COOLING OF WOOD BRIQUETTES

by

Miroljub M. ADŽIĆ [a*] and Radmilo A. SAVIĆ [b]

[a] Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia,
[b] Public Utility Company Beogradske elektrane, Belgrade, Serbia

Original scientific paper
DOI: 10.2298/TSCI121106009A

This paper is concerned with the experimental research of surface temperature of wood briquettes during cooling phase along the cooling line. The cooling phase is an important part of the briquette production technology. It should be performed with care, otherwise the quality of briquettes could deteriorate and possible changes of combustion characteristics of briquettes could happen. The briquette surface temperature was measured with an infrared camera and a surface temperature probe at 42 sections. It was found that the temperature of briquette surface dropped from 68 to 34 °C after 7 minutes spent at the cooling line. The temperature at the center of briquette, during the 6 hour storage, decreased to 38 °C.

Key words: *wood briquettes, briquette cooling, briquette quality*

Introduction

Biomass has a significant potential as a renewable energy source. Share of biomass and renewable wastes in the EU gross energy consumption, in 2009, was about 6.1%, while the consumption of wood briquettes and pellets was about 10 million tons. The EU Commission forecasts that in 2020 total heat and power production from biomass will double [1, 2].

Since mid XIX century wood briquettes have been used worldwide. Production of wood pellets and briquettes is an old technology mostly based on experience. It is rather common that in the cases of old, relatively simple technologies, many of the procedures, or elements of procedures, are accepted as mature and therefore less interesting for research. Such is the case with cooling of briquettes after pressing phase.

During pressing phase, friction, shear between particles, particles and briquetting machine and molecular adhesive forces are responsible for heating and temperature increase of briquettes. After pressing, the temperature of briquettes is usually 60-90 °C and the moisture content is around 15%, while in the final product, ready for use, packing, transport and storage, the final moisture content should be less than 12% or 15%, depending on the briquette class. Usually, briquettes are purposely cooled down in the ambient air. If briquettes are not properly cooled and dried, the stress between layers with different temperatures can induce cracks and loss of materials. At the same time, if there is a surplus of moisture it can soften the surface and affect the mechanical resistance and physical appearance of briquettes. Cooling to thermal stabilization of briquettes should be reached before packing and shipping.

Temperature and moisture together affect the quality of briquettes. The moisture, at increased pressure and temperature, evaporates and partially hydrolyzes lignin and cellulose to lower molecular mass products that act as an adhesive and binder for biomass particles resulting

* Corresponding author: e-mail: mikce2001@gmail.com

in a stronger solid structure of briquettes. Cooling and concurrent drying further increase strength and hardness of briquettes and improves the resistance to abrasion and fracture during transport, storage and utilization.

The mechanism of increase of hardness and strength of wood after briquetting is still not fully understood, but can be explained by the behavior of basic components of wood matter: cellulose, hemicellulose, lignin and others. Characteristics of raw materials and operating parameters, such as, wood species, wood particle size, moisture content, pressure, temperature, presence of additives, briquette dimensions, rate and time of cooling, affect more or less the process of formation of bonds. They are responsible for the quality of briquettes in what concerns their hardness, abrasion behavior, bending strength, shock and impulse load resistance. In order to get brief insight into the factors responsible for hardness and strength of wood briquettes, for a given raw material, a short overview of some influential parameters is given below.

Moisture content

The moisture content of the raw material is one of the key factors regarding quality of briquettes. The moisture, at increased pressure and temperature, evaporates and partially hydrolyzes lignin, hemicellulose and cellulose to lower molecular mass products that further act as an adhesive binder for biomass particles, resulting in a stronger solid structure [3-11]. In addition to the effects of hydrolysis, moisture affects mechanical properties of briquettes. If the moisture content of raw materials is low, hydrolysis and heat transfer through the material will be lower and higher pressures should be applied. If the moisture is too high, one can expect poor bonding and micro-explosive evaporation of water micro-pockets during and after pressing and as a consequence, disintegration of briquettes. Recommended moisture content varies from 8 to 18%. The final product moisture after cooling will be lower for about 2-3%. With this recommended moisture content after cooling briquettes will be free of cracks with good quality regarding hardness and strength.

Pressure

The work that is delivered by pressure is partially transformed into heat which increases the temperature of briquettes, reaching about 80, but even 200 °C in extreme cases. Under high pressure and high temperature, components of lower molecular weight become particles' binding elements. On the other hand, the lignin, which represents one fifth to one third of biomass, at temperatures 80-120 °C, and under the influence of moisture, becomes tender and acts as a binder, especially during conditions of high pressures [4, 5, 12].

Temperature

The effects of temperature cannot be separated from the influence of moisture content. Elevated temperature softens the structure and bonds between wood particles, reduces energy consumption, increases productivity, reduces wear and damage of the briquetting production line [3-5]. The upper limit of temperature is about 200 °C when chemical decomposition of biomass begins.

