DESIGN AND CONSTRUCTION OF A HYDRAULIC BRIQUETTING MACHINE FOR HAZELNUT HUSK AGRICULTURAL RESIDUE

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Abstract
Briquetting is the most widely-used waste compaction technology. Briquette quality is evaluated mainly by briquette density. Briquette density is very important for the impact of technological parameters compacting pressure, burning speed, briquette stability, etc. Briquettes made by hydraulic briquetting presses are of the highest quality. This developed hydraulic briquetting system is manufactured in Terme Industrial zone Samsun Turkey. The objective of the present study is to give theoretical analyses of parameters which have an impact on briquette quality. Hazelnut husk briquettes were dried up to 13 – 15 % moisture content and they were grinded into (2-5)-(7-10) mm size and were pressed under 160 MPa pressure. The physical-mechanical properties of the briquettes were investigated.

Key words: *briquetting; hydraulic press; physical parameters, design.*

INTRODUCTION

Biomass defined as different materials of biological origin mainly plant material and animal wastes (*Sampson, et al., 1993; Trebbi, 1993*), used primarily as domestic energy source is naturally abundant and present a renewable energy opportunity that could serves as an alternative to fossil fuel. Behind coal and oil, biomass is the third largest energy resource in the world (*Bapat, et al., 1997*) having dominated the world energy consumption until the mid-19th century (*Tumuluru, et al., 2010*). Utilization of agricultural residues is often difficult due to their uneven and troublesome characteristics. The process of compaction of residues into a product of higher density than the original raw material is known as densification. Densification has aroused a great deal of interest in developing countries all over the world lately as a technique for upgrading residues as an energy source (*Bhattacharya, et al., 2002*). Briquetting is the most widely-used waste compaction technology (*Biath & Ondruska, 2012*). High-density, compressed biomass simplifies the logistics of handling and storage, improves biomass stability, facilitates the feeding of solid biomass fuels into energy utilization devices and offers higher energy density, cleaner burning solid fuels that in some cases can approach the heating value of coals (*Klass, 1998*).
The objective of study is to develop of a hydraulic briquetting machine with horizontal pressing in order to enable material back up for hazelnut husks. This developed hydraulic briquetting system is manufactured in Terme Industrial zone Samsun Turkey. The objective of the present study is to give theoretical analyses of parameters which have an impact on briquette quality. Hazelnut husk briquettes were dried up to 13 – 15 % moisture content and they were grinded into (2-5)-(7-10) mm size and were pressed under 160 MPa pressure. The physical effects of the briquettes were investigated.

MATERIALS AND METHODS

A Hydraulic type briquetting machine with a horizontal pressing course, designed and constructed in Terme industrial zone of Samsun was used for briquetting the hazelnut husk residues. Briquetting pressure range of this machine is adjustable from 0 to 320 MPa by a manometer on it.
Piston and cylinder of the machine is bedded horizontally thus the briquetting is done in a horizontal course. The pump of the machine has a tank of 25 L capacity of hydraulic oil with a 1.2 $m^3.s^{-1}$ flow rate. Stroke of the piston is 310 mm and the velocity of the stroke is adjusted to 10 $mm.s^{-1}$ at 160 MPa briquetting pressure.
Machine dimensions are 1280x1155x740 (AxBxC) mm. Operation of the machine is controlled by a start-stop button embedded on it. Hydraulic pump functions by a 15 kW powered 3-phase electrical engine with a star delta starter. The mold for the briquette was not heated. As a support block for the

pressing a rectangle shaped metal plate is placed at the end of the course having 125x105x30 mm dimensions. Movement of this plate is done manually. Main parts are given in Figure 1, the mold in Figure 2 and finally manufacturing stages of this machine are given in Figure 3, below.

