American Journal of Applied Science and Technology

VOLUME Vol.05 Issue 10 2025
PAGE NO. 83-88
DOI 10.37547/ajast/Volume05Issue10-17

Influence Of Screw-Press Operating Parameters On The Mechanical Strength Of Briquetted Materials

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Received: 26 August 2025; **Accepted:** 22 September 2025; **Published:** 24 October 2025

Abstract: In this study, the effect of the pressing dynamics of a screw press on the mechanical strength of coal briquettes was investigated. The strength behaviour was examined under different ranges of the compressive force exerted by the screw. During the experiments, the following variables were selected as changing parameters: aqueous solutions of paraffin waste at concentrations of 5%, 7%, and 10%; aqueous solutions of distillery stillage (alcohol bard) at 10%, 15%, and 20%; binder liquid content of 10%, 11%, and 12%; nozzle diameters of 20, 25, and 30 mm; screw compressive forces of 1.8, 2.4, and 3 kN; and a working chamber diameter of 120 mm. The results revealed that when the nozzle diameter was D□ = 25 mm, the exponential curves on the strength–parameter graphs indicated that the briquettes prepared with a 15% aqueous mixture of distillery stillage and a 15% aqueous mixture of paraffin waste exhibited strength levels that met the required standards.

Keywords: Paraffin waste, alcohol stillage, binder liquid, pressing force, screw dynamics, nozzle.

INTRODUCTION:

The briquetting of coal dust plays a vital role in the production of efficient and environmentally sustainable solid fuel. Despite its wide potential in improving fuel utilisation and reducing environmental pollution, the process faces several technical and operational challenges that significantly affect the quality and mechanical strength of the briquettes [1,2].

One of the primary issues lies in the characteristics of the raw material. The granulometric composition of coal dust strongly influences briquette strength, as excessively fine or coarse particles lead to poor compaction and structural instability. Likewise, the moisture content of the raw material must be maintained within an optimal range—typically 8–12%—to ensure uniform shaping and to prevent disintegration during handling and drying [3,4].

Another important factor concerns the choice of binder materials. A variety of binders, such as clay, lime, cement, molasses, and resin, are commonly used; however, improper selection or proportioning of binders may result in low mechanical strength or poor combustion quality of the final product. The pressure and temperature parameters of the briquetting process are also critical: insufficient pressure prevents adequate densification, whereas excessive pressure or temperature accelerates wear of the screw press components and moulds, reducing equipment lifespan.

Moreover, the quality of the press equipment itself largely determines process efficiency. Many small-scale facilities continue to employ outdated or improvised screw presses, which negatively impact both briquette quality and production capacity. Improperly compacted briquettes generate high levels of smoke and incomplete combustion, thereby reducing energy efficiency and increasing environmental pollution.

In addition to these technical constraints, storage and transportation pose further difficulties. Briquettes tend to absorb moisture or crumble under mechanical stress, which necessitates the use of appropriate packaging and controlled storage conditions. Economic and environmental considerations are also crucial: excessive consumption of binders and energy increases production costs, while the use of certain chemical binders can create environmental risks.

Therefore, optimising the operating parameters of screw-type presses and the composition of binding materials is of particular importance for ensuring the production of durable, efficient, and eco-friendly coal briquettes. This study focuses on analysing the influence of screw press parameters on the strength characteristics of briquettes produced under varying process conditions.

METHODOLOGY

The experimental studies were conducted to investigate the influence of screw press operating parameters on the strength of coal briquettes. During the research, several technological and structural parameters of the pressing process were systematically varied and their combined effect on the mechanical integrity of the briquettes was analysed.

As the main variables, the following parameters were selected: aqueous solutions of paraffin waste at concentrations of 5%, 7%, and 10%; aqueous solutions of distillery stillage (alcohol bard) at 10%, 15%, and 20%; binder liquid content of 10%, 11%, and 12%; nozzle diameters of 20, 25, and 30 mm; screw compression forces of 1.8, 2.4, and 3 kN; and a working chamber diameter of 120 mm.

