Research of factors influencing the quality of wood briquets

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Výskum vplyvu faktorov na kvalitu výliskov z dreva

In the modern energy carriers producion is very important to know the impacts of several factors which influence the final quality of briquets. In our department we realized opening measurements of some factors' impact on the briquet quality. I monitored the impact of compacting pressure, fraction largeness and the material humidity. In this contribution, I would like to describe this opening experimental research.

Key words*: compacting, briquet quality, compacting pressure, material humidity, fraction largeness*

Introduction

As we know there are still problems with the briquet quality of various types of materials. For me, as a constructer of compacting machines is very hard to design the machines if I totally do not know the process for which I design the machine. The main goal is to design such a machine which will produce briquets with a quality according to norms. There are norms DIN and Ő-Norm which tell about the briquet quality requirements. In Slovakia and Czech Republic doesn't exist a norm which would define the briquet quality requirements and that's why the producers conduct their production according to these norms. These norms define the briquets terminology, evaluate the energy carrier dimensions and define also the chemical-thermic and mechanical indicators of briquet quality. To the group of chemical-thermic indicators belong the briquet humidity, ash content, heat value, nitrogen content, sulphur content, chlorine content and the trace elements content. Among mechanical indicators are the briquet density, briquet strength in pressure and the abrasion.

However to be able to design good compacting machine constructions I also have to know the compacting process itself. It means I have to know to impact of various factors on the briquet quality. Aforesaid norms will evaluate the briquet quality in dependence on the monitoring factors.

Briquet quality requests

The briquets density is very important from the view of manipulation, burning speed, briquet stability, etc. Briquets must be consistent. Otherwise, cracks, scratches and fine elements will occur what isn't acceptable. The briquets with a higher density have a longer burning time. The norm Ő-Norm M 7135 defines the briquet density value for the group HP (wood briquets) and for the group RP (crust briquets) more than 1,12 kg.dm^{-3} (g.cm^{-3}), for other briquets this value must be more than 1 kg.dm^{-3} (g.cm^{-3}). Norm DIN 51731 defines interval of briquets density values 1 – 1,4 kg.dm^{-3} (g.cm^{-3}).

The norm DIN 52182 (additional to the norm DIN 51731) describes also the method of briquets' density testing. I have to weight a piece of briquet and to measure his diameter and length. After that, I evaluate the briquet density before the stabilization from these values according to the following ratio (1).

$$\rho_N = \frac{m_N}{V_N} \qquad \text{[kg/dm3]} \qquad (1)$$

in which V_N is the briquet volume [dm3], m_N – weight [kg].

Next comes the stabilization by which the dilatation occurs. The dilatation is a standard but inconvenient effect. It arises by the pressure loosed by the humidity escaped from the briquet as a steam. The stabilization period lasts until the weight of briquet during the last 24 hours is changed about 0,1 %. After this I have once more to weigh the briquet and to measure his diameter and length. I have to evaluate the briquet density after the stabilization according to the ratio (1). With this value of density I have to work next.

The briquet strength is a maximal pressure on die which develops in the pressure test at determined conditions. For the examination of the cylindrical briquets' strength in pressure two ground tests are suitable

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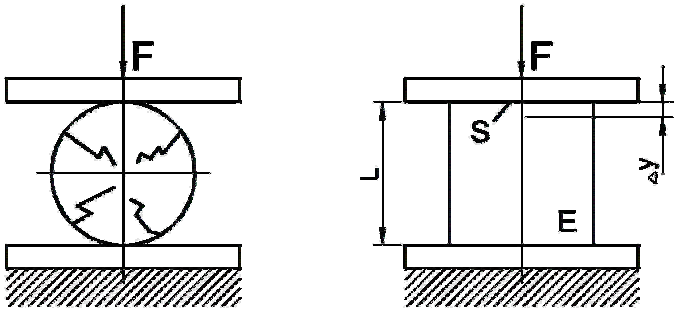
(Recenzovaná a revidovaná verzia dodaná 12. 10. 2007)

– the test by cleft (pressure affecting briquet which is in horizontal position) and strength test in simple pressure (pressure affecting the briquet which is in a vertical position). The briquet is put between round dies of compactor where is equally stressed with a raising pressure till his crush. For testing, only compact and intact briquets are used. I put the briquet between two round dies of testing compactor with the diameter of about 30 mm to the centre of the die surface. The pressure die equally raises the stress of briquets during the test. The examined maximum value specifies the briquet strength in pressure. In both tests was measured maximal force attained by infracting briquet. In the test by the cleft, the maximal force - briquet length ratio is an indicator of strength.



