

## UNIVERSAL DEVICE FOR ASSESSMENT OF THE KINETIC DURABILITY OF PRESSURE AGGLOMERATION PRODUCTS

### Summary

This paper presents a universal prototype testing device for determining the kinetic durability of products of pressure agglomeration (pellets and briquettes). The device presented in the paper is equipped with replaceable test chambers enabling to combine Pfof's and Holmen's methods for the determination of kinetic durability of pellets, and a method for the determination of kinetic durability of briquettes. Equipping the device with an air blower and perforated chamber walls increases aggressiveness and allows an outlet for crushed particles from the chamber. The presented device will allow to perform tests that would make it possible to determine relationships between density and strength parameters of briquettes and pellets.

**Key words:** pressure agglomeration, product quality, kinetic durability

## UNIWERSALNE URZĄDZENIE DO OCENY WYTRZYMAŁOŚCI KINETYCZNEJ PRODUKTÓW CIŚNIENIOWEJ AGLOMERACJI

### Streszczenie

W pracy przedstawiono uniwersalne prototypowe urządzenie badawcze do określania wytrzymałości kinetycznej produktów ciśnieniowej aglomeracji (granulatu i brykietów). Przedstawione w pracy urządzenie posiada wymienne komory testujące, co pozwala na połączeniu metody Pfofa i Holmena do określania wytrzymałości kinetycznej granulatu oraz metody określania wytrzymałości kinetycznej brykietu. Zastosowanie nadmuchu powietrza i perforowanych ścianek komór w urządzeniu zwiększa agresywność i pozwala wyprowadzić rozkruszone cząstki z komory. Przedstawione urządzenie pozwoli na prowadzenie badań pozwalających ustalenie zależności pomiędzy gęstością a parametrami wytrzymałościowymi brykietów i granulatu.

**Słowa kluczowe:** ciśnieniowa aglomeracja, jakość produktu, wytrzymałość kinetyczna

### 1. Introduction

One of the main criteria of pellets assessment is their durability, i.e. retaining shape during transport, storage, warehousing, etc. A knowledge of pellets durability (hardness, kinetic durability, drop durability, shear durability, etc.) is extremely important, despite the tendency of Polish producers to under-rate it.

Among methods for assessing the quality (durability) of pellets there are [9, 12, 13, 16, 22, 24, 25]:

- tests of hardness of pellets,
- tests of static durability of pellets,
- tests of shear durability,
- tests of drop durability of pellets,
- tests of kinetic durability of pellets.

Hardness of pellets is determined with the use of measuring equipment that measures the force needed to crush them. These devices work on the premise of compression, tension, or impact applied to the sample. They are constantly being improved both in order to obtain reliable results in scientific research and for ongoing quality assessment in modern fodder production plants [22, 24].

Among the devices used for hardness measurement there is the Kahl hardness tester, the Schleuniger tester, the pendulum tester, the Kramer apparatus, or universal testing machines [7, 22, 24].

When measuring static durability of a sample consisting of several tens to several hundreds of pellets with a specific mass, a tensile force of a known value is applied to it for a known period. Static durability of pellets is determined as the ratio of the mass of pellets sieved after the test to the mass of pellets before the test [9].

A device for testing shear durability of briquettes is presented in fig. 1.

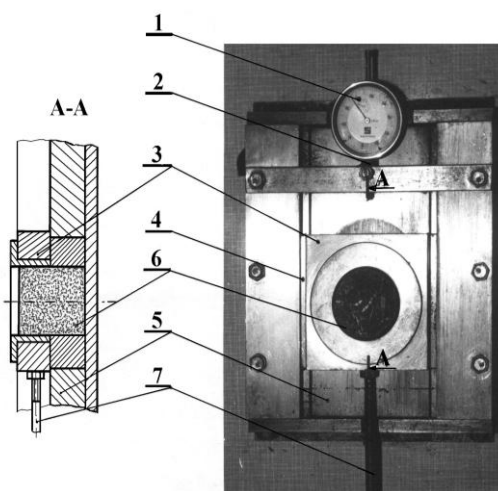


Fig. 1. Device for testing shear durability of briquettes [9]: 1- clock sensor, 2- clock sensor fixing, 3- mobile plate, 4- guide plate, 5- base, 6- briquettes, 7- screw with a system for applying load to the mobile plate

