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STABILIZATION TIME AS AN IMPORTANT PARAMETER AFTER DENSIFICATION OF SOLID BIOFUELS

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Abstract. The aim of this paper is to present some preliminary results from experimental research on the densification process of solid high-grade biofuels. The findings presented in this paper contribute to an investigation of the stabilization time, which is an important parameter in the densification process. During the densification process, various parameters are present in the pressing chamber of the machine, and each of these parameters influences the stabilization time of the briquette. This time (procedure) is very important, because the briquette can change in dimensions and in weight throughout the stabilization process, and this can reflect negatively on the resulting briquette. This paper presents some important effects which impact the stabilization time, and obtains relationships between these effects and their influence on densification.

Keywords: briquette, densification, briquette density, stabilization time, compacting pressure, pressing temperature.

1. Introduction

The most important quality indicator for high-grade biofuels is the density of the briquettes. Briquette density is important for handling and in terms of energy. Briquettes must be compact, or else they may crack and small pieces of material can separate. Pressing needs to be carried out at high pressure and at high temperature in order to achieve a compact shape with relatively high density. However different pressing parameters and different types of pressed material result in briquettes of varying density. Briquette density during densification is not constant. It changes on the basis of dilatation, meaning that the diameter and the length of the briquette varies under the influence of internal pressure. Dilatation is an unfavourable effect, but it must be taken into account after biomass densification. The goal of our study was to measure and verify the impact of important technological parameters on briquette dilatation after densification. This information can help in predicting the effect of briquette dilatation, and can therefore help decrease the impact of dilatation on the final briquette density.

2. Briquette stabilization time vs. briquette dilatation

Briquette dilatation is an effect during which the dimensions (diameter, length) and the weight of briquettes vary. These changes come from the internal parameters of the briquette material, and also from external parameters of the pressing technology. Dilatation directly influences the briquette density, because the density is calculated from the dimensions of the briquettes. The dilatation effect is generated when the compacting pressure is released, and is caused by mutual interactions with the pressing temperature, material moisture and input fraction size. In the experiment we can distinguish between two basic types of briquette dilatation:

Dilatation with decreasing briquette density — when the diameter and the length of the briquette increase and the weight of the briquette decreases (associated effects are crack formation, material fragmentation and briquette decomposition);

Dilatation with increasing briquette density — when the diameter and length of the briquette decrease and the weight of the briquette increases (an associated effect is briquette shrinkage and increased hardness);

Both of these types of dilatation effects are significantly influenced by the type of pressed material, the material moisture, the input fraction size, the applied compacting pressure, the applied pressing temperature during pressing, and the duration of the briquette holding time.

The *briquette stabilization time* is the time interval during which dilatation occurs, and it is also the time interval during which the briquette stabilizes. Briquette stabilization takes approximately 24 hours, according to the type of the pressed material and densification technology used, though it can also take longer. Standard DIN 52182 [2] (additional Standard to Standard DIN 51731 [11]) describes the process for detecting briquette density. After pressing, the briquettes have to be placed into stable climate conditions. From time to time the briquette diameter, length and weight are measured. During this stabilization time, the briquette dimensions must be measured often and the weight and density of the briquettes

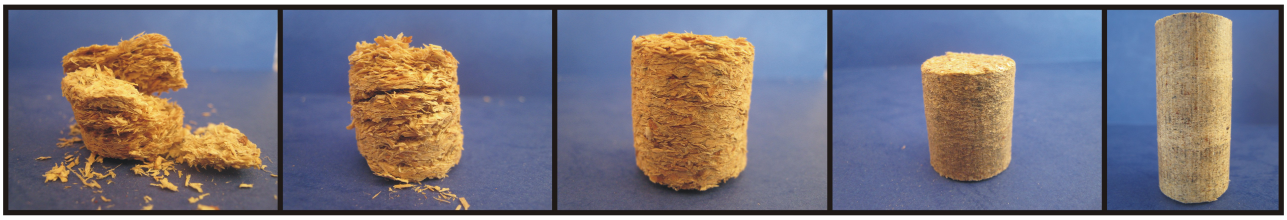

FIGURE 1. Influence of compacting pressure on pine sawdust briquettes [4].

