UDC 662.6:662.7 https://doi.org/10.70769/2181-2284.ME.3(24).2026.3

INVESTIGATION OF THE MATERIAL BALANCE OF A UNIT FOR THE PREPARATION AND COMBUSTION OF ALTERNATIVE COAL-WATER FUEL

Uzakov Gulom Norboevich-DSc, Professor,
https://orcid.org/0009-0005-7386-8075 e-mail: uzoqov66@mail.ru
Uzboev Maftun Dusiyarovich-Researcher
e-mail: uzboyev.maftun@samdaqu.edu.uz

Karshi State Technical University, Karshi, Uzbekistan

Abstract: Introduction. *The growing demand for environmentally acceptable and resource-efficient fuel technologies makes the development of alternative coal–water fuels based on biomass pyrolysis products increasingly relevant.*

Materials and methods. *This study evaluates the material balance of an integrated unit designed for the preparation and combustion of alternative coal-water fuel while simultaneously converting biomass into useful pyrolysis products.*

Results. *Experiments were conducted with cotton stalk chips and wood chips at 500-550 °C. For a reactor volume of 0.196 m^3, 26 kg of cotton stalk chips yielded 6.4 kg of pyrolysis gas, 9.2 kg of pyrolysis liquid, and 9.6 kg of pyrolysis char, with a mass loss of 0.8 kg. For 30 kg of wood chips, the corresponding yields were 7.8, 10.4, and 11.2 kg, with a loss of 0.6 kg.*

Conclusions. *The results confirm that the proposed unit enables effective biomass conversion and internal regeneration of fuel components, improving resource efficiency and supporting integrated alternative-fuel production under practical operating conditions.*

Keywords: *coal-water fuel, biomass pyrolysis, material balance, pyrolysis gas, pyrolysis liquid, pyrolysis char, alternative fuel.*

Дата поступления: 10.08.2026. После обработки: 15.08.2026 Принято печать: 23.09.2026

For citation: *Uzakov G.N., Uzboev M.D. Investigation of the Material Balance of a Unit for the Preparation and Combustion of Alternative Coal-Water Fuel based on Biomass Pyrolysis Products. Muqobil energetika. 2026. 3(24). pp. 35-39.*

UO‘K 662.6:662.7

MUQOBIL “SUV-KO‘MIR” YOQILG‘ISINI TAYYORLASH VA YOQISH QURILMASINING MODDIY BALANSINI TADQIQOT QILISH

Uzoqov G‘ulom Norboyevich-DSc, Professor,
https://orcid.org/0009-0005-7386-8075 e-mail: uzoqov66@mail.ru
Uzboyev Maftun Dusiyarovich-mustaqil izlanuvchi,
e-mail: uzboyev.maftun@samdaqu.edu.uz

Qarshi davlat texnika universiteti, Qarshi, O‘zbekiston

Annotatsiya. Kirish. *Ekologik maqbul va resurslardan samarali foydalanishga asoslangan yoqilg‘i texnologiyalariga bo‘lgan talabning ortib borishi biomassa pirolizi mahsulotlari asosida muqobil “suv-ko‘mir” yoqilg‘ilarini ishlab chiqishning dolzarbligini oshirmoqda.*

Materiallar va usullar. *Mazkur tadqiqot ishida biomassa xomashyosini foydali piroliz mahsulotlariga aylantirish bilan bir vaqtda muqobil “suv-ko‘mir” yoqilg‘isini tayyorlash va yoqishga mo‘ljallangan qurilmaning moddiy balansi aniqlandi.*

Natijalar. *Tajriba jarayonida g‘o‘zapoya qipig‘i va yog‘och qipig‘i 500-550 °C haroratda piroliz qilindi. Hajmi 0,196 m^3 bo‘lgan reaktorda 26 kg g‘o‘zapoya qipig‘idan 6,4 kg piroliz gazi, 9,2 kg piroliz suyuqligi va 9,6 kg piroliz ko‘miri olindi, moddiy yo‘qotish 0,8 kg ni tashkil etdi. 30 kg yog‘och qipig‘i qayta ishlanganda esa mos ravishda 7,8 kg piroliz gazi, 10,4 kg piroliz suyuqligi va 11,2 kg piroliz ko‘miri olindi, moddiy yo‘qotish 0,6 kg ni tashkil etdi.*

