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Effect of selected factors on grain mass creep test under simulated load conditions

Rafał Nadulski, Elżbieta Kusińska, Zbigniew Kobus, Tomasz Guz

Faculty of Engineering and Food Processing Machinery, University of Life Sciences in Lublin
Doświadczalna Str. 44, 20-236 Lublin, Poland, e-mail: rafal.nadulski@up.lublin.pl

Summary. The paper presents the results of a study on the effect of vertical load, moisture and species of cereal on the course of grain mass creep test. The experiment demonstrated that the relative change in the height of grain column after a specific time, i.e. after 1, 2 and 8 days, depends on the species of grain, its moisture, and the value of the vertical load. The greatest range of changes in the height of the grain mass column (14.8%) was recorded after 8 days for oat grain with moisture of 22% under vertical load of 70 kPa.

Key words: grain, cereal species, moisture, vertical load, creep.

INTRODUCTION

At present a variety of designs of grain storage silos are in use [15, 1]. Harvested grain must meet specific quality requirements [4]. High quality of material stored in a silo can be maintained through active ventilation of the grain mass. Forced movement of air through a grain deposit involves flow resistance related with the porosity of the material. The airflow resistance of cereal grain and seeds is affected by the following factors: thickness of the layer of granular material, porosity, density, moisture of the material, size and shape of particles and the degree of compaction of the material, as well as the time of storage and the method of silo filling [11, 10, 12]. A majority of agricultural produce can be classified as viscoelastic bodies [7, 13], liquids as well as solids – amorphous bodies with high viscosity. The behaviour of such materials under certain conditions can be approximated by means of classical mechanical models [2]. Under other conditions those bodies display totally different responses to loads. In viscoelastic bodies a certain time has to elapse for a stabilised state of deformation to appear. In such bodies the phenomenon of creep occurs, causing permanent and irreversible deformation of the material [17, 5]. Creep consists in a change of the state of deformation of an element in time under the effect of constant strain acting at a constant temperature. The phenomenon is observed after a sufficiently long period of time and it occurs commonly in materials of plant origin, creating problems in their post-harvest processing.

The main factor determining the mechanical properties of kernels is water [3, 18]. High moisture content of kernels results in their susceptibility to plastic deformations. This can cause the appearance of internal damage and micro-damage to the seed coat. At low moisture content kernels are brittle and macro-damage to the external structures may take place. Changes in the shape of kernels are an important factor that determines grain quality and the conditions in the process of grain ventilation in a silo [6, 20].

During the storage of cereal grain and seeds in silos the bottom layers of the material are subjected to the greatest effect of vertical load and undergo deformation related with the rheological properties of grain mass [9, 8]. That problem is of particular importance during the storage of granular materials in silos with large dimensions [14]. This is indicated by studies by Kusińska and Szwed [19], simulating the conditions of storage of wheat grain in industrial silos with filling height of about 40 metres. The phenomena of self-sorting and increase of grain column pressure during the filling of silos cause compaction of the grain mass and a change in the tribological properties, which leads to a reduction of the ability of the material to return to its original shape after the removal of the load [3].

Analysis of the available literature shows that the behaviour of grain mass under the effect of loads appearing in large silos is still not sufficiently known.

OBJECTIVE AND SCOPE OF RESEARCH

The objective of the study was to perform, under laboratory conditions, a test of grain mass creep. The factors chosen as those that may have a significant effect on the behaviour of grain mass in the creep test included vertical load with values occurring in large silos, grain moisture and the species of the cereal.

METHOD

The experiment was performed on grain of winter wheat cv. Tonacja, winter rye cv. Słowiańskie, oat cv. Sławko, winter triticale cv. Pawo, and spring barley cv. Stratus. The initial moisture of the grain was ca. 13%. The grain was moistened in containers, adding water in the form of mist from a sprayer. When the moistening operation was completed, the containers were tightly sealed and then the grain was vigorously stirred. As a result of that operation three levels of grain moisture were obtained, of 14%, 18% and 22%. The moisture content of the grain was assayed in accordance with the standard PN79/R-69950. The the grain was poured into steel containers with diameter of 100 mm and height of 150 mm, equipped with a moving cover that permitted, through a system of four springs, to obtained the assumed level of load (Fig. 1).

