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Investigation of Emissions Released During the Combustion of Coal Briquettes Produced from Distillery Stillage and Paraffin Waste

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Abstract: This article presents the results of analytical research on the formation of smoke and exhaust gases during the combustion of coal briquettes produced with the addition of binding agents. Separate briquettes were prepared using distillery stillage and paraffin waste, and the emissions generated during combustion were analysed in accordance with standard Maximum Allowable Concentration (MAC) requirements. During the experimental study, the variable parameters were defined as follows: screw press with variable-pitch auger and nozzle diameter of Dnozzle = 25 mm, pressing force Fpress= 2.4 kN, working chamber diameter Dchamber= 100 mm, and a moisture and binder content of 15%. The distillery stillage had a 17% water content, while the paraffin waste had 15% water content. These components were used as part of the briquetting mixture to evaluate their combustion behaviour and associated emissions. The experimental findings include quantitative data on smoke density, ash content, and concentrations of harmful gases such as carbon monoxide (CO) and sulfur dioxide (SO_2), all measured against environmental safety standards.

Keywords: Briquette, powder, MAC, distillery stillage, paraffin waste, carbon monoxide, sulfur dioxide, ash content, smoke emissions.

Introduction:

The combustion of coal briquettes releases various gases and solid residues that are subject to environmental and sanitary regulations. These standards are defined in terms of Maximum Allowable Concentrations (MAC), which may vary depending on the country and specific industry legislation. In this context, Uzbekistan has established a set of MAC values for pollutants typically emitted during the combustion of coal-based briquettes [1,2,3].

The primary gases released during the burning process include:

1. Carbon Monoxide (CO)

○ MAC (according to air quality standards in Uzbekistan and Russia):

▪ For short-term exposure: 5 mg/m³

▪ For average concentrations in working environments: up to 3 mg/m³

2. Carbon Dioxide (CO_2). Although CO_2 is not directly classified under MAC limits, its accumulation during combustion requires sufficient ventilation.

○ Acceptable exposure in normal working conditions: 9,000 mg/m³ (0.5%)

○ Short-term exposure: 27,000 mg/m³ (1.5%)

2. 3. Nitrogen Oxides (NO_x) – hazardous to human health:

○ Nitric oxide (NO): 0.4 mg/m³

○ Nitrogen dioxide (NO_2): 0.085 mg/m³ (as per Uzbekistan's sanitary regulations)

3. 4. Sulfur Dioxide (SO_2)

○ MAC in Uzbekistan: 0.5 mg/m³

In addition to gaseous emissions, the combustion of briquettes produces solid residues, such as:

5. Ash content. Ideally, the ash content in coal briquettes should not exceed 10%, with technical standards (e.g., GOST) allowing up to 15%. The median particle size typically ranges from 0.1 to 10 µm.
6. Particulate Matter (PM). These are fine airborne particles that pose health risks when inhaled:

- PM_{10} MAC: 0.05 mg/m³
- $PM_{2.5}$ MAC: 0.025 mg/m³

Research Object

Based on the aforementioned considerations, this study investigates the environmental impact of combusting briquettes produced from distillery stillage and paraffin waste [1,3,4]. For the purpose of the analysis, separate briquette samples were prepared from each type of waste material, and their performance was tested in accordance with established environmental and combustion standards.

The following experimental parameters were applied:

- Press type: Variable-pitch screw press
- Nozzle diameter D_{nozzle} = 25 mm
- Compression force F_{press} = 2.4 kN
- Working chamber diameter $D_{chamber}$ = 100 mm

Figure 1 presents the general view of the variable-pitch screw press apparatus, while Figure 2 illustrates the briquette production process.

The moisture and binder content used for briquetting was fixed at 15%, with the distillery stillage having a 17% water content, and paraffin waste containing 15% moisture in the selected mixture ratios.

Environmental parameters were also taken into account during the experimental procedures. Since the experiments were conducted during the months of May and June, the ambient temperature for the Fergana region of Uzbekistan was assumed to be approximately 30°C, with average relative humidity measured at 18.7%.

The research was carried out in two stages, involving both laboratory preparation and combustion testing phases [1,4,5].