Rys. 1. Przyrząd do badania wytrzymałości brykietów na ścinanie [9]: 1- czujnik zegarowy, 2- mocowanie czujnika zegarowego, 3- płyta ruchoma, 4- płyta prowadząca, 5- podstawa, 6- brykiet, 7- śruba z układem obciążającym płytę ruchomą

The device consists of base 5, to which guide plates 4 are fixed, over which mobile plate 3 moves. In base 5 and mobile plate 3, a centric hole is made, into which pellets (briquettes) 6 are fed. Screw 7, to which static or dynamic

load is applied through a tie rod and a block, is fixed to mobile plate 3. Clock sensor 1 is fixed to guide plate 4, which in its zero position (both the holes, in mobile plate 3 and in base 5, overlap) is tensed to a certain position. Moving mobile plate 3 when applying load results in indications of clock sensor 1 that show the absolute deformation of briquettes. The measurement result is the maximum force that causes a destruction of pellets (briquettes) [9].

Determination of drop durability of pellets (briquettes) consists in dropping briquettes (pellets) onto a steel plate, set horizontally, from a certain height (2.0m, 1.8m, 1.5m), adopted for a given material. Drop durability is determined as the quotient of the mass of briquettes (pellets) after sieving after the test to the mass before the test [12].

However, the most commonly determined quality parameter characterizing pellets (briquettes) is their kinetic durability. The measuring equipment used for its determination measures the size of a crushed fraction of pellets (briquettes) obtained after a performed test. In practice, pellets (briquettes) are exposed to the action of various external factors causing their crumbling. Hence, the proportion of the fine-grained fraction increases, which has a negative impact on their general assessment. For this reason, pellets (briquettes) should display a certain resistance to forces they are subjected to during movement [24].

As far as strength tests of agglomerate (pellets, briquettes) are concerned, of both the fodder and the fuel type, carried out throughout many years [1, 4, 5, 6, 10, 11, 14, 21, 23, 26], many devices for determining the kinetic durability of products of pressure agglomeration have been created. They are characterized by different methods for the determination of kinetic durability, diverse designs, and most importantly, large time spans needed to perform the tests. Among methods used to determine kinetic durability of pellets (briquettes) there are the "Handling system" method, the Schatter apparatus, the Pfof apparatus, a modified Holman apparatus, and the Ligno Tester.

As Hejft and Demianiuk [12] show, the "Handling system" method is a reference base for all other methods of measurement. In this method, the movement of pellets approximates the conditions of their movement during transport (fig. 2).

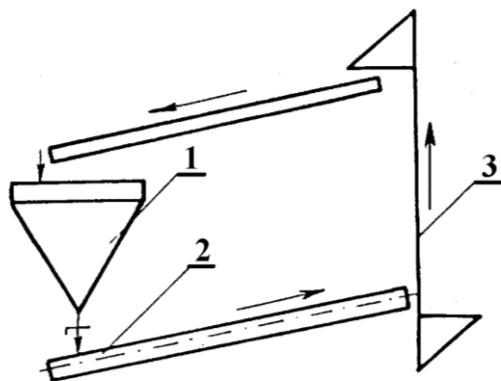


Fig. 2. Scheme of the transport model for determination of pellets durability [12]: 1- charging hopper, 2- screw conveyor, 3- bucket conveyor

Rys. 2. Schemat transportowego modelu do określania trwałości granul [12]: 1- lej zasypowy, 2- przenośnik ślimakowy, 3- przenośnik czepakowy

In the presented closed system (fig. 2), a pellets sample with a mass of 6.5 kg is moved for 10 min. After sieving the fines, the mass of pellets that have not been crushed is determined. The ratio of the mass of pellets after the test to the mass of pellets before the test is the measure of the kinetic durability of pellets [12].

In the Schatter method, a special apparatus is used, in which pellets are conveyed by a stream of compressed air and hit a plate. The crushed parts of the sample are sieved on a sieve with a mesh dimension smaller by 1 mm than the dimension of a pellet (a briquette), while the part remaining on the sieve is weighed with an accuracy of 0.01g. The kinetic durability of pellets is determined as the ratio of the mass of the sample after the test to the mass of the sample fed to the tester [12, 24].

The most commonly used and normalized (pursuant to PN-R-64834:1998 [18], and pursuant to PN-EN 15210-1:2010 [19], devices for determining kinetic durability are: the Pfof apparatus, the Holmen tester, and an apparatus for determining the kinetic durability of briquettes.