Each experimental series was performed under controlled laboratory conditions to ensure the reproducibility of results. The briquettes were formed using a screw-type press equipped with a replaceable nozzle system and a calibrated force-measurement unit. After pressing, the briquettes were dried at ambient temperature until a constant mass was achieved.

The mechanical strength of the produced briquettes was evaluated through standard compression tests, in which the maximum load required to cause structural failure was recorded. Experimental data were processed using statistical and graphical methods to identify the correlation between press parameters and briquette strength.

The obtained results served as the basis for determining the optimal ranges of screw compression force and nozzle diameter that ensure the highest briquette strength while maintaining process efficiency and equipment durability.

RESULTS

Based on the experimental conditions described above, a series of analytical investigations were conducted to determine the optimal parameters for producing coal briquettes that meet industrial quality requirements. The main variable parameters included aqueous solutions of paraffin waste at concentrations of 5%, 7%, and 10%; aqueous solutions of distillery stillage at 10%, 15%, and 20%; binder liquid contents of 10%, 11%, and 12%; nozzle diameters of 20, 25, and 30 mm; screw compression forces of 1.8, 2.4, and 3 kN; and a working chamber diameter of 120 mm [5]. The experiments were carried out under controlled environmental conditions, taking into account the average air temperature and humidity in the Fergana region of Uzbekistan during May and June (average temperature 30 °C and relative humidity 18.7%).

For each combination of parameters, the feed mixtures were prepared separately and briquetted using a variable-pitch screw press. The resulting briquettes were dried at room temperature until a constant mass was achieved. Their mechanical strength was then determined in accordance with GOST 21289-2018 [6,7].

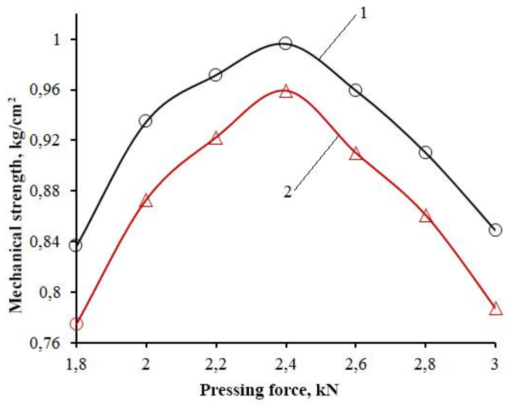
The experimental results demonstrated that an increase in the proportion of binder solution within the coal dust mixture, along with a higher compression force, led to a substantial improvement in the mechanical strength of the briquettes. The nozzle diameter was also found to have a significant effect on the final product strength. For example, at lower loading levels, increasing the nozzle diameter from 20 mm to 30 mm raised the briquette strength from 0.12 kg/cm² to 0.26 kg/cm², whereas under higher load conditions, the same change increased strength from 0.5 kg/cm² to 0.9 kg/cm². This relationship reflects the combined influence of binder concentration and press parameters on the internal compaction of the coal mass.

It was also observed that the technological factors affecting the briquetting process are interrelated, and establishing correlations between these parameters is essential for process optimisation. The analysis of the results allowed the identification of both primary and secondary factors influencing briquette performance. According to the findings, the briquettes produced with paraffin-waste and distillery-stillage binders demonstrated the most favourable combination of mechanical strength, production efficiency, and economic feasibility, fully meeting technological and regulatory requirements without significantly increasing production costs.

