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ANALYSIS OF THE POSSIBILITIES OF ADAPTING THE MANURE SPREADER FOR SUBSOIL APPLICATION OF DEHYDRATED DIGESTATE

Summary

The possibilities of adapting the manure spreader to the soil application of dehydrated digestate are presented. Based on the analysis, a virtual model of the device consisting of a modernized manure spreader and aggregated disc harrow was developed. Based on the virtual model, computational models were developed and strength analyses were carried out. The conclusion is that modernized manure spreader, in terms of functionality and strength, can work with a disc harrow, which mixes the scattered digestate with the soil. The work was carried out at the Industrial Institute of Agricultural Engineering as part of the BIOSTRATEG 1/269056/NCBR/2015 project.
***Key words**: digestate, soil application, manure spreader, disc harrow, virtual model, computational model*

ANALIZA MOŻLIWOŚCI PRZYSTOSOWANIA ROZRZUTNIKA OBORNIKA DO DOGLEBOWEJ APLIKACJI ODWODNIONEGO POFERMENTU

Streszczenie

Przedstawiono możliwości przystosowania rozrzutnika obornika do doglebowej aplikacji odwodnionego pofermentu. Na podstawie analizy opracowano wirtualny model urządzenia składającego się ze zmodernizowanego rozrzutnika obornika i zagregowanej z nim brony talerzowej. Na podstawie modelu wirtualnego opracowano modele obliczeniowe i przeprowadzono analizy wytrzymałościowe. Stwierdzono, że zmodernizowany rozrzutnik obornika, pod względem funkcjonalnym i wytrzymałościowym, może współpracować z broną talerzową, która miesza z glebą rozrzucony poferment. Prace przeprowadzono w Przemysłowym Instytucie Maszyn Rolniczych w Poznaniu w ramach projektu BIOSTRATEG 1/269056/NCBR/2015.
***Słowa kluczowe**: poferment, aplikacja doglebowa, rozrzutnik obornika, brona talerzowa, model wirtualny, model obliczeniowy*

1. Introduction

Digestate (post-fermentation pulp) is a by-product produced during the production of biogas from organic substrates (natural fertilizers, vegetable biomass, by-products of agri-food industry) in agricultural biogas plants. Due to its properties it can be successfully used as a valuable and cheap fertilizer combining the positive features of natural fertilizers (source of organic matter) and mineral (source of macro- and micronutrients in mineral forms) [2], and its quality depends on the input in biogas plant [1]. A liquid digestate with a low content of dry matter (4-7%) and a relatively low concentration of nutrients as well as a solid and liquid fraction of digestate subject to separation to separation [1] can be used as a fertilizer. The need for post-fermentation treatment results mainly from the need to reduce the space necessary for its storage [1], but the possibility of obtaining a solid fraction with a higher concentration of nutrients is no less important. Non-separated digestate (post-fermentation pulp) resembles slurry with a consistency, and the solid fraction of digestate after dehydration as a result of separation, containing a maximum of about 30% of dry matter, resembles fresh compost. However, the liquid post-separation fraction of digestate contains less dry matter (2.5-4.5%) than pulp and can be used as fertilizer or reintroduced into the post-digestion chamber of the biogas plant to dilute the charge.

The liquid digestate, both before and after separation, can be applied in the field by slurry tankers, which are increasingly equipped with subsoil applicators [4]. A separated solid fraction of digestate, like compost, can be applied on the surface, e.g. with the help of special orchard spreaders [3] or traditional manure spreaders. However, spreading the digestate in the form of a solid manure spreader requires its plowing or mixing with soil in the next treatment, and in accordance with the Code of Good Agricultural Practices, natural and organic fertilizers must be covered or mixed with the soil using cultivation tools not later than the day after they were applied [5].

At the Industrial Institute of Agricultural Engineering in Poznań, as part of the BIOSTRATEG 1/269056/NCBR/2015 project, a device for soil application of dehydrated digestate was prepared, consisting of a modernized manure spreader and aggregated disc harrow.

