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DETERMINING THE POSSIBILITIES OF USING FLY ASH OF DTEK PRYDNIPROVSKA TPP AS ADDITIONAL RAW MATERIAL

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Abstract. Accumulated ash and slag waste (ASW) from fuel and energy complex facilities in Ukraine are considered potentially dangerous sources of environmental pollution in adjacent areas. More than 80% of the mineral composition of coal during combustion passes into fly ash (FA), up to 20% into slag. Ashes of coal-fired thermal power plants of Ukraine contain carbon in an amount of 5% to 30%. The increased content of unburned ash in ash and the complex granulometric composition do not allow for the widespread use of ash in the construction industry in large volumes (for concrete - it is prohibited by standards). At the same time, ash is a valuable raw material for recycling. For widespread use in the construction sector, it is necessary to bring the quality of ash to indicators that meet the standards. The conducted studies of fresh (dry) fly ash showed the prospects of its processing, the products of which are of industrial interest. The unburned carbon remaining in the ash is distributed unevenly by the size classes of the original product, the samples contain from 18.53% to 30.48% of unburned coal. The ash content is most in the +0-0.05 mm class, from 44.97% to 81.47%. If the ash is divided by the boundary size of 0.05 mm, it is possible to obtain an oversize product with a coal content of C_c from 6.05% to 14.6% with an ash content of C_a from 2.41% to 24.87%. Dry ash does not require dehydration and drying, additional transportation to the processing site. When processing dry ash, an important factor is stopping the build-up of the fly ash accumulators. The products of the complex technology of processing dry fly ash are the silicate part and carbon. The carbon part is presented in the form of dust-like particles of coke, which after extraction from the ash can be returned for further combustion. The silicate part of the ash requires additional research, since its mineralogical composition, its value and the feasibility of inclusion in the technology of complex processing for the purpose of subsequent disposal have not been determined. With appropriate methods of use and available technologies, ASW becomes a high-quality, cheap, accessible, wear-resistant, frost-resistant substitute for natural materials, having binding properties that are used in world practice in the production of concrete, bricks, asphalt concrete mixtures, ceramic tiles, thermal insulation, etc.

Keywords: coal, ash and slag waste from thermal power plants, coal combustion products, fly ash, processing experience, fly ash processing, classification.

1. Introduction

In Ukraine, as of 2021, about 30% of all electrical energy produced by enterprises of the fuel and energy complex came from thermal power plants (TPPs) [1–5]. Every year, during the combustion of coal at TPPs, ash and slag waste is generated in the amount of 7...9 million tons (50...200 grams per 1 kW/hour of produced electricity) [6]. The existing ash and slag storage facilities are overloaded (they already contain about 360 million tons), have large areas (about 3170 hectares) and require significant operating costs, which affect the increase in the cost of electricity production [6]. Accumulated ash and slag waste from fuel and energy facilities in Ukraine are potentially hazardous sources of environmental pollution and pose risks to the health of the population living in adjacent areas [1–20].

The mineral part of solid fuel usually includes calcium and magnesium carbonates, clay minerals, micas, quartz, feldspars, sulfides, oxides and iron hydroxides. During combustion, the components of the mineral part change, interact with each other and form different compounds, causing the formation of ash and slag of variable chemical and mineralogical composition. More than 80% of the mineral composition of coal during combustion passes into fly ash, up to 20% – into slag [6].

In world practice, coal combustion products (CCP) have proven themselves as valuable resources for the production of building structures and materials [15–18].

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Fly ash is also a valuable raw material for processing. The feasibility of technological and economic utilization follows from its huge reserves, complex chemical composition and physical properties [15–18, 21–23]. To take into account all these features, it is necessary to carry out a set of studies to study the properties and determine the consumers of the final products of fly ash processing [21–23]. The need for a complex method of its processing follows from the results of the studies [7, 8], which showed its complex elemental composition.

Due to obsolete thermal power plants and a number of other reasons, the specific weight of waste recycling in Ukraine is about 10%, while in the USA this figure reaches 80%, in Great Britain – 60%, in France – 72%. In Western Europe and Japan, ash dumps have been virtually eliminated on the territory of thermal power plants [6].

In Ukraine, for example, ash is not used in the production of autoclaved aerated concrete. This is due, on the one hand, to the availability of high-quality quartz sand, higher costs for transporting fly ash compared to quartz sand, the lack of guaranteed stability of ash properties, which is extremely important and noticeable in the production of low-density aerated concrete [6].

In the conditions of the energy crisis, environmental problems associated with the pollution of territories and emissions of greenhouse gases into the atmosphere, Ukraine should use the experience of developed countries to increase the volumes of use of fly ash, blast furnace granulated slag and other natural and man-made mineral impurities in cement compositions [21–23].

With appropriate methods of use and available technologies for disposal, ASW becomes a high-quality and cheap secondary resource, including a substitute for natural materials with binding properties, which are used in world practice in the production of concrete, bricks, asphalt concrete mixtures, ceramic tiles, thermal insulation, etc. This approach will allow us to solve a range of social, economic and environmental problems, save natural resources and obtain additional raw materials for the production of building materials [7, 8, 21–23].

2. Methods

The following methods were used in this study: analytical review of literary sources, comparative analysis; experimental studies; study of the composition of fly ash, as well as the possibilities and prospects of its use. Information resources of the Internet were used in the analysis of the state of the issue.

The aim of the work is to determine the possibilities of using fly ash from DTEK Prydniprovska TPP as additional raw materials.

Research object: use of fly ash (FA) of the DTEK Prydniprovska TPP.

To achieve the set goal, the following tasks were solved:

– to analyze previous studies of the properties of fly ash and the possibility of extracting useful components from it;

– to study the properties of fly ash collected at various points of the DTEK Prydniprovska TPP process flow chart (under different boilers and sections);

– to study the range of changes in the amount of carbon in ash under different boilers and sections and analyze the results obtained;

– to determine promising areas of application of fly ash as an additional raw material for the manufacture of various materials.

