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STRESS STATE IN GRAIN IN LAYER

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INTRODUCTION

The preservation of agricultural products which are produced in a relatively short period of time, and thereby the provision of a steady food supply can only be achieved by the establishment of an adequate number of storage facilities.

During the course of history man has devised various storage structures, from the Egyptian underground storage places and through the wattle-and-daub "silos" of African tribes which are in use even today to our modern reinforced concrete, steel plate, plastic and wooden storage towers.

Therefore it is justified to study the behaviour of materials in agricultural products stored in bulk, because the mechanical conditions during storage are not yet completely clarified. Knowledge of the loads applied to confining structures is essential in designing storage structure dimensions. Here is an example illustrating the importance of this problem. In metal storage towers a certain stress state prevails at a given time and at a given temperature in the interior of the bulk. Reduction in outside air temperature causes the metal shell to be contracted, and, as a result, the stress state in the shell and in the bulk is also changed. The Young modulus which is necessary for a numerical expression of relationships is a function of compressive stress and therefore the dependence of the elasticity modulus on compression must be known for a material stored.

From among the many problems in this field I have selected stress state and in the past few years I have aimed my efforts at getting a better understanding there of. In the following an account is given of the work carried out in this field.

Besides investigating plastic critical states (active — passive), which can be followed quite well by means of theory, I have devoted most of my attention to the "non-plastic" stress state. In this case agricultural products are characterized by visco-elasticity. As a model of investigation I chose the Poynting-Thompson test (PTh) and development an instrument for determining mechanical properties by measurement. The PTh model is shown in Fig. 1. The differential equation of the law of material for a single-axis stress state is

$$\sigma + b_1 \dot{\sigma}_1 = a_0 \varepsilon + a_1 \dot{\varepsilon},$$

where: σ is axial compressive stress σ_1

$$a_o = \frac{e_1 \cdot e_3}{e_1 + e_3},$$

$$a_1 = \frac{e_1 \cdot \eta_o}{e_1 + e_3},$$

$$b_1 = \frac{\eta_o}{e_1 + e_3},$$

e_1, e_3 are the spring constants of the model, measured values.
η_o is the damper constant, a measured value.

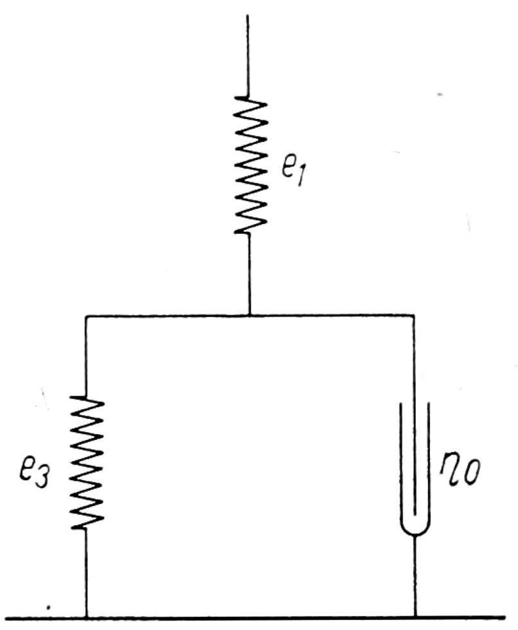

Fig. 1. Poynting-Thompson model

The solution of the differential equation is:

1) for the loading stage (Fig. 2.) $o < t < T_1$

$$\varepsilon(t) = \frac{\delta_1}{T_1}\left\{\frac{t}{e_1} + \frac{t}{e_3} - \frac{\eta_o}{e_3^2}\left[1 - \left(\exp\frac{-e_3}{\eta_o}t\right)\right]\right\}.$$

2) for the permanent load stage (Fig. 3.): $T_1 < t < \infty$

$$\varepsilon(t) = \frac{\delta_1}{e_1} + \frac{\delta_1}{e_3} + \frac{\delta_1}{T_1}\frac{\eta_0}{e_3^2}\left[1 - \left(\exp\frac{e_3}{\eta_0}T_1\right)\exp\frac{-e_3}{\eta_0}t\right].$$

