическими моделями, состоящими из пружин и сопротивлений. Для описания реологического поведения мы применили модель Пойнтинга-Томсона.

Мы разработали специальную измерительную установку для наших реологических исследований. Для обработки и анализа результатов измерений разработали различные программы на ЭВМ. Мы показали математически и доказали измерениями, что в области, описываемой линейной моделью, модуль упругости травяных растений лежит между двумя определенными значениями.

Эти два значения модуля упругости можно определить из диаграммы растяжения, из констант реологических моделей или из констант дифференциального уравнения, поэтому они могут действительно рассматриваться как материальные характеристики.

Address of the author

Dr Zoltan Müller,
Agricultural University, 2103 Gödöllő, Hungary