

STUDY OF MECHANICALLY ACTIVATED COAL COMBUSTION

by

**Anatolij P. BURDUKOV, Vitalij I. POPOV, and
Valentin A. FALEEV**

Original scientific paper
UDC: 662.612/.613:66.088
BIBLID: 0354-9836, 13 (2009), 1, 127-138
DOI: 10.2298/TSCI0901127B

Combustion and air gasification of mechanically activated micro-ground coals in the flux have been studied. Influence of mechanically activated methods at coals grinding on their chemical activeness at combustion and gasification has been determined. Intense mechanical activation of coals increases their chemical activeness that enables development of new highly boosted processing methods for coals with various levels of metamorphism.

Key words: *combustion, gasification, micro-grinding, coals, fuel*

Introduction

Growth of world prices for energy carriers urges search for simple and saving methods of substitution of expensive natural gas and heavy fuel oil in power technologies. At present, the role of coals in the national and world energy balance is increasing. Thereby, need in improvement of known and development of new power technologies has become apparent.

These technologies should be characterized by high quality, and furthermore, meet strict environmental standards related to harmful emissions. Owing to the quality decrease of the power station coals in the world great attention is paid to new technologies of coals combustion and gasification.

Environmentally pure technologies and their implementation can serve to solve problems of preliminary preparation of fuel to combustion or gasification. Among such problems there is, first of all, enrichment with reduction of the coal ash and sulphur content and other additives.

Often, technologies of fuel preparation, combustion, and gas purification have close connections and only taken as a complex serve to achieve economically and environmentally required results.

In Russian power engineering coal is mostly combusted in the dust and coal flame; in most cases such coal is mined mainly in Kuznetskoe and Kansko-Achinskoe deposits and is characterized by relatively high quality. In some cases use of low-reactive coals may cause problems of flame combustion stabilization. To ignite dust and coal boilers we most often use gas, requiring a station nearby, or mazut that are much more expensive than coal. All above proves that the most topical today is approximation of physical and chemical properties of coals to gas or heavy fuel oil, for instance by their mechanically activated treatment. It should also be taken into account in new technologies for coal processing, including gasification being the main step of gas and vapor lines development.

During the last 15-20 years technologies of air, vapor and air, and vapor and oxygen gasification of coals in various gasifiers – in boiling bed, circulating boiling bed, in the suspended dust-powder flux for combined cycle plant using solid fuel – are actively developing. Their main advantages are increased efficiency of power cycle up to 44-47% resulted from increased power generation in the gas-turbine units up to 45-60%, high level of environmental purity, wide range of the units productivity adjustment, and capacity to use fuel with high ash and sulphide content.

Gas with low calorie content produced at air or vapor and air gasification (4-7 MJ/m³) is expedient to use on site; at oxygen (vapor and oxygen) gasification – the obtained gas is characterized by the combustion heat of 10-16 MJ/m³, gas with the combustion heat of 20-40 MJ/m³ – is produced at vapor and oxygen gasification at the pressure of $p > 10$ MPa.

The most prospective are gasification methods in the flow and in the boiling bed.

It should be noted that in accordance with diffusion and kinetics theory of combustion and gasification general resistance to the oxidizer substance transfer to the reacting particle $1/K^1 = 1/K + 1/\beta = 1/K + d/\text{Nu}D$, consists of chemical $1/K$ and diffusion $d/\text{Nu}D$ resistances.

In various power technologies depending on aerodynamic and heat conditions both types of slowdown are possible and for the acceleration of highly boosted both their aerodynamic and chemical factors shall be influenced. This work reviews possible effect of mechanic activation of coals at their preparation to thermal treatment on combustion and gasification velocities.

Combustion processes of natural fuels in particular coals are complicated by the whole range of series and parallel processes: heating of fuel particles, moisture evaporation, emission and combustion of volatiles, combustion of coke residue, external and internal diffusion of oxidizer, *etc.*

At that, many chemical reactions with frequently unknown kinetic characteristics are realized.

To calculate heat effects of fuel combustion for specific power lines it is necessary to be aware of the resulting expressions of complex chemical reactions but not their particular elements. So, for carbon combustion main result is its composition with oxygen in reactions: $C + O_2 = CO_2$ and $2C + O_2 = 2CO$, usually called primary ones. At that, there are also the so called secondary reactions: $2CO + O_2 = 2CO_2$ and $C + CO_2 = 2CO$, and the role of each reaction in the overall process depends on specific physical and chemical terms.

Most researchers have come to general conclusion that carbon combustion resulted from interaction with oxygen always yields both in carbon oxide and dioxide as primary gaseous oxide [1].

