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# BRIQUETTING OF COAL-SLURRY MIXED WITH WOOD SAWDUST PELLETS

**Abstract.** Experimental data obtained in the development of technology for the production of briquetted fuel from screenings of brown coal using various components - coal slurry and sawdust are presented. The influence of humidity, granulometric composition of coal, the type and concentration of binder, pressing pressure on the mechanical properties of materials, the optimal compositions were determined. Combined briquetting of coal screening and coal slurry with wood sawdust in a certain granular composition allows to obtain fuel briquettes with the required strength of state standard. The use of sludge and sawdust will significantly reduce the cost of briquettes while maintaining their performance. The presence of sawdust in the briquette increases the porosity of the briquette, improves the ignition process. The sizing composition of the coal and the distribution of grains of various sizes in the charge must correspond to its maximum compaction, which ensures the greatest strength of contacts between the grains and high strength of the briquettes with a minimum consumption of the binder for briquetting. The results of the pilot studies show the possibility and prospects of using local raw materials (coal mining waste, wood processing) for the production of briquetted fuel.

**Key words:** fuel, briquettes, brown coal, coal sludge, sawdust.

**Introduction.** Currently, there is an increasing interest in the world over the use of non-traditional renewable energy sources in various sectors of the economy. The driving force behind this process is the ongoing changes in the energy policy of countries with the restructuring of the fuel and energy complex for energy-saving and resource-saving technologies both in industry and in the housing and civil complex. The existing environmental tension in the mining and processing regions of the country is largely associated with the storage of solid combustible wastes, which, losing their energy and economic value, violate the natural environment. Thus, in 2007, when processing 29.2 million tons of steam coal, 156,000 tons of slurry and 7,516,000 tons of screening were formed, coking coal - 377,000 tons of slurry and 2,023,000 tons of screening. Every year, forest-industry complexes process more than 300 million $m^3$ of timber, and about 150 million $m^3$ of usable wood waste is produced [3-6]. The development of these local technogenic deposits with obtaining improved fuel resources is feasible on the basis of briquetting technology. Great Britain, France, Germany, Poland, Turkey, the USA, Australia and other countries produce briquettes and pallets based on coal waste and biomass (wood sawdust, straw, flax, sunflower husks, maize cobs, etc.) using various technologies. This is due to the fact that combustion of coal briquettes, compared to ordinary coal, increases the efficiency of combustion devices by 25-30%, more than two emissions of solid substances with flue gases decrease [4-8]. The only large enterprise in Kazakhstan that produces briquetted coal from the small fraction by Turkish technology, which was previously simply poured into ash dumps, was launched in 2013 in the Pavlodar region [9]. Thus, it is very important to develop a technology for briquetting coal dust, screenings, sludges and biomass wastes.

The obtaining processes of coal-fuel briquettes with wood sawdust are not fundamentally new, however, producing briquettes in specific technological conditions is a sought-after solution. For example, the work [10] describes a method for manufacturing fuel briquettes from coal dust, sawdust, crushed bark, straw and other organic waste. Disadvantages of the briquettes obtained with this technology are low compressive strength (0.3-1.1 MPa), the presence of clay in briquettes, which increases the ash content of the briquette, reduces the heat of combustion of briquettes. In the patent [11], with brown coal less than 2.5 mm in size and sawdust of coniferous trees, a mixture without a binder is produced, from which, with a sawdust content of 17±1% by weight, a briquetting temperature of 90±5°C and a briquetting specific pressure of 50±2 MPa, briquettes with a mechanical compressive strength of at least 7.8 MPa are manufactured. Each of the above methods has drawbacks, affecting the price and properties of the briquettes obtained. Moreover, the used binder additives are generally scarce, have a high cost, and their purchase for small enterprises is inefficient.

