THE BEATER SHREDDING ASSEMBLY – CLASSIC AND NEW CONSTRUCTION

Marcin ZASTEMPOWSKI[1], Andrzej BOCHAT[1]

[1]*Faculty of Mechanical Engineering, UTP University of Science and Technology, Poland.*

Abstract
New design solutions of the working assembly of the beater shredder, the traditional construction of which is commonly used in the agri-food industry, are presented in the article. There has been described the test stand, methodology of the studies and the selected results obtained from the experiment. New construction of the beater shredder's rotor is characterised by a lower power consumption, higher effectiveness and better partitioning of the shredded material into fractions as compared to its traditional construction.

Key words: *beater shredder; shredding of grain material; new construction of a beater shredding.*

INTRODUCTION

Shredding of the cereals' grains is one of the main technological operations in the agri-food industry and on farms. From among many types of shredders, that is: radial plate grinding mills, roller mills, crushing mills and beater shredders, these are the beater shredders that are the most widely used ones because of the shredding efficiency *(Bochat, Wesolowski, & Zastempowski, 2015; Bochat & Zastempowski, 2018; Zastempowski & Bochat, 2016)*.

The design solutions of beater shredders existing at present, are characterised by high energy consumption of shredding, as a result of what, for their drive it is necessary to use engine of high powers. The fundamental elements of a typical beater shredder are a rotor with pivotably or rigidly mounted beaters, screens, shredding plates and a supporting structure with a driving system.

The disadvantage and inconvenience of known, traditional design solutions of beater shredders is their low efficiency as compared to energy consumption *(J. Flizikowski, Sadkiewicz, & Tomporowski, 2015; J. B. Flizikowski, Mrozinski, & Tomporowski, 2017; Macko et al., 2017; Tomporowski, Flizikowski, & Al-Zubiedy, 2018; Tomporowski, Flizikowski, & Kruszelnicka, 2017)*. It is most of all determined by a rotor's design, where the beaters are of rectangular plates' shape. As an effect of that, under the influence of the beaters' strokes, the material's particles start to move along the paths similar to a circle. They form a thin layer circulating along the internal perimeter of a shredding chamber, what causes that in spite of sometimes insufficient degree of shredding, the material is not enough shredding degree, material still for a long time circles before it goes through the holes in the screens.

Therefore, the purpose of the article is to determine the efficiency and power consumption in the shredding process for both construction of beater shredder - traditional and new construction as described in the article. For this purpose, the authors conducted tests using their own test stand.

MATERIALS AND METHODS

In fig. 1a there is presented a traditional rotor of a beater shredder from the isometric view with beaters in the form of rectangular plates. The essence of a new construction (fig. 1b) consists in the fact, that the working assembly of a shredder consists of a disk rotor assembled on a shaft to the which there are fixed the self-aligning beaters. These beaters are in the form of plates in the form of circular sectors of the angle of flare of at least 35^0, while the beater's fixing hole lies on the symmetry axis of the circular sector close to its arch base. Such a construction of the beater shredder's rotor causes, that the particles of the shredded material hit by the beaters do not move along the wheel track and do not form a rotating ring, but they move approximately radially as compared to the screens and immediately hit against them. It results in quicker going of the material's through the holes in the screens.

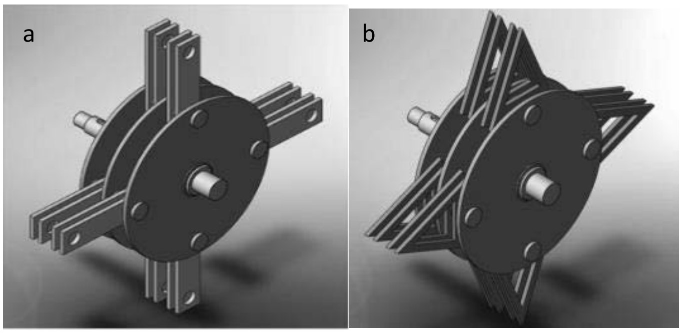

Fig. 1 Isometric view of a beater shredder (own study): a – traditional design solution of the rotor ($\propto = 0^0$) b – new design solution of a rotor with beaters in the shape of a circular sector ($\propto = 45^0$)

The authors have conducted experimental studies of the material's shredding process, aiming at determination the demand for power by the shredders' working assemblies.
For the purposes of the studies' performance, the test stand was designed and constructed, which is presented in fig. 2.

