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MUTUAL INTERACTION OF SELECTED PARAMETERS OF OAK SAWDUST DENSIFICATION PROCESS BY THE DENSITY RESPONSE SURFACE

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Abstract: The aim of this contribution is to present research results - the impact and mutual interaction of selected parameters of the oak sawdust densification process by the response surface. The briquette density represents a measurable indicator of briquette quality. In most cases (analysis) is final density considered with numerical values which are under review by the individual criteria. The response surface creates a separate section and a possibility of its appraisal. A three-dimensional graph creates the response surface of the final briquettes density, whose points are the individual density values in a particular setting of selected parameters of densification process. By an intersection of the individual response surfaces with the selected parameters it´s possible to optimized these parameters with the aim to improve the quality of briquette. Showing the possibility to apply this optimizing method of the technological parameters and to analyse their mutual interaction represents our intention through this article.
Keywords: biomass, briquetting, densification, mutual interaction, briquette density, data evaluation, response surface

INTRODUCTION

Our workplace has been dealing with the research of various parameters impact on the final briquettes density for some time. We have been trying to quantify and define mutual relations of individual influencing parameters to gain complex overview of the parameters behavior present within the densification process. All experiments were conducted in laboratory conditions and an experimental compacting stand was used during the experiments. There are used several methods and procedures for the collected data evaluation and processing considering the type of outcome we would like to reach.

The aim of this article is to present a type of analysis used for the interaction and the selected parameters influence on the final briquette density within the process of densification when the used compacted material is oak.

A mathematical model was used for the purpose of this analysis to calculate the density value. A set of individual density values gained during combining individual settings and iteration steps creates the response surface.

Response surface forms an individual evaluation category of the output value behavior in the individual points. In our case the response surface is formed by the set of density values in the individual settings points represented by a three-dimensional graph. Using this graph and its shape enables monitoring the curving of the surface and analyzing its minimum and maximum values. At the same time the surface analyses the output value increase direction – in our case the briquette density value or the behavior within the range of input values.

EXAMINED PARAMETERS OF DENSIFICATION PROCESS

While selecting the parameters, the following parameters present within the densification process were considered – pressing temperature, compacting pressure, fraction size and the compacted material moisture.

Pressing temperature – during the compression process it is necessary to focus on the effectiveness of the used temperature. One reason is the plastification and volatilizing of lignin, which is the joining material of the individual compacted particles. Consequently the bond between the particles is decreased, which decreases the compactness of the briquette.

Compacting pressure – the amount of the compacting pressure is important not only for the final quality of the briquette itself but also because the type of used compacting equipment depends on the amount of compacting pressure. In the end, this also influences the economic side of the compacting and therefore also the production price of the briquette.

Compacted material moisture – high amount of moisture does not have any significance during compacting as the briquette does not become sufficiently integrated due to the evaporating steam. Similarly, when using compacting material with too low amount of moisture, the briquette can become sintered and too fragile which influences its further use.

Compacted material fraction size – also when considering the compacting material fraction size, higher fraction is practically useless as high fraction size causes low compactness of the briquette due to weak bonds. Due to lower fraction, stronger inter-particle bonds are expected.

DENSITY RESPONSE SURFACE AT VARIOUS VALUES OF MATERIAL MOISTURE

Response surface is a great and useful tool for presenting the process in maximum amplitudes of individual parameters. As presented in functionalities Figure 1 and Figure 2, it is limiting to present the functionality with fixation of several parameters. Using the response surface we can get clear presentation of the process within the given extend by the means of surfaces. These represent set-up levels.

Analysis considering fixation of compacting pressure and fraction size

In this section the analysis of the final briquette density while using the fixation of compacting pressure and compacted material fraction size, is discussed.

In Figure 1 one can see the two-dimensional display of the relation, the influence of the pressing temperature on the briquette density. As the presented graph shows, the influence was monitored by various values of the compacted material moisture, while the fraction size was a fixed parameter –1mm and similarly the compacting pressure – 95 MPa. These parameters were selected upon experience.