The Pfof apparatus is a cuboidal tank with strictly defined dimensions, with a plate transversely placed in it [3, 5, 21]. A 500 gram pellets sample is fed to the tester. The tester casing rotates for 10 min., with a speed of 50 rpm. After the test, particles that underwent crushing are separated on the sieve. Kinetic durability of pellets  $P_{dx}$  is determined as the ratio of the mass of the sample after the test to the mass of the sample fed to the tester. In Poland, determination of the kinetic durability of pellets is carried out pursuant to PN-R-64834:1998 [18], and PN-EN 15210-1 [19].

Another device for determining the kinetic durability of pellets is a modified Pfof apparatus, i.e. a set of sieves vibrating with a known frequency, onto which a sample of material is placed. Rubber balls that are part of the design cause a quicker wear of pellets. In this device it is possible to change the dimensions of the sieve mesh, the number of balls, the amplitude of vibrations, and the time of measurement. The granulometric composition determined later is helpful when determining the quality of the tested pellets [24].

The Holmen tester simulates a more rigorous treatment of pellets, which occurs during pneumatic transport. In this device, a 100 g sample is entered into a stream of air and while circulating in it, it hits, among other things, the metal partition placed therein. After a standard time has elapsed (30 or 60 s), depending on the pellet diameter, the part remaining on the sieve is weighed and then it is possible to calculate the kinetic durability of pellets as the ratio of the mass of the sample after the test to the mass of the sample before the test [22, 24].

According to Walczyński [24], the Ligno Tester is a device combining the speed of Holmen's method with the mechanical simplicity of the Pfof apparatus. It consists of an inverse square based pyramid with perforated walls and a system for blowing the air into the measurement chamber. During the test, a 100 g pellets sample is placed inside the device and blown with air for 30 s. During the blower's action, crushed pellets are automatically sieved through the holes in the walls. After the cycle is over, the remaining pellets are poured onto a scale, on which it is immediately possible to read the mass of whole pellets. The result is given, similarly to the previous methods, in per cent. The fact that this process is so quick gives the possibility for on-the-fly adjustment of the parameters of the technological process

that influence the quality of the final product, e.g. the quantity and quality of the added technological steam, the performance of the pellet mill, the arrangement of pellet mill rolls relative to the matrix, or even a selection of matrix for a given type of densified material [24].

There also exist numerous design solutions for devices for determining the coefficient of durability of briquettes. They are mostly based on the GOST-18691-73 [8] and ASAE S 269.4 norm [2]. Pursuant to it, such a device is built from a 300 x 300 x 460 mm cuboid with vertices built from a 25 x 25 x 3 mm profile encased in a steel 12 x 12 mm mesh, whose axis of rotation crosses the cuboid diagonal. Such a device is described in papers [1, 4, 15, 21].

Another solution for a stand for testing the coefficient of durability of briquettes (presented in papers [5, 21]) is a device in the form of a drum with an internal diameter of 598 mm, driven by an electric motor equipped with a belt transmission that makes it possible to achieve a rotational speed of the drum of 21 rpm. The drum is equipped with a 200 x 598 mm latch. Pursuant to ISO 3310-1, the tested material is placed in the drum and subjected to a test, using 105, 210, 315, 410, and 630 rotations in ascending order, the material being inspected by means of a 30-40 mm wire mesh and weighed with an accuracy of 0.1 g [5].

## 2. The aim of the paper

The aim of the paper is to present the concept of a universal testing device for determining the kinetic durability of products of pressure agglomeration.

## 3. Universal device for determining kinetic durability

The core of the proposed solution for a universal test stand for determining the kinetic durability of products of pressure agglomeration (fig. 3) is the use of replaceable test chambers, which allows to combine Pfost's method for determining the kinetic durability of pellets, Holmen's method for determining the kinetic durability of pellets, and a method for determining the kinetic durability of briquettes. In the proposed solution, both in tests making use of Pfost's method and when determining the kinetic durability of briquettes, the use of perforation in the replaceable chambers as well as an air blower that will tear the crushed particles escaping from the perforated chamber walls, is planned.

The prototype testing device presented in fig. 3 consists of a working (testing) system, a drive unit, an air convection system, and a steering system.