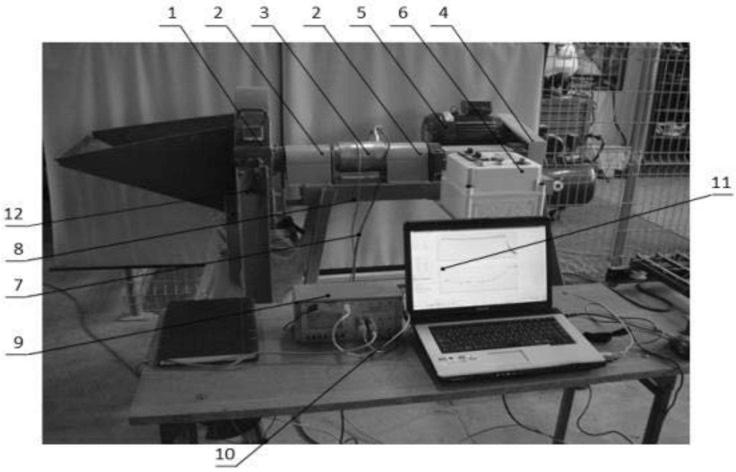

Fig. 2 View of the test stand (own study): 1 – modified beater shredder type WIR RB-1.3, 2 – flexible claw coupling Poly-Norm, 3 – torque measuring device with revolution counter type MIR 20, 4 – belt transmission, 5 – electric engine 7 kW, 380 V, 6 – control box with frequency converter Lenze SMD, 7 – transmission cable of a turning moment, 8 – transmission cable of rotational speed, 9 – two-channel measuring device MW2006-4, 10 – transmission cable type USB, 11 – computer system with a programme for data registering PP203 and an author's computing programme RB01, 12 – supporting structure.

The test bed consists of a modified beater shredder type WIR RB-1.3, equipped for studies with a traditional and a new working assembly – a rotor, control and measuring apparatuses in the form of an electric engine's control system ensuring smooth adjustment of a rotor's rotations and a torque measuring device for determining the power consumption on the rotor's shaft.
Within the frames of the experiment, there were shredded the grains of triticale (winter triticale Krakowiak, of humidity 11,69%, of bulk density 795,15 kg·m^{-3}). That material has been chosen for the studies due to commonness of cultivation and its designation for fodder purposes. The studies were conducted for the diameter of holes in the screens of d =5 mm, size of gap between the endings of the beaters and the surface of screens of $s = 10$ mm and the peripheral speed of the beater's endings respectively: 38; 45; 52; 59; 66 m·s^{-1}.

RESULTS AND DISCUSSION

The selected results of the tests are presented in fig. 3 and 4.

In fig. 3 there is presented the diagram of power consumption at the time of shredding for both the constructions of the beater's working assemblies.

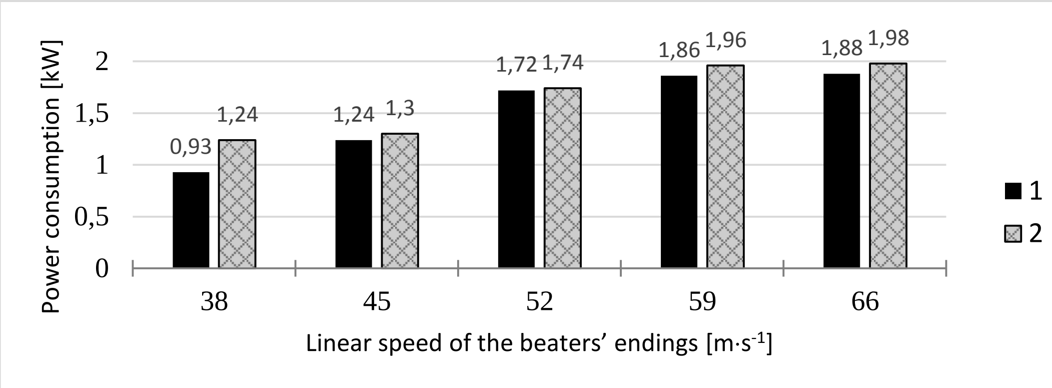

Fig. 3. Comparative diagram of the beater shredder's power consumption (own study): 1 – new design of a rotor, 2 – traditional rotor's design

It results from the conducted experimental studies, that an essential impact on power's consumption on the shredder's shaft and its efficiency at the time of the triticale grain's shredding there have: the design form of a rotor – the angle of the beaters and the peripheral speed of the beaters' endings while maintaining the constant diameter of the holes in the screens and the gaps between the endings of the beaters and the screens' surface.