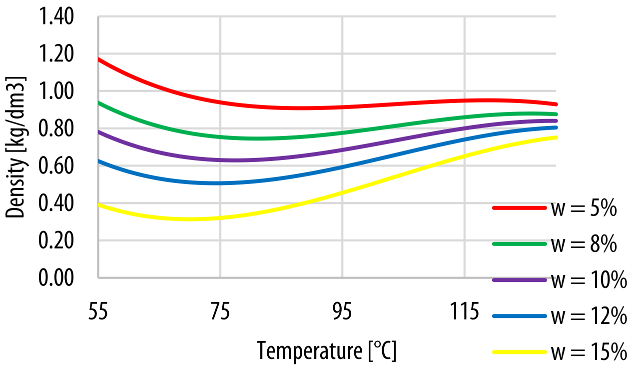


Figure 1*: The influence of the pressing temperature on the briquette density*

As visible in the graph, at increased moisture of the input compacting material, part of the temperature is used in the first phase for drying out the material to the level of moisture necessary for quality binding of individual particles and then the briquette is compacted to the required density. At higher levels of moisture, the binding of the compacted material structures is not firm that is why the briquette does not reach sufficient density. On the contrary, at the lowest level of moisture, the material becomes hard dried and the quality of particles binding is lowered which causes slight decrease of the briquette density while the pressing temperature is higher. With higher pressing temperature, positive impacts on the briquettes density can be observed. After comparing individual levels of compacting material moisture it is evident that moisture is an important parameter within compacting process.

Analysis considering fixation of pressing temperature and fraction size

The same method was used for analysis of final density using fixation of other two parameters – pressing temperature and compacting material fraction size. Also in this case, the final briquette density was closely analyzed. Figure 2 presents two-dimensional display of the relation and the impact of compacting pressure on the briquette density. The graph shows that the impact was monitored at various values of compacted material moisture while the fraction size was the fixed parameter – 1mm and similarly the pressing temperature – 85 °C. Compared to the impact of pressing temperature described in the previous section, the increase of final briquette density while increasing the compacting pressure is not as significant and its development is rather linear.

The test also confirmed that when using pressing temperature of 85°C at higher levels of material moisture, firstly the temperature is spent on excessive moisture, the contained water in the compacted material evaporation. Thus it stresses the importance of pressing temperature.

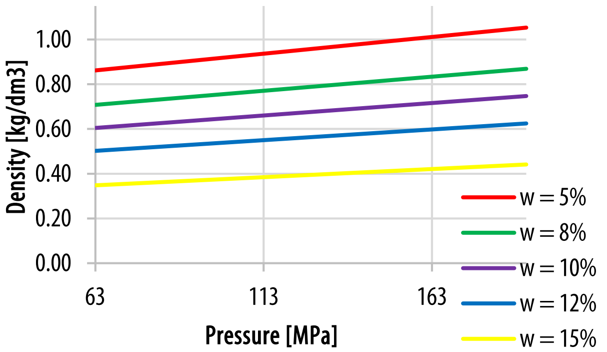
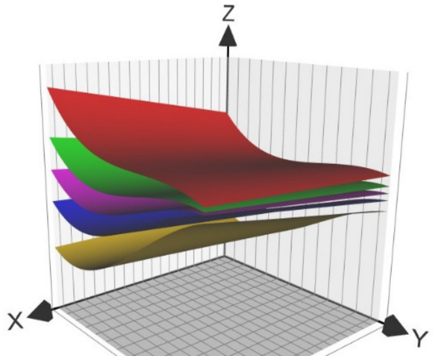
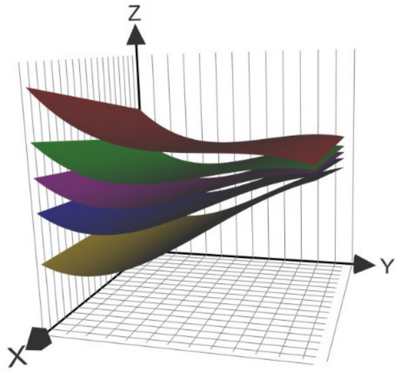


Figure 2*: Impact of compacting pressure on the briquette density*

The pattern of the response surface of the final briquettes density can be seen in Figure 3. The following graphs show the development of briquettes density (Axis z) during the increase of compacting pressure (Axis x) and pressing temperature (Axis y) at different levels of compacted material moisture. The presented response surfaces are shown at constant value of fraction size - 1mm, and various values of the compacted material moisture (5%, 8%, 10%, 12% and 15%). The initial value (point zero on the axis) is in this case compacting pressure of 63MPa and pressing temperature of 55°C. As it can be seen, at lower levels of moisture and with increasing compacting pressure the final briquette density increases. At higher levels of moisture, when the pressing temperature is spent on evaporating of the excessive moisture, with the increased pressure the final value of briquette density increases too. It can be noticed that increasing the pressing temperature has more positive impact on the briquette density increase than increasing the compacting pressure. This response surface graph confirms the hypothesis about using the suitable temperature during compacting and at the same time about the suitable initial level of compacted material moisture. Such graphic presentations offer complex overview of the selected parameters mutual interaction within the compacting process and the influence on the briquettes final density. Based on the calculated and proposed mathematical model it is possible to get specific values for each monitored parameter at any point on the presented surfaces.