In this paper we describe the results of studying the optimal conditions for obtaining coal-fuel briquettes based on the brown coal screening of the Ekibastuz deposit in a composition with slurry and sawdust. The use of sludge and sawdust will significantly reduce the cost of briquettes while maintaining their performance.

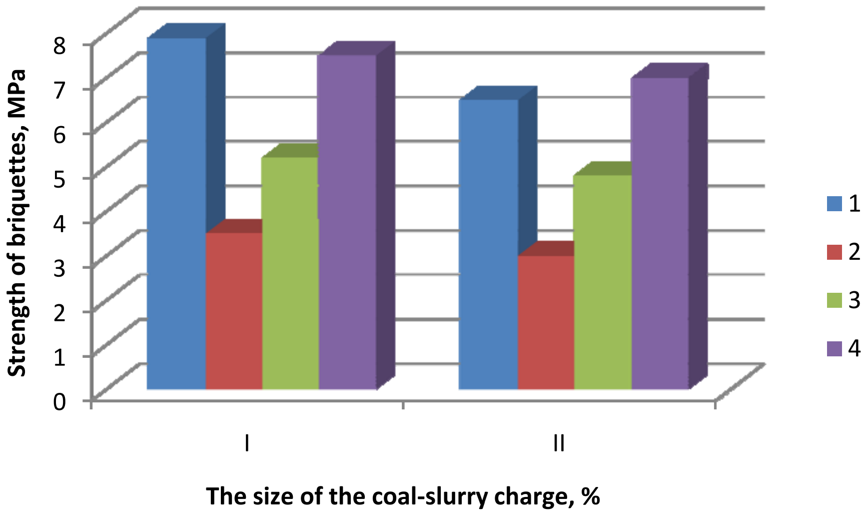
**Experimental part.** The briquetting process involved preparing the components, compiling the compositions, heating the mixture (if necessary), pressing, drying and cooling. The briquetting process was carried out on a plant including a sieving machine, a ball mill, a dispersant mixer, a briquette press and a drying cabinet. The experiments were conducted with coal dust from the Ekibastuz field with the following technical characteristics: ash content ($A^d$) 22-25%, total moisture ($W^a$) 6.8-7.3 %, volatile-matter yield ($V^{daf}$) 24-26 %, mass fraction of sulfur ($S^d_t$) 0.4-0.7%, net calorific value ($Q_i^r$) 4300-4500 Kcal/mol. Dispersion of coal dust for experiments was d = 0÷5 mm and coal slurry ЦОФ-7 (marks КЖ, К, К-12): ash content ($A^d$) 34.5 %; total moisture ($W^a$) 14.1-18.2 %; volatile-matter yield ($V^{daf}$) 25.6 %; mass fraction of sulfur ($S^d_t$) 0.63 %; net calorific value ($Q_i^r$) 4450 Kcal/kg. In all experiments, the ratio of coal:slurry (coal charge) in the composition was 8:2, wood (pine) sawdust was used in the following percentage: 2; 3; 5; 7 and 10. The costs of binders - the sodium salt of carboxymethyl cellulose (CMC-H) and liquid glass, ranged from 1 to 12%, the moisture content of the blend composition was 16-18%. The resulting mixture was placed in a matrix (diameter 25 mm) and pressed on presses PGR-20, P-10 and P-250 with holding briquettes at a pressure of 10 s. The briquetting was also carried out on a screw extruder press ПШ 1000 (extrusion pressure 275 kgf/cm$^2$ (27 MPa) .The strength of briquettes converged in the range of 3-5%. The granulometric composition of the charge corresponded to the given parameters at all stages of the experiments. 7 briquettes for each series of experiments were produced in accordance with GOST 21289-75.

