Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 136 (2016) 263 – 268

Procedia Engineering

www.elsevier.com/locate/procedia

The 20th International Conference: Machine Modeling and Simulations, MMS 2015

Mechanical properties investigation of natural polymers

Ireneusz Malujda[a], Dominik Wilczyński[a,]*

[a]*Chair of Basics of Machine Design, Poznań University of Technology, Street Piotrowo 3, 60-965 Poznań, Poland*

Abstract

The paper presents a methodology of tests of mechanical properties of natural polymers. Aging test of polymers in an atmosphere of high humidity by using the climate chamber was discussed. The effect of humidity value changes on the degree of compaction was researched for different degrees of humidity. Next part of the paper presents the results of determination of friction coefficient of agglomerated natural polymers. The values of friction coefficient were calculated for different values of polymer temperature. The temperature values were similar to the values of temperature for polymer during agglomeration process.

Peer-review under responsibility of the organizing committee of MMS 2015

Keywords: natural polymers; mechanical properties; shredded fibrous materials; compressive force; compressed straw; relative density of straw; coefficient of friction; degree of compaction

1. Introduction

Heat and electrical energy production with the application of consolidated biomass is getting more and more important in power industry [1]. Many countries aim at the increase of percentage portion of fuels from biomass in energy production by running the proper politics [2]. Biomass is a material with nonhomogeneous structure and composition, low density and calorific power [3]. Different consolidation techniques for biomass are applied e.g. pelletization or briquetting which should improve the above mentioned parameters [4].

The calorific power of the solid fuel obtained from fragmented fibrous biomass, which belongs to natural polymers, depends on the properties of material, operation parameters of consolidation process – especially compressive force and temperature [5, 6]. During consolidation process of this material the decrease of moisture and

* Corresponding author. Tel.: +48 61-224-4512; fax: +48 61-665-2074.
E-mail address: dominik.wilczynski@put.poznan.pl

Peer-review under responsibility of the organizing committee of MMS 2015
doi:10.1016/j.proeng.2016.01.208

elimination of volatile and degraded elements of carbohydrates fraction exist. This has an influence on the increase of calorific value and resistance to air humidity effect [7–9].

The paper presents the investigation results of consolidation of two types of fibrous materials i.e. reed and rice straw. The application of huge sources of this biomass for energetic purposes is accepted as the best method of waste management. The investigation results will be applied to elaborate consolidation methods and plasticization methods of external surface of nonclassical materials with the application of real structure and thermomechanical properties [10–12].

2. Experimental investigations

The investigations of thermomechanical properties of samples made of reed and rice straw have been conducted on the basis of the elaborated methodology and research programme [10–12]. Special measuring device has been applied. It consisted of instrumentation for preliminary consolidation (Fig. 1), testing machine MTS integrated with climatic chamber 1 (Fig. 2), stationary chamber for seasoning the samples 2 (Fig. 2) and moisture analyser 3 (Fig. 2) [10–12]. Two types of natural materials i.e. reed and rice straw have been investigated for a proper number of samples.

First the characteristics of consolidation grade–moisture have been elaborated for preliminary consolidated samples with the application of device presented in Fig. 1. Before the preliminary consolidation, fragmented material was seasoned in stationary climatic chamber 2 up to the defined moisture (Fig. 2).

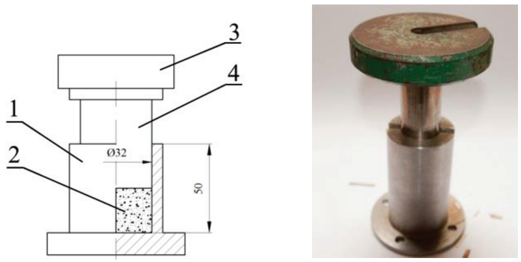


Fig. 1. Device for preliminary consolidation of examined material: 1 – sleeve, 2 – consolidated material, 3 – weight with mass 1070 g, 4 – punch.

Before the investigations of consolidation grade, the value of moisture of sample was defined with the application of moisture analyser 3 (Fig. 2).

Fig. 2. View of measuring apparatus: 1 – testing machine MTS with sleeve-punch assembly, 2 – chamber for material seasoning, 3 – moisture analyser.

Samples have been tested for compression with the force 40 kN on the testing machine.

Next stage of the investigations was the determination of the value of coefficient friction between the sample and steel surface of the plate with roughness R_a equal to 0.63 μm [10–12].