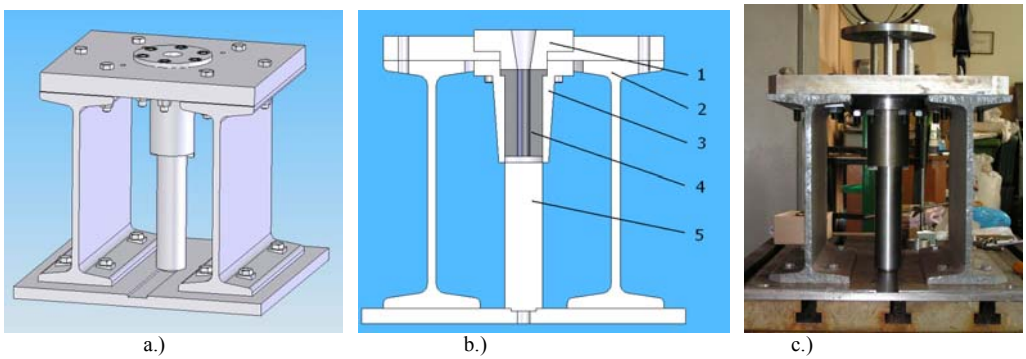
a) b)

Fig. 1. Briquet strength estimate a.) test by cleft; b.) strength test in simple pressure.

Briquet quality can be evaluated also with the briquet hardness. Basically, stronger briquets are of a better quality. The briquet hardness and thereby the briquet quality is possible to check very easily by inserting the briquet to the glass of water. A quality briquet should fall on the bottom in a moment because it has a higher specific density than water. Next, when the briquet dipped to water falls as to pieces sooner than in 5 minutes, we are usually dealing with a very low briquet quality. When the briquet fall as pieces before 15 minutes, it is a medium quality briquet and up to 20 minutes we deal with a good quality briquet.

Experiments and results

To be able to find the influence of parameters, I had to design a measuring experimental stand, see Fig. 2. This stand is inserted to the hydraulic press WPM. The main goal of my experiments is to find out the impact of all parameters can be measure the frame of stand. It is necessary to say that I designed the compacting stand to be able to measure the impacts of the compacting pressure, the compacting temperature, the material humidity, the fraction largeness, the impact of input material heating and the impact of compacting speed, the compacting stand will also be possible to measure the impact of changes of various constructional parameters which have also an impact on the output briquet quality. For example - changing of the compacting chamber length, changing of the compacting chamber conicalness, the impact of cooling canal usage, the impact of compacting chamber heating. But, these experiments will be carried out at the end of this research.



a.) b.) c.)

Fig. 2. Experimental compacting stand a.) 3D model; b.) 3D model in section (1-upper flange, 2-frame, 3-heating conic, 4-compacting chamber, 5- counter pressure); c.)Compacting stand made and composed.

The Experiments were carried out in laboratory conditions at a room temperature around 23 °C. At the beginning I chosed parameters for which the opening experiments were carried out to find out the impact of the compacting pressure. The chosen parameters are: the type of material pine, the fraction largeness 2 mm and fraction humidity 10 %. For one value inserted to the graph I always made 10 briquets which were measured and weighted. After 24 hours stabilization I repeated the weighting and measuring.

Every following dependencies were executed in the same way and I strove to retain equal compacting conditions during a full experiment. The hydraulic press works in the range 10000 – 100000 N. Therefore I chose the step of increasing compacting force - 10000 N. For a completeness and correctness I had re-calculated the compacting force on the compacting pressure.