2. The virtual model of the device for soil application of dehydrated digestate

The virtual model of the device for the soil application of dehydrated digestate, reflecting its general structural form, was developed on the basis of the premise assumed in the project that the manure spreader base should be modernized, and the mixing of the digestate with the soil should be ensured by aggregated disk harrow. The specificity of the manure spreader construction forces the use of different spreading adapter that does not lift the spreading matter as widely as the standard adapters, and aggregates the disc harrow with the spreader in the attached manner. On the basis of the identification of manure spreader Tytan 18, it was found that it is possible to adapt spreader to a new application after modernization of the hydraulic system and mounting new equipment: low sides, an attachment spreading the digestate and disc harrow hitch (Fig. 1).

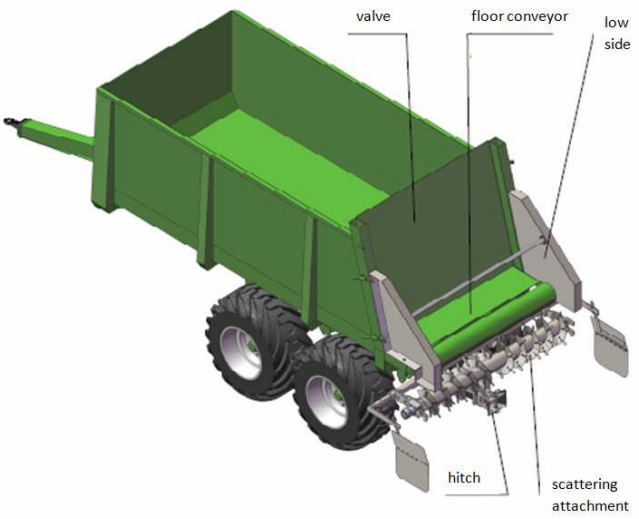

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Fig. 1. Virtual spreader model with new equipment
Rys. 1. Wirtualny model rozrzutnika z nowym osprzętem

Modernized hydraulic system in addition to the supply of native components of the manure spreader (floor conveyor drive, cylinders fixing the position of the gate valve) provides power supply for new units (drive of the auger-type beater, cylinders fixing the position of the disc harrow). The low sides protect from the flanks the end of the floor conveyor, open after disassembling the standard spreading adapter. The spreading attachment is mounted in the handles at the end of the manure spreader chassis and is located below the floor conveyor. The working assembly of the spreading attachment is a horizontally positioned, hydraulically driven auger-type beater with right and left spirals and knives screwed on their circumference (Fig. 2). The elements of the spreading attachment are also the side screens which limit the spread of the digestate to a width of 3 m, corresponding to the working width of the disc harrow. The hitch for the disc harrow (Fig. 3) consists of a fork bracket and a hitch pocket. The fork bracket is connected to the handles of the manure spreader chassis and shaped in such a way that the attached hitch pocket is located below the chassis and the spreading attachment.

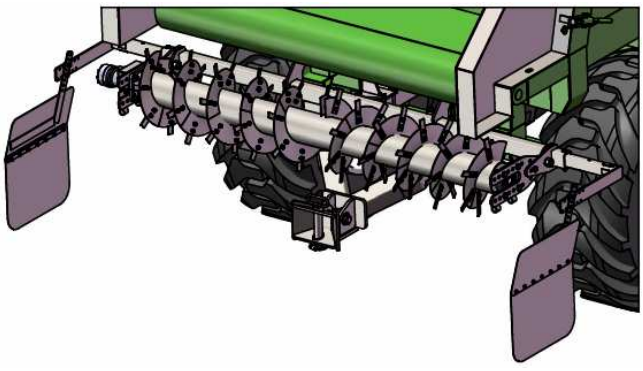

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Fig. 2. Digestate spreader attachment, equipped with a auger-type beater and side screens
Rys. 2. Przystawka rozrzucająca poferment, wyposażona w bęben ślimakowy i ekrany boczne