Test stand presented in Fig. 3 has been applied for this investigation. Fragmented material 2 was consolidated in preheated steel sleeve 5 – the temperature was controlled by sensors 6. The displacement of moveable plate 3 in relation to consolidated material 2 which had been placed in fixed sleeve 5 was performed as a result of the motion of piston 8 (Fig. 3). During the motion of plate 3 the force was measured by sensor 7 – this force was required to move the plate [10–12].

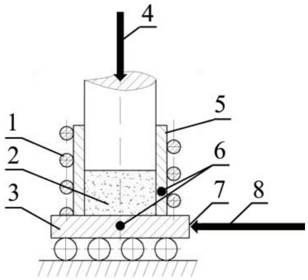
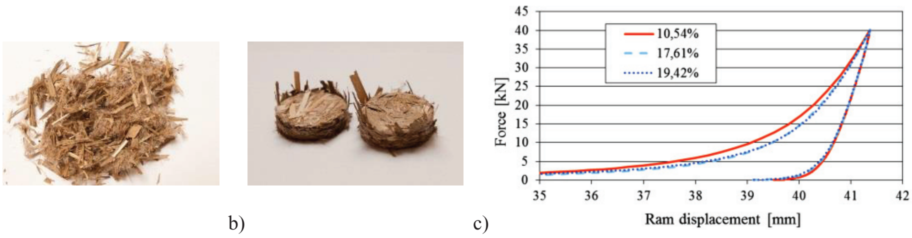


Fig. 3. Scheme of operation principle of test stand for the measurement of friction coefficient: 1 – coil heater, 2 – consolidated material, 3 – moveable plate, 4 – compressive force, 5 – fixed sleeve, 6 – temperature sensor, 7 – force sensor, 8 – drive.

3. The results of experimental investigations

3.1. The investigations of reed straw

Fig. 4 presents fragmented material of reed straw before consolidation (Fig. 4a) and after consolidation (Fig. 4b). Fig. 4c shows the characteristic of variation of compressive force for preliminary consolidated reed straw in function of guide displacement of testing machine for different moisture content of samples 10.54 %, 17.61 % and 19.42 %.



a) b) c)

Fig. 4. View of fragmented reed straw: a) before consolidation, b) after consolidation, c) characteristic of variation of compressive force in function of guide displacement for different moisture content.

On the basis of this characteristic we can state the following:

– the increase of force for sample with moisture content 10.54 % for the same displacement values is the highest in comparison to samples with moisture contents 17.61 % and 19.42 %,
– after unloading, we can see plastic deformations with similar values (the decrease of the force during unloading for moisture content 10.54 % is the lowest).

Fig. 5a presents the variations of consolidation grade for reed straw in function of moisture content of the material. Consolidation grade for defined moisture content was calculated for constant compressive force with value 40 kN (Fig. 5a).

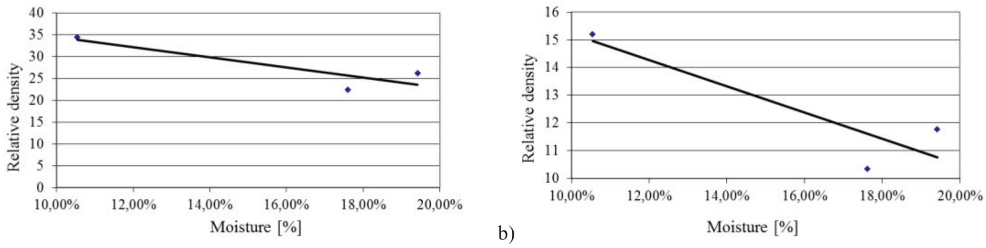


Fig. 5. Consolidation grade for reed straw in function of moisture content: a) loading state, b) unloading state.

As we can see in Figures 5a and 5b, the increase of moisture content is connected with the decrease of consolidation grade. It can be explained by higher content of water in porous structure of straw and this is the reason of smaller load capacity. Figure 5b shows the variation of consolidation grade of reed straw in function of moisture content after unloading. The higher the moisture content, the lower the consolidation graded. Friction coefficient for reed straw sample was obtained by loading the sample with normal force equal to 30 kN (stress ca. 50 MPa). The measurement of friction force was done for temperatures 50 °C, 100 °C, 150 °C and 200 °C. Fig. 6a presents view of consolidated sample after the investigations.

On the basis of characteristics (Fig. 6b) we can see a proportional increase of friction coefficient for the increase of temperature.