**Results and discussion.** In the scientific literature there are no strict criteria for assessing the briquetting of coals and carbon-containing materials. When developing the technical features of the briquetting process, we studied the influence on on processability and the quality of briquettes of factors such as the grain composition of the coal-slurry mixture, the ratio of the charge components, the temperature of the closing mixture, the extrusion pressure, the briquetting hardening regime. At the initial stage of the study, the influence of the moisture content of coal dust on the mechanical properties of briquettes was considered, which plays an important role in the mechanism of briquette formation, the humidity of the air-dry state of coal material, which is within 10-11% [12]. An increase in the moisture content of coal from 12 to 20% has a weakening effect on the adhesion between coal and binder due to a sharp disruption of direct adsorption contacts in the interphase zone, which leads to a drop in strength.

The optimal moisture content of coal charge, corresponding to the highest strength of briquettes, is not constant and depends on the extrusion pressure, grain size and coal nature. When the extrusion pressure is increased and the particle size is reduced, as well as the hardness is increased and the coal briquetteability is deteriorated, the optimum moisture is shifted towards smaller values. The size of the batch particles affects the optimum moisture content mainly at high extrusion pressures [13].

The next important point, which plays a significant role in the briquetting process, is the preparation of coal charge. The main criterion for optimization was the strength of the finished briquette, while also taking into account the economic and technical aspects of the use of each component. The coal-slurry charge, having a certain granular composition and moisture content of about 10-12%, was carefully moved with the binder until a homogeneous mass was achieved. As a binder, 5% solutions of liquid glass and CMC-H were used. At this stage, miniature cylindrical briquettes with a diameter of 25 mm and a height of 13-15 mm were made to establish the optimum value of the component composition. The extrusion pressure was assumed to be constant (20 MPa). The resulting raw briquettes were sent to the drying cabinet at 105$^0$C for 1 hour after pressing. Humidity of briquettes after drying did not exceed 1-1.5%. After cooling to room temperature, the resulting samples of briquettes were subjected to uniaxial compression in order to measure the fracture pressure. At the moment of briquette destruction, the indications of the press dynamometer were taken, the average value of the fracture force was calculated, and the average compressive strength of the briquette was determined per unit area of the insert.

As a result of the research, it was established that the strength of compositions, consisting of coal grains of 2,5-3,0 mm in size, is approximately 2.5 times lower than that of briquettes obtained from coal of 0-1,25 mm in size with the same briquetting parameters. This fact is probably due to that during the pressing process, large coarse grains are destroyed and additional surfaces not wetted by the binder are formed. The results of the investigation of the influence of the granulometric composition of the coal-slurry charge on the mechanical properties of briquettes are shown in Fig. 1, it is seen that the increase in compressive strength is particularly noticeable in briquette samples containing grains with the smallest size (coal class 0-1.25 mm).