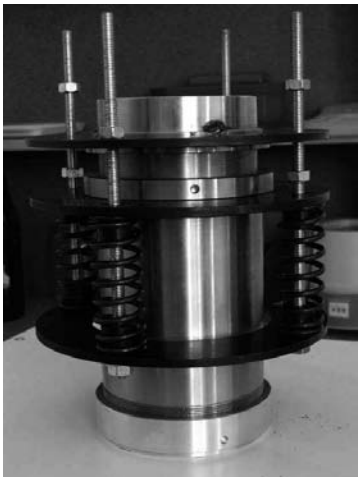

Fig. 1. Cylinder generating stresses in the grain mass

The grain mass was loaded obtaining a constant vertical load, and then stored at temperatures of 6°C and 22°C for 8 days. The experiment was conducted on grain mass subjected to vertical loads of 35, 52 and 70 kPa, and on a control sample, i.e. without any load applied. The design of the test system permitted the determination of the grain column height immediately after achieving the load desired load [12]. Then, changes in the grain column height were recorded after specific periods of time, i.e. successively after the first day, after two days and after 8 days. The parameters adopted as characterising the creep of the material was the relative change of grain column height ΔH after time t calculated from the formula:

$$\Delta H = \frac{(H - H_t) \cdot 100}{H}, \quad (1)$$

where:

ΔH – relative deformation of grain mass column after time t, %,

H_t – height of grain mass column after time t, mm,

H – initial height of grain mass column, mm.

Statistical analysis was conducted with the of the program Statistica ver. 6, StatSoft, Inc. [StatSoft, Inc. 2003]. Estimation of the effect of the variables (vertical load, cereal species, grain moisture) on the value of ΔH, i.e. the relative change of grain column height after time t was performed with the use of the module of variance analysis ANOVA.

RESULTS

The statistical analysis revealed that the relative deformation of the grain mass column ΔH after time t depended on the species of the cereal, grain moisture, and on the vertical load applied. In each case an increase of the value of the vertical load caused an increase in the value of ΔH. At grain moisture levels of 14% and 18% ΔH assumed values that did not exceed 5%. Extension of the time of grain mass loading caused a distinct increase in the value of ΔH.

Fig. 2 presents the range of changes of the height of grain mass column ΔH for rye grain with moisture of 22%. The effect of vertical load and time of storage on the relative deformation of grain mass column ΔH for wheat grain with moisture of 22% is presented in Fig. 3, and for triticale grain in Fig. 4. Comparing the grain of rye, wheat and barley with moisture of 22% the greatest range of changes in the value of ΔH was recorded for rye, for which ΔH after 8 days was from 5.5% to 11.1%.

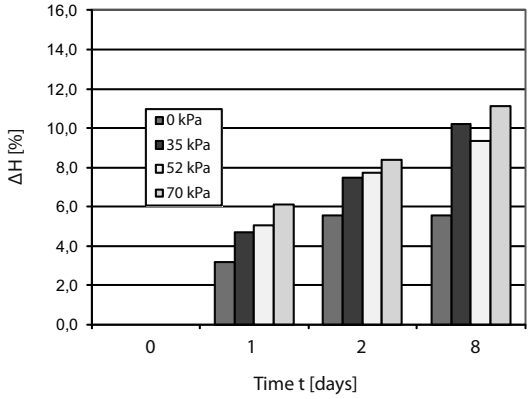

Fig. 2. Relative deformation of grain mass column ΔH for rye grain with moisture of 22% in relation to vertical load and time of storage

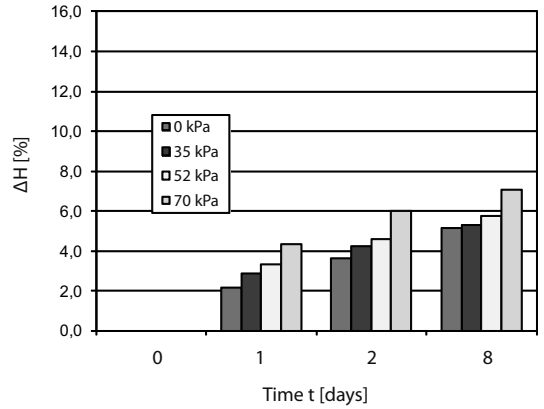

Fig. 3. Relative deformation of grain mass column *ΔH* for wheat grain with moisture of 22% in relation to vertical load and time of storage

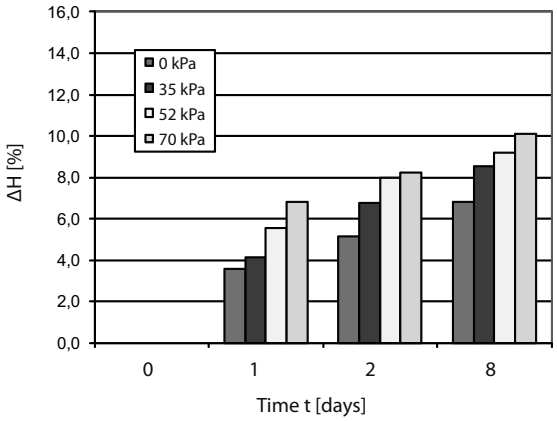

Fig. 4. Relative deformation of grain mass column *ΔH* for triticale grain with moisture of 22% in relation to vertical load and time of storage

Figures 5 and 6 present the range of changes of the relative deformation of grain mass column *ΔH* for grain of barley and oat with moisture of 22%. Note should be taken of the fact that in the case of non-loaded grain of barley small changes were observed in the values of *ΔH* with the passage of time, within the range from 1.3% to 1.9%.