Xulosa. *Olingan natijalar taklif etilgan qurilma biomassani samarali qayta ishlash hamda hosil bo‘lgan piroliz mahsulotlaridan muqobil “suv-ko‘mir” yoqilg‘isini tayyorlashda qayta foydalanish imkonini berishini ko‘rsatdi.*

Kalit so‘zlar: *suv-ko‘mir yoqilg‘isi, biomassa pirolizi, moddiy balans, piroliz gazi, piroliz suyuqligi, piroliz ko‘miri, muqobil yoqilg‘i.*

УДК 662.6:662.7

ИССЛЕДОВАНИЕ МАТЕРИАЛЬНОГО БАЛАНСА УСТАНОВКИ ДЛЯ ПРИГОТОВЛЕНИЯ И СЖИГАНИЯ АЛЬТЕРНАТИВНОГО ВОДОУГОЛЬНОГО ТОПЛИВА

Узаков Гулом Норбоевич- д.т.н., проф.,
https://orcid.org/0009-0005-7386-8075 e-mail: uzoqov66@mail.ru
Узбоев Мафтун Дусиярович-исследователь,
e-mail: uzboyev.maftun@samdaqu.edu.uz

Каршинский государственный технический университет, Карши, Узбекистан

Аннотация. Введение. *Рост потребности в экологически приемлемых и ресурсоэффективных топливных технологиях повышает актуальность разработки альтернативного водоугольного топлива на основе продуктов пиролиза биомассы.*

Материалы и методы. *В работе исследован материальный баланс интегрированной установки, предназначенной для приготовления и сжигания альтернативного водоугольного топлива с одновременным преобразованием биомассы в полезные продукты пиролиза.*

Результаты. *В качестве сырья использовались измельченные стебли хлопчатника и древесные отходы, пиролиз которых осуществлялся при температуре 500-550 °C. При объеме пиролизного реактора 0,196 $м^3$ из 26 кг измельчённых стеблей хлопчатника было получено 6,4 кг пиролизного газа, 9,2 кг пиролизной жидкости и 9,6 кг пиролизного угля, при этом потери массы составили 0,8 кг. При переработке 30 кг древесной щепы выход пиролизного газа составил 7,8 кг, пиролизной жидкости - 10,4 кг, пиролизного угля - 11,2 кг, а потери массы - 0,6 кг.*

Заключение. *Полученные результаты подтверждают, что разработанная интегрированная установка обеспечивает эффективную переработку биомассы и позволяет повторно использовать полученные продукты пиролиза в качестве компонентов при приготовлении альтернативного водоугольного топлива.*

Ключевые слова: *водоугольное топливо, пиролиз биомассы, материальный баланс, пиролизный газ, пиролизная жидкость, пиролизный уголь, альтернативное топливо, регенерация топлива.*

Introduction

Globally, considerable attention is being paid to the development of new scientific and technological solutions aimed at introducing alternative, environmentally acceptable, and economically efficient fuels into the energy production sector, as well as improving the preparation and combustion technologies of coal-water fuel (CWF) in order to reduce harmful atmospheric emissions [1-2]. Although the utilization of renewable energy sources has been steadily expanding, coal continues to occupy an important position in the global fuel and energy balance, accounting for approximately 30% of total energy consumption. Therefore, the future development of coal

combustion technologies requires the creation of highly efficient and environmentally acceptable scientific and technological solutions [3].

According to industry estimates, the global coal–water fuel market was valued at USD 2.55 billion in 2023 and is projected to reach USD 3.45 billion by 2030, expanding at an average annual growth rate of 5.05% during 2024-2030 [3,4].

In this context, particular attention is being focused on the development of a new generation of coal-water alternative fuel compositions with an optimized formulation based on biomass pyrolysis products, the improvement of their thermophysical properties, the development of an optimal design for coal–water fuel combustion systems, and the enhancement of combustion process efficiency [5].

Materials and methods

To determine the material and heat balance of the preparation and combustion processes of alternative coal–water fuel, the technological scheme and experimental setup proposed in this study were used. The system consists of a combustion chamber, biomass pyrolysis reactor, water-heating chamber, condenser, liquid pyrolysis product collection tank, filter, and gas holder [2].

The high-temperature combustion products generated during the combustion of the alternative coal-water fuel (CWF) in the combustion chamber provide the required thermal regime for the biomass pyrolysis reactor. After passing through the pyrolysis reactor, the residual heat of the combustion products is recovered in the water-heating chamber located in the upper section of the unit.