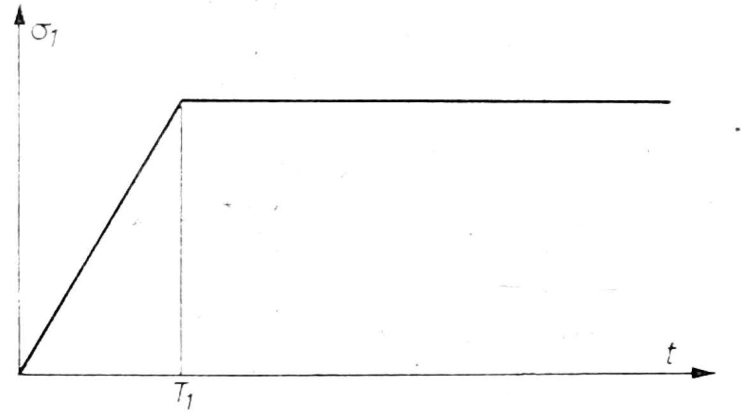

Fig. 2. Load-time diagram

In these experiments barley, rye and winter wheat were used. Most of the results refer to the variety Mironovskaja 808 (of the 1972 crop).

The subject of this paper is to give an account of the development of the measuring instrument, the measuring technique and investigations of the law of material in wheat stored en masse.

DEVELOPMENT OF MEASURING INSTRUMENT

The measuring instrument was constructed of pieces of equipment available in the department and used for general purposes, supplemented by newly designed elements (Fig. 3).

Loading is provided by water through double transmission equipment *2*. In applying compressive loading, water was fed into the loading vessel *5* through a compensating tank *3* fitted with an adjustable jet. The compensating tank ensured constant discharge rate, which was determined by jet size. The water in the loading vessel, through two series-connected two-armed levers, exerts pressure on the push-bar *15* with the pressure disc at its end. The vertical core-line of the pressure-communicating push-bar is ensured by a self-aligning sleeve *7*.

The grain mass was placed in a 10 cm high steel cylinder with an internal diameter of 18 cm, open along one gene ratrix. The gap is connected by two electric dynamometers made of plate and properly calibrated. For the communication of axial pressure a plastic pressure disc with a diameter slightly smaller than that of the internal diameter of the cylinder was used.