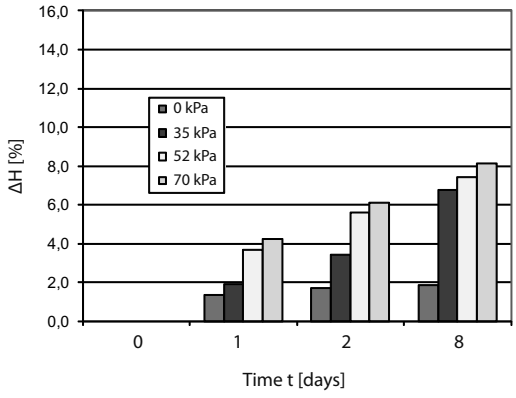

Fig. 5. Relative deformation of grain mass column *ΔH* for barley grain with moisture of 22% in relation to vertical load and time of storage

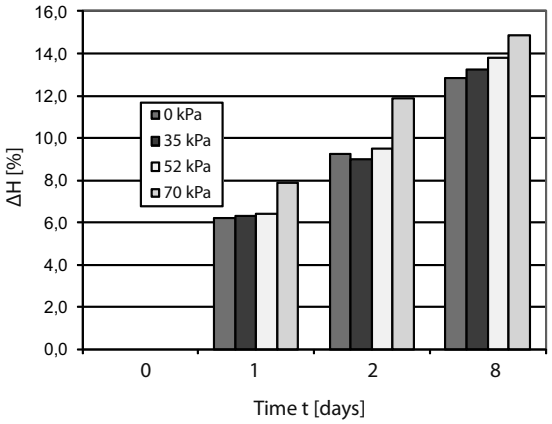

Fig. 6. Relative deformation of grain mass column *ΔH* for oat grain with moisture of 22% in relation to vertical load and time of storage

Among all the cereals tested at grain moisture of 22% the greatest range of changes of the relative deformation of grain mass column *ΔH*, amounting to 14.8%, was recorded after 8 days for oat grain subjected to a vertical load of 70 kPa.

After one day, among all of the cereals tested the smallest changes in the relative deformation of gain mass column *ΔH* occurred in the case of barley (from 1.3% to 4.2%) and wheat (from 2.2% to 4.3%), and the greatest for oat (from 6.2% to 7.8%). The study demonstrated that at grain moisture of 22% there appears a distinct and statistically significant effect of vertical load on changes in the grain column height *ΔH*. Among the cereal species tested, the greatest range of changes in the height of grain mass column was observed for oat, and the smallest for wheat. The experiment performed indicates the necessity of taking into account the phenomenon of grain material creep during the storage of cereal grain.

CONCLUSIONS

The study permitted the formulation of the following conclusions:

1. The creep test demonstrated that the relative deformation of grain mass column *ΔH* depends on the cereal species, moisture content of the kernels, vertical load applied, and on the duration of the loading.
2. In each case, with the passage of time an increase was observed in the relative deformation of grain mass column *ΔH*.
3. Increase in the value of vertical load causes a statistically significant increase of the relative deformation of grain mass column *ΔH* after 1, 2 and 8 days.
4. At grain moisture levels of 14% and 18% the relative deformation of grain mass column *ΔH* assumes values not exceeding 5%.
5. The greatest range of changes of the relative deformation of grain mass column *ΔH* (14.8%) was recorded after 8 days in the case of oar grain with moisture of 22% subjected to a vertical load of 70 kPa.

6. In the case of grain of the remaining species of cereals with moisture of 22%, after 8 days the range of changes of the relative deformation of grain mass column ΔH varied from 7.1% for wheat to 11.1% for rye.

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WPŁYW WYBRANYCH CZYNNIKÓW NA PRZEBIEG TESTU PEŁZANIA MASY ZIARNOWEJ W SYMULOWANYCH WARUNKACH OBCIĄŻEŃ

S t r e s z c z e n i e. W pracy przedstawiono wyniki badań dotyczące wpływu nacisku pionowego, wilgotności i gatunku zboża na przebieg testu pełzania. W wyniku przeprowadzonego eksperymentu stwierdzono, że względna zmiana wysokości słupa ziarna po określonym czasie tj. po 1, 2 i 8 dniach zależy od gatunku ziarna, jego wilgotności i nacisku pionowego. Największy zakres zmian wysokości słupa masy ziarnowej (14,8%) zarejestrowano dla owsa o wilgotności 22% po upływie 8 dni poddanego naciskowi pionowemu wynoszącemu 70 kPa.

S ł o w a k l u c z o w e: ziarno, gatunek, wilgotność, nacisk pionowy, pełzanie.