Research on the compaction process of loose materials with use of helix technology

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Abstract. In present times, there is an emphasis on facilitating energy generation from renewable sources. The energy generated in this manner is considered green with low environmental impact. One of the sources of renewable energy is biomass. The term biomass refers to all kinds of natural (organic) materials like sawdust, which can be processed to generate energy. In practice, the majority of the biomass is processed before it can be utilized. This process usually entails compaction to form pellet or briquette. It calls for utilizing briquetting machines with sufficient efficiency. The article presents the results of experimental research on the process of sawdust compaction in a screw briquetting machine. During compaction, the values of moment on the screw were recorded. These data will be used in the design of more efficient briquetting machines.

1. Introduction
Green energy sources are becoming increasingly more common and popular. This is partially related with efforts to reduce costs, as many different government subsidy programs are announced to co-finance the purchasing of equipment for generating energy from renewable sources, which include among others, the biomass. Biomass is understood as all types of natural (organic) materials which may be processed into energy. These materials include organic waste from agricultural production (including waste of plant and animal origin), forest production and related branches of industry, including fishing and aquaculture, but also biogases and biodegradable fractions of industrial and communal waste such as sawdust and all types of plants from energy crops [1].

In practice, the majority of the biomass needs to be reprocessed before use. This usually entails its compaction to pellet or briquette [2–5]. Such a process requires using a fragmenting-briquetting machine with suitable processing efficiency [6–8] which depends on the employed technology, construction and characteristics of the compacted material [9]. Furthermore, the degree of fragmentation of the compacted material is important [9]. In practice, a given machine will be optimized for compacting a singular type of biomass. Whenever a different type of medium is to be briquetted, another dedicated machine has to be purchased, which incurs additional expenses. It was therefore decided to examine the possibility to compact sawdust using an auger compactor, which was primarily intended for briquetting straw.

2. Experiment
The study utilizes a BIOMASSER briquetting machine by Asket (figure 1). The device is intended for compressing materials such as: straw (rye, wheat, barley, oat, canola, corn, rice, soy), hay (mix of dried grass), reed, alfalfa, Tanzania grass, silvergrass, common bird’s foot as well as post-fermentation
sediment from a biogas installation into briquette form. The briquetting machine comprises of straw feeder, motor drive for the helix which compacts and forms the briquette. The helix is encased in a heater sleeve. This allows to achieve the suitable temperature of the formed briquette which causes plasticization of the lignin in the straw and form a cohesive glazed surface which holds the briquette together.

![Helix briquetting machine adapted for compacting straw. Product by Asket [10].](image)

**Figure 1.** Helix briquetting machine adapted for compacting straw. Product by Asket [10].

![View of the stabilizing channel of the helix compactor; a) and b) stabilizing channel with installed weights, c) heat forming sleeve exit with installed stabilizing channel.](image)

**Figure 2.** View of the stabilizing channel of the helix compactor; a) and b) stabilizing channel with installed weights, c) heat forming sleeve exit with installed stabilizing channel.
The final important component of the machine is the stabilizing channel in which the final stage of the briquette forming and cooling takes place (figure 2). The forming channel itself comprises three rods which prevent deformation of the briquette and its bursting by gas trapped inside of the material. Additionally, the forming channel increases the resistance of moved briquette which causes an increase in the force of straw compaction and at the same time provides an additional axial force which compresses the briquette as it cools down and prevents its separation along the axis. The resistances present in the axial direction can be adjusted by installing additional weights/clamps. For the purpose of the performed study, the machine was equipped with a set of sensors allowing to register the drive shaft torque during the compaction process as well as the distribution of temperature in the heating sleeve along its axis.

The drive employed for the briquetting machine is a 4kW three-phase electric motor by Tamel. The torque is transferred from the motor to the helix shaft through a chain transmission with 1:2 ratio. Motor speed control is achieved via inverter, whereas the revolution speed is measured via an induction sensor in the drive shaft. Torque measurement is achieved by NCTE 4000-250-1-A-0-0 sensor.

3. Results
The aim of the performed study was to determine the possibility to utilize the above mentioned device for briquetting broken down wood waste. At the first stage of the experiment, oak sawdust was introduced into the feeder. After starting the machine, it produced several dozen centimeters of briquette, after that the material was blocked inside the forming channel and the machine drive stopped. It was necessary to dismantle the machine and clean the forming channel. During the examination, the drive torque was registered and the results in form of a value change graph are presented on figure 3.