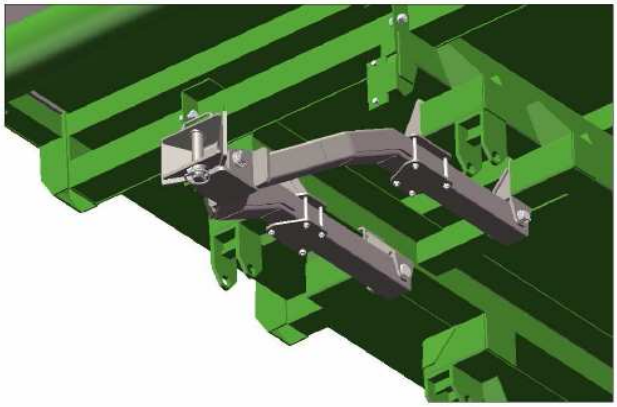

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Fig. 3. Disc harrow hitch, mounted to the chassis of the spreader
Rys. 3. Zaczep do brony talerzowej, zamontowany do podwozia rozrzutnika

The disc harrow designed for aggregation with a spreader (Fig. 4) is a compact harrow, with a working width of 3 m, equipped with 560 mm discs, a tire shaft and a long connecting bar. The discs are mounted by springs and arranged in two rows, with the side disks folded for transport. The disc harrow, like the spreading attachment, is equipped with side screens to prevent the loose soil from being thrown out of the work space. The tire shaft fulfills the working function (setting the disc depth, compacting the loosened soil) and the transport function (supporting the back of the harrow). The right positioning of the harrow behind the spreader during operation (Fig. 5) and transport (Fig. 6) is determined by drawbar hydraulic cylinders and tire shaft, equipped with stroke limiter.

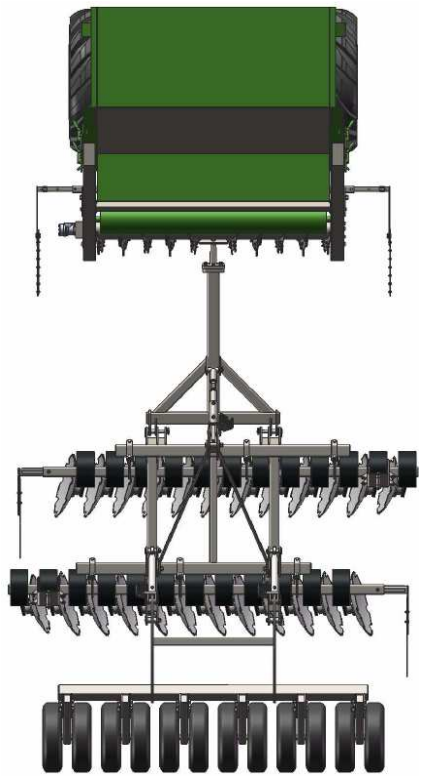

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Fig. 4. Disc harrow aggregated with a spreader
Rys. 4. Brona talerzowa zagregowana z rozrzutnikiem

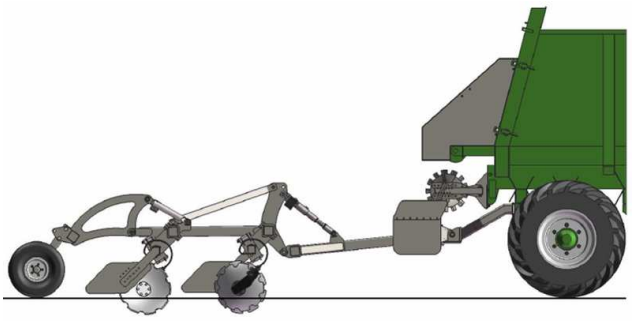

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Fig. 5. Disc harrow in working position
Rys. 5. Brona talerzowa w położeniu roboczym

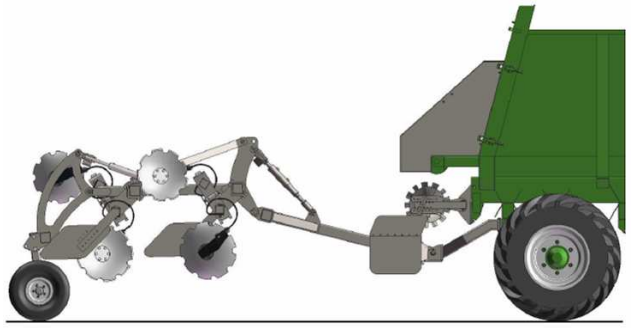

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Fig. 6. Disc harrow in transport position
Rys. 6. Brona talerzowa w położeniu transportowym

The digestate is poured from the manure spreader's tank through the adjustable slot under the tank damper and falls from the end of the conveyor floor, shielded from the flanks with the low sides, onto the spreading attachment. The auger-type beater of the attachment, rotating counter-clockwise, shatters and spreads the digestate without lifting it up. The width of the scatter space, limited by the side screens, is 3 m, with the width of the floor conveyor 2 m and the width of the 2.1 m auger-type beater. The fertilizer falls on the field surface in front of the harrow discs that mix it with the soil and the tire shaft tights the soil together with the fertilizer.