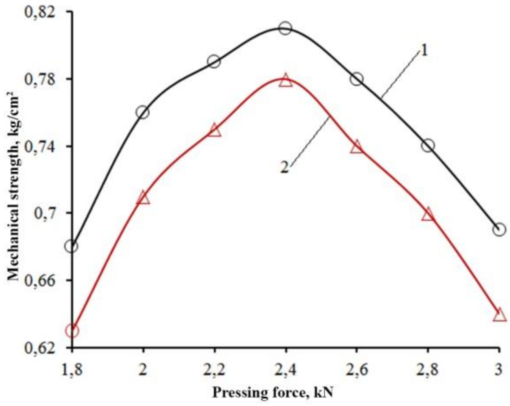
The study confirmed that briquette strength can be improved by adding a binder; however, the interaction of each binder with the coal structure and the environmental impact of the additive must also be considered. A higher binding capacity tends to prolong the ignition time of the briquettes, and this factor must be taken into account when selecting binder types and proportions. Briquettes based on paraffin waste achieved the required strength at the highest binder content and exhibited a prolonged combustion period, but the emission of volatile compounds into the atmosphere increased. Conversely, briquettes produced with distillery stillage satisfied the strength requirements even at a minimal binder concentration, though their burning duration decreased.

Therefore, combining these two binders in appropriate proportions is recommended to produce briquettes that simultaneously meet strength, combustion, and environmental criteria. In addition, managing the internal porosity and temperature distribution during the burning process remains an important aspect of product optimisation.

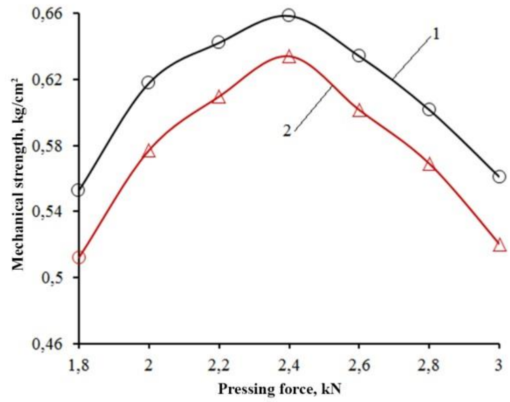
Taking these observations into account, further experiments were carried out to determine the moisture resistance of coal briquettes produced with an average binder concentration of 15% using paraffin-waste and distillery-stillage solutions separately. The influence of the screw-press compression force on the mechanical strength of the resulting briquettes was also analysed. Figures 1 a–c illustrate the dependence of briquette mechanical strength on the pressing force applied to the coal dust during compaction.



(a) Nozzle diameter D⍰ = 20 mm;



(b) Nozzle diameter D⍰ = 25 mm;



(c) Nozzle diameter D⍰ = 30 mm

1. briquette obtained on the basis of a 15% mixture of alcohol bar in water;
2. briquette obtained on the basis of a 15% mixture of paraffin waste in water;

Figure 1. Dependence of the mechanical strength of coal briquettes on the force of pressing coal powder

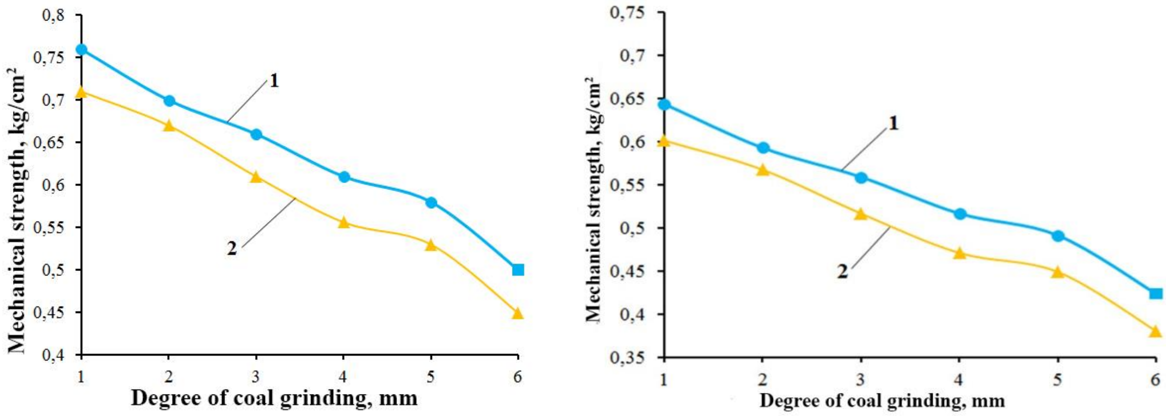
As shown in Figure 1, briquettes produced under a pressing force in the range of 2.2–2.6 kN fully meet the requirements of GOST 21289-2018. However, changes in the nozzle diameter significantly affect the mechanical strength of the final product.