Since combustion of coal particle regardless of the combustion method goes through the range of stages proceeding in series – parallel it is conventional to discriminate [2] areas where the total intensity of combustion process is influenced by different factors.

At the low temperature and respective low velocity of chemical reaction total velocity of reaction is determined by chemical kinetics and reaction goes practically over all accessible for oxygen external and internal surface *i. e.* oxidizer concentration on the external contour surface of the particle and in its center is practically the same.

In this area the intensity of the reaction process is approximately the same for the overall volume and can be fairly determined by the kinetic equation of the chemical reaction of carbon and oxygen.

At that, kinetic characteristics of coal – pre-exponential factor and activation energy are determinative for the process of fuel inflammation and often can play specific role at burner development and selection of coefficient value for air excess.

Mechanical activation of coal substance depending on the grinding method can influence the process velocity in different ways at different stages of inflammation and combustion process and respectively influence the velocity of the process transfer from one mode to another. This area of reaction is purely kinetic.

With the temperature growth the oxidizer diffusion velocity directed far into the particle turns out to be insufficient to provide reaction of the whole surface at purely kinetic mode on the contour surface.

Such mode is commonly called an internal transfer area. At further temperature growth or increase of the particle diameter the process velocity is determined solely by the value of external contour surface of the particles and the surface temperature; at that, the external diffusion has no impact onto the process velocity. This area is known as the external kinetics.

At further temperature growth combustion velocity depends on both the process diffusion and kinetics, *i. e.* external transfer mode is realized, and at the higher temperature level the running one is external diffusion mode where the combustion velocity is completely determined by the intensity of the oxidizer supply to the external surface of the particle [3].

Abovementioned argumentation is mostly formal since at combustion of polydisperse dust and coal flame even in the absence of the relative velocity at the reacting surface of the particles of different size at $Nu \approx 2$ coefficient of the oxidizer transfer to the reaction surface differs in times, *i. e.* their combustion modes also differ a lot.

Besides, in the process of volatilization, inflammation and combustion particles porosity and kinetic characteristics of the material change. At that, reaction area boundaries for various particles and the burnout velocity of individual particles and the whole flame surely change.

It is obvious, that the value of kinetic characteristics of the coal substance determines the velocity of inflammation and combustion of the coal and dust flame, that is significant for the development of combustion chamber in the boiler units. Kinetic characteristics of coals apart from dependence on the metamorphism degree are to a great extent determined by grinding method, *i. e.* mechanical and chemical characteristics of the coal substance destruction.

It is known that at mechanical impact onto coals decomposition of some chemical bonds occurs and free radicals speeding up the development of various chemical reactions are formed [4].

At that, deformation of the organic component being a high molecular formation occurs where at macromolecular deformation the structure of intermolecular chains and interatomic and intermolecular intervals change. This goes along with intra and intermolecular bonds breaking and respective increase of free energy of the substance. At the deformation of electronic shells energy barrier of reaction decreases.

This is mostly observed at static mechanically fields; at alternating fields for instance at grinding chemical conversion with bond opening and macromolecule destruction occur. All in all, at coal dispersion structural changes along with the decrease of the packing density, decrease of layer ordered carbon share, *etc.* occur.

Already in the 1970-ies large number of works on structure and properties of mechanically effected coals appeared.

At long term grinding of coals in the vacuum ball mill coal macromolecule depolymerization occurs, and under the unidirectional pressure molecular orientation of grids depending on the pressure value is observed; at fine grinding (1-10 μm) compound and number of functional groups, composition of emitted gaseous products change, solubility in organic solvent increases, depth of the coal organic mass conversion into liquid products at hydrogenation grows, thermal decomposition progress changes [5].

Unfortunately, in most known works on mechanical activation of coals laboratory vibrating mills with recurring operation and low power density with rather long time of mechani-

cally treatment and monitoring of chemical activeness of the mechanically activated coal in liquid medium were used.

So in [6] influence of vibrating grinding conditions onto the properties of the coal oxidation by physical and chemical methods was studied. It was shown that at vibrating grinding mechanical destruction of humic acids occurs; it is accompanied by fraction and component changes, decrease of average molecular mass and change of hydrogen functional groups structure.

In [7] influence of vibrating grinding onto coal physical and chemical properties and their capacity to react with the oxidizer – potassium permanganate in alkaline medium was revealed. Significant increase of coal reaction capacity after vibrating grinding compare with initial samples was identified, and at that the value of this indicator for all grinding periods in air medium is higher for brown coal.