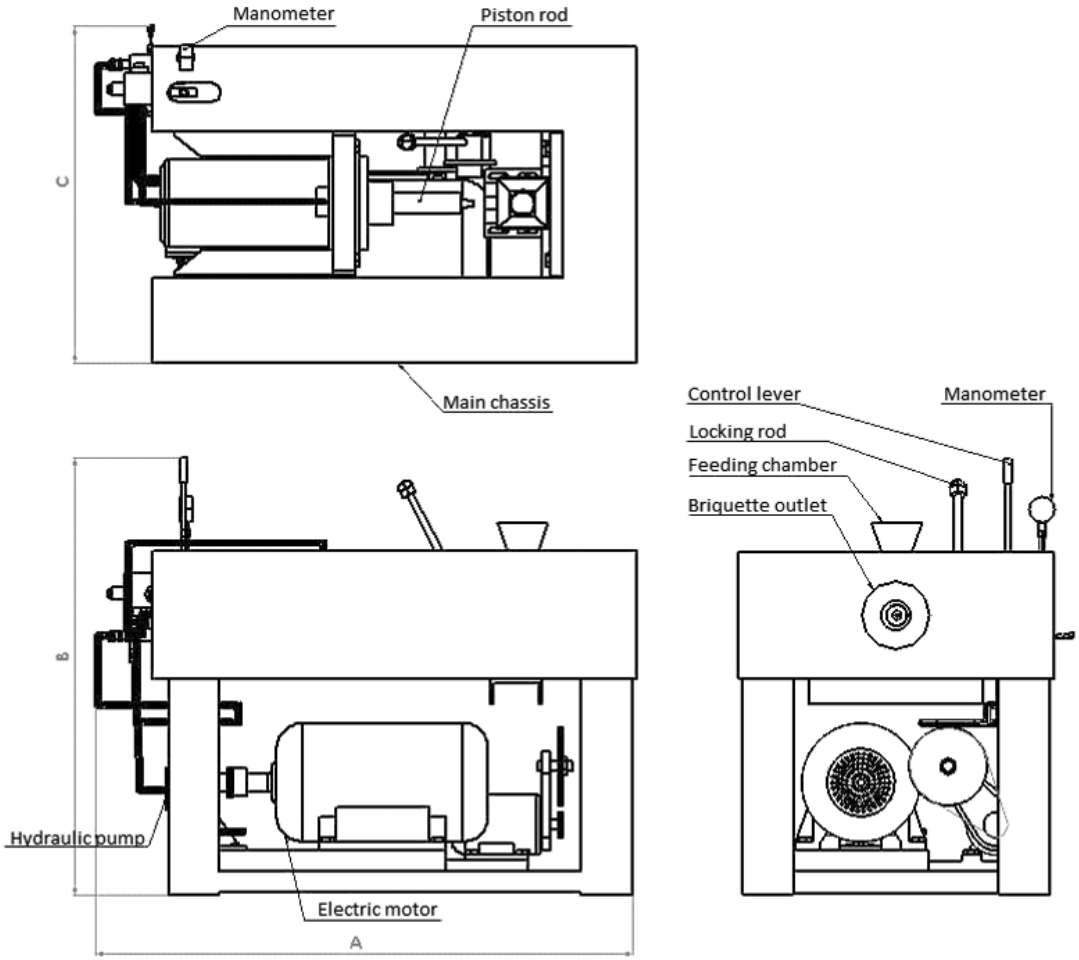

Fig. 1 Main parts of the briquetting machine

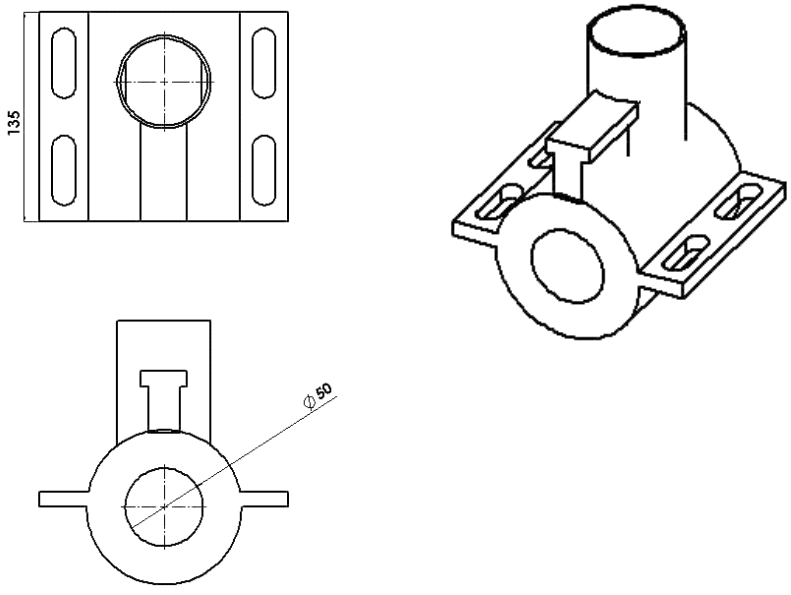

Fig. 2 The mold

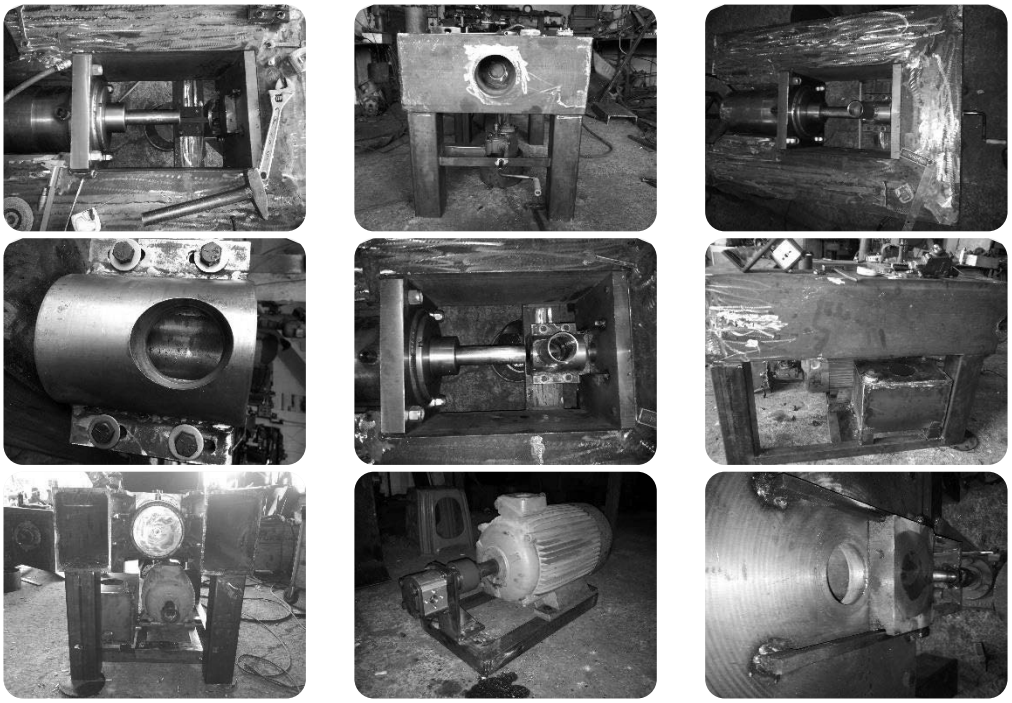

Fig. 3 Manufacturing stages

Briquetting of Hazelnut Husk Agricultural Residue

The residues were first dried in normal conditions under the sun and their moisture contents were decreased down to 13-15 %. Then the dried material was ground by a knife-hammer mill till the required particle sizes were obtained (2-5; 7-10 mm). Their moisture contents were controlled again and they were briquetted under 160 MPa briquetting pressures.

The briquetting pressure was chosen as 160 MPa showed that the briquettes were enough solid and durable both physically and in shape. This working pressures also matches with the studies defined in *Krizan, et al., (2015), Zhang & Guo (2014) and Sun, et al., (2014)*. Feeding of material was done batch wise during the briquetting process in order to avoid occlusion. The material prepared for briquetting was poured into the cylindrical mold and they were squeezed by a piston in the mold and the briquettes were obtained. Pressing process continued 20 seconds more after the completing of squeezing in order to avoid expansion in the produced briquettes. Full cylindrical shape briquettes having 50 mm diameter and 80 to 110 mm varying lengths were produced by this process.