![Figure 3. Graph describing the variance in axial force and torque values as a function of time in the process of sawdust compaction.](image)

Earlier examination has indicated that the torque value during straw compaction should be approx. 15–20 Nm [11]. Consequently, for the second stage of the examination, it was decided to reduce the torque and carry out the briquetting process for a mix of sawdust and straw which was cut into sections not longer than 5 cm. The examination utilized oat straw with moisture content approx. 10%. The material mix was prepared in 1:1 ratio by weight. After startup, the machine operated in a stable manner and the drive did not seize. The measurements were taken at two temperature settings of the forming channel 200 °C and 250 °C. Additionally, during measurements for temperature setting of
200 °C, the load placed on the stabilizing channel of the machine was gradually increased. This load was to increase the radial force affecting the briquette and to prevent it from coming apart during cooling down. Additionally, we observe an increase in resistance of the sliding motion in the briquette channel which causes a minor increase in the axial force. This does not materially increase the axial force on the helix; however, it is sufficient to prevent the briquette from coming apart along the axis (the so called rondeling). The briquette obtained in the course of examination is presented on figure 4.

![Figure 4](image)

**Figure 4.** Compacted material obtained during the examination; a) briquette from compacted sawdust, b) briquette from compacted sawdust and straw, c) and d) compacted material for examination in the stabilizing sleeve.

In the second stage of the examination, the change of torque value on the drive shaft was measured. Initially, only 1 additional weight was installed on the stabilizing channel and the obtained results in form of a graph of the torque value as a function of time are presented on figure 5. This allows us to determine that the torque value varies in the range of 10–20 Nm, whereas the average value is below 15 Nm. Installing additional weights causes a significant increase in torque, up to the value of 15–35 Nm. It is noted that the value range has increased significantly. The very fact that at such large variance of the measured values, as can be seen in particular on figure 6, results from the device operating characteristics. The compacted material is fed to the worm cyclically via a revolving helix mixer. Additionally, the material mix is not always uniform. Depending on the ratio of sawdust to straw fed to the helix, the maximum torque value changes which is reflected on the graph (figure 6).

During the examination, temperature was also measured. Four sensors were used to register the change in temperature value, placed in the forming channel along its axis. This allowed to measure the temperature on entry point of the briquette to the sleeve, inside the sleeve and on exit. The value distribution is presented on figure 5 and figure 7. Noticeably, the temperature distribution along the sleeve axis is not uniform. The lower value is observed at the entrance point of the briquette to the forming sleeve and is more than two times lower than the setting. Additionally, its value does not change noticeably after changing the temperature setting from 200 °C to 250 °C.
The measurement of torque can be carried out in a relatively simple manner, with minor modifications to the machine to facilitate sensor installation between the drive and the compacting helix shaft [11]. It is much more problematic to carry out the measurement of axial force affecting the helix. This calls for employing special solutions such as the ones provided in [12]. The axial force value affecting the helix depends on the torque value and can be described with a linear function in which the slope coefficient value is constant, depending on helix geometry [13]. In the case of the machine under examination, the value of this coefficient is 8 [13]. This allows to determine the axial force affecting the helix during biomass compaction. The axial force variance values are provided on figures 3 and 6.

![Figure 5](image1.png)

**Figure 5.** The graph presents the variance in the value of torque and temperature as a function of time for the process of compaction of straw and sawdust mix.

![Figure 6](image2.png)

**Figure 6.** The graph presents the variance in the value of torque and axial force as a function of time for the process of compaction of straw and sawdust mix.
Figure 7. Distribution of variance of temperature values as a function of time along the forming sleeve axis for the process of compaction of straw and sawdust mix.

Table 1. Torque values measured on the drive shaft and axial force value affecting the helix in the process of compaction of straw and sawdust mix for different number of weights affecting the stabilizing sleeve.

| Torque (Nm) | Force (kN) |
|------------|------------|
| 1 weights  | 10–20      | 1.25–2.125 |
| 2 weights  | 12–25      | 1.5–2.5    |
| 3 weights  | 16–35      | 2–4.25     |

4. Conclusion

The performed study demonstrates that the drive motor installed in the device has insufficient power rating to use the briquetting machine for compacting sawdust into briquette form in its current configuration. It is likely that the increased motor power rating will allow to compact sawdust with utilization of the discussed helix technology. However, it is also necessary to consider the axial force values affecting the helix. Too high force value may damage the unit. Therefore, it would be justified to carry out examinations to determine the strength of the helix of a given geometry (shape).

The solution to the above problem may be to use a mix of straw and sawdust for the compaction process. One needs to consider that sawdust being heavier exhibits a tendency to move to the bottom of a container. Therefore, with current construction of the helix, one needs to introduce straw first into the feeder and then add sawdust in batches. This prevents a situation in which the heavier sawdust will move to the bottom of the container and only the sawdust will be briquetted. Such a scenario may cause the drive motor to seize, overheat or even cause catastrophic damage to the helix.

5. References

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