This provides a very simple tool for briquettes density prediction for any specific setting.





Axis designation: axis X⟶compacting pressure [MPa]; axis Y⟶pressing temperature [°C]; axis Z⟶density [kg/dm³]
Legend of colours⟶ material moisture level: red = 5%; green = 8%; purple = 10%; blue = 12%; yellow = 15%
***Figure 3:** The pattern of the response surface – constant value of fraction size*

DENSITY RESPONSE SURFACE AT VARIOUS VALUES OF MATERIAL FRACTION SIZE

The next part is dedicated to density analysis using the response surface at constant value of material moisture and different values of fraction size. Presented response surfaces (Figure 6) are calculated with constant value of moisture - 10% and different values of compacted material fraction size (0.5 mm, 1 mm, 2mm, 3mm, 4 mm).

Analysis considering fixation of compacting pressure and material moisture

This section deals with analysis of briquettes final density using fixation of the compacting pressure and compacted material moisture. Fig. 4 shows two-dimensional presentation of the pressing temperature influence on the briquette density. As the graph shows the influence was monitored at various values of compacted material fraction size while the fixed parameters were the moisture of the compacted material – 10%, and compacting pressure – 95 MPa. As it can be seen in the graph, increase of temperature during compacting causes briquette density value increase at all levels of fraction size. When compared to the following graph it is obvious that the influence of higher pressing temperature causes more significant density increase at constant pressure than at increased compacting pressure and constant pressing temperature.

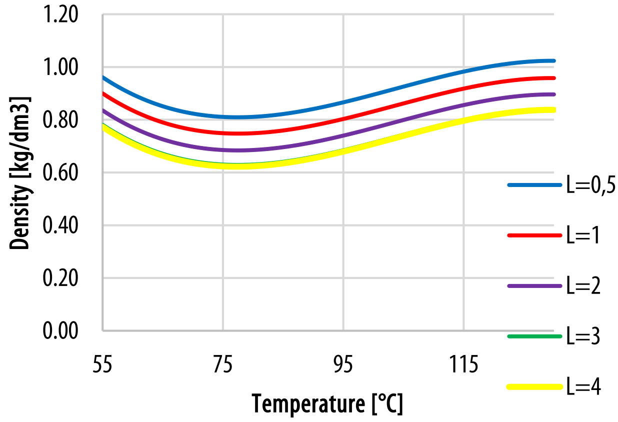


***Figure 4**: The influence of the pressing temperature on the briquette density*

Analysis considering fixation of pressing temperature and material moisture

The following section discusses analysis of the final briquette density using fixation of pressing temperature and the compacted material moisture. Figure 5 presents two-dimensional display of the relations, the influence of the compacting pressure on the briquette density. As the graph shows, the influence was monitored at different values of compacted material fraction size while the pressing temperature was the fixed parameter - 85°C as well as the compacted material moisture level – 10%. As the following graph shows, higher fraction size requires higher compacting pressure to get higher value of final density. In total, the level of final density value is lower due to the choice of fixed moisture value -10% and also the temperature, while the density increase would be reached by increasing pressing temperature combined with moisture. Comparing to the previous graph, it is obvious that the higher pressure influence does not cause so significant increase of density as the higher pressing temperature.