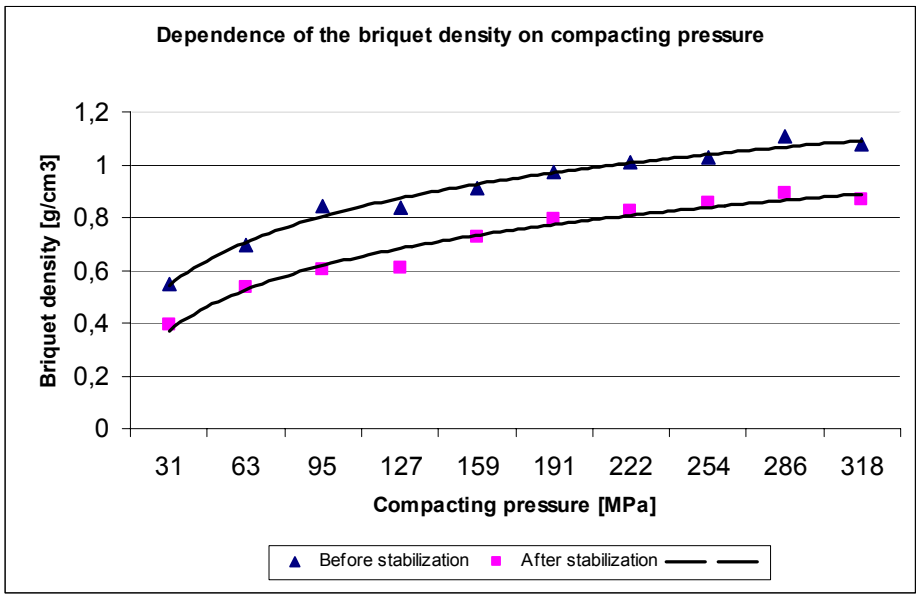


Fig. 3. Dependence of the briquet density on the compacting pressure.

In Fig. 3 you can see a graphical dependence of the briquet density on the compacting pressure. There are two graphs, one is made from the values before stabilization and another one from the values after stabilization. You can see that stabilization is needed and necessary to consider. The impact of dilatation is large. According to the measured and calculated values I rendered a curve of logarithmic regression. You see that with an increase of the compacting pressure briquet density also increases. The curve has a character which I have expected. But, when you are watching on the briquets density values after stabilization, you see that none of them meets the norm listed density 1-1,4 g.cm^{-3}. This is caused by the fact that I compacted at the compacting temperature in the compacting chamber about 25 °C. And this is a very low temperature for a needed lignin plastification. An optimal value according to my experiences is 120 °C. When I would have a heating equipment, the density values would meet the norms for rare bio fuels.

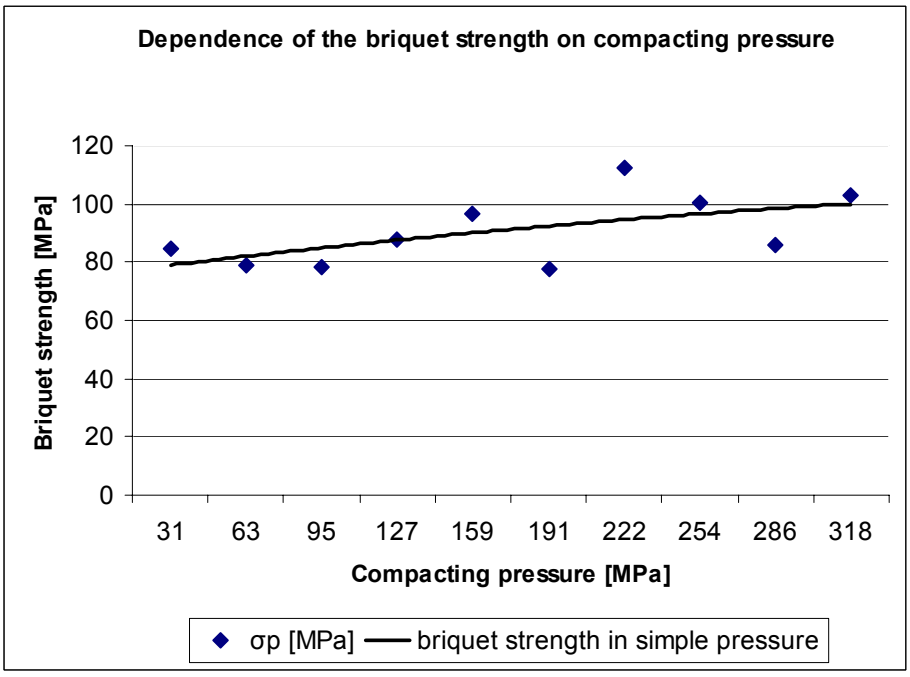


Fig. 4. Dependence of the briquet strength in simple pressure on the compacting pressure.