Mechanical activation of non-cocking coal for combustion and gasification intensification

In this work we have made an attempt to study kinetic characteristics of coals with various levels of metamorphism activated in different technological mills with high power density and impact of this change on characteristics of immediate coal combustion. On the basis of obtained data we will consider realistic use of coals with different metamorphism level instead of gas and heavy fuel oil in different power technologies – in the units of small and large-scale power engineering, also at heavy fuel oil free ignition and stabilization of dust and coal combustion.

To identify particular influence of coal grinding methods on its kinetic characteristics we have studied changing physical and chemical properties of brown coal mechanically dispersed in the mills of higher power density (planetary, vibrating mill, disintegrator) of brown coal of B-2 grade from Kansk-Achinsk deposit with the following characteristics, $A^p = 20.4\%$, $V^{dat} = 46.5\%$, and $W^r = 34.2\%$.

It has been proved that in dispensers with rather high energies at intense mechanical effect on the coal substance along with the decrease of the particles dimensions and specific surface increase coal activation takes place (tab. 1). It appears to be a partial mechanical destruction related to high molecular components of organic mass of coal that leads to significant change of its physical and chemical properties, including reaction capacity increase.

First time it has been found out that at dispersion of brown coal in the mills with the increased power density (planetary, vibrating mill) formation of structures with less thermal stability occurs resulting in particular in the lesser activation energy of the thermo-oxidizing destruction of the coal substance.

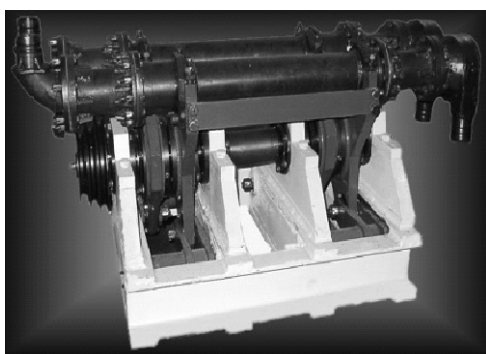
Data on mechanical and chemical treatment of coal at its preparation to combustion and gasification are in practice absent. If the transfer velocity increase for the account of the fuel particles diameter decrease is obvious the influence of mechanical and chemical process on kinetic characteristics of coals requires special research.

The authors have carried out research on direct inflammation and combustion of coals with different metamorphism levels ground in the vibrocentrifugal mill – VCM (fig. 1) and disintegration (D) type unit (fig. 2).

Figure 3 demonstrates measurement results of the brown coal particles dimensions after grinding in the mills of both types. It is clear that the average size of particles is practically the same and equals to $\sim 40\text{--}42\ \mu\text{m}$, *i. e.* reacting surface in both cases is practically the same and therefore velocities of inflammation and combustion of the dust coal flame should be identical at combustion of such coal. However, experiments demonstrated that velocities of inflammation

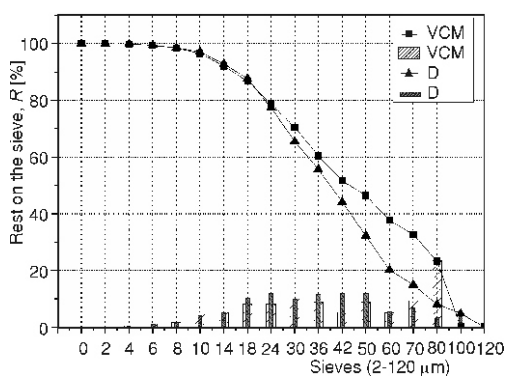
Table 1. Structure of particles [%] of different size depending on the conditions of coal dispersion

Dispersion conditions	Size of particles [μm]				
	<2	2-20	20-50	50-100	>100
Basic sample	–	7.62	9.18	9.27	73.93
Vibrocentrifugal mill, 90 s	2.31	28.53	27.41	21.84	19.91
Disintegrator	6.16	45.94	39.6	7.48	0.82
Planetary type mill, rpm, 45 s	16.96	66.39	13.91	2.74	–
Planetary mill, rpm, 5 minutes	14.63	55.9	23.19	5.06	1.22
Planetary mill, rpm, 15 minutes	10.12	48.58	29.79	8.02	3.49
Planetary mill, rpm, 30 minutes	12.72	53.29	27.82	5.3	0.87
Light fraction of basic coal ($d < 1.4 \text{ g/cm}^3$)	2.12	19.25	16.0	19.78	42.85
Decomposed light fraction, rpm, 45 s	15.04	47.81	25.86	8.54	2.75

**Figure 1. Vibrocentrifugal mill VCM 30-G; productivity up to 100 kg per hour****Figure 2. Disintegration type mill; productivity up to 150 kg per hour**

and combustion of dust suspension after the disintegrator-mill are much higher than at grinding by VCM (figs. 4 and 5). To clarify this issue we have carried out research jointly with Prof. O. I. Lomovski (Institute of Solids and Mechanochemistry) and Prof. T. S. Yusupov (Institute of Geology SB RAS).