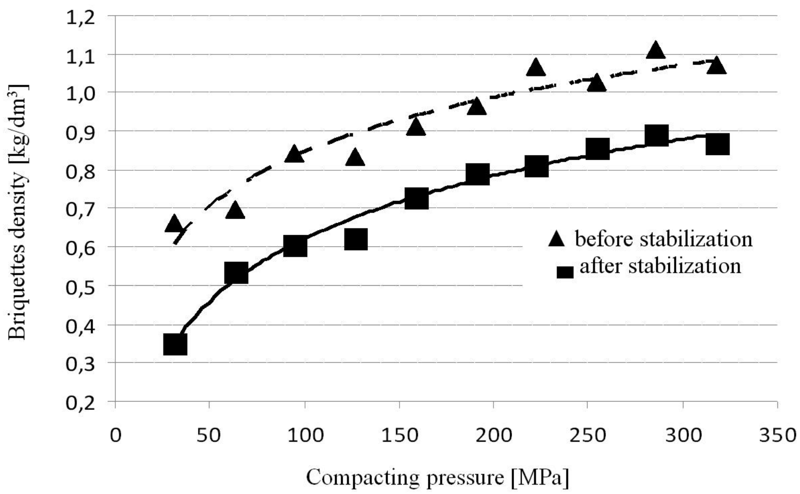

FIGURE 2. Dependence of briquettes density on compacting pressure (pine sawdust) [4, 5].

must be evaluated. If over a period of 24 hours the briquette weight has changed by a maximum of 0.1 %, the briquette is considered stable [2]. The achieved weight is defined as briquette weight m_n (kg; g). The briquette volume V_n (m^3; cm^3) and its density ρ_n (kg m^{-3}; g cm^{-3}) can be calculated from the measured geometrical dimensions [2].

It is very important to consider the stabilization time or briquette dilatation mainly due to the changes in briquette density. In laboratory experiments, this effect can significantly distort the results of the experiment. As was mentioned above, briquette density is important for the cohesion of the material particle. During densification, lignin is releasing from the biomass which acts as a natural glue. A thin layer also forms on the briquette surface, and it prevents moisture from entering the briquette from its surroundings. If the briquette is not formed in optimally adjusted conditions, dilatation can also significantly influence the absorption of moisture from the surroundings [1]. In practical applications, the stabilization time can be decreased by cooling. Cooling is also an important consideration for packaging [3]. Insufficient cooling before packaging can condense the escaping moisture, and this can cause biodegradation of the briquettes.

3. EXPERIMENT

It is very important and useful to know the dilatation properties and to predict the dilatation behaviour. An experiment was therefore prepared specifically for an investigation of briquette dilatation: dilatation size, parameters which influence dilatation, etc. The experiment was performed at the Faculty of Mechanical Engineering, STU in Bratislava, Slovakia and a specially designed experimental pressing stand was used. This paper presents the results of this experiment to investigate the impact of compacting pressure and pressing temperature on briquette dilatation.

The pressing stand can be adjusted for different compacting pressures and pressing temperatures. In the experiment, pine and sawdust material were used with constant material moisture (10 %) and fraction size (2 mm). The experiment was performed at compacting pressures from 31 MPa to 318 MPa [4]. The impact of pressing temperature was investigated at 25 °C, 85 °C and 115 °C. Seven briquettes were formed for each imbedded value. Each briquette was measured (diameter, length and weight) immediately after pressing and after 24 hours of stabilization. In each case, the briquette density was also calculated. All results and values presented in this paper were obtained with the same procedure. All findings are compared on the basis of the final briquette density, as this parameter is the decisive quality indicator. According to Standard DIN Plus, high-grade briquettes must have a density of more than 1.12 kg dm^{-3}; g cm^{-3} [10].

Number of setting	Compacting pressure [MPa]	Density ρ [kg dm^{-3}]		Density difference [%]
		Before stabilization	After stabilization	
1	31	0.664	0.350	47 %
2	63	0.699	0.535	23 %
3	95	0.841	0.605	28 %
4	127	0.836	0.625	25 %
5	159	0.913	0.729	20 %
6	191	0.967	0.792	18 %
7	222	1.066	0.813	24 %
8	254	1.026	0.856	17 %
9	286	1.113	0.893	20 %
10	318	1.074	0.869	19 %

Table 1. Briquette density values at various compacting pressures — pine sawdust [4].