In Fig. 4 you can see a dependence of the second briquet quality indicator the briquet strength in simple pressure on the compacting pressure. As I wrote above, the briquet strength test is executed also in simple pressure and also in cleft. In this dependence you see only one curve. Briquets for the test were taken after stabilization. From the figure is clear, that with anincrease of the compacting pressure the briquet strength also increases. I can say that I achieved an expected result.

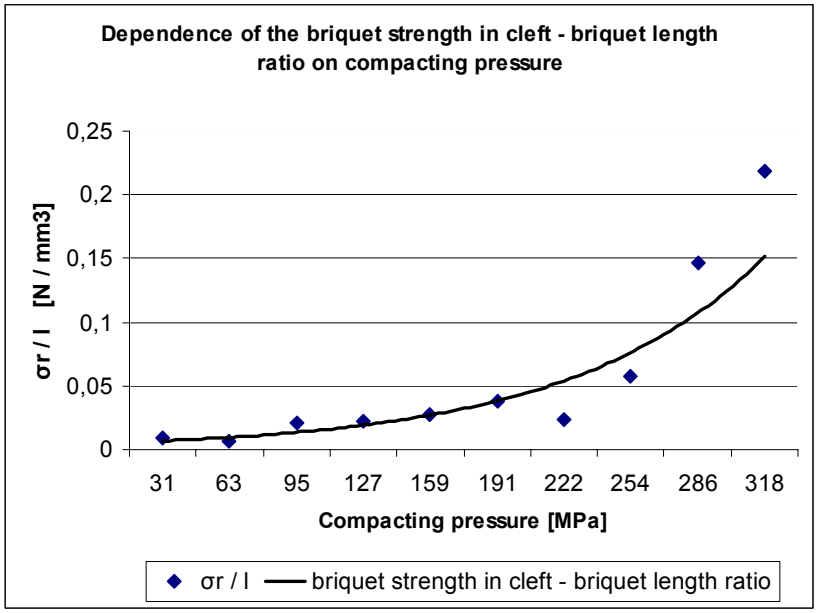


Fig. 5. Dependence of the briquet strength in cleft – briquet length ratio on compacting pressure .

In Fig. 5 is a dependence of the briquet strength in cleft – the briquette length ratio on the compacting pressure. The curve is the onlz, as in the previous figure. In this case, the briquets were taken after stabilization, too. But I had to divide the examined strength value with the briquet length. These ratios were inserted to the graph. You see that the ratio $\sigma_r \, .l^{-1}$ increases exponentially with the compacting pressure.

In Fig. 6 is a dependence of the briquet density on the fraction size. I worked with 5 various fractions (from each fraction we made 10 briquets. The chosen parameters were the type of material pine, the compacting pressure 286 MPa and the fraction humidity 10 %. The evaluation was analogous with the dependence of the briquet density on the compacting pressure. I inserted the values into the graph before stabilization and also after stabilization. Once again, it was confirmed, that it is necessary to let the briquet stabilize because of dilatation. You can notice that before stabilization I achieved the norm density of briquets but not after stabilization. This dependence shows us that the optimal fraction size is 2 mm. But in reality I have experienced that when the fraction is smaller, - the briquet will have a higher density. Once again, the reason can be an absence of pressing chamber heating. The lower compacting temperature has also is an impact on the low briquet density after stabilization and also on the fact that the optimal fraction size 2 mm. Temperature, as I already written has an impact on the lignin plastification from cellular structures of materials. At a higher compacting temperature I will not have to use so high compacting pressure for the qualitative briquet compacting. I think that for a lower fraction size the plastification will be more continuous than for a higher fraction.