The working system of the device consists of replaceable test chamber 1, built from perforated sheet. Replaceable chamber 1 is fixed to drive shaft 2 by means of fixing plates 3 and 4, or in the case of a pellet tester, mounted by means of plate 4 alone. In the case of determining the kinetic durability of pellets, a 305x305x150 mm cuboidal tester chamber (built pursuant to PN-R-64834:1998 [18]) is mounted in the device, whereas in the case of determining the kinetic durability of briquettes, a 300x300x450 mm chamber for briquettes (pursuant to GOST-18691-73 [8] and ASAE S269.4 [2]) is mounted.

In order to increase the effectiveness of the test, perforated sheet is used for the construction of tester chambers, which makes it possible to convey the fraction shredded during the test outside the chamber. The whole of the working system of the testing device is placed in tight casing 5, which al-

lows to eliminate only fine agglomerate (pellets, briquettes) particle dusting to the environment. The drive unit of the device consists of motor 6 connected with reducer 7 and belt transmission 8 conveying the drive to drive shaft 2. The air convection system (pneumatic) consists of air vent 9 mounted to a steel frame made from stainless steel channel bars. The steering system consists of control cabinet 10, which contains a power inverter responsible for alternating the motor's rotation. Drive from electric motor 6 is conveyed through reducer 7, belt transmission 8, in this order, to shaft 2 (bearing-mounted in two supports), on which test chamber 1 is fixed by means of fixing plate 4. A change of the rotational speed of the chamber is actuated by means of a power inverter placed in control cabinet 10, coupled with motor 6.

The chamber for testing briquette durability is mounted on the other side by means of fixing plate 3 fixed to guide 11 for changing its position, facilitating mounting and demounting. The drive unit and the pneumatic system are mounted on support frame 12. Control panel 13 allows to adjust test times. Safety switches 14 allow to terminate the test at any time.

For testing pellets, a modified chamber built pursuant to PN-R-64834:1998 [18] is used, rotating with a rotational speed of 50 rpm; for briquettes, a chamber built pursuant to GOST-18691-73 [8] and ASAE S 269.4 [2], rotating with a speed of 13 rpm. The high-speed air vent 9 conveys air to the tester chamber at a high speed, causing the tested pellets to hit the tester casing, increasing the aggressiveness of the test. In order to eliminate dusting of fine-grained pellet particles into the environment, the testing device is housed in tight casing 5, mounted to frame 15. Adjustment of test times is carried out by means of control panel 13.

In order to ensure safety of device operation, safety switches 14 are used, which allow to terminate the test at any time.

The device for determining the kinetic durability of products of pressure agglomeration is equipped with guides and frames made from profiles equipped with special adjustable feet that make it possible to adjust the size of the chamber for a given method.

The stand presented below and experimental tests performed on it would make it possible to design an unambiguous method for testing the quality of both pellets and briquettes in the area of their strength properties. This could result in establishing a research methodology for determining another parameter, e.g. *d y n a m i c c o h e s i o n* (proposed by Institute of Agricultural Engineering of Poznań University of Life Sciences [4, 5] as an alternative to the coefficient of durability).

## 4. Summary

In industrial practice one can come across numerous methods for the determination of strength properties of agglomerate (pellets, briquettes): crumpling durability, drop durability, wear durability (resistance), shear durability, lateral and longitudinal pressures. The great number and diversity of experimental methods results in there often being no mutual correlation between the quoted values of individual strength properties. Therefore, research work that would make it possible to determine the relationships between density and durability parameters of pellets and briquettes play a significant role.