Particle size

The size and geometry of wood particles is of substantial importance. The presence of particles of different size improves the dynamic packaging and strength of briquettes. A finer chip size gives briquettes of higher density and better mechanical characteristics. On the other hand, too fine particles are prone to clogging and poorer bonding [4].

Cooling of briquettes

During pressing and extruding the temperature of briquettes rises and in extreme cases can reach 200 °C. Pressing phase is followed by cooling phase which releases moisture and hardens briquettes. Cooling of briquettes is an important step in briquette production technology. As cooling happens naturally, less attention has been paid to this production step, as can be seen from the literature survey. The initial cooling is usually performed by natural convection at the production line during transport of briquettes. After pressing, briquettes are easily breakable. The cooling releases moisture and hardens briquettes. Dynamics of cooling has a substantial influence on the quality of briquettes. If the cooling is too fast, the central zone of briquettes is still warm and humid. If immediately stored, the briquettes soften and can stick to each other. Also, cracks and fissures can appear on the surface which lowers the resistance of briquettes to abrasive wear. If the cooling is too slow, briquettes can become too dry leading also to the increase of the abrasive wear. The humidity of ambience can affect briquettes, as well. If the ambience air humidity is too low the stresses in the outer layers of briquette can cause cracks and loss of materials, which, in turn, degrades its quality. The opposite situation, when the ambience humidity increases (briquettes in water, in the rain, or high air humidity), may be associated with swelling, accompanied by decrease of hardness, which can result in the appearance of cracks and softening of the structure of briquettes, followed by loss of material.

At the end of production line briquettes are cut to the desired length. Briquette cutting is done by a saw or by a barrier. In the first case, the exact length briquettes have smooth cross sections. The second, simpler method, gives briquettes of approximate dimensions, uneven surface sections, less attractive to buyers. The time of cooling should be selected on the spot and continuously monitored keeping in mind possible changes of raw materials and other influential parameters, including the ambient conditions.

It is interesting to note that the available literature lacks data on surface temperature behavior of wood briquettes during cooling phase. Actually the authors have not found in the available literature published data on temperature dynamics of wood briquettes during cooling phase. This paper is aiming at contribution to further understanding of the dynamics of briquette cooling.

Methodology

The experimental study has been performed at a wood briquetting plant. The raw material was beech chips and saw dust. After pressing and extruding, the briquettes (9 cm in diameter) moved horizontally down the 26 m long transport line (about 1 m high from the workshop floor). The velocity of briquettes was about 6 cm/s. At the end of the line the briquettes were cut into pieces (about 25 cm in length). The ambient temperature of air was 10 °C, relative humidity about 65%, and air pressure 930 mbar.

The surface temperature of briquettes was measured by an infrared InfraCAMTM FLIR Systems AB camera. The spectral range of the camera is 7.3 to 13 micrometers, temperature range of 10-350 °C, and ±2 °C accuracy. Surface temperatures were also measured by a surface sensor of DWYER Instruments with ±2 °C accuracy. The temperature of surface of briquettes was measured at three points: top, bottom and both sides, and 42 sections along the cooling line.

Results and discussion

A view of the briquette cooling line is shown in fig. 1. The briquette press head surface temperature was measured as well and it was found that the temperature was uneven: at the sides 107, bottom 142 and top 188 °C. Occasionally the temperature of the press was over 200 ° C. The reasons for these higher temperature excursions have not been investigated.

Figure 1. Cooling line

The briquette press head surface temperature is shown in fig. 2. The infrared camera (IR) recording of briquette temperature along the cooling line is shown in fig. 3.

Immediately after leaving the press, the surface temperature of briquettes was 68 °C.

Close-up IR image of cross-section of a briquette is shown in fig. 4. The uneven temperature distribution can be seen which is due to uneven surface cut.

The surface temperatures of briquettes along the cooling line are shown in fig. 5 (the distance between two adjacent points is 0.06 m, or on a time scale, 11 s).