3. Computational models and strain analysis

On the basis of the virtual model, computational models of the modernized manure spreader (Fig. 7) and disk harrow aggregated with it were developed (Fig. 8) and strength analyzes were carried out. The models were developed in SolidWorks 2017 system and the calculations were carried out in the IDEAS NX 6.3 system. The purpose of the analysis was to check if is possible to load the spreader with additional disc harrow and if its supporting structure meets the strength requirements. The calculations take into account the loads occurring during operation and transport, resulting from the weight of the spreader and disc harrow, the mass of digestate, the working resistance of the harrow discs and the rolling resistance of the manure spreader wheels and the tire shaft of the harrow.

The results of calculations are presented in the form of stress maps (Figs 9-12). It was found that during transport in places with the greatest strain there are points connecting the leaf springs beams with longitudinal beams of the ma nure spreader's chassis.

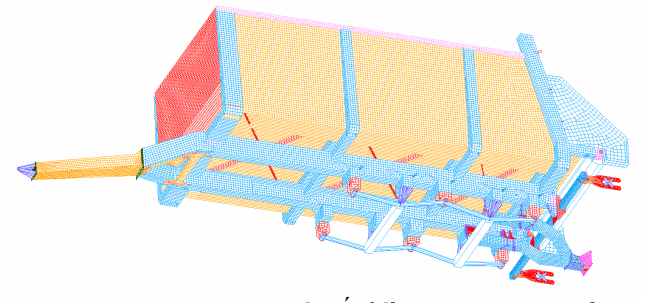

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Fig. 7. Computational model of the modernized spreader
Rys. 7. Model obliczeniowy zmodernizowanego rozrzutnika

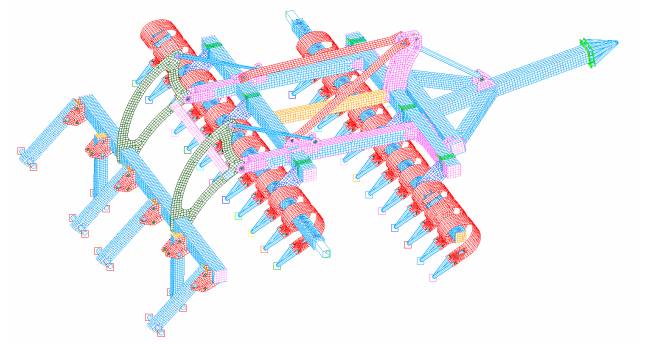

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Fig. 8. Computational model of disc harrow
Rys. 8. Model obliczeniowy brony talerzowej

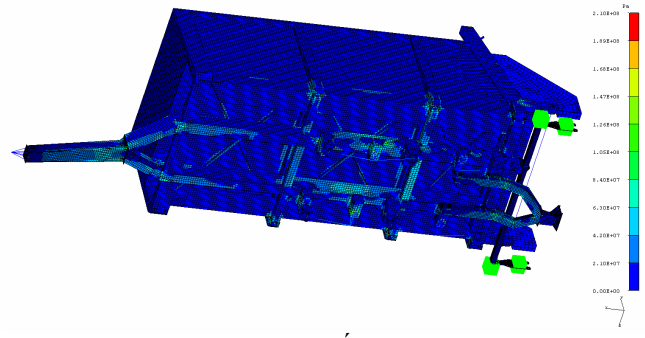

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Fig. 9. Map of reduced stresses in the manure spreader's chassis during operation
Rys. 9. Mapa naprężeń zredukowanych w podwoziu rozrzutnika podczas pracy