RESULTS AND DISCUSSION

As mentioned the residues obtained after harvesting of hazelnut were briquetted under 160 MPa briquetting pressure with 13-15 % moisture content and with two different particle sizes (2-5 mm and 7-10 mm). Then the solid biofuel properties of these briquettes at each application were analyzed. Samples of full cylindrical shaped briquettes for each application are given in Figure 4, below.

M: 13-15 %	
	
PS: 2-5 mm P: 160 MPa	PS: 7-10 mm P: 160 MPa

Fig. 4 Briquettes produced from different particle sizes

Volume mass of the material and the briquettes with compression ratios are given in Table 1. The highest compression ratio (7.03) was achieved at 160 MPa briquetting pressure, 13-15 % moisture content of the material and with 7-10 mm particle sizes.

Tab. 1 Compression ratios of the hazelnut husk briquettes

P (MPa)	M (%)	PS (mm)	Volume mass of material ($kg.m^{-3}$)	Volume mass briquettes ($kg.m^{-3}$)	Compression ratio
160	13-15	2-5	176.79	1143.23	6.47
		7-10	142.90	1005.43	7.03

Tumbler Index

Tumbler index is an indicator of resistance of briquettes against the forces they face during loading, discharging, transporting procedures. Thus it is an indicator of solidness of briquettes (*Zhang & Guo, 2014; Niedziolka, et al., 2015*).