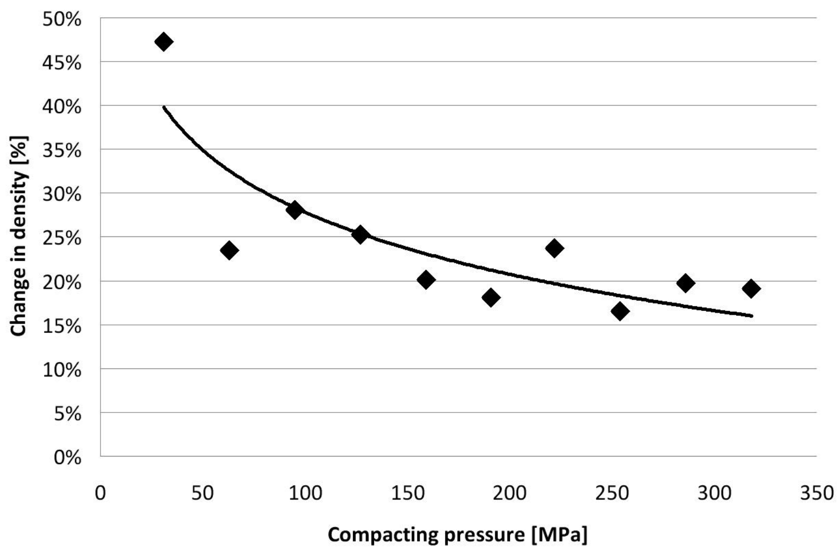

Figure 3. Change in density at various compacting pressures — pine sawdust [5, 6].

4. Impact of compacting pressure on briquette dilatation

Compacting pressure is a parameter which significantly influences briquette density. It also influences briquette strength. Briquettes with optimal strength prevent moisture intrusion and crack propagation (see Fig. 1). Fig. 2 shows that briquette density increases with increasing compacting pressure. Fig. 2 also shows two curves, which represent the dependence before stabilization and the dependence after stabilization. In this case, dilatation had a negative influence on briquette density.

Table 1 lists density values before and after stabilization at various levels of compacting pressures. Each of the listed density values is an average value calculated from 7 briquette densities. The difference in density before and after stabilization is shown, and this demonstrated the influence of dilatation. The results are shown graphically in Fig. 3.

Fig. 4 shows the dilatations of each briquette under various pressure conditions. The impact of dilatation varies according to the pressure value. The biggest differences between the density before and after stabilization were observed at lower compacting pressures. As the compacting pressures increase, the differences in density decrease. The impact of dilatation was most significant at low compacting pressure (31 MPa). In this case, the difference between the density before and after stabilization was 47 %. At the highest compacting pressure value (318 MPa), the density difference before and after stabilization was 19 %. Fig. 3 shows the dependence of differing density before and after stabilization on the compacting pressure. This dependence proves the impact of compacting pressure on briquette dilatation, and means that briquette dilatation decreases with increasing compacting pressure.

FIGURE 4. Dilatation process and briquette density values at various compacting pressures (description of dependences: x-axis – briquette; y-axis – briquette density [kg dm^{-3}]; blue curve – state before stabilization; red curve – state after stabilization) [4, 5].