To the loading and storing equipment instruments for measuring va-

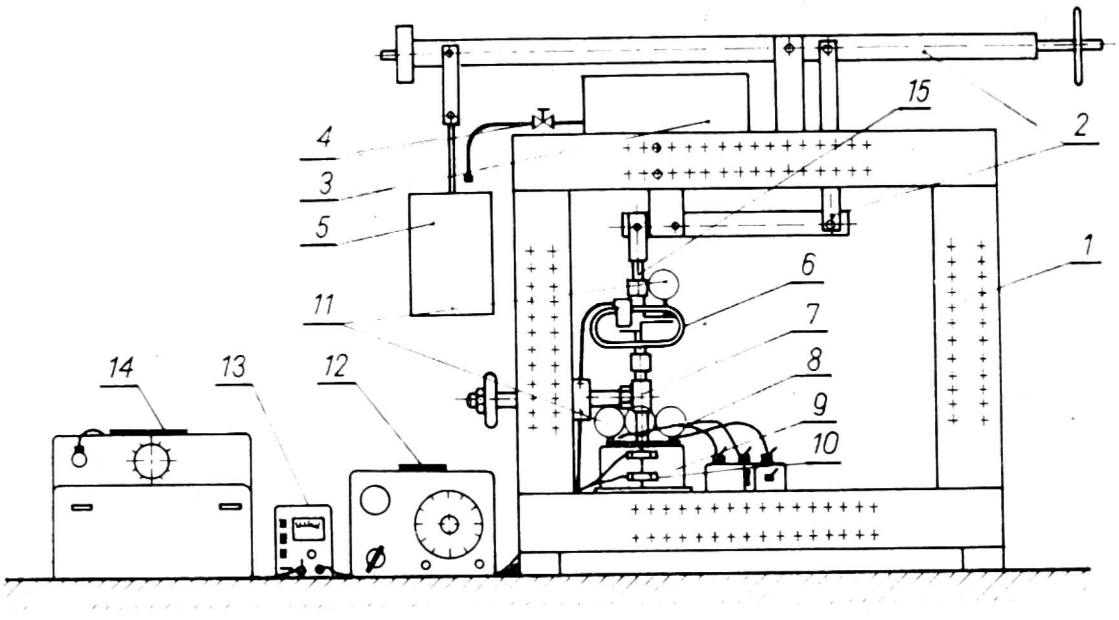

Fig. 3. Measuring instrument

rious mechanical quantities were connected, such as mechanical dynamometers, dial gauges, strain gauge etc.

The measuring equipment seen in Fig. 3. is suitable for the mechanical testing of the grain mass placed in the cylinder. Thus, it is suitable for the determination of the relationships,

loading force applied — deformation,
deformation — time (with constant load),
loading force applied — time (with constant deformation).

MEASURING EQUIPMENT AND MEASURING TECHNIQUE

The compressive force created on the pressure disc with the help of the loading equipment exerts an axial pressure of 0,500 kg on the grain mass in the cylinder. Due to the rigidity of the cylindrical vessel, radial pressure will also arise in the cylinder. On an imaginary elementary prism taken out from the balk internal space forces acts which are characterized by mechanical stresses, as usual with homogenous materials. In this way, the stress state is triaxial: σ_1 and $\sigma_2 = \sigma_3$

The value of σ_3 can be calculated from the compressive force applied to the disc and with this diameter-length ratio $\left(\frac{D}{H} = 9\right)$ it can be taken to be constant along the length [2].

The value of σ_3 can be calculated from the force measured with the electric dynamometer as the value of an open ring pressure loaded by internal pressure (Fig. 4).

Due to the pressure created through the pressure disc stresses σ_1:

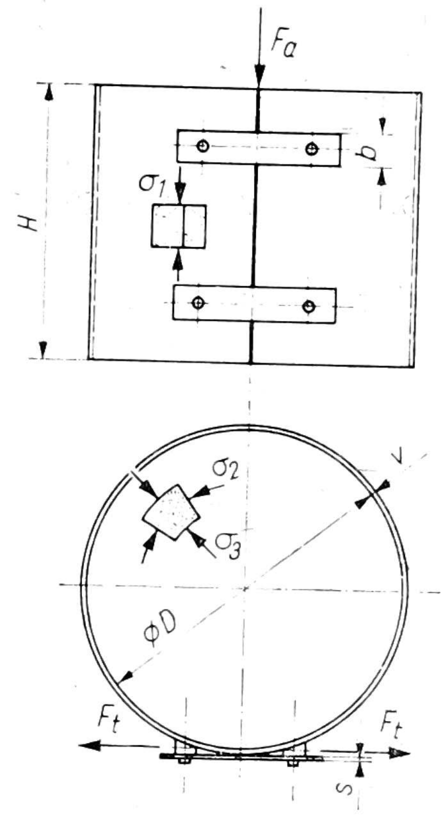

Fig. 4. The figur of steel cylinder

$\sigma_2 = \sigma_3$ arise, within the material, giving rise to tangential stress in the steel cylinder wall [4].

$$\delta_t = \frac{D \cdot \delta_3}{2v}.$$

The cohesive force arising along the cut-up generatrix is:

$$F_t = \delta_t \cdot v \cdot H = \frac{D \cdot \delta_3}{2} H,$$

hence

$$\delta_3 = \frac{2F_t}{DH}.$$

Force F_t causes specific strain in the two joint plates, measured by means of gauge technique.

The relationship between value ε supplied by the measuring bridge and the value σ_3 which is to be determined, using the data from the mechanical dynamometer, is:

$$\delta_3 = \frac{4 \cdot E \cdot b \cdot s}{DH} \cdot \varepsilon$$

where

E ist the elasticity factor of steel.