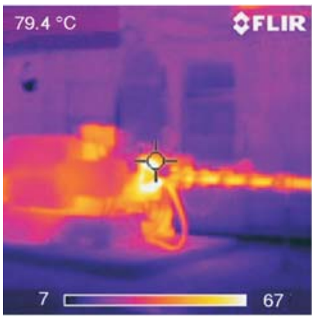

Figure 2. Briquette press head

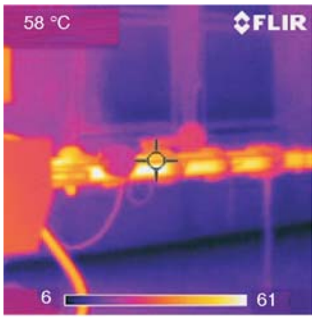

Figure 3. Briquette surface temperature

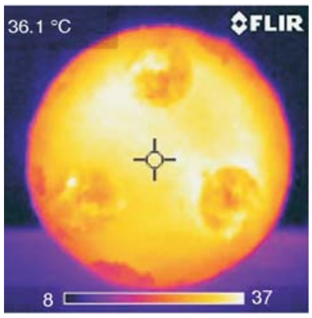

Figure 4. Close-up IR image of cross-section of a briquette

As can be seen in fig. 5, the temperature of briquette surface dropped from 68 to 34 °C during the cooling period of about 440 seconds at the production line. The differences between the side and the top briquette surface temperatures were maximum 5 °C, due to the different local heat transfer rates.

The temperature and the moisture of a briquette are closely related. For example, in a research on biomass torrefaction the authors of this paper measured surface temperature of a densified biomass as a function of time, fig. 6. The graph clearly shows the beginning of water evaporation and the decrease of heat transfer rate by convection due to the increased rate of moisture evaporation at about 100 °C.

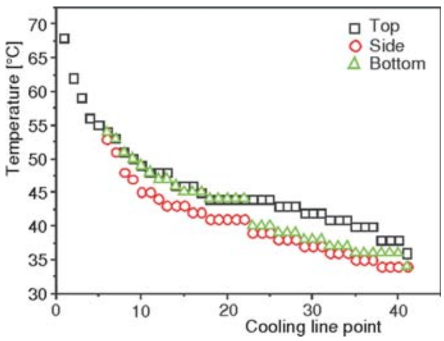

Figure 5. Briquette surface temperature as a function of position (time)

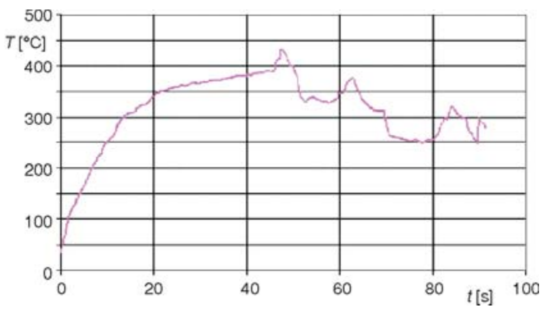

Figure 6. Surface temperature of a densified biomass (beech) as a function of time

After leaving production line the briquettes should be stored in piles for further cooling, as shown in figs. 7 and 8.

Depending on the arrangement of the piled briquettes, air circulation and ambient air parameters, the cooling rates could differ which should be taken into account in practice. The measured temperature history at the center of a briquette during the storage is shown in fig. 9.

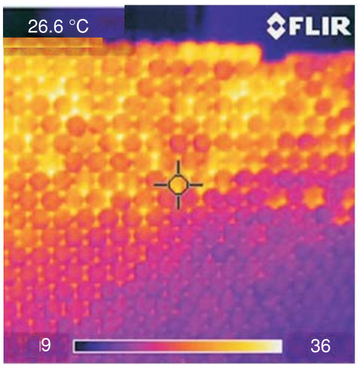

Figure 7. Piles of briquettes during cooling

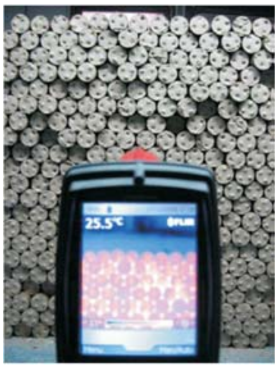

Figure 8. Piles of briquettes during cooling

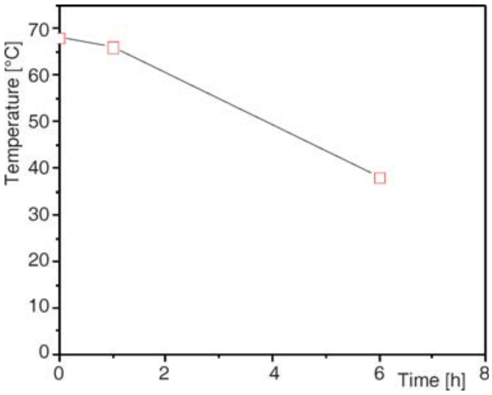

Figure 9. Briquette center temperature as a function of time

Figure 10. Packed briquettes in plastic bags

Cooling to thermal stabilization of briquettes should be reached before packing and shipping. According to the European wood briquettes standard EN 14961-3, regarding quality requirements, moisture as received for briquette classes A and B, should be: A1 < 12%, A2 and B < 15% by mass. A briquette manufacturer should define criteria for thermal stabilization depending on standard quality and whether the products will be used shortly after production, transported, stored or stored for longer period of time and how the product will be packed. An example of packing is given in fig. 10.