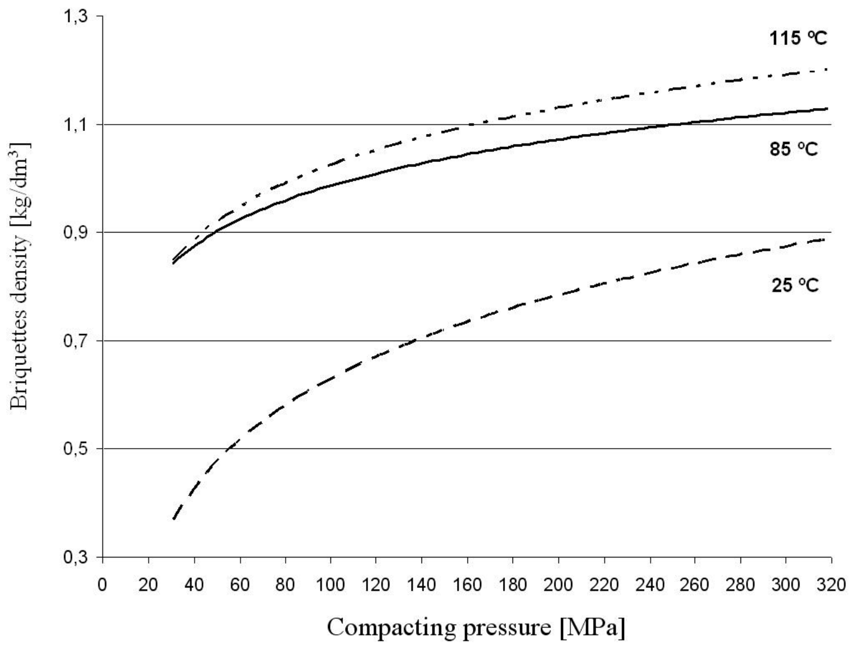

FIGURE 5. Dependence of briquette density on compacting pressure at various pressing temperatures [5, 9].

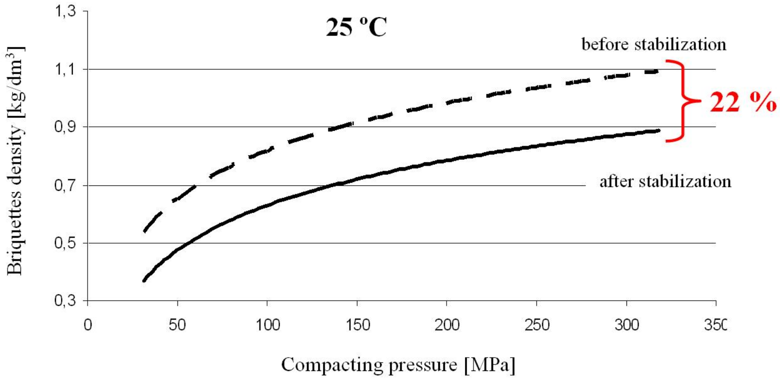

FIGURE 6. Dependence of briquette density on compacting pressure temperature (25 °C) [5, 9].

5. Impact of pressing temperature on briquette dilatation

The next phase of the experiment was to detect the impact of pressing temperature. The results in the previous section were obtained at a pressing temperature of 25 °C. In this phase, the pressing temperature was increased to 85 °Cand then to 115 °C. Fig. 5 shows the dependence of briquette density on compacting pressure at three different pressing temperatures. It is clear that temperature has an impact on the final quality of the briquette. Briquette density increases with the pressing temperature. The pressing temperature has a positive impact on the lignin component of the pressed material [8]. The pressing temperature influences the plastification of the lignin [7, 8]. With increasing pressing temperature during densification, the lignin becomes more and more liquid and more plastic. If the lignin is in liquid form during densification, it has a positive influence on the binding between material particles (glue effect) [7, 8]. It also causes higher briquette density and strength after the briquette is pressed and cooled.

The dependences shown in Fig. 5 are drawn only from the density values after stabilization. In Figures 6–8, the transparent comparison of curves represents the state before stabilization and after stabilization for each temperature level.

Fig. 6 shows the situation at 25 °C. It can be seen that the density after stabilization decreases. This was caused by the absence of a suitable pressing temperature, and optimal binding between the cell structures of the pressed material and the lignin component therefore did not take place [6].

The average differences between density values before stabilization and after stabilization were approximately 22 %. The pressing temperature also has a significant influence on the binding mechanisms created between the solid particles of the pressed

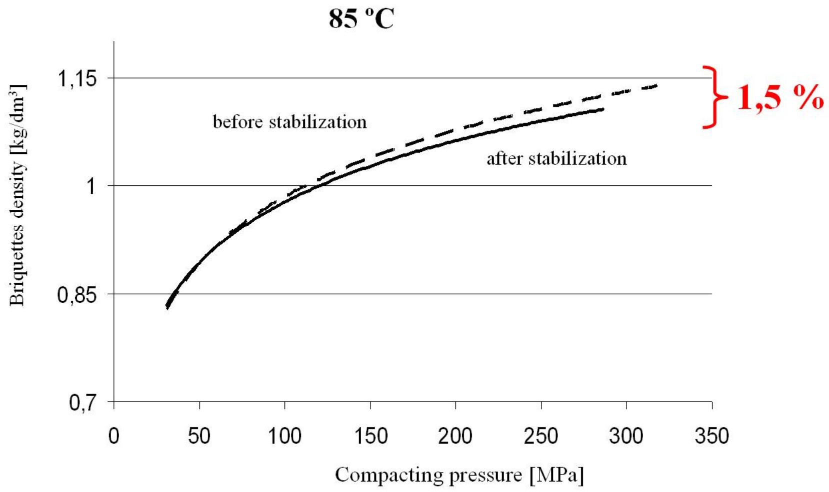

FIGURE 7. Dependence of briquette density on compacting pressure at 85 °C[5, 9].