In fig. 4 there is presented the diagram of efficiencies obtained in the shredding process for a shredder equipped with a traditional and new rotor.

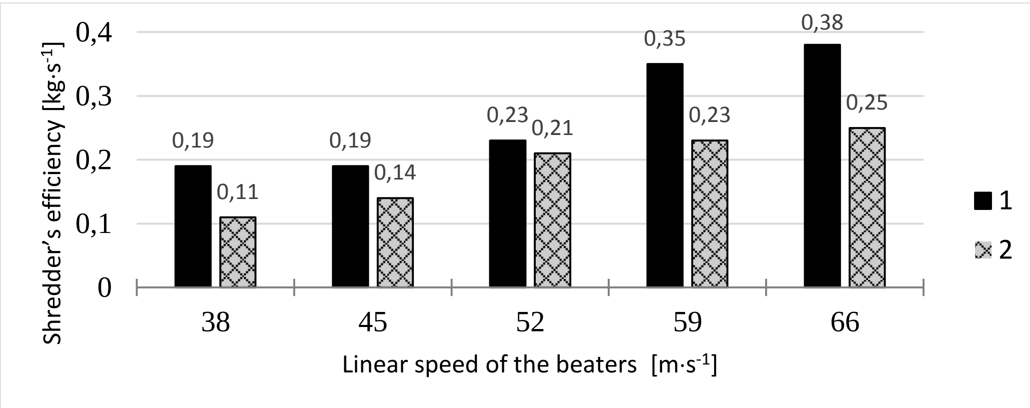

Fig. 4. Comparative diagram of the beater shredder's efficiency (own study): 1 – new construction of the rotor, 2 – traditional rotor's construction

Application in a beater shredder of a new construction of a working assembly (fig. 1b) equipped with beaters of the shape of a circular sector, resulted in a considerable increase of the shredder's efficiency from 11 up to 32%, and minimum decrease of power consumption for about 5% as compared to the traditional rotor's constructional solution. As a final effect, the shredder with a new design of the shredder, has a lower power consumption for shredding of the triticale's grain as compared to the traditional design. Additionally, application of a new construction of the beater shredder's design, equipped with beaters of the shape of a circular sector, results in the decrease of dust fraction in shredded cereal as compared to the traditional design solution.

Application of the beaters of the angle $\propto = \mathbf{45^0}$ has an impact on:

- decrease of the content of dust fraction from 7,26 to 7,75% ,
- decrease of the content of fine fraction from 8,58 to 9,23%,
- increase of the content of heavy fraction from 16,33 to 16,49%.

The conducted assessment of shredding efficiency has proved, that in case of shredding triticale, the most effective design solution of the beater assembly is application of beaters in the shape of circular sector $\propto = \mathbf{45^0}$, a beater's gap of the value of $\boldsymbol{s = 10\,mm}$ and screens of the holes' diameter $\boldsymbol{d = 5\,mm}$. The use of a gap of the value of $\boldsymbol{s = 15\,mm}$ and screens of the diameter $\boldsymbol{d = 3\,mm}$ proved to be less efficient.
The authors of the study did not have an opportunity of direct comparison of the results of their studies with the ones presented in the literature by other researchers. It is caused by the fact, that the results of the studies presented in this article, concern mainly a new construction of the shredder's rotor, which is covered by legal protection. However, for a traditional construction of a shredder's rotor, there is no direct comparison encountered in the world's literature to the data for direct comparison because of: the differences in the shredders designs' solutions *(J. Flizikowski, Sadkiewicz, & Tomporowski, 2015; Tomporowski, Flizikowski, & Kruszelnicka, 2017)*, different materials exposed to the shredding process, *(Macko et al., 2017; Tomporowski, Flizikowski, & Al-Zubiedy, 2018)* and different geometric and dynamic features of the shredders.

CONCLUSIONS

New constructional solutions of the beater shredder with new design of the rotor and its tests presented in the study show unequivocally, that by way of evolutionary changes of the existing constructions, one may contribute to lowering the costs of production of food, fodder or power materials of biomass's type. The new construction of the working assembly developed at the Institute of Mechatronics and Machinery is the subject matter of the patent and is more and more commonly used in new machine's constructions.

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Corresponding author:
Marcin Zastempowski, assocc. prof: Faculty of Mechanical Engineering, UTP University of Science and Technology, Poland., Al. Prof. Kaliskiego 7, 85-796 Bydgoszcz, e-mail: zastemp@utp.edu.pl