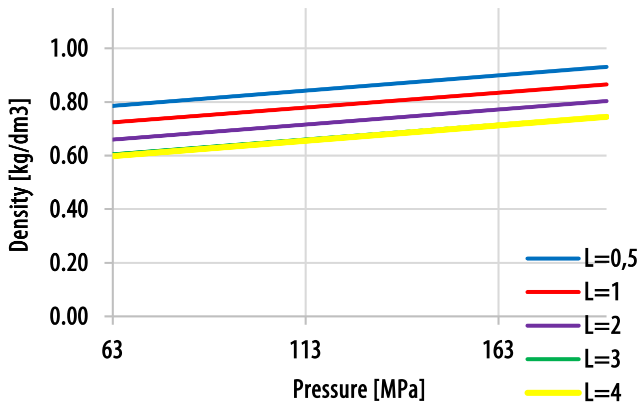
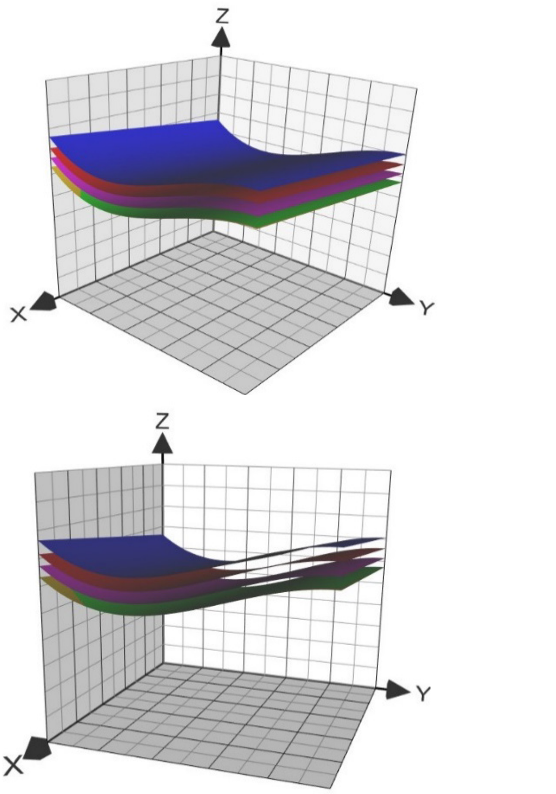


***Figure 5**: Impact of compacting pressure on the briquette density*

Similarly as in the first section, also here we took a moment to look closely at the pattern of the response surface of the final briquette density – Figure 6. The following graphs present development of the briquettes density (Axis z) at the increase of compacting pressure (Axis x) and pressing temperature (Axis y) at different levels of the compacted material fraction size.



Axis designation: axis X⟶compacting pressure [MPa]; axis Y⟶pressing temperature [°C]; axis Z⟶density [kg/dm^3]
Legend of colours ⟶ material fraction size level: blue = 0,5mm; red = 1mm; purple = 2mm; green = 3mm, yellow=4mm
Figure 6: *The pattern of the response surface – constant value of moisture*

Presented response surfaces are displayed at constant moisture value - 10%, and different values of compacted material fraction size (0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm). The initial value (point zero on the axis) is in this case the compacting pressure of 63 MPa and pressing temperature of 55°C, the same as in the previous case. From both perspectives it is clear that the final briquette density increases with increasing compacting pressure. However, the influence of the pressing temperature, its increase, increases the final briquette density even more, at all fraction sizes. This graph of response surface confirms again that using the pressing temperature in combination with optimal set-up of compacted material moisture and fraction size represent significant parameters which have an impact on the final density of the briquette.

CONCLUSION

The article presented results of a research performed at our workplace, aim of which was to define the influence of selected parameters mutual interaction within the process of densification to the final quality of oak briquettes. We also tried to point out how significant role the response surface can have within the analysis of output quantity – in our case the final briquette density. Thanks to the three-dimensional spatial display of the output, it is possible to better define the characteristics of analyzed quantity and predict its further development and direction. In the future we are planning to work with the response surface by the means of intersection of compacted materials individual surfaces and optimization of various compacting materials mixtures. We believe that the presented method will be beneficial and also utilizable for briquettes quality increase.

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REFERENCES

[1.] Križan, P.; Svátek, M.; Matúš, M.: Analysis of the significance of technological parameters at briquetting of selected types of hardwood and softwood. In: Aplimat 2011. Proceedings. - Bratislava : FX s.r.o., 2011. - ISBN 978-80-89313-51-8. - pp. 395-404

[2.] Svátek, M.; Križan, P.: Experimental plan and evaluation methodology for research of densification process of different types of material mixtures. In: Annals of Faculty Engineering Hunedoara – International Journal of engineering.- ISSN 1584-2665.- Vol. 12, No. 2 (2014)

[3.] Križan, P.; Šooš, Ľ.; Matúš, M.; Svátek, M.; Vukelič, Dj.: Evaluation of measured data from research of parameters impact on final briquettes density. In: Aplimat - Journal of Applied Mathematics. - ISSN 1337-6365. - Vol. 3, No. 3 (2010), pp. 68-76

[4.] Križan, P.; Matúš, M.; Beniak, J.; Kováčová, M.: Stabilization time as an important parameter after densification of solid biofuels. In: Acta Polytechnica. - ISSN 1210-2709. - Vol. 54, No. 1 (2014), pp. 35-41

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