In figures 7 and 8 you can see that with decrease in the fraction size the briquet strength increases also in the simple pressure in cleft. Here were confirmed my speculations about the absence of compacting temperature and its impact on the measured dependencies. The evaluation of measured and calculated values for designing of these dependencies was the same as the evaluation of values in dependencies of briquet strength on the compacting pressure. The dependencies are not completely according to my expectations because I thought that differences of briquet strength values will be more expressive but dependencies have a correct character. I expected that the dependence will be more expressive confirming the theory that with a decrease in the fraction size, the briquet strength increases. As I wrote above the differences result from the absence of compacting temperature.

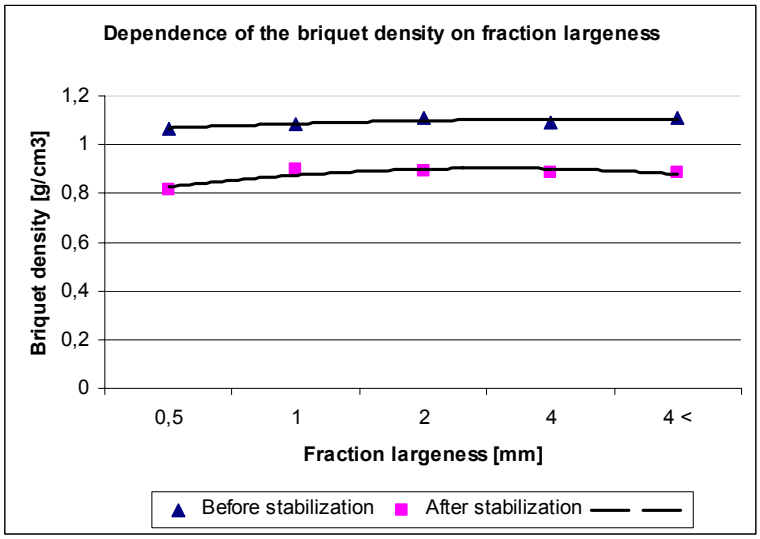


Fig. 6. Dependence of briquet density on the fraction size.

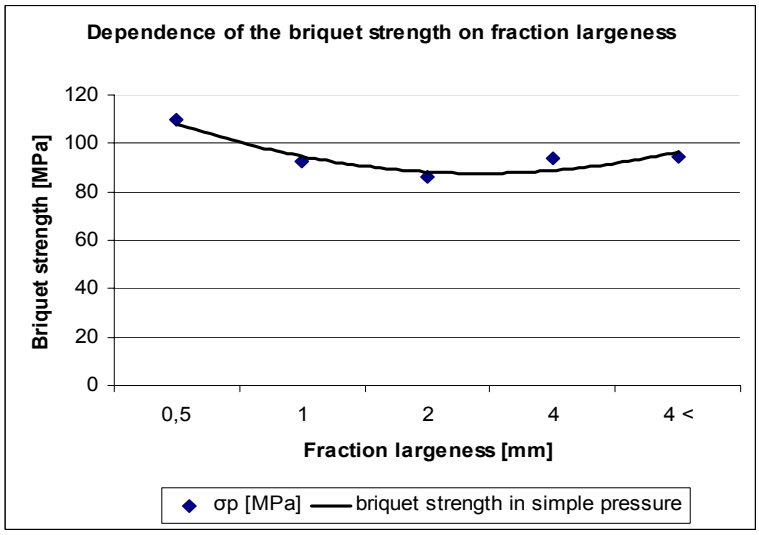


Fig. 7. Dependence of briquet strength in simple pressure on the fraction size.