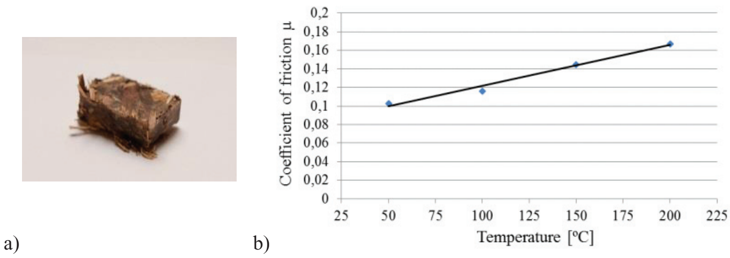


Fig. 6. Friction coefficient investigation: a) consolidated reed straw, b) value of friction coefficient in function of temperature.

3.2. The investigations of rice straw

The investigations of thermomechanical properties of rice straw have been done with the application of the above mentioned test stands and methodology. Fig. 7 presents a view of fragmented and consolidated rice straw. Fig. 7c shows the characteristic of variation of compressive force for preliminary consolidated rice straw in function of guide displacement of testing machine for different moisture content of samples 8.37 %, 18.71 % and 25.47 %.

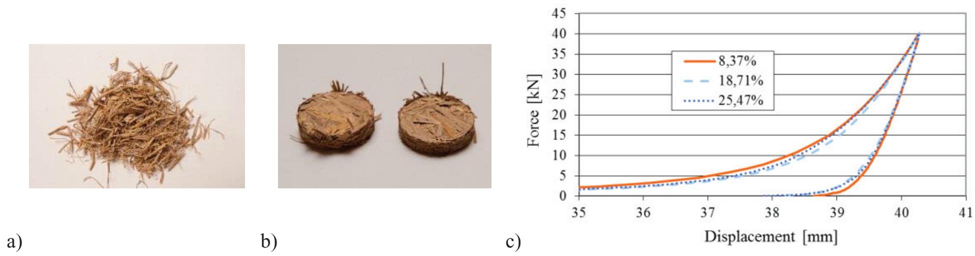
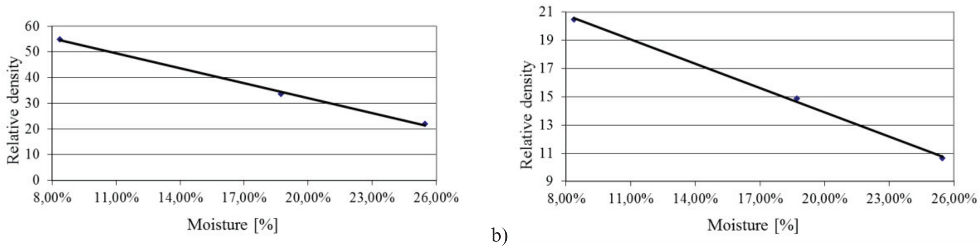


Fig. 7. View of fragmented rice straw: a) before consolidation, b) after consolidation, c) characteristic of variation of compressive force in function of guide displacement for different moisture content.

On the basis of this characteristics we can state the following:

- the increase of force for sample with moisture content 8.37 % for the same displacement values is the highest in comparison to samples with moisture contents 18.71 % and 25.47 %,
- after unloading, we can see plastic deformations with similar values (the decrease of the force during unloading for moisture content 8.37 % is the lowest).

Fig. 8a presents the variations of consolidation grade for rice straw in function of moisture content of the material. Consolidation grade for defined moisture content was calculated for constant compressive force with value 40 kN (Fig. 8a).

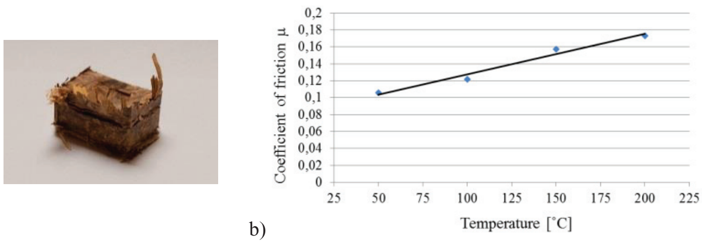


a) b)

Fig. 8. Consolidation grade for rice straw in function of moisture content: a) loading state, b) unloading state.

As we can see in Figures 8a and 8b, the increase of moisture content is connected with the decrease of consolidation grade. It can be explained by higher content of water in porous structure of straw and this is the reason of smaller load capacity. Fig. 8b shows the variation of consolidation grade of rice straw in function of moisture content after unloading. The higher the moisture content, the lower the consolidation graded. Friction coefficient for rice straw sample was obtained by loading the sample with normal force equal to 30 kN (stress ca. 50 MPa). The measurement of friction force was done for temperatures 50 °C, 100 °C, 150 °C and 200 °C. Fig. 9a presents view of consolidated sample after the investigations.