The vapor-gas mixture generated during the pyrolysis process is directed to the condenser, where the condensable products are separated and collected in the liquid pyrolysis product storage tank. The non-condensable pyrolysis gas is subsequently passed through the filtration system and supplied to the gas holder.

The technological scheme and the general view of the experimental prototype of the proposed unit are presented in Figures 1 and 2, respectively.

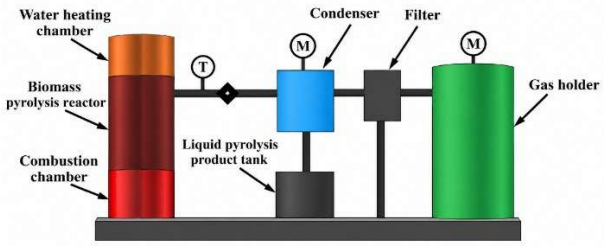

Fig. 1. Technological scheme of the experimental setup.

Fig.2. Experimental setup.

Material Balance of the Preparation and Combustion Process of Alternative Coal-Water Fuel

The material balance of the preparation and combustion process of the alternative coal-water fuel (CWF) was determined in three consecutive stages. This approach makes it possible to quantitatively evaluate the material flows entering and leaving the combustion chamber, the

distribution of biomass pyrolysis products, and the amount of alternative fuel that can be regenerated within one operating cycle of the proposed unit.

Stage 1. Material balance of the combustion chamber

At the first stage, the material balance of the combustion chamber was determined. According to the law of conservation of mass, the total mass of the alternative coal–water fuel and combustion air supplied to the combustion chamber must be equal to the total mass of the combustion products leaving the chamber:

$$m_{in} = m_{out} \tag{1}$$

or,

$$m_{CFW} + m_{air} = m_{f.g.} + m_{ash} \tag{2}$$

here, m_{CFW} is the mass of the coal-water fuel, kg; m_{air} is the mass of air supplied for combustion, kg; $m_{f.g.}$ is the mass of flue gases, kg; and m_{ash} is the mass of ash, kg.

These equations provide the basis for determining the distribution of the initial fuel mass between gaseous combustion products and solid mineral residue. The obtained results are subsequently used in the overall material and heat balance of the integrated combustion–pyrolysis system.

Stage 2. Material balance of the biomass pyrolysis reactor

At the second stage, the material balance of the biomass pyrolysis reactor was established. During thermal decomposition, the biomass feedstock is converted into three main useful products-liquid pyrolysis products, non-condensable pyrolysis gas, and solid carbonaceous residue-as well as a certain amount of unaccounted or retained mass.

Accordingly, the material balance of the pyrolysis reactor can be expressed as

$$m_b = m_{pl} + m_{pg} + m_{pc} + m_{lost} \tag{3}$$

m_b is the mass of biomass feedstock loaded into the pyrolysis reactor, kg; m_{pl} is the mass of liquid pyrolysis products, kg; m_{pg} is the mass of pyrolysis gas, kg; m_{pc} is the mass of pyrolysis char, kg; and m_{lost} is the unaccounted mass loss, kg.

$$m_b = \rho_b \cdot V_r \cdot \varphi \tag{4}$$

where ρ_b is the bulk density of the biomass feedstock, kg/m^3; V_r is the effective volume of the pyrolysis reactor, m^3; and φ is the biomass filling coefficient of the reactor. In the present study, the reactor filling coefficient was taken as **0.90**, corresponding to a biomass loading level of 90%.

The mass loss is determined using the following equation:

$$m_{lost} = m_{f.w.} + m_{f.c.} = \left(m_{f.w.}^{last} - m_{f.w.}^{first}\right) + \left(m_{f.c.}^{last} - m_{f.c.}^{first}\right) \tag{5}$$

where, $m_{f.w.}^{first}, m_{f.c.}^{first}$ – is the total mass of the water and charcoal filters before the experiment, kg; $m_{f.s.}^{key}, m_{f.k.}^{key}$ – is the total mass of the water and charcoal filters after the experiment, kg.

Stage 3

The distribution balance of the obtained alternative fuels is calculated as follows:

$$m_{pl} = m_{pl,wcf} + m_{pl,r} \tag{6}$$

$$m_{pc} = m_{pc,wcf} + m_{pc,r} \tag{7}$$

where, wcf- is the fraction of the pyrolysis products used for preparing the alternative coal-water fuel, and r is the fraction remaining in reserve.

The material balance for preparing new batches of the alternative coal-water fuel is calculated as follows:

$$m_{wcf} = m_c + m_{pl,wcf} + m_{pc,wcf} + m_{water} + m_{pl} \tag{8}$$

Based on the material-balance equations describing the preparation and combustion of the alternative coal-water fuel, the concept of the fuel regeneration coefficient K_{reg} is introduced and calculated as follows:

$$K_{reg} = \frac{m_{wcf}}{m_{wcf,burn}} \tag{9}$$

where, m_{wcf} –is the mass of alternative coal-water fuel prepared from the alternative fuel products obtained during one operating cycle of the unit, kg; $m_{wcf,burn}$ – is the mass of alternative coal-water fuel combusted in the combustion chamber during one operating cycle of the unit, kg.

If $K_{reg} = 1$, the amount of newly prepared alternative coal–water fuel is equal to the amount of fuel consumed during one operating cycle. If $K_{re} > 1$, the unit produces more alternative coal-water fuel than is required for its own operation, and vice versa.

Results

The experimental results obtained for the alternative fuels produced from biomass feedstock loaded into the pyrolysis reactor section of the alternative coal-water fuel preparation and combustion unit are presented in Table 1.

Table 1.

Results of the material balance of biomass processing in the pyrolysis reactor of the unit

Biomass type	PR volume, m^3	Density,, kg/m^3	m_b, kg	Pyrolysis temp., °C	Pyrolysis gas, kg	Pyrolysis liquid, kg	Pyrolysis char, kg	m_{lost} kg
Cotton stalk chips	0,196	147	26	500-550	6,4	9,2	9,6	0,8
Wood chips		170	30		7,8	10,4	11,2	0,6

According to the experimental results presented in Table 4.1, when 26 kg of cotton stalk chips or 30 kg of wood chips were loaded into a pyrolysis reactor with a volume of 0.196 m^3 during one operating cycle and processed at a temperature of 500–550 °C, the corresponding yields were 6.4 and 7.8 kg of pyrolysis gas, 9.2 and 10.4 kg of pyrolysis liquid, and 9.6 and 11.2 kg of pyrolysis char, respectively.

The material losses amounted to 0.8 kg for cotton stalk chips and 0.6 kg for wood chips. The experimental results showed that the yields of pyrolysis char and pyrolysis gas from wood chips were higher than those obtained from cotton stalk residues.

Conclusions

The conducted studies demonstrated that the developed unit for the preparation and combustion of alternative “coal-water fuel” based on biomass pyrolysis products enables the integrated utilization of the initial feedstock and allows quantitative assessment of material-flow distribution during combustion, pyrolysis, and subsequent reuse of the obtained products. The obtained results confirm the feasibility of the proposed technological scheme for increasing the utilization efficiency of biomass-derived products and developing a resource-efficient technology for producing alternative “coal-water fuel”.

References

[1]. Toshmamatov B.M., Uzboev M.D., Mamatova M. Development of a Method for Obtaining Energy-Efficient Water-Coal Fuel Based on Biomass Pyrolysis Products // Muqobil energetika. - 2025. - Vol. 4, No. 21. - P. 38-44.

[2]. Toshmamatov B.M., Uzboev M.D., Toshboev A.R. FTIR Analysis of Coal-Water Alternative Fuel // Muqobil energetika. - 2025. - Vol. 4, No. 21. - P. 45-48.

[3]. Uzboyev M.D., Davlonov X.A., Toshmamatov B.M. Suv-ko‘mir yoqilg‘isini tayyorlash texnologiyasi va uning takomillashtirish usullari tahlili // Muqobil energetika - 2025. - Vol. 3, No. 19. - P. 174-179.

[4]. Toshmamatov B.M., Uzboev M.D., Mamatova M.Sh. Analysis of Thermal and Technical Parameters of Alternative Fuels Obtained from Biomass Pyrolysis // American Journal of Applied Science and Technology. - 2025. - Vol. 5, No. 12. - P. 161-166.

[5]. Toshmamatov B.M., Uzboev M.D. Analysis of Technologies and Devices for Burning Alternative Biomass-Derived Fuels // International Journal of Science and Technology. - 2026. - Vol. 3, No. 2. - P. 13-17.