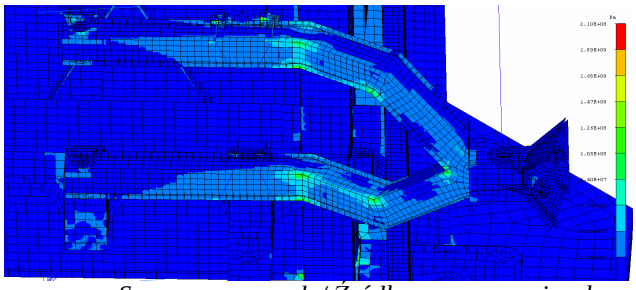

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Fig. 10. A map of reduced stresses in the disc harrow hitch during operation
Rys. 10. Mapa naprężeń zredukowanych w zaczepie do brony talerzowej podczas pracy

On an even ground, the stress value at these points reaches 170 MPa, and on the slope increases up to 183 MPa. In the case of a disc harrow rolled on the tire shaft, the highest stresses (point up to 203 MPa) occur in the frame support braces. In case of working, the strain in the attachment points of the spreader springs reaches 210 MPa, and in the longitudinal beams of the disc harrow frame - up to 132 MPa. In the manure spreader shaft, the stress value does not exceed 123 MPa, and in the drawbar handle 134 MPa (Fig. 12). The value of stresses in the bolt mounted to the chassis of the manure spreader is 82 MPa (Fig. 11). The analyzes carried out showed compliance with the strength requirements in terms of allowable stresses for S355JO steel for the supporting structure of both the modernized spreader and the disc harrow aggregated with it, and, above all, showed that the operation of spreader with the disc harrow is possible in terms of strain.

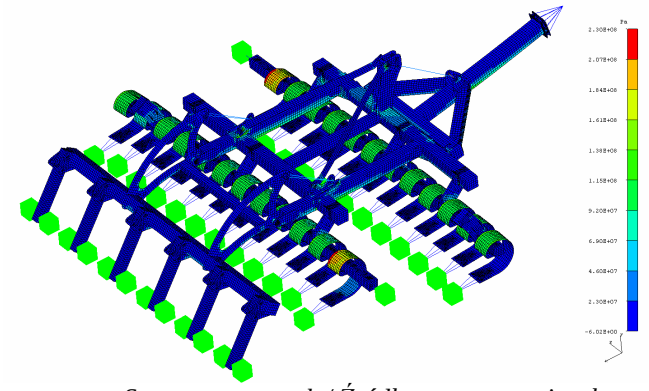

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Fig. 11. Map of reduced stresses in the disc harrows support structure during operation
Rys. 11. Mapa naprężeń zredukowanych w konstrukcji nośnej brony talerzowej podczas pracy

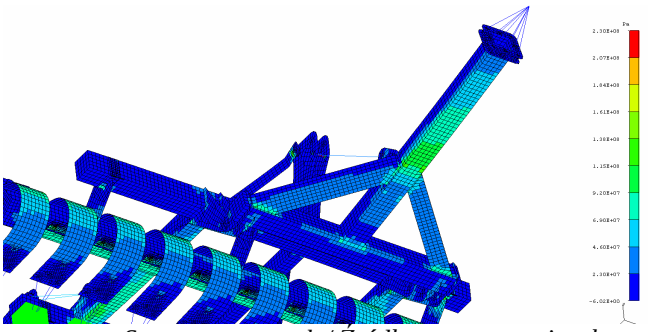

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Fig. 12. The map of reduced stresses in the disc harrows drawbar during operation
Rys. 12. Mapa naprężeń zredukowanych w dyszlu brony talerzowej podczas pracy

4. Conclusions

1. The functional analyzes carried out have shown that it is possible to adapt the manure spreader to the soil application of dehydrated digestate by modernizing the spreader and aggregating it with a disc harrow.

2. Modernization of the manure spreader includes the modernization of the hydraulic system and mounting new equipment: low sides, a spreading digestate attachment and a hitch for a disc harrow.

3. The disc harrow should be aggregated with the manure spreader in the attached manner, and the hydraulically adjusted drawbar and tire shaft should ensure its proper working and transport position.

4. Strength analyzes have shown that it is possible to load the Tytan 18 manure spreader with a disc harrow with a working width of 3 m.

5. References

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