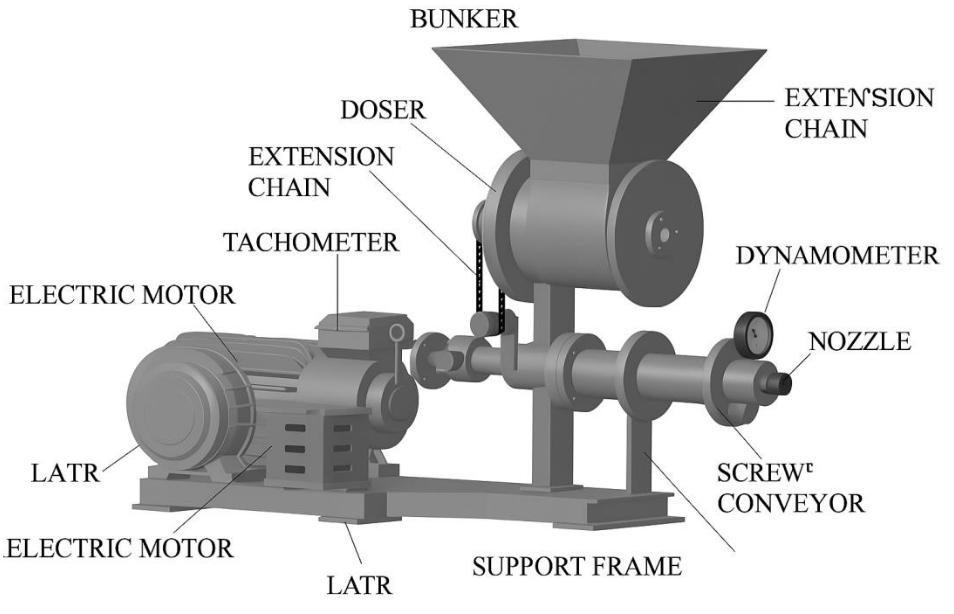


Figure 1. Overview of the briquetting device.

Figure 2. Briquette production process.

Results of Theoretical and Experimental Studies

In the first stage of the research, the amount of smoke and exhaust gases released during the combustion of the briquettes was determined experimentally. The volume of volatile substances generated during combustion was measured in accordance with GOST 6382-2001 (State Standard) [1,4,7]. The procedure involved heating the sample to 90°C in an oxygen-free environment for a duration of 7 minutes.

The mass loss of the sample was recorded, and corrections were made by subtracting the portion of the mass loss associated with the initial moisture content of the briquette. The final value represents the loss due solely to the volatilisation of combustible compounds.

The amount of volatile matter V_a released during briquette combustion was calculated using the following equation [1,8]:

$$V^a = \frac{100(m_2 - m_3)}{m_2 - m_1} - W^a \quad (1)$$

Here:

m_1 – mass of the steel tray used for burning the briquette, kg;

m_2 – combined mass of the steel tray and the ash produced after combustion, kg;

m_3 – combined mass of the steel tray and the coal briquette before combustion, kg;

W_a – mass fraction of moisture in the analytical sample, %.

The formation of non-volatile residues (ash, salts, and other types of solid substances) during the combustion of the test briquette is determined using the following formula, in grams [1,9]:

$$(NV)^a = \frac{100(m_3 - m_1)}{m_2 - m_1} \quad (2)$$

If the mass fraction of carbon dioxide from carbonates formed during the combustion of fuel briquettes is more than 2%, then the volume of volatile substances is determined by the following formula: the output from carbonates corrected for carbon dioxide is determined by the formula CO_{V2},%, gr [1.9];

$$V^a{}_{CO_2} = V^a - \left[(CO_2)^a - (CO_2)^a_{NV} \times \frac{(NV)^a}{100} \right] \quad (3)$$

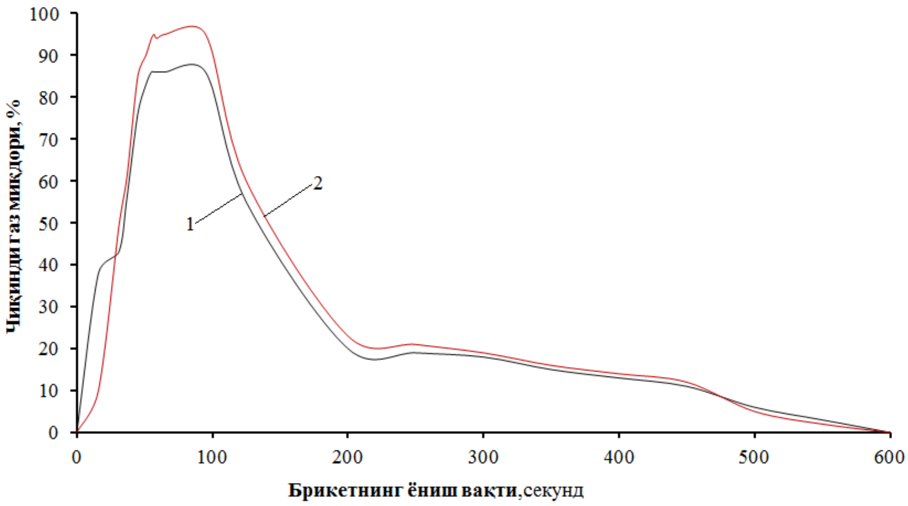
Here,

$(SO_2)^a$– mass fraction of sulfur dioxide (SO_2) derived from carbonates in the analytical sample (volatile form);