Tab. 2 Effect of particle size on tumbler index

	Tubler Index (%) $\bar{X} \pm S_{\bar{x}}$
PS (mm)	
2-5	78.92 ± 3.57
7-10	73.23 ± 3.16
Sig.	**<0.01**

The highest Tumbler Index (78.92 ± 3.57) was achieved with the briquettes made from 2-5 mm particle sizes at 160 MPa briquetting pressure and at 13-15 % moisture content of material. The difference between the Tumbler Indexes of the briquettes at different particle sizes was found to be statistically significant ($P<0.01$). The reason for this was estimated as that the hazelnut husk has ligneous structure so, the briquettes made from a higher particle sized material can be more brittle. The remaining briquettes after Tumbler Index tests are given in Figure 5.

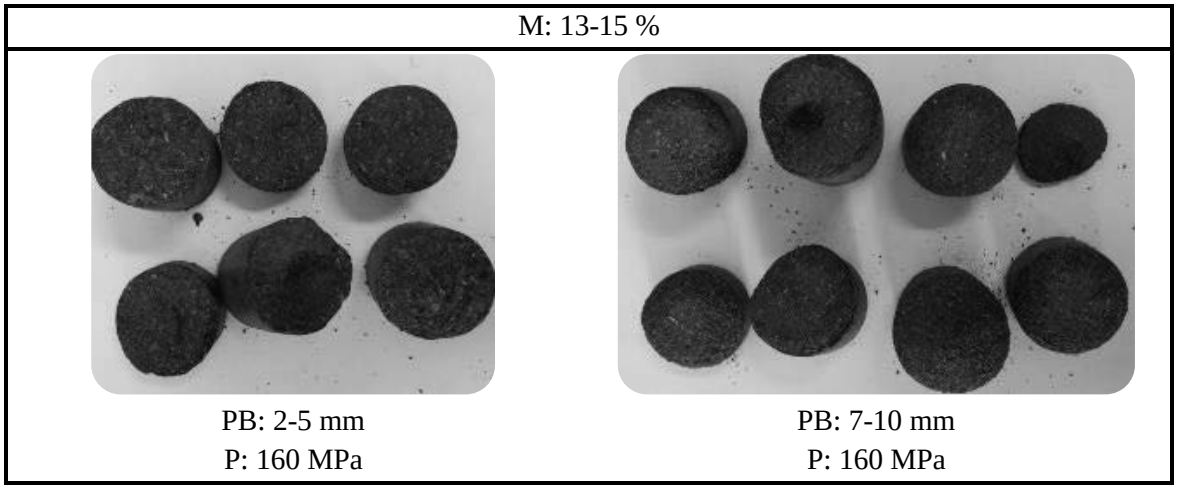

Fig. 5 The remaining hazelnut husk briquettes after Tumbler Index tests

The results of Tumbler Index tests showed that the main abrasion and breakdowns realized at the both ends and at the middle part of the briquettes. The reason for that can be the batch squeezing procedure depending on the material feeding which ends up with layered structure. The breaking mainly occurred in that layer borders.

Shatter Index

The resistance of briquettes against impacts during loading and discharging processes are tested by Shatter Index. In this test the briquettes were intentionally dropped down 10 times from a height of 1 m above ground level. The results of Shatter Index tests are given in Table, below.

Tab. 3 Effect of particle size on Shatter Index

	Shatter Index (%)
	$\bar{X} \pm S_{\bar{x}}$
PS (mm)	
2-5	91.27 ± 1.68
7-10	91.17 ± 1.82
Sig.	**0.947**

The difference between the Shatter Indexes of the briquettes produced from two different particle sizes was not found to be statistically important. The views of briquettes after Shatter Index testes are given in Figure 6.