3. Theoretical and experimental parts

The composition of ash varies greatly depending on the type of coal used, combustion technology and waste disposal.

Ash of the same type of coal has different properties, especially from different types of coal. Almost all ashes contain organic inclusions (underburnt) in the form of coke and semi-coke – in the form of either independent particles or inclusions in large fractions. Ashes of coal-fired thermal power plants in Ukraine contain carbon in an amount of 5% to 30%. The increased content of underburnt in ash and the complex granulometric composition do not allow the widespread use of ash in the construction industry in large volumes (for concrete, it is prohibited by standards) [7, 8]. Therefore, technologies are needed that allow the use of ash with a high carbon content to obtain a useful product, or to bring the quality of ash to the indicators required by standards for widespread use in the construction industry.

As follows from publications [1–20], ash has an unstable chemical, granulometric and material composition, the yield of size classes and the content of useful components in them are also different, which indicates the impossibility of using the results obtained from one storage facility for others. This also indicates the need to create and implement various enrichment schemes for ash. Therefore, before developing a storage facility, it is necessary to study the physicochemical properties of the utilized components and the resulting commercial products, develop a processing scheme and determine promising areas for their use.

It should also be noted that the TPP has long-term ash from the waste storage facility (waterlogged) and fresh (dry) ash obtained immediately after the combustion of coal, i.e. before its storage. The technologies for processing fresh ash and ash from a waste storage facility differ, since ash from a storage facility is a compacted rock that requires preliminary preparation for processing (crushing and dehydration).

Dry ash does not require dehydration and drying, additional transportation to the processing site. When processing dry ash, an important factor is stopping the build-up of the fly ash accumulators.

The M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NAS of Ukraine) has been studying the properties of mineral raw materials from man-made deposits, including waste from thermal power plants, for many years. Determining the area of utilization of ash materials should be based on a detailed study of the fractional composition and properties of ash [7, 8, 21–25]. In this work, the properties of fresh ash (smoke filtrate) collected at various points in the technological scheme of DTEK Prydniprovska TPP (under different boilers and sections) were studied.

Figures 1–18 show the results of studies of averaged (based on the results of 5 samples) characteristics of ash samples, carried out in laboratory conditions of the IGTM of the NAS of Ukraine (designations K and RVV are the boiler and section numbers). The following notations are used in Figures 1–18: γ, % – output of classes; *d*, mm – particle size in classes; A^d, % – ash content of class; C_a, % – the amount of ash of a given class in the original product; C_c, % – the amount of coal of a given class in the original product.

3. Discussion of the results and prospects for the use of waste ash

As it can be seen from Figures 1–18, the unburned carbon remaining in the ash is distributed unevenly across the size classes of the original product, with samples containing from 18.53% to 30.48% unburned coal. If the +0.05-0.2 mm class is extracted from the ash, an oversize product containing coal can be obtained C_c from 6.05% to 14.6% with ash content C_a from 2.41% to 24.87%, which corresponds to the standard indicators for coal supplied to thermal power plants (the ash content of the product should not exceed 27%).

During laboratory studies it was found that in all samples ash is in the form of a sphere, in classes +0-0.02 mm a significant part is clay. It was established that the most ash part is contained in the class +0-0.02 mm from 44.97% to 81.47%. If the classification is carried out by the boundary size of 0.02 mm, it is possible to additionally extract from 5% to 7% of carbon with standard ash content [24, 25].

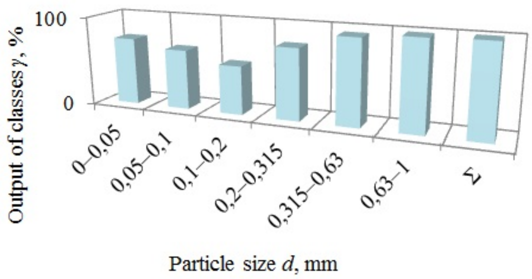
As a result of separation, the carbon content in the undersize product (silicate part with particle size less than 20 microns) can be reduced to 5–6% (it meets regulatory requirements), i.e. 4–5 times less than in the original product [24, 25].

The conducted studies show that the products of the complex technology of processing dry fly ash are the silicate part and carbon. The carbon part is presented in the form of dust-like particles of coke, which after extraction from the ash can be returned for further combustion. This saves the consumption of incoming coal. The silicate part of the ash requires additional research, since its mineralogical composition, its value and the feasibility of including it in the technology of complex processing for the purpose of subsequent disposal have not been determined.

It should be noted that dry ash does not require dehydration and drying, additional transportation to the place of additional enrichment. When processing dry ash, an important factor is stopping the build-up of the fly ash accumulators.