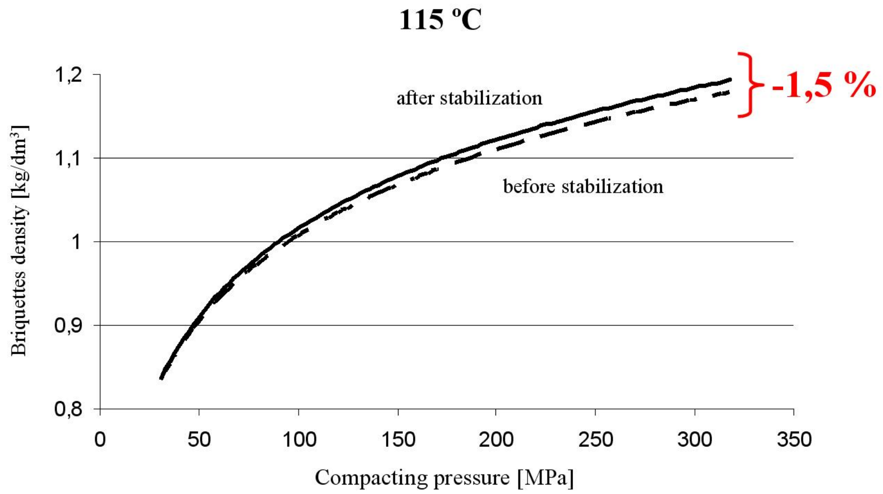

FIGURE 8. Dependence of briquette density on compacting pressure at 115 °C[5, 9].

material. In this case, Van der Waals forces were created between the particles [6]. A "liquid bridge" is formed based on the reduced distances between solid particles at higher pressure [6]. With higher compacting pressure, material particles are closer together and the bindings between the particles are stronger, forming so-called shape bindings [6]. Wood is an elastic material. Optimal technological conditions must be achieved in order to overcome the modulus of elasticity. A stronger binding between material particles must be achieved than that of the elastically pressed material alone. In this case, for the given conditions, such bindings were not achieved. After the compacting pressure was released the briquettes changed their dimensions. There was therefore lower density after stabilization than before stabilization. It is important to note that the briquette density given in the Standards was not achieved either after stabilization or before stabilization in this case.

Fig. 7 shows the dependence of briquette density on compacting pressure at a temperature of 85 °C. It can be observed that the average difference between the curves representing the state before and after stabilization decreased by 1.5 %. This is due to the positive influence of pressing temperature on the process. There were still briquettes with higher density before stabilization, but the briquette dilatation was reduced. We obtained briquettes with density according to the Standards. In this case, stronger bindings were formed between the material particles and the lignin components. At 85 °C, briquettes with higher density were achieved with lower dilatation than at a pressing temperature of 25 °C.

The dependence of briquette density on compacting pressure at 115 °C(Fig. 8) provides proof for our research findings. Pressing at higher temperatures results in the ability to reduce the compacting pressure for producing briquettes of the same density as in the previous cases. There was a decrease in the average differences between the curves representing the state before and after stabilization. It is interesting to note that the result after stabilization showed a density that was higher than before stabilization. This is quite different from the previous case. The briquettes wrinkled during dilatation, so the obtained density was higher. The briquette density given by Standards was obtained at lower pressures than in previous cases.

6. Conclusions

The goal of this paper was to present the results of our research on the parameters impacting briquette dilatation. The results have proved that compacting pressure and pressing temperature have an effect on briquette dilatation. With increasing compacting pressure, briquette dilatation can be decreased. With increasing pressing temperature, briquette dilatation can be decreased. However there is a pressing temperature threshold at 130 °C, since the volatile components of the wood and lignin can combust beyond this temperature, negatively affecting the densification of the briquette. Further research is needed to investigate the impact on briquette dilatation of material moisture, input fraction size, and the type of pressed material. These parameters have a significant impact on the densification of the final briquette quality. Densification and the quality of the final briquette, and it is therefore expected that they also influence briquette dilatation.

Acknowledgements

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