During the study of combustion of mechanically treated coal samples it has been found out that *ceteris paribus* flame parameters, namely, dimensions and propagation of temperature zones greatly depend on the equipment type used for the treatment (figs. 4a and b and 5a and b). In particular treatment up to approximately identical dispersity in mechanically activating mills with constrained impact (vibrocentrifugal

**Figure 3. Spectrum of the particle sizes of the brown coal with the grade B-2; VCM – residue in the sieve after grinding by the disintegrator mill**

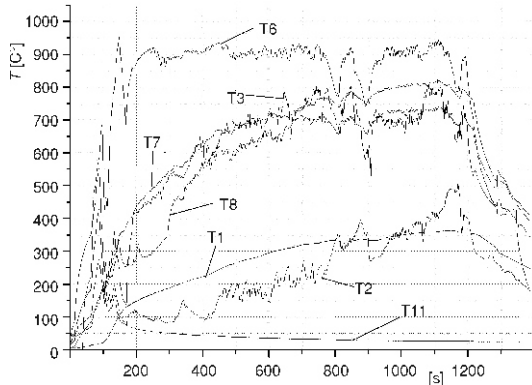


Figure 4a. Temperature dynamics of combustion of brown coal after grinding by vibrocentrifugal mill with transition to autothermal combustion mode

T_i – thermocouples are numbered starting from the beginning of the torch and further away: 1, 2, 3 – thermocouples in the furnace extension prechamber, $L = 0$; 6 – $L = 160$ mm; 7 – $L = 510$ mm; 8 – $L = 850$ mm; 11 – at the end of the afterburning shaft of 3.5 m height

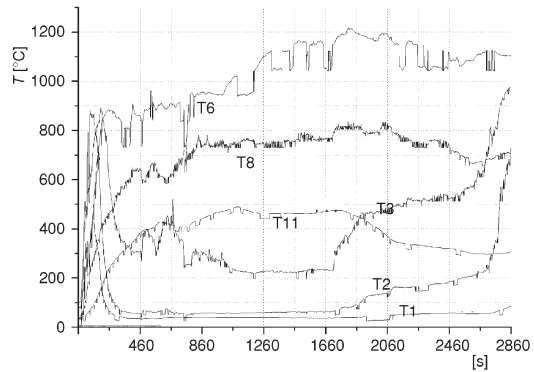


Figure 5a. Temperature dynamics of combustion of brown coal after grinding by desintegrator mill with transition to the outlet to autothermal combustion mode

T_i – thermocouples are numbered starting from the beginning of the torch and further away; 1, 2, 3 – thermocouples in the furnace extension prechamber $L = 0$; 6 – $L = 160$ mm; 8 – $L = 850$ mm; 11 – at the end of the afterburning shaft of 3.5 m height

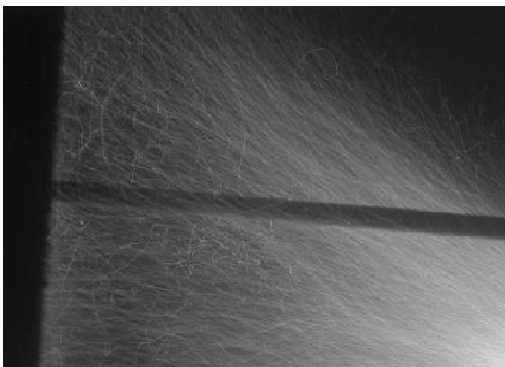


Figure 4b. Torch combustion of brown coal ground by vibrocentrifugal mill



Figure 5b. Combustion of flame with brown coal ground by disintegrator mill

activating mill VCM) and in the mills with free impact (disintegrator) has resulted in different flame parameters.

Since the flame parameters appear to be determinant for the heat generator design, studies of physical and chemical reasons of the discovered phenomenon are of current interest. On the other hand, development of the control method for flame parameters on the basis of mechanical and chemical phenomenon also opens new technical perspectives.

Earlier it was believed, that the increase of chemical activeness of coal caused by the applied mechanical load results from dispersion, formation of new and opening of previously unavailable pores, leading to the increased external and internal surface