The axial displacement of the disc Δh was given by centesimal dial gauges fixed in a magnetic frame.

TESTING OF MECHANICAL PROPERTIES

1. Testing of compressive force — deformation. Force from 0 to 5000 N was applied continuously through the disc to a wheat mass of known moisture content placed loosely in the cylinder and three dial gauges positioned at 120 degrees from each other were used to measure the displacement of the disc. With the calibrated electric dynamometers the radial force and therefrom the stress σ_3, were determined, while the mechanical dynamometer served to determine the axial compressive force and therefrom the stress σ_1.

With respect to the triaxial loading Mohr's equivalent stress $q = \sigma_1 - \sigma_3$ was represented, as usual in the [5] literature.

The curves obtained in this way are fairly congruent with the diagrams found in literature, which proves the suitability of the equipment and the correctness of the measurement [8].

TESTING OF THE RELATIONSHIP BETWEEN DEFORMATION AND TIME (CREEP TEST)

To determine the suitability of the PTh test as a creep model a force linearly increasing in time was applied to the grain mass in the cylinder (see Fig. 3.), then with the load held constant the displacement of the

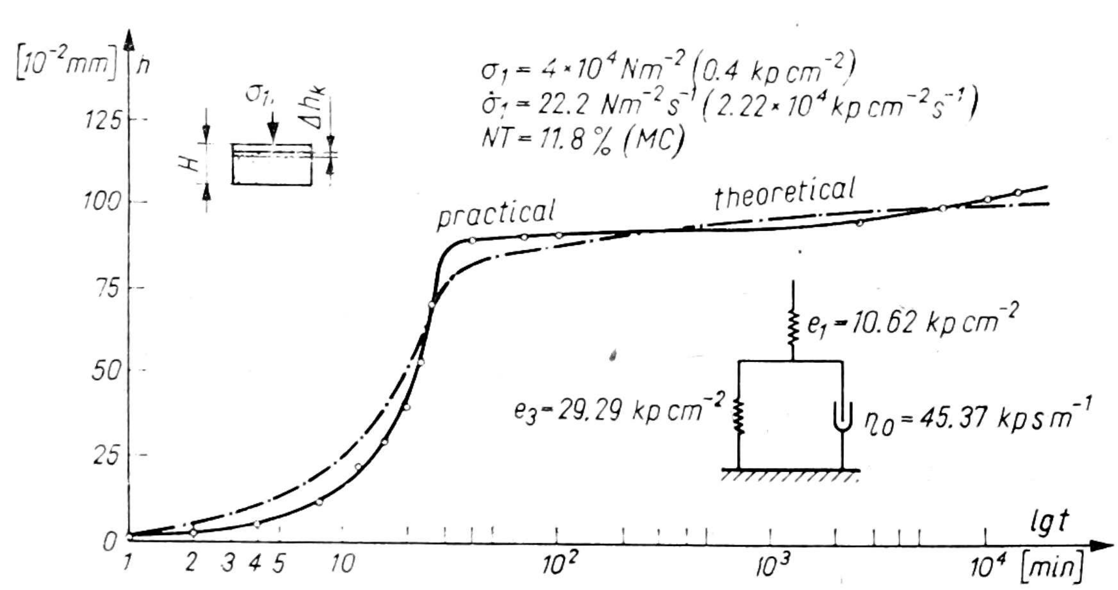

Fig. 5. Creep curve of winter wheat en masse. Mironovszkaja 808 (1972)

pressure plate was measured. The set of volues obtained by reading periodically the three dial gauges was fed to a computer programme worked out for uniaxial stress state and evaluated by computer. The computer compared the measured values to the theoretical curve, using for error calculation the method of least squares. The results were also expressed in a diagram (Fig. 5.). In this diagram, for the purpose of comparison with the calculated creep curve corresponding to the PTh model the calculated curve was also drawn. This indicates that the difference is relatively greater on the loading section, while on the section for constant load the congruence is good. The value $\Delta H/H$ belonging to the time $t = \rightarrow \infty$ definitely flows from this measurement, which was achieved by keeping the conditions at a constant value. Creep tests last as long as two or three weeks, and it is unreasonable to continue to make measurements after a deformation of a certain value has been reached, as the temperature and air humidity changes in the laboratory may influence the results.