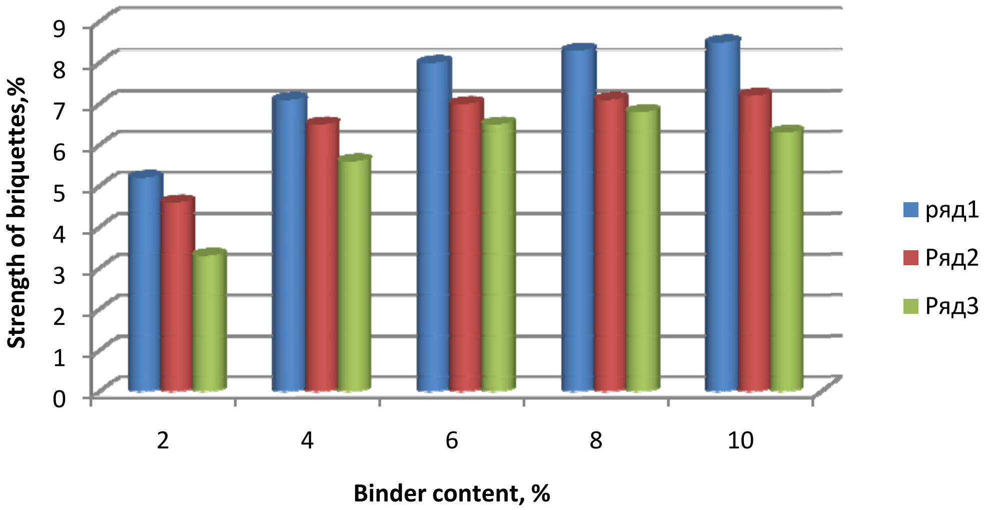

1 – grind size 0-1.25mm; 2 – grind size 1.25-3.0mm; 3 – 0-1.25 mm (50%), 1.25-2.5mm (45%);
4 – 0-1.25 mm (70%), 1.25-2.5mm (25%), 2.5-5.0mm (10%).
Binder: I – liquid glass (5 mass.%), II – CMC-H (mass.%)

Figure 1 – Influence of coarseness of coal-slurry charge on the strength of briquettes, MPa

In further studies, the optimal granulometric composition of the coal-slurry charge was (%): class particles of the 0-1 mm - 40-60; 1-2 mm -30-35%.

At the next stage, the influence of the content of pulverized sawdust on the strength of the finished coal-fuel briquette was studied. The criterion for evaluation was, as before, the mechanical strength of the obtained briquettes. In order to study the change in the strength of a raw briquette from the content of wood sawdust, briquetting of the obtained charge mixtures with sawdust in matrices with a diameter of 25 mm at a pressure of 50±2 MPa was carried out. The briquettes were made in a cylindrical shape 45-50 mm in height and 30 g in weight. The costs of binders ranged from 1 to 10% of the mass of coal-slurry charge. Figure 2 shows the graphical dependence of the strength of briquettes on the proportion of binder in the composition of coal-slurry charge with different content of sawdust.

The resulting raw briquettes were sent to the drying cabinet at 105$^0$C for 1 hour after pressing. Further, for the obtained briquettes, the mechanical strength for compression was determined in accordance with GOST 21289-75. Test conditions and physical and mechanical parameters of briquettes are presented in a graph-diagram. From the presented data of the diagram it follows that the mechanical strength of the compression briquettes reaches the value required by GOST (7.8 MPa) with the content of sawdust equal to 2% in the mixture and 6% of the binder content. Briquettes, obtained with a content of




Content of sawdust, %: row 1 - 2; row 2 –10; row 3 – 15%

Figure 2 – Dependence of the strength of the finished briquette on the binder content (liquid glass) and wood sawdust in the coal-slurry charge

wood sawdust above 10% by weight, have a mechanical compressive strength of not more than 7.4 MPa (GOST - minimum 7.8 MPa) at 10% binder content, i.e. These combinations of compositions and briquetting pressures are unacceptable.

The formed coal-fuel briquettes with sawdust (2%, diameter 25 mm, length 60-100 mm), obtained on the extruder press, had strength (6-7 MPa), sufficient to ensure that the briquettes did not break during transportation to the place of hardening and storage in bags. Hardening of briquettes is possible both in conditions of natural hardening at an ambient temperature of 18-20$^0$C and relative humidity of 55-60%, and at forced drying. To intensify the processes of structure formation, it is possible to heat the briquettes under the following conditions: temperature 105-110$^0$C, holding time 1 h, cooling air. Briquettes are easily ignited and burn with a barely discernible red glow without the formation of an open flame, soot and smell. The specific heat of combustion is 28-30 MJ. The density of the briquettes is 350-450 kg/m$^3$. The presence of sawdust in the briquette increases the porosity of the briquette, and, consequently, improves the ignition process, the strength of briquettes is sufficient for stacking and transportation. An increase in the amount of sawdust above 5%, reduces the strength characteristics of briquettes, and when burned, these briquettes do not retain their shape (they begin to crumble).