On the basis of characteristics (Fig. 9b) we can see a proportional increase of friction coefficient for the increase of temperature.



a) b)

Fig. 9. Friction coefficient investigation: a) consolidated rice straw, b) value of friction coefficient in function of temperature.

4. Conclusions

On the basis of obtained results we can conclude the following statements:

- the higher the moisture content, the lower consolidation grade for every type of straw,
- the higher the moisture content, the lower consolidation grade after unloading of every type of straw,
- rice straw is characterised by the highest increment speed of moisture content,
- rice straw is characterised by lower moisture content at the initial state,
- during seasoning rice straw absorbs the water better than reed straw,

– rice straw with lower initial moisture content than initial moister content for reed straw has higher consolidation grade for the same loading conditions,
– character of variation of friction force coefficient in function of temperature increase is similar for both types of straws,
– friction coefficient of rice straw is smaller than friction coefficient of reed straw for temperatures 150 °C and 200 °C,
– friction coefficients of rice straw and reed straw are similar for temperatures 50 °C and 100 °C,
– next investigations should take into account the form deviations of punch and sleeve which have an effect on the size of contact surface between these elements – one should examine the cooperation as a connection between the shaft and hole [13–15]. Surface contact can have an influence on friction force between the punch and sleeve and this in consequence can have a negative effect on the accuracy of obtained results.

References

[1] A. Tolón-Becerra, X. Lastra-Bravo, F. Bienvenido-Bárcena, Proposal for territorial distribution of the EU 2020 political renewable energy goal, Renewable Energy 36(8) (2011) 2067–2077.
[2] A. Neville, Biomass cofiring: a promising new generation option, Power 155(4) (2011) 52–56.
[3] A.A. Rentizelas, A.J. Tolis, I.P. Tatsiopoulos, Logistics issues of biomass: the storage problem and the multi-biomass supply chain, Renewable and Sustainable Energy Rev. 13(4) (2009) 887–894.
[4] J.S. Tumuluru, C.T. Wright, J.R. Hess, K.L. Kenney, A review of biomass densification systems to develop uniform feedstock commodities for bioenergy application, Biofuels Bioprod Biorefin 5(6) (2011) 683–707.
[5] S. Mani, L.G. Tabil, S. Sokhansanj, Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets from grasses, Biomass and Bioenergy 30 (2006) 648–654.
[6] S. Mani, L.G. Tabil, S. Sokhansanj, Evaluation of compaction equations applied to four biomass species, Canadian Biosystem Engineering 46 (2004) 3,55–3,61.
[7] H. Li, X. Liu, R. Legros, X.T. Bi, C. Jim Lim, S. Sokhansanj, Pelletization of torrefied sawdust and properties of torrefied pellets, Applied Energy 93 (2012) 680–685.
[8] W. Stelte, C. Clemons, J.K. Holm, R.A. Sanadi, L. Shang, J. Ahrenfeldt, et al., Pelletizing properties of torrefied spruce, Biomass and Bioenergy 35(11) (2011) 4690–4698.
[9] M.J.C. Van der Stelt, H. Gerhauser, J.H.A. Kiel, K.J. Ptasinski, Biomass upraging by torrefaction for the production of biofuels: a review, Biomass and Bioenergy 35(9) (2011) 3748–3762.
[10] I. Malujda, K. Talaśka, Experimental testing of the strength of wood subjected to higher temperature and moisture conditions – tension, Proceedings of the World Congress on Engineering 2011 Vol. III WCE 2011, July 6 – 8, 2011, London, U.K.
[11] I. Malujda, K. Talaśka, Testing of the shear strength of compressed material at increased temperature, Proceedings of the World Congress on Engineering 2011 Vol. III WCE 2011, July 6 – 8, 2011, London, U.K.
[12] I. Malujda, Modelowanie pól naprężeń i temperatury w procesach uplastyczniania i zagęszczania drewna zorientowane na potrzeby projektowania maszyn, Wydawnictwo Politechniki Poznańskiej, Poznań, 2012.
[13] M. Dudziak, B. Błaszczyk, A. Kołodziej, K. Talaśka, The evaluation of form deviations during teeth manufacturing of gear rings, Procedia Engineering 96 (2014) 44–49.
[14] M. Dudziak, G. Domek, A. Kołodziej, K. Talaśka, Contact problems between the hub and the shaft with a three-angular shape of cross-section for different angular positions, Procedia Engineering 96 (2014) 50–58.
[15] M. Dudziak, A. Kabała, A. Kołodziej, The Topic of Contact Zone Problems in the Shaft and Hole Joint, Taking into Account Component Form Errors, Journal of Mechanics Engineering and Automation 3 (2013) 586–590.