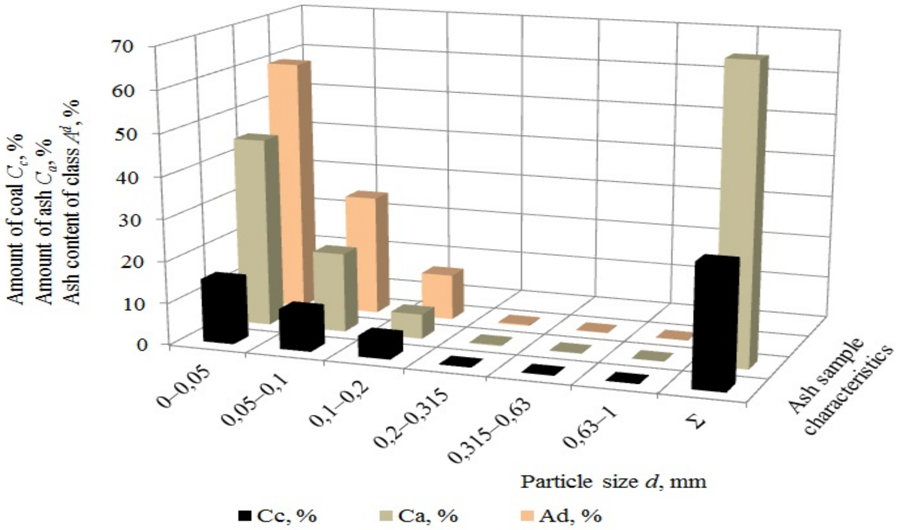
4. Conclusion

Thus, the accumulated ash and slag waste of the fuel and energy complex of Ukraine are considered to be potentially available secondary resources for use. During combustion, the components of the mineral part change, interact with each other and form different compounds that cause the formation of ash and slag of variable chemical and mineralogical composition. More than 80% of the mineral composition of coal during combustion passes into fly ash, up to 20% – into slag. Ash is a valuable raw material for disposal. Dry ash does not require dehydration and drying, additional transportation to the processing site. When processing dry ash, an important factor is stopping the build-up of the fly ash accumulators. The studies of fresh (dry) fly ash showed the prospects of its processing, the products of which are of industrial interest.



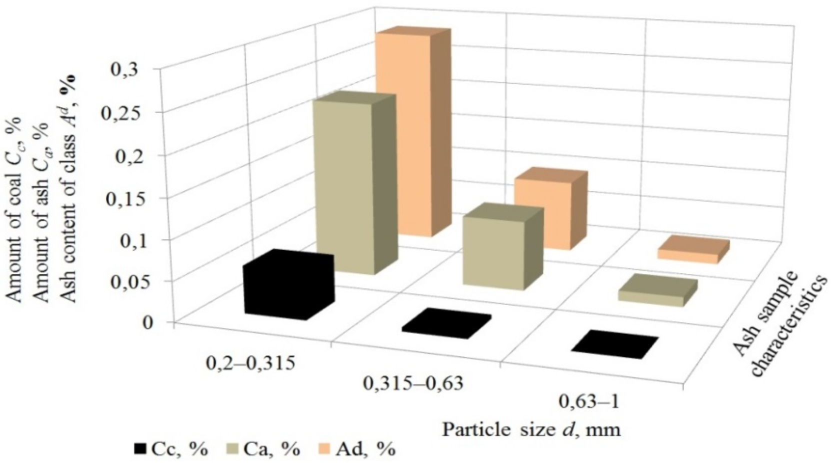
Σ – total output of classes

Figure 1 – Dependence of the output of classes γ on the particle size d (sample 1, K13, left section)



Σ – total amount of ash C_a and coal C_c in size classes

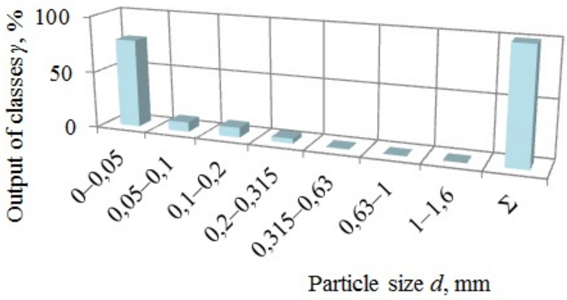
a)



b)

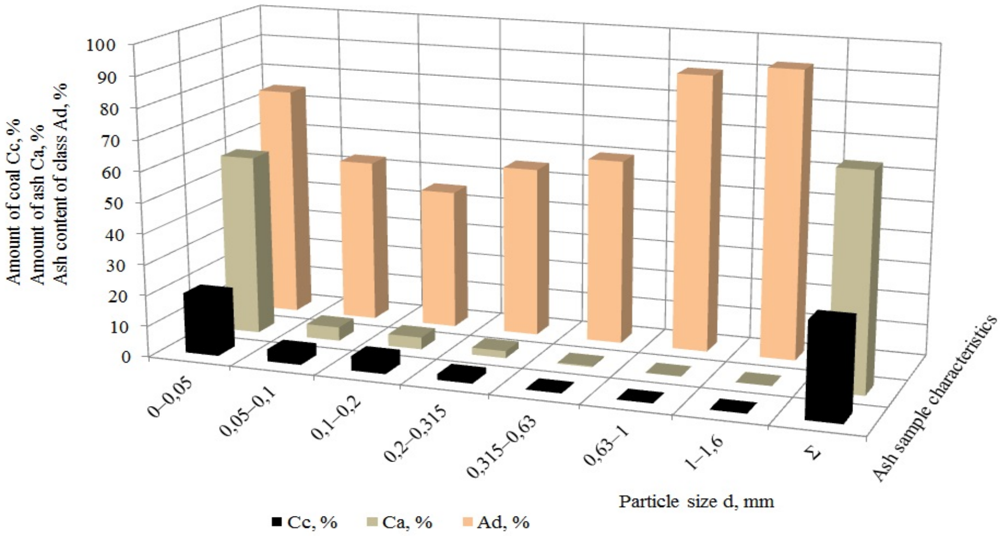
a) – size range from 0 mm to 1.0 mm; b) – size range from 0.2 mm to 1.0 mm

Figure 2 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 1, K13, left section)