The analytical results indicate that, according to standard requirements, the most optimal conditions for producing coal briquettes are achieved when the nozzle diameter is D⍰ = 25 mm. Under this configuration, the exponential curves on the strength–parameter graphs show that briquettes prepared with a 15 % aqueous mixture of distillery stillage and a 15 % aqueous mixture of paraffin waste exhibit strength values that meet regulatory standards.

An increase in the pressing force within the range of 2.2–2.6 kN enhances the mechanical strength of the briquettes, whereas a further increase to 3 kN results in an exponential decrease in strength. This phenomenon can be explained by structural changes occurring within the briquette at high compression pressures: under excessive load, re-pressing causes the binder to dislocate and redistribute unevenly throughout the coal matrix, leading to internal deformation and a subsequent decline in mechanical integrity.

Furthermore, as noted earlier, the addition of a binder alone does not solely determine the strength of the product; the particle-size distribution of the coal dust is also a key influencing factor. Therefore, within the 2.2–2.6 kN pressure range, the effect of coal particle size on briquette strength was further investigated. In these experiments, the proportion of coal particles smaller than 5 mm was limited to not more than 10 % of the total mass, in accordance with standard requirements. Based on the previous findings, the nozzle diameter was fixed at D□ = 25 mm.

The corresponding experimental results are presented in Figures 2 (a) and (b) [8,9,10].



(a) D□ = 25 mm and F□ = 2.2 kN (constant); (b) D□ = 25 mm and F□ = 2.6 kN (constant).

1 – Coal briquette produced using a 15% aqueous mixture of distillery stillage;

2 – Coal briquette produced using a 15% aqueous mixture of paraffin waste.

Figure 2. Dependence of briquette strength on the degree of coal particle size reduction.

DISCUSSION

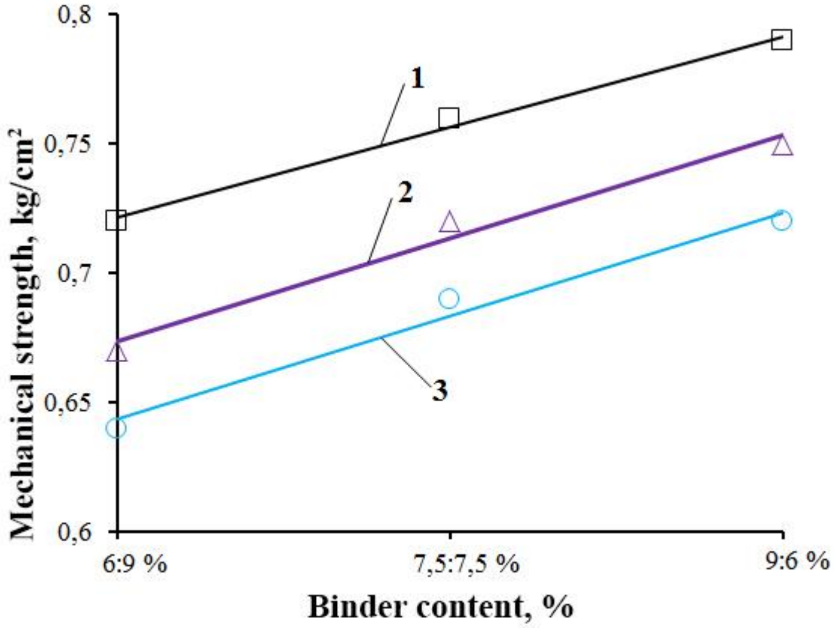
As can be seen from Figure 2, when the proportion of coal particles smaller than 5 mm in the prepared mixture does not exceed 10%, the briquette strength remains at its lower critical point. An increase in the proportion of coal particles larger than 5 mm leads to a sharp decrease in strength. This tendency is observed in briquettes produced using both 15% aqueous solutions of distillery stillage and paraffin waste as binders [14,15,16].