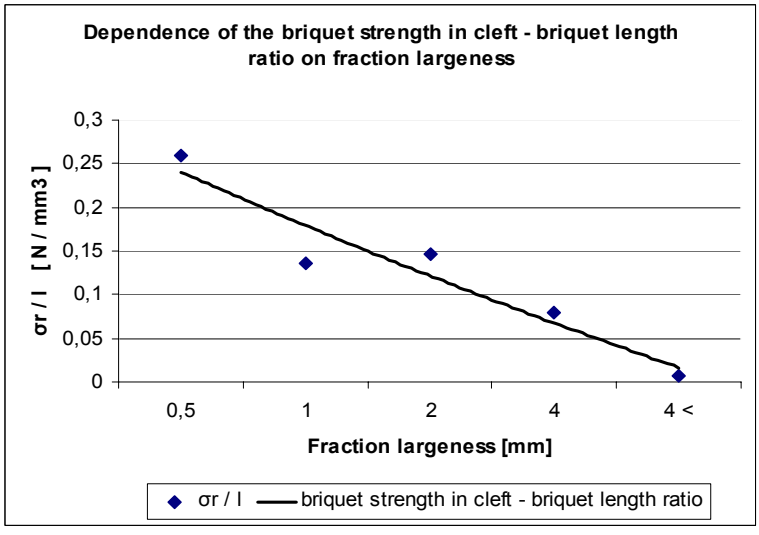


Fig. 8. Dependence of briquet strength in cleft – briquet length ratio on the fraction size.

I measured also animpact of the fraction humidity. I have to say that with the humidity I had some problems because the material humidity changed very quickly. Just only the fact that the humidity I strove to achieve with material drying in laboratory dryer in one room and compacting itself I executed in another one, much cooler room - made me problems. But I achieved some results. The chosen parameters: the type of material pine, compacting pressure 286 MPa and the fraction size of 2 mm.

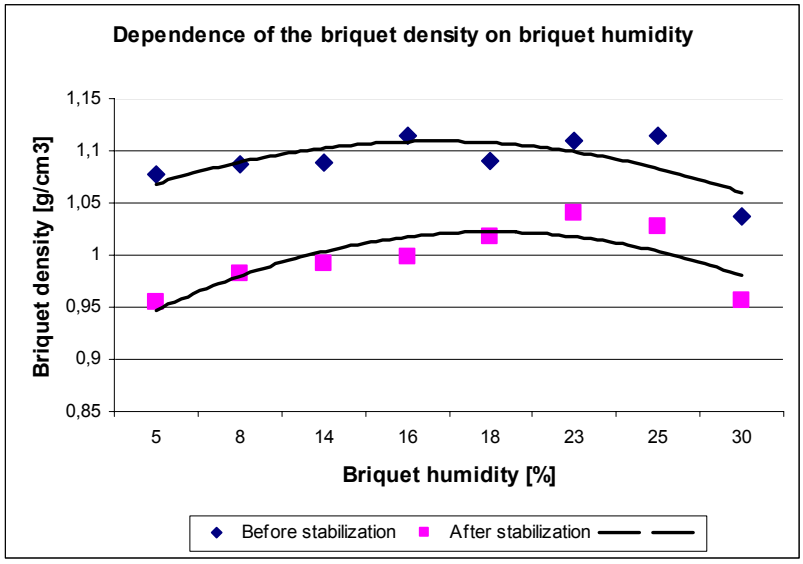


Fig. 9. Dependence of the briquet density on briquet humidity.

These experiments and also the evaluation of values was analogous to the above dependencies. But I need to pay attention to the fact that my experiments were taken in laboratory conditions. This allowed me to find also values of briquet density and strength compacted from a material with a higher humidity as is widely known (25 % and 30 %). When you look at the described graphs you can see that the optimal area of material humidity values is from 10 % - 20 %. With these values I met also in various literatures about suitable values of material humidity for compacting of wood biomass. In figure 9 is shown a dependence of the briquet density on the briquet humidity. In the presented interval of humidity values I achieved the norm density before stabilization and also after stabilization. But it is necessary to say that the humidity 1 $g.cm^{-3}$ is a lower limit of the listed interval and I would like to achieve of course higher density values. This I would solve by an increase of compacting temperature. You see that briquets with a humidity value lower than 10 % and also above 20 % aren't suitable. Weaves in cellular structures don't exist because of higher humidity and thereby higher water content, or vice-versa. Also in dependencies of the briquet strength on the briquet humidity the graphs show us that briquets from fractions at the humidity from 10 % - 20 % achieve higher values of strength - also in simple pressure in cleft.