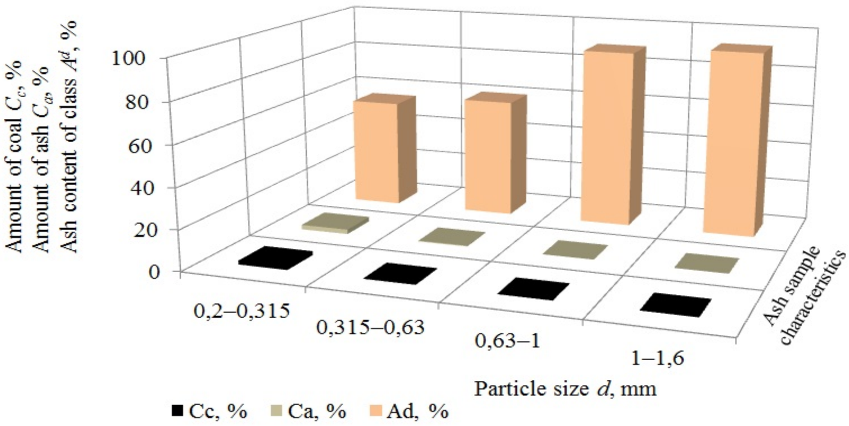
Σ – total output of classes

Figure 3 – Dependence of the output of classes γ on the particle size d (sample 2, K14, right section)



Σ – total amount of ash C_a and coal C_c in size classes

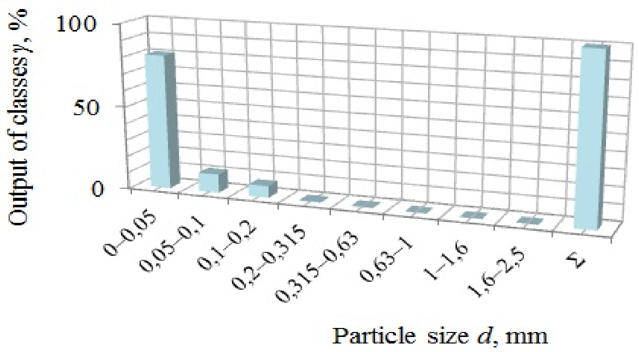
a)



b)

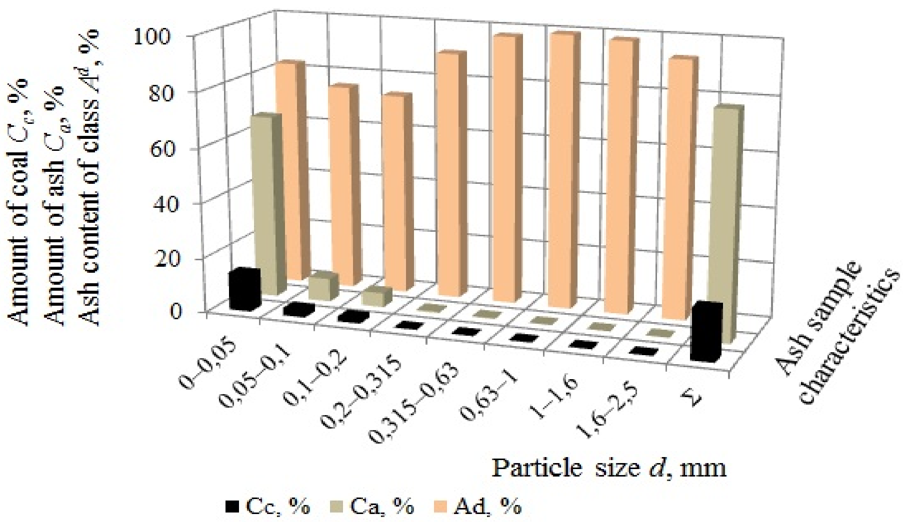
a) – size range from 0 mm to 1.6 mm; b) – size range from 0.2 mm to 1.0 mm

Figure 4 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 2, K14, right section)



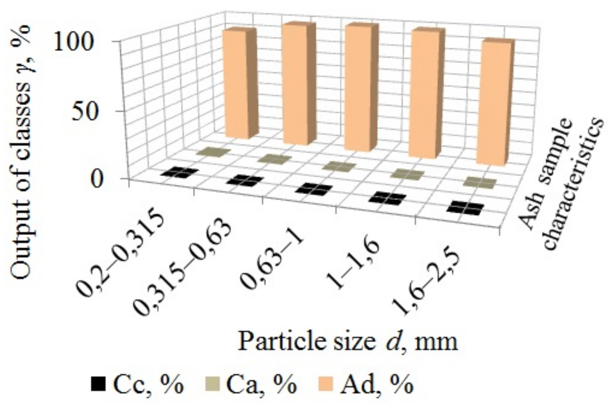
Σ – total output of classes

Figure 5 – Dependence of the output of classes γ on the particle size d (sample 3, K19, RVV-1)



Σ – total amount of ash C_a and coal C_c in size classes

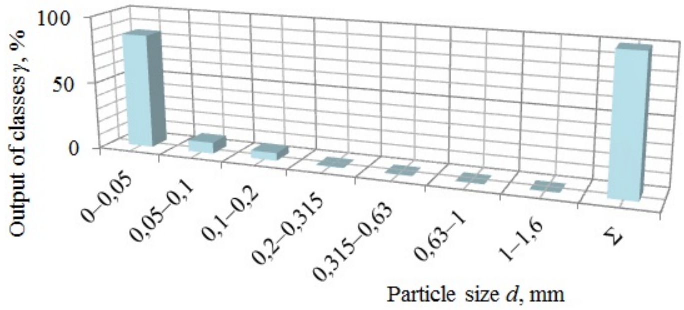
a)



b)