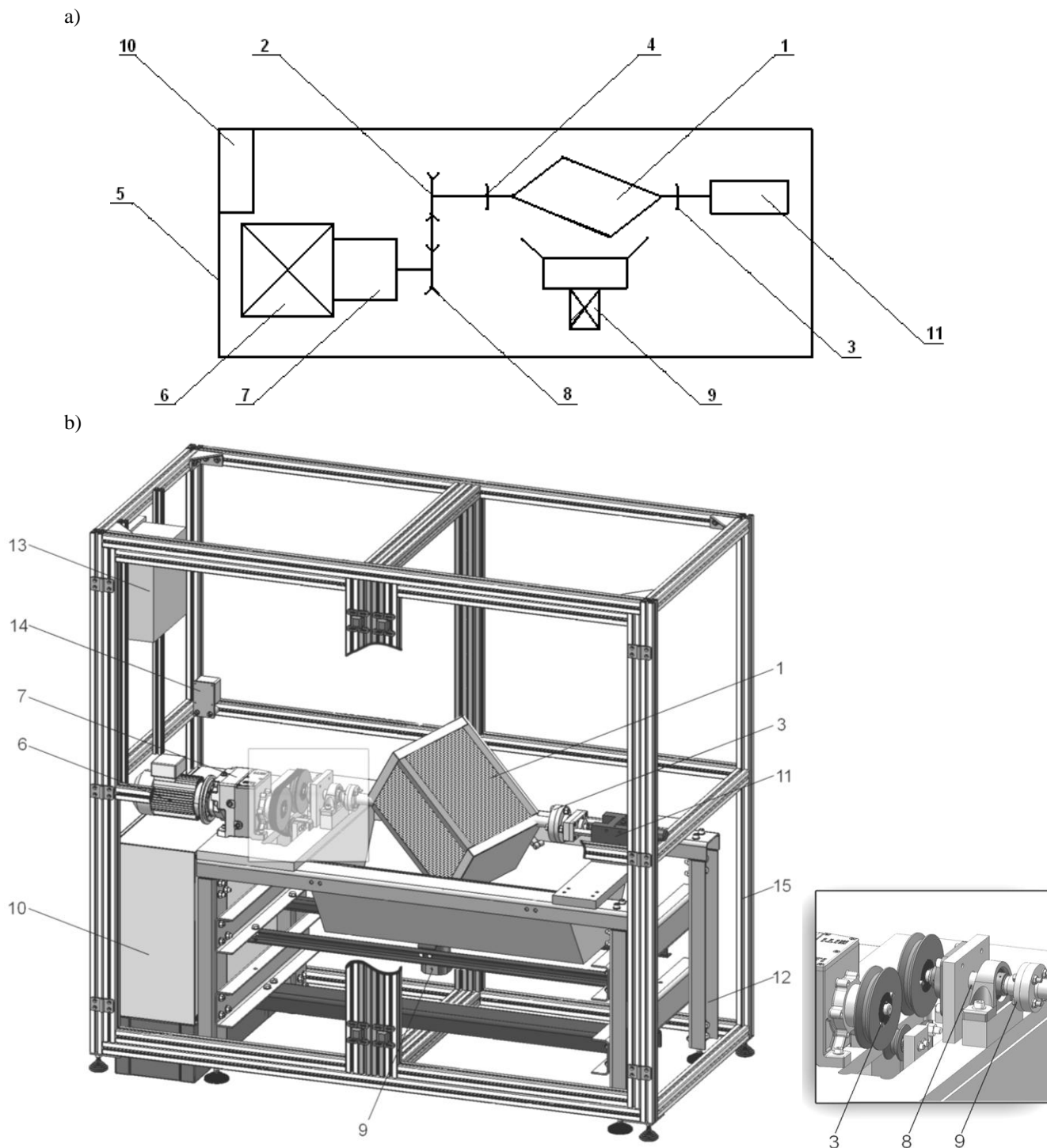


Fig. 3. Universal stand for testing the kinetic durability of products of pressure agglomeration [17]: a) scheme of the device, b) tender drawing of the device: 1- replaceable test chamber, 2- drive shaft, 3, 4- fixing plates, 5- sealed casing, 6- drive motor, 7- reducer, 8- transmission belt, 9- air vent, 10- control cabinet, 11- guides, 12- supporting frame, 13- control panel, 14- safety switch, 15- frame

Rys. 3. Uniwersalne stanowisko do badania wytrzymałości kinetycznej produktów ciśnieniowej aglomeracji [17]: a) schemat urządzenia, b) rysunek ofertowy urządzenia: 1- wymienna komora testująca, 2- wał napędowy, 3, 4- tarcze mocujące, 5- hermetyczna obudowa, 6- silnik napędowy, 7- reduktor, 8- przekładnia pasowa, 9- wentylator, 10- szafa sterująca, 11- prowadnice, 12- rama nośna, 13- panel sterujący, 14- wyłącznik bezpieczeństwa, 15- rama

Experimental tests pave the way to creating an unambiguous method for testing the quality of both pellets and briquettes in the area of their durability properties, which would make it possible to establish a research methodology for another parameter as an alternative to the coefficient of durability.

The device proposed in this paper makes it possible to perform such tests. Being equipped with replaceable test

chambers allows to combine Pfof's method for determining the kinetic durability of pellets, Holmen's method for determining the kinetic durability of pellets, and a method for determining the kinetic durability of briquettes. The use of an air blower and perforated chamber walls in Pfof's method and the method for determining the kinetic durability of briquettes increases the aggressiveness and allows an outlet for crushed particles from the chamber.

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