TESTING OF THE RELATIONSHIP BETWEEN LOAD APPLIED AND TIME (RELAXATION TEST)

Holding deformation at a constant value (Fig. 6) with relatively simple equipment is no easy task. The equipment developed at our deparment, however, is suitable for altering load in small steps. The electric

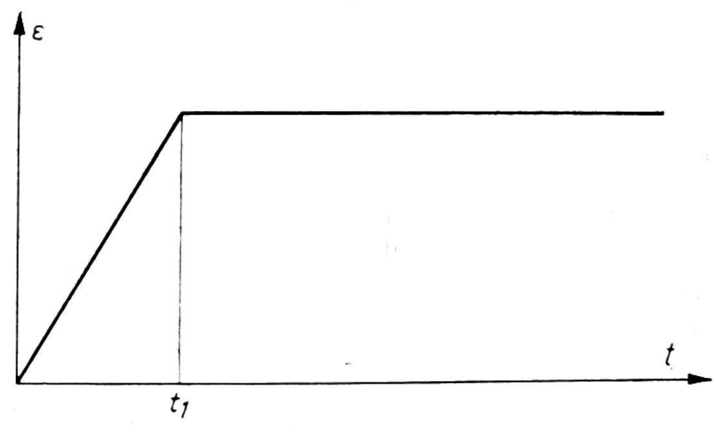

Fig. 6. Deformation-time diagram

switch-valve system is operated by the pointer of a dial gauge employed as an electric switch. The decrease in loading belonging to permanent deformation is created by the periodic draining off the water in the loading vessel.

The results of a measurement are listed in a diagram seen in Fig. 7. The relaxation curve has also been drawn.