The problem that manufacturer and user could face is due to water condensation from the air or from the briquette moisture. The condensed water could seriously affect the quality of briquettes. In the wet surrounding development of micro-organisms, fungi, slow oxidation and other problems can occur. In that sense, manufacturer/user should take care of local climate characteristics, air temperature, relative humidity, dew point, equilibrium moisture content (EMC) of briquettes and how possible combinations of these factors could affect briquettes. The influence of air humidity and temperature on moisture equilibrium content in wood [13], given in fig. 11.

The influence of air temperature is relatively small. On the other hand, the data on the EMC of wood briquettes are scarce [14, 15]. According to [14] the EMC of briquettes is about 2-3% lower in comparison with the wood EMC.

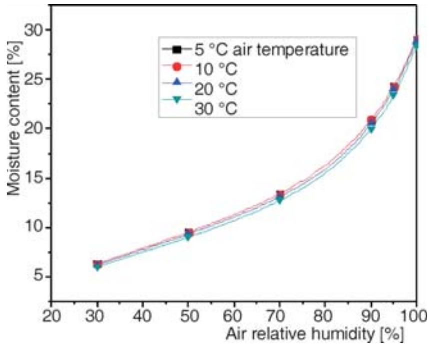

Figure 11. Moisture equilibrium content of wood as a function of air relative humidity and temperature

Conclusions

Cooling is one of the influential steps in briquetting technology that affects strength, durability and quality of briquettes.

Cooling of wood briquettes on a production line has been investigated experimentally by using an IR and a surface temperature sensor. The briquette surface temperature has been measured for various radial locations and time. The experimental findings of briquette surface temperatures indicate that the temperature of briquette surface dropped from 68 to 34 ° C during the period of 440 seconds. The differences between the side and the top briquette surface temperatures were maximum 5 °C, due to the different local heat transfer rates. The temperature at the center of briquette, during the 6 hour storage, decreased to 38 °C.

References

[1] Michael Hogan, M., *et al*., Biomass for Heat and Power, the European Climate Foundation, 2010
[2] Sikkema, R., *et al*., The European Wood Pellet Markets: Current Status and Prospects for 2020, *Biofuels, Bioprod, Bioref*., *5* (2011), 3, pp. 250-278
[3] Perre, P., On the Importance of the Temperature Level on Coupled Heat and Mass Transfer in Wood and Ligno-Cellulosic Biomass Fundamental Aspects, Formulation and Modeling, European Drying Conference – Euro Drying, 2011 Palma, Spain, 2011
[4] Mande, S. P., *Thermochemical Conversion of Biomass*, TERI, New Delhi, 2007
[5] Nielsen, N. P., *et al*., Importance of Temperature, Moisture Content, and Species for the Conversion Process of Wood Residues into Fuel Pellets, *Wood and Fiber Science, 41* (2009), 4, pp. 414-425
[6] Kaliyan, N., Morey, R. V., *Factors Affecting Strength and Durability of Densified Biomass Products*, Elsevier, London, 2009
[7] Rowell, R. M., *Handbook of Wood Chemistry and Wood Composites*, CRC Press, Boca Raton, Fla., USA, 2005
[8] Plistil, D., *et al*., Mechanical Characteristics of Standard Fuel Briquettes on Biomass Basis, *RES. AGR. ENG., 51* (2005), 2, pp. 66-72
[9] Zhanbin, C., Normal Temperature Briquetting Technology for Biomass with Original Moisture Content, International Conference on Bioenergy Utilization and Environment Protection – 6th LAMNET Conference, Dalian, China, 2011
[10] Menind, A., *et al*., Optimal Conditions for Evaluation of Wood Waste by Briquetting, International DAAAM Baltic Conference Industrial Engineering, Tallinn, 2012
[11] Lehtikangas, P., Quality Properties of Pelletised Saw Dust, *Biomass and Bioenergy, 20* (2001), 5, pp. 351-360
[12] Stelte, W., *et al*., Fuel Pellets from Biomass: The Importance of the Pelletizing Pressure and its Dependency on the Processing Conditions, *Fuel, 90* (2011), 11, pp. 3285-3290
[13] Simpson, W., Equilibrium Moisture Content of Wood in Outdoor Locations, United States Department of Agriculture, Forest Service, Research No. FPL-RN-0268, 1998
[14] Hartley, I. D., Wood., J. L., Hygroscopic Properties of Densified Softwood Pellets, *Biomass and Bioenergy, 32 (*2008), 1, pp. 90-93
[15] Singh, R. N., Equilibrium Moisture Content of Biomass Briquettes, *Biomass and Bioenergy, 26* (2004), 3, pp. 251-253

Paper submitted: November 6, 2012
Paper revised: December 19, 2012
Paper accepted: March 24, 2013