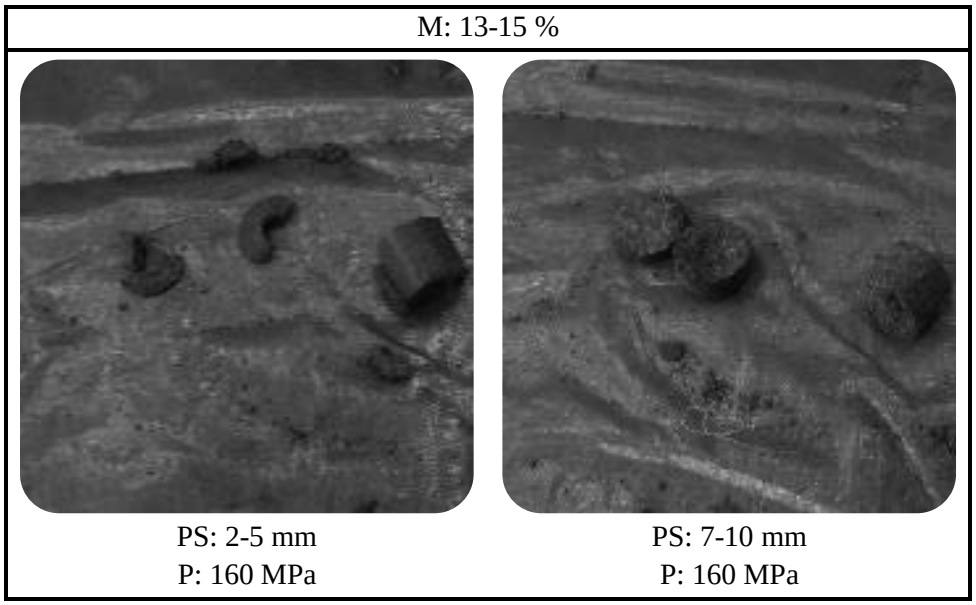

Fig. 6 Shatter tests of briquettes

The tests showed again that all the breakings and split ups happened at the both ends and in the middle of the briquettes due to batch squeezing of the material.

CONCLUSIONS

In this study a particular hydraulic type briquetting machine with a horizontal course was designed and developed for the briquetting of hazelnut husk agricultural residues in order to be evaluated as solid biofuel. Effect of two different particle sizes were analysed on the physical-mechanical parameters of briquettes which are produced under 160 MPa pressure and at 13-15% moisture content. The results showed that the developed hydraulic type briquetting machine is very suitable for briquetting of hazelnut husk agricultural residues. After all the tests it's found that the effect of particle size on volume mass of material, volume mass of briquettes, compression ratio, Tumbler Index were statistically important but, its effect on Shatter Index was not found to be important. These kinds of researches will help to improve the design and function of briquetting machines for the future and by this way for the energy deficiency of the world by converting agricultural residues to energy sources.

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REFERENCES

1. Bapat, D. W., Kulkarni, S. V. & Bhandarkar, V. P. (1997). Design and operating experience on fluidized bed boiler burning biomass fuels with high alkali ash. Proceedings of the 14th International Conference on Fluidized Bed Combustion, New York: Vancouver ASME, 165–174.
2. Bhattacharya, S.C., Leon M.A., Rahman, M.M. (2002). A Study on improved biomass briquetting. Energy for Sustainable Development, 6(2), pp. 67–71.
3. Biath, P., Ondruska, J. (2012). Idealized compression ratio for a screw briquetting press. Acta Polytechnica, 52(3), 13-16.
4. Francis, O. O. (2013). Development of an appropriate biomass brıquetting machine for use in rural communities. Department of Agricultural and Bioresources Engineering Faculty of Engineering, University of Nigeria, Nsukka (pp. 158).
5. Klass, D. L. (1998). Biomass for renewable energy, fuels, and chemicals. Academic Press.
6. Križan, P., Šooš, L., Matúš, M., Beniak, J., Svátek, M. (2015). Research of significant densifcation parameters influence on final briquettes quality. Wood Research 60(2), 301-316.
7. Niedziołka, I., Szpryngiel, M., Jakubowska, M.K., Kraszkiewicz, A., Zawislak, K., Sobczak, P., Nadulski, R. 2015. Assessment of the energetic and mechanical properties of pellets produced from agricultural biomass. Renewable Energy, 76, 312-317.
8. Sampson, R. N., Wright, L. L., Winjum, J. K., Kinsman, J. D., Benneman, J., Kursten, E., Scurlock, J. M. O. (1993). Biomass management and energy. Water, Air, and Soil Pollution, 70(1–4), pp. 139–59.
9. Sun, B., Yu, J., Tahmasebi, A., Han, Y. (2014). An experimental study on binderless briquetting of chinese lignite: effects of briquetting conditions. Fuel Processing Technology, 124, 243–248.
10. Trebbi, G. (1993). Power-production options from biomass: The vision of a southern Euorpean utility. Bioresour. Technol., 46, 23-29.
11. Tumuluru, J. S., Wright, C. T., Kenny, K. L., and Hess, J. R. (2010). A review of biomass densification technologies for energy application. A report prepared for the U. S. Department of Energy by the Idaho National Laboratory, Biofuels and Renewable Energy Technologies Department, US.
12. Zhang, J., Guo, Y. (2014). Physical properties of solid fuel briquettes made from caragana korshinskii kom. Powder Technology, 256, 293–299.

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