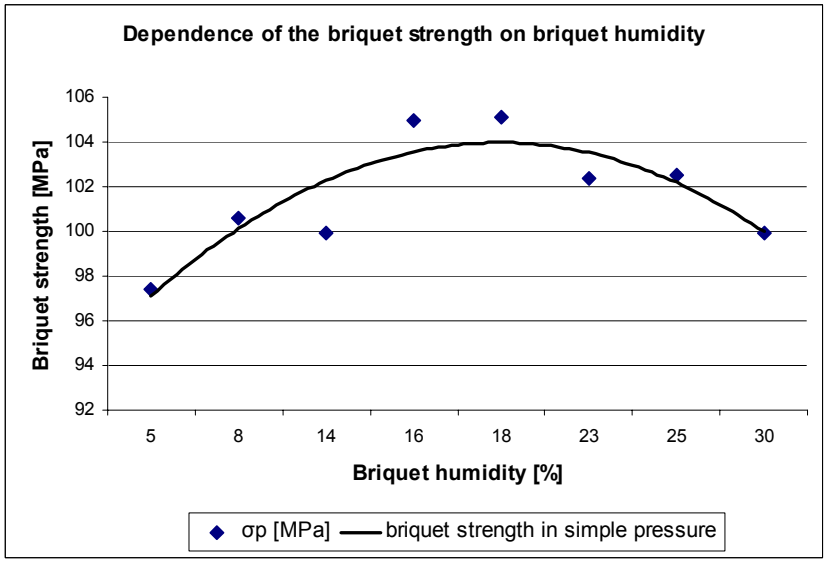


Fig. 10. Dependence of briquet strength in simple pressure on the briquet humidity.

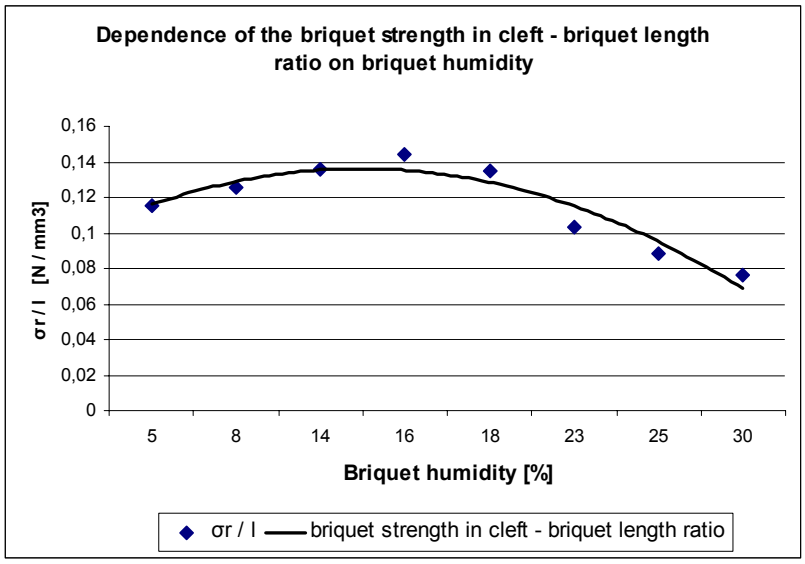


Fig. 11. Dependence of briquet strength in cleft – briquet length ratio on the briquet humidity.

Conclusion

All experimentally measured graphic dependencies should be a base for additional experiments, (the results will be a design of mathematical model of compacting). This mathematical model will include impacts of all parameters which take part in the increase or decrease of briquet quality. Of course, it is necessary yet to find out impacts of other eminent factors on the briquet quality. Experiments run at a high value of compacting pressure (286 MPa). But this I can assign to the above fact that at the experiments wasn't present a higher compacting temperature. When I would compact for example at the temperature 120 °C I would definitely achieve normed briquet density at a lower compacting pressures. The goal is also to find a relation between the compacting temperature and the compacting pressure and to find their optimal ratio. It is because the design of the compacting machines constructions is easier and cheaper to provide a higher compacting temperature than a compacting pressure.

The experimental stand was designed able (in laboratory conditions) to find out impacts of constructional parameters. Now, I would like to add an stand heating equipment, a tensometer for scanning of compacting force and tensometers for scanning of radial and axial forces applied to briquet into the compacting chamber. After this, I will be able to obtain a more complex view of the compacting process itself – about applied factors and their impact on weaves in materials and thereby on the briquet quality.

This work was supported by the Science and Technology Assistance Agency under the contract No.APVT-20-021104

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