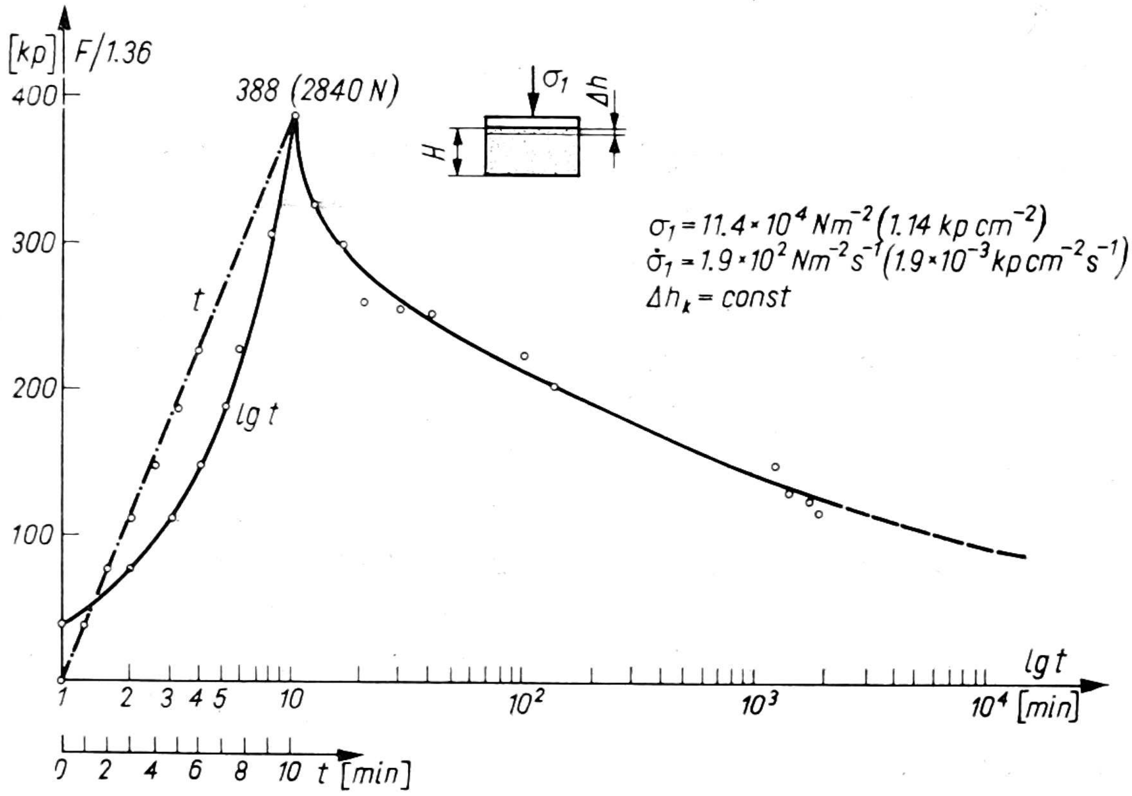

Fig. 7. Relaxation curve of the winter wheat in layer Miranovszkaja 808

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B. Szabó

WARUNKI NAPRĘŻEŃ W WARSTWIE ZIARNA

Streszczenie

Warstwa ziarna w silosach może zasadniczo przyjąć trzy różne stany naprężeń, a mianowicie:

1) aktywny plastyczny stan limitujący,
2) bierny plastyczny stan limitujący,
3) pośredni stan nieplastyczny.

Rozważano stan „nieplastyczny". Zachowanie warstwy ziarna jest charakteryzowane przez lepkosprężyste odkształcenie spowodowane obciążeniem. W związku z tym musimy znaleźć odpowiedni model mechaniczny. Jedną z możliwości jest przyjęcie, że będzie on liniowy, w nadziei, że trójczłonowy model Poytinga-Thomsona da się zastosować.

Skonstruowano aparat do prób eksperymentalnych, umożliwiający przeprowadzenie prób odkształcenia (pełzanie i relaksacja) z trójosiowym obciążeniem. Komora jest naczyniem cylindrycznym, otwartym wzdłuż jednej z tworzących. Ciśnienie w kierunku osiowym było zapewniane przez obciążenie, które powodowało powstawanie trójosiowego ciśnienia w komorze. Siła ciśnienia w kierunku osiowym była mierzona bezpośrednio przez dynamometr mechaniczny, podczas gdy ciśnienie promieniowe było mierzone przez dynamometr elektryczny umieszczony w otworze cylindra.

Ruch tłoka zapewniającego ciśnienie pionowe był rejestrowany przez miernik i przetwornik indukcyjny. Rezultaty pomiarów były oszacowane za pomocą komputera. Krzywa otrzymana w ten sposób została porównana z krzywą eksperymentalną, odchylenia były łatwe do zbadania.

Według naszych pomiarów zachowanie warstwy ziarna może być dobrze opisane przez reologiczny model Poyntinga-Thomsona.

Б. Сабо

НАПРЯЖЕНИЯ В СЕМЕННЫХ МАТЕРИАЛАХ

Резюме

Семенные материалы в силосных башнях могут находится в трех различных состояниях напряжения: активно-пластичном, пассивно-пластичном граничных состояниях и непластичном состоянии между ними.

Я намерен заниматься „непластичным" состоянием. Поведение семенных материалов характеризуется упруго-вязким изменением формы вследствие нагрузки. Значит, мы должны искать подходящую механическую модель. Эту модель можно предполагать линейной и поэтому можно попытаться применить трехчленную реологическую модель Пойнтинга-Томсона.

Для экспериментальных исследований мы изготовили установку. С ее помощью можно было проводить исследования релаксации и ползучести при триа-

ксальной нагрузке. Измерительной камерой служил сосуд цилиндрической формы, открытый вдоль одной из его образующих.

Осевое давление было осуществлено с помощью нагрузки через передачу, вследствие чего получилось триаксальное давление в измерительной камере. Осевая сила давления измерялась непосредственно механическим динамометром, а радиальное давление — электрическим динамометром, расположенным в перевязках открытия цилиндра. Смещение поршня, вызывающего вертикальное давление, было прочитано прямо с указательного механизма и записано индуктивным датчиком.

Результаты измерений были обработаны на ЭВМ.

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