The optimal pressing force for the process was found to be within the range of 2.2–2.6 kN. In addition to this, the influence of briquette strength on combustion time is also an important factor, as the physical and chemical properties of the binders significantly affect the burning behaviour.

As noted earlier, when a higher proportion of paraffin-waste binder is used, both the strength and the combustion duration of the briquettes improve. However, the emission of secondary gases into the atmosphere also increases. In contrast, briquettes produced with distillery stillage meet the strength requirements even at minimal binder content, but their combustion time becomes shorter. Therefore, for producing high-quality briquettes that comply with regulatory standards, the combination of both binders is considered the most effective approach.

Based on these findings, briquettes were produced using mixed binders composed of distillery stillage and paraffin waste, and their mechanical strength was experimentally examined. The experiments were carried out under the following variable parameters: nozzle diameter D□ = 25 mm; screw compression forces F□ = 2.2, 2.4, and 2.6 kN; working chamber diameter D_a = 100 mm; total water and binder content 15%; and binder mixture ratios of distillery stillage to paraffin waste equal to 6:9%, 7.5:7.5%, and 9:6% [17,18].

The tests were performed under ambient conditions typical for the Fergana region of Uzbekistan during May and June, when the average air temperature is approximately 30 °C and the relative humidity is 18.7%. The obtained experimental results are presented in Figure 3.



1 – Pressing force F▯ = 2.6 kN (constant);

2 – Pressing force F▯ = 2.4 kN (constant);

3 – Pressing force F▯ = 2.2 kN (constant).

Figure 3. Dependence of briquette strength on the proportion of different binder mixtures.

As illustrated in Figure 3, within the combination of binder materials, an increase in the proportion of distillery stillage improves the mechanical strength of the briquettes; however, it reduces the duration of combustion. Conversely, when the proportion of paraffin waste in the binder mixture increases, the combustion time becomes longer, but the emission of secondary gases and the amount of ash released into the environment also rise.

In addition, during cold briquetting, incomplete homogenisation between the binder and the fine coal particles occurs, which leads to the formation of dislocations within the internal structure of the briquettes. This structural inhomogeneity contributes to a partial reduction in their mechanical stability.

From the graphical dependence, it can be observed that the most optimal parameters—ensuring compliance with the established regulatory requirements—are achieved at a screw-press compression force of F▯ = 2.4 kN, a working-chamber diameter of D_a = 100 mm, and a total water-plus-binder content of 15 %, using a binder mixture composed of 9 % distillery stillage and 6 % paraffin waste.

Therefore, in modern briquetting technologies, the application of heat during the pressing process is of particular importance. The pressing temperature is undoubtedly one of the key factors influencing the proper formation and structural stability of the produced coal briquettes.

CONCLUSION

The study demonstrated that both the amount of binder in the coal–water mixture and the increase in pressing force have a significant effect on enhancing the mechanical strength of the produced briquettes. In addition, the diameter of the screw-press nozzle was found to exert a considerable influence on the final product’s strength.

The analytical results indicated that, according to standard requirements, the optimal conditions for producing high-quality coal briquettes are achieved when the nozzle diameter is D▯ = 25 mm, and the briquettes are prepared using 15% aqueous mixtures of distillery stillage and paraffin waste as binders. Under these conditions, the experimental curves displayed exponential strength behaviour that fully satisfied the regulatory criteria.

When paraffin waste was used as the primary binder, both the briquette strength and burning duration improved; however, the emission of secondary gases into the atmosphere increased. In contrast, briquettes produced with distillery stillage achieved the required strength even at minimal binder content, though their combustion time was shorter.

Therefore, the experimental findings confirm that combining both binders—distillery stillage and paraffin waste—in appropriate proportions is the most effective approach for producing briquettes that meet technical standards, ensure mechanical stability, and maintain favourable combustion and environmental characteristics.

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