**Conclusion.** The results of the pilot studies show the possibility and prospects of using local raw materials (coal mining waste, wood processing) for the production of briquetted fuel. Combined briquetting of coal screening and coal slurry with sawdust in a certain granulometric size composition allows to receive fuel briquettes with the required strength by GOST. The sizing composition of the coal and the distribution of grains of various sizes in the charge must correspond to its maximum compaction, which ensures the greatest strength of contacts between the grains and high strength of the briquettes with a minimum consumption of the binder for briquetting.

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## КӨМІР ҚОҚЫСЫ МЕН АҒАШ ҮГІНДІЛЕРІНІҢ ҚОСПАСЫН БРИКЕТТЕУ

**Аннотация.** Қоңыр көмірлердің қалдықтарынан, әртүрлі компоненттерді - көмір ұнтақтары және ағаш үгінділерін қолдана отырып брикеттелген отындарын өндіру технологиясын әзірлеуде алынған тәжірибелік мәліметтер көрсетілген. Көмірдің гранулометриялық құрамы, ылғалдылығына әсері, байланыстырғыштың түрлері мен концентрациясы, материалдарды тығыздау қысымының механикалық қасиеттеріне әсері зерттеліп, оңтайлы құрамдары анықталған. Көмір қалдықтары және көмір қоқысы мен ағаш үгінділермен бірге нақтылы бір гран құрамында құрамалы брикеттеумен ГОСТ-пен талап ететін берік отын брикеттерін алуға мүмкіндік береді. Қоқысты және ағаш үгінділерін қолдану брикеттерді сақтау кезінде олардың қолдану сапаларының өзіндік құнын төмендеуіне маңызды мүмкіндік береді. Брикетте үгінділердің болуы брикеттің қуыстылығын жоғарылатады және тұтану процессін жақсартады. Дәндер арасы байланысуында ең үлкен беріктікті және байланыстырғыштың ең төменгі шығымында брикеттердің жоғары беріктілігін қамтамасыз ететін брикеттеу кезінде көмірдің елеуіштік құрамы және шихтада әртүрлі ірілікте дәндердің таралуы оның өте жоғары тығыздықтығына сәйкес келуге тиісті. Өткізілген тәжірибелік зерттеулердің нәтижелері брикеттелген отын өндірісі үшін жергілікті шикізат қорларын (көмір өндірісі қалдықтары, ағаш өңдеу қалдықтары) қолдану мүмкіндіктерін және даму келешегін көрсетеді.
**Түйін сөздер:** отын, брикет, қоңыр көмір, көмір қоқысы, ағаш үгінділері.

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## БРИКЕТИРОВАНИЕ УГОЛЬНО-ШЛАМОВОЙ СМЕСИ С ДРЕВЕСНОЙ ОПИЛКОЙ

**Аннотация.** Представлены экспериментальные данные, полученные при разработке технологии производства брикетированного топлива из отсевов бурых углей с использованием различных компонентов – угольного шлама и древесных опилок. Исследовано влияние влажности, гранулометрического состава угля, вида и концентрации связующего, давления прессования на механические свойства материалов, установлены оптимальные составы. Комбинированное брикетирование угольного отсева и угольного шлама с древесными опилками в определенном грансоставе позволяет получать топливные брикеты с требуемой ГОСТом прочностью. Использование шлама и древесных опилок позволит существенно снизить себестоимость брикетов при сохранении их эксплуатационных качеств. Присутствие в брикете опилок повышает пористость брикета, улучшает процесс воспламенения. Ситовый состав угля и распределение зерен различной крупности в шихте должны соответствовать ее максимальной уплотняемости, при которой обеспечиваются наибольшая прочность контактов между зернами и высокая прочность брикетов при минимальном расходе связующего на брикетирование. Результаты проведенных экспериментальных исследований показывают возможность и перспективность использования местных сырьевых ресурсов (отходов угледобычи, деревообработки) для производства брикетированного топлива.
**Ключевые слова:** топливо, брикеты, бурый уголь, угольный шлам, древесные опилки.

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