$(CO_2)^a_{NV}$ – mass fraction of non-volatile sulfur dioxide remaining in the residue (non-volatile form).

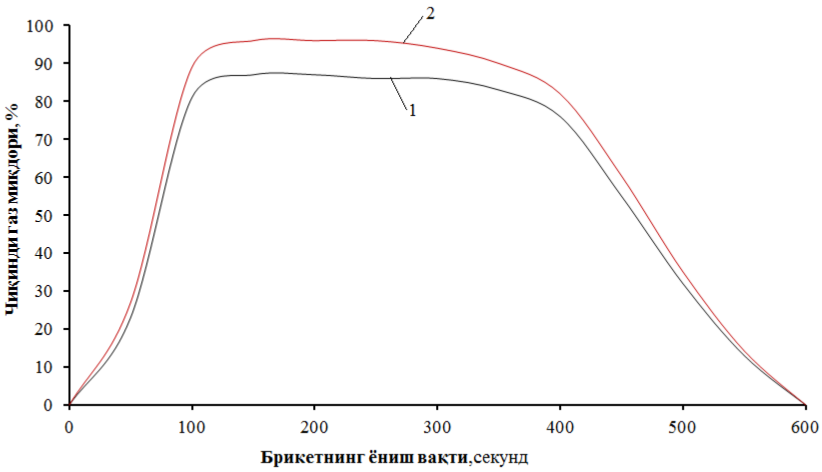
As a result, the arithmetic mean of the two measured values — within the range of permissible deviation — was accepted as the final result.

The outcomes of the study are presented in Figures 3 and 4 [1,10].



Briquette obtained based on 1 bar of alcohol; 2-briquette obtained based on paraffin waste.

Figure 3. The amount of smoke released during briquette burning.



Briquette obtained based on 1 bar of alcohol; 2-briquette obtained based on paraffin waste.

Figure 4. The amount of exhaust gas released during briquette burning.

From the graphical dependencies presented in Figures 2 and 3, it can be seen that as the ignition delay time of the coal briquette increases, the amount of smoke and exhaust gases released also increases. For example, in the graph shown in Figure 3, when the ignition delay time was in the range of 90–100 seconds, the smoke emissions from the briquette made from distillery stillage increased up to 83–86%. However, starting from 120 seconds, a sharp decrease was observed.

Similarly, for briquettes made from paraffin waste, smoke emissions increased up to 90–95% within the ignition delay range of 90–100 seconds, followed by a sharp decline starting from 125 seconds. This behaviour is associated with the transition of the briquette into the complete combustion phase.

In contrast, the graph in Figure 4 shows that the volatile components (light volatile gases formed during combustion) in the briquette exhibit a slight increase at the beginning of combustion. This occurs until the briquette reaches full combustion. During the period of glowing, stable combustion (between 150–400 seconds), the curve remains relatively flat for some time, and as the heat capacity of the briquette decreases, the release of light volatile gases also declines. This process continues until the briquette is fully burned out.

The conducted studies show that in both cases, the amount of exhaust and smoke gases released does not exceed the MAC (Maximum Allowable

Concentration) standards. This fully satisfies the environmental requirements imposed on such briquettes. The difference from theoretical calculations did not exceed 4.1%.

CONCLUSION

The conducted studies revealed that the addition of binders to increase briquette strength has a minimal effect on the amount of smoke and exhaust gases released during combustion. Experimental results showed that this effect also depends on the proportion of the binders added. For example, when the binder content exceeded 15%, the amount of smoke increased in coal briquettes made from paraffin waste, whereas a noticeable decrease in smoke was observed in briquettes made from distillery stillage. Conversely, the volume of light volatile gases increased in inverse proportion.

The reprocessing of experimental results and laboratory analyses confirmed that both types of binders are suitable options for producing quality briquettes. However, in order to comply with MAC (Maximum Allowable Concentration) environmental standards (see paragraph two), it was determined that the use of a combination of these binder types is more appropriate.

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