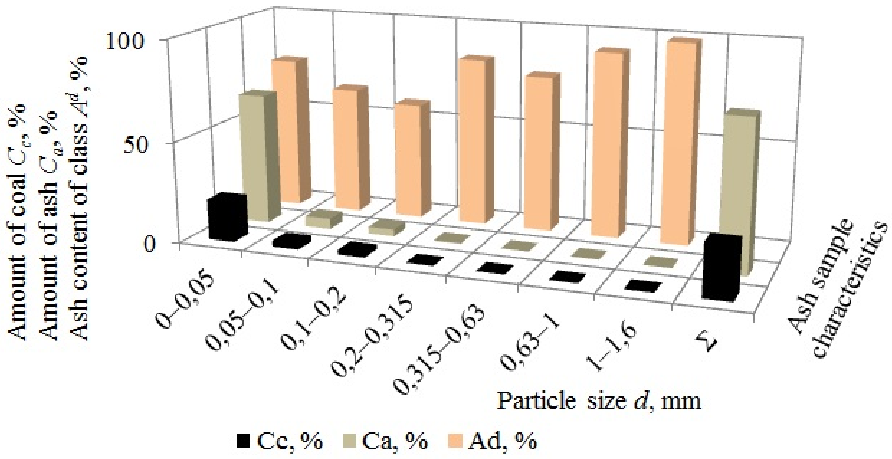
a) – size range from 0 mm to 1.6 mm; b) – size range from 0.2 mm to 1.0 mm

Figure 6 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 3, K19, RVV-1)



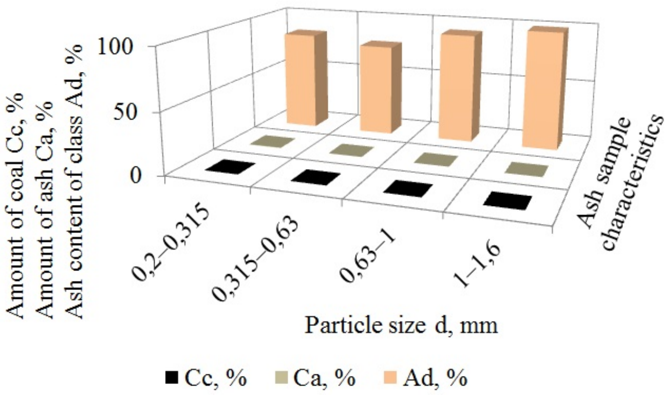
Σ – total output of classes

Figure 7 – Dependence of the output of classes γ on the particle size d (sample 4, K19, RVV-2)



Σ – total amount of ash C_a and coal C_c in size classes

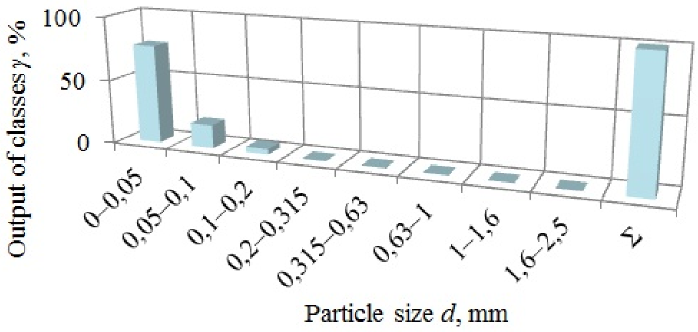
a)



b)

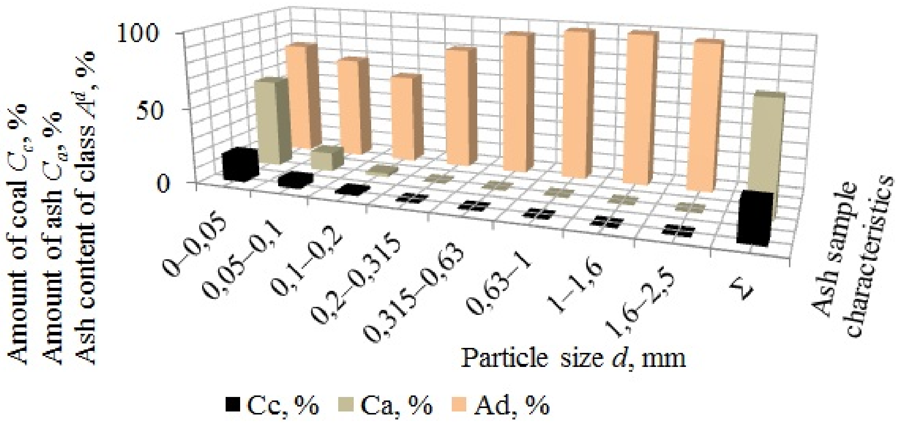
a) – size range from 0 mm to 2.5 mm; b) – size range from 0.2 mm to 1.0 mm

Figure 8 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 4, K19, RVV-2)



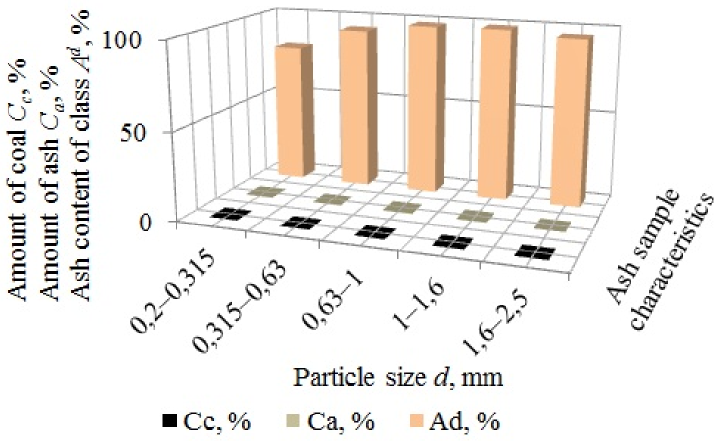
Σ – total output of classes

Figure 9 – Dependence of the output of classes γ on the particle size d (sample 5, K19, RVV-3)



Σ – total amount of ash C_a and coal C_c in size classes

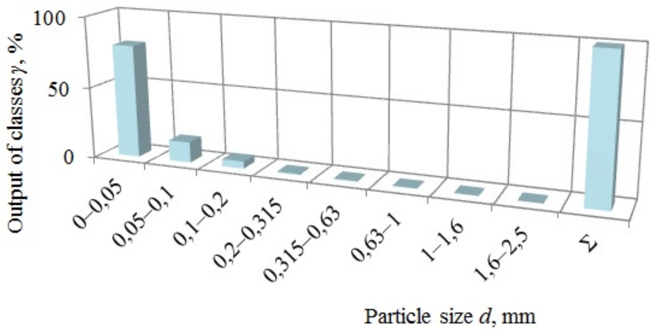
a)



b)

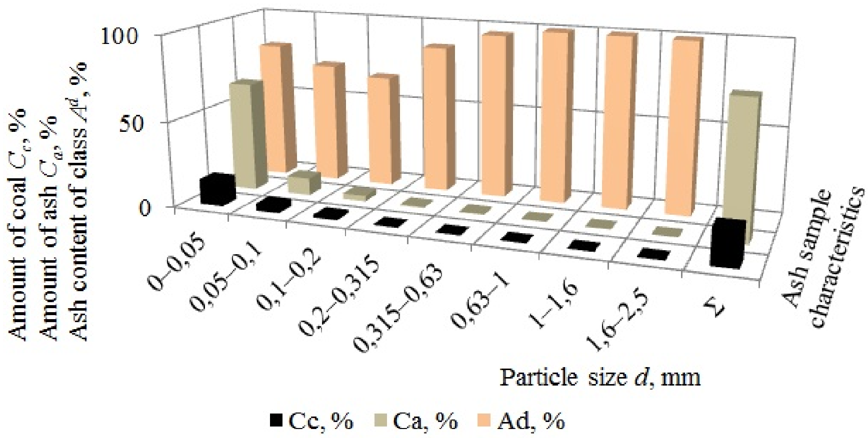
a) – size range from 0 mm to 1.6 mm; b) – size range from 0.2 mm to 1.6 mm

Figure 10 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 5, K19, RVV-3)



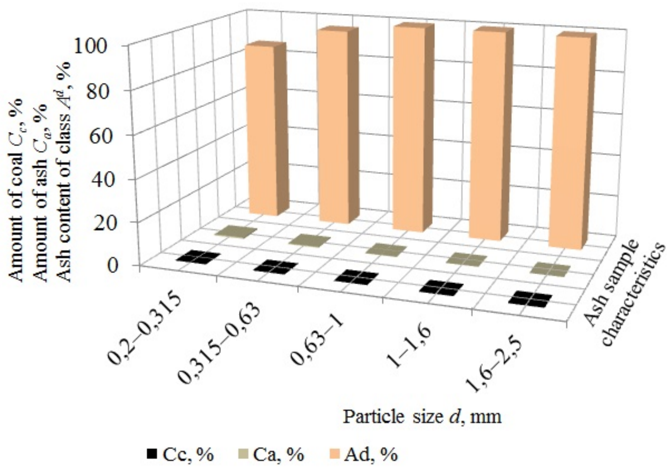
Σ – total output of classes

Figure 11 – Dependence of the output of classes γ on the particle size d (sample 6, K19, RVV-4)



Σ – total amount of ash C_a and coal C_c in size classes

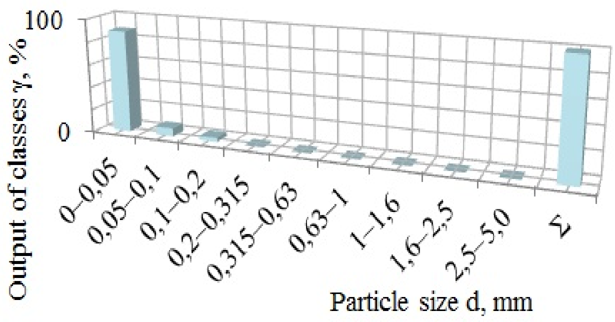
a)



b)

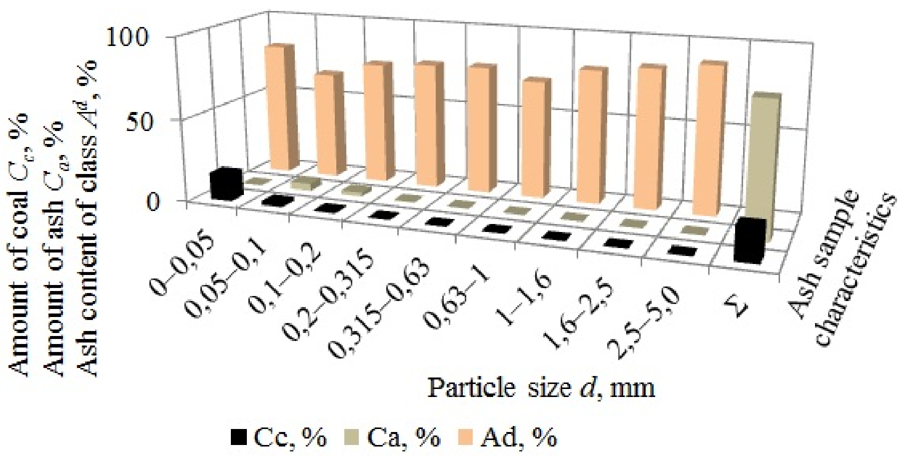
a) – size range from 0 mm to 2.5 mm; b) – size range from 0.2 mm to 2.5 mm

Figure 12 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 6, K19, RVV-4)



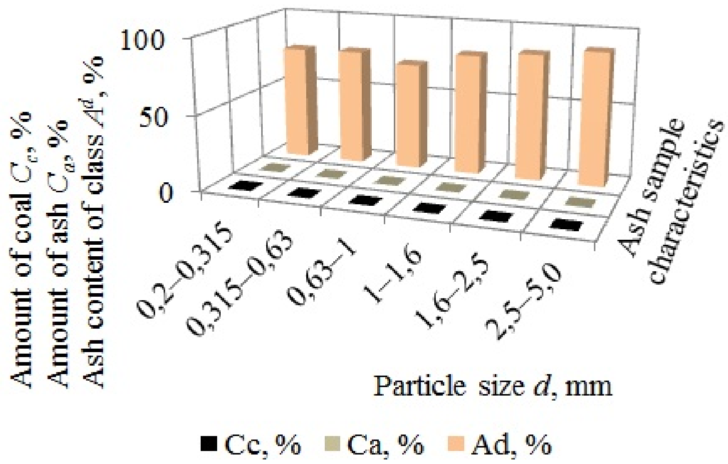
Σ – total output of classes

Figure 13 – Dependence of the output of classes γ on the particle size d (sample 7, block 10)



Σ – total amount of ash C_a and coal C_c in size classes

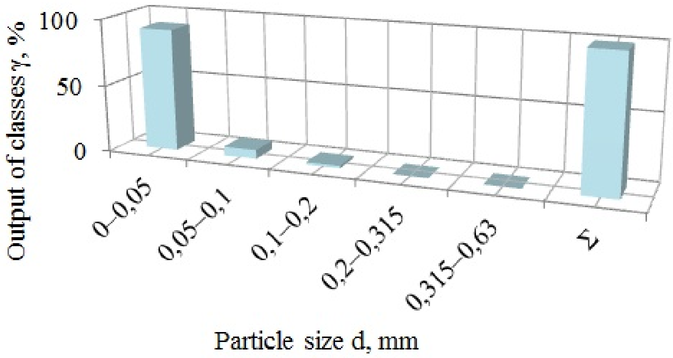
a)



b)

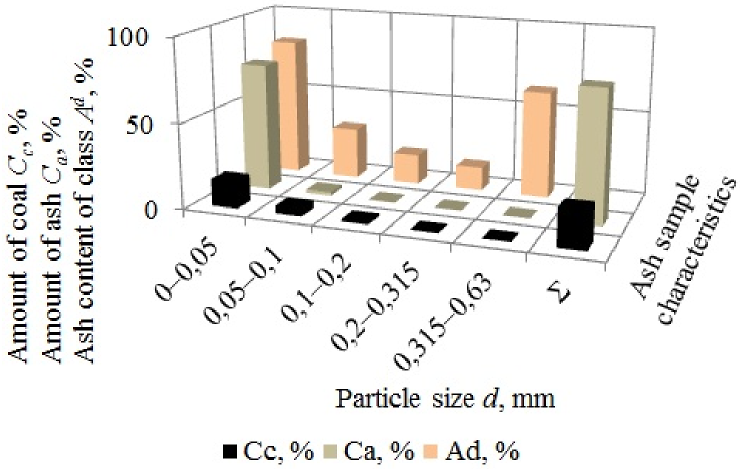
a) – size range from 0 mm to 5.0 mm; b) – size range from 0.2 mm to 5.0 mm

Figure 14 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 7, block 10)



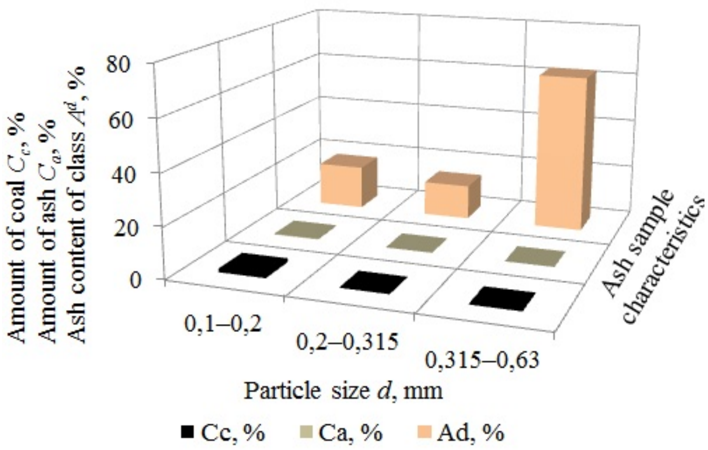
Σ – total output of classes

Figure 15 – Dependence of the output of classes *γ* on the particle size *d* (sample 8, block 11, boiler 17)



Σ – total amount of ash C_a and coal C_c in size classes

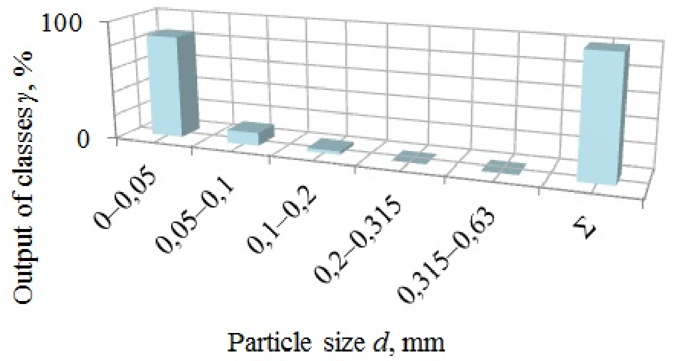
a)



b)

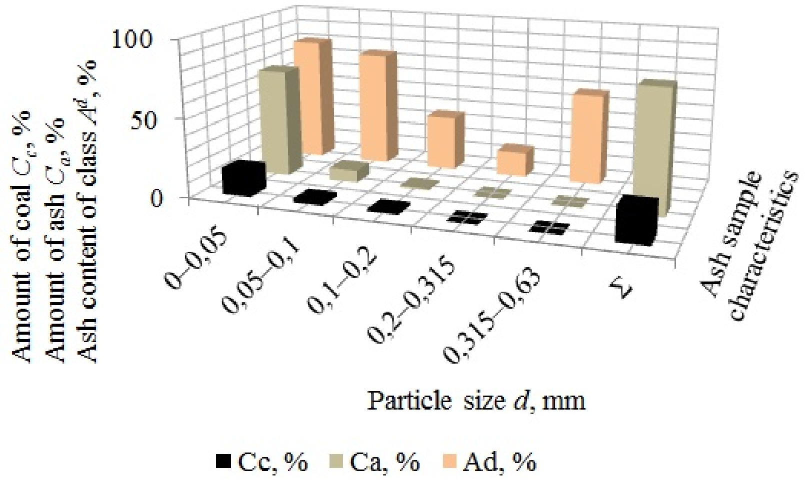
a) – size range from 0 mm to 1.6 mm; b) – size range from 0.2 mm to 1.0 mm

Figure 16 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 8, block 11, boiler 17)



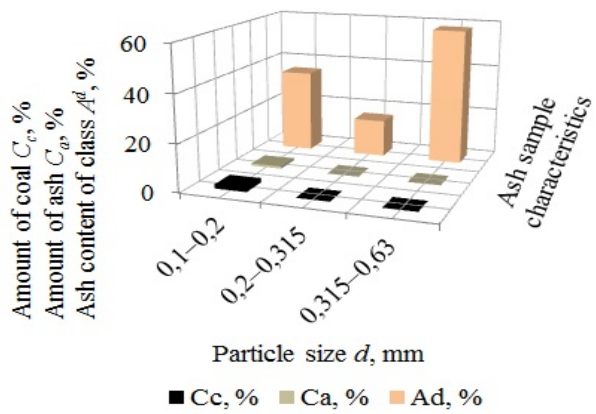
Σ – total output of classes

Figure 17 – Dependence of the output of classes γ on the particle size d (sample 9, block 12)



Σ – total amount of ash C_a and coal C_c in size classes

a)



b)

a) – size range from 0 mm to 1.6 mm; b) – size range from 0.2 mm to 1.0 mm

Figure 18 – Distribution of ash content A_d, amount of ash C_a and amount of coal C_c in size classes (sample 9, block 12)

The unburned carbon remaining in the ash is distributed unevenly across the size classes of the original product; the samples contain from 18.53% to 30.48% of unburned coal. The ashiest part is contained in the +0-0.05 mm class, from 44.97% to 81.47%. If the ash is divided by the boundary size of 0.05 mm, it is possible to obtain an oversize product with a coal content of C_c from 6.05% to 14.6% with an ash content of C_a from 2.41% to 24.87%.

The products of the complex technology for processing dry fly ash are the silicate part and carbon. The carbon part is presented in the form of dust particles of coke, which after extraction from the ash can be returned for further combustion. The silicate part of the ash requires additional research, since its mineralogical composition, its value and the feasibility of including it in the technology of complex processing for the purpose of subsequent utilization have not been determined.

With appropriate methods of use and available technologies for disposal, ASW becomes a high-quality and cheap secondary resource, including a substitute for natural materials with binding properties, which are used in world practice in the production of concrete, bricks, asphalt concrete mixtures, ceramic tiles, thermal insulation, etc.

Conflict of interest

Authors state no conflict of interest.

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ВИЗНАЧЕННЯ МОЖЛИВОСТЕЙ ВИКОРИСТАННЯ ЛЕТУЧОЇ ЗОЛИ ДТЕК ПРИДНІПРОВСЬКОЇ ТЕС В ЯКОСТІ ДОДАТКОВОЇ СИРОВИНИ

Лапшин Є., Шевченко О.

Анотація. Накопичені золошлакові відходи (ЗШВ) об'єктів паливно-енергетичного комплексу України належать до потенційно небезпечних джерел забруднення навколишнього природного середовища на прилеглих територіях. Більше 80% мінерального складу вугілля під час спалювання переходить у летючу золу (ЛЗ), до 20% – у шлак. Золи вугільних ТЕС України містять вуглець у кількості від 5% до 30%. Підвищений вміст у золі недопалу та складний гранулометричний склад не дають можливості широкого застосування золи у будівельній індустрії у великих обсягах (для бетонів – заборонено стандартами). Разом з тим, зола є цінною сировиною для утилізації. Для широкого застосування в будівельній сфері необхідно довести якість золи до показників, що відповідають стандартам. Виконані дослідження свіжої (сухої) золи показали перспективність її переробки, продукти якої становлять промисловий інтерес. Незгорілий вуглець, що залишився у золі, за класами крупності вихідного продукту розподілений нерівномірно, в пробах міститься від 18,53 до 30,48% вуглецю, що не згорів. Найбільш зольна частина міститься у класі +0-0,05 мм від 44,97% до 81,47 %. Якщо розділити золу по граничній крупності 0,05 мм, можна отримати надрешітний продукт із вмістом вугілля C_c від 6,05% до 14,6 % при зольності

C_a від 2,41% до 24,87%. Суха зола не вимагає зневоднення та сушіння, додаткового транспортування до місця переробки. При переробці сухої золи важливим фактором є припинення нарощування відвалів летючої золи. Продуктами комплексної технології переробки сухої летючої золи є силікатна частина та вуглець. Вуглецева частина представлена у вигляді пилоподібних частинок коксу, яка після вилучення із золи може бути повернена для подальшого спалювання. Силікатна частина золи вимагає додаткових досліджень, оскільки не визначено її мінералогічний склад, його цінність та доцільність включення до технології комплексної переробки з метою подальшої утилізації. При відповідних методиках використання та доступних технологіях утилізації ЗШВ стають якісним та дешевим вторинним ресурсом, у тому числі замінником природних матеріалів, що мають в'яжучі властивості, які у світовій практиці використовуються у виробництві бетонів, цегли, будівельних, асфальтобетонних сумішей, керамічної плитки, теплоізоляції, тощо.
Ключові слова: вугілля, техногенні відходи, золошлакові відходи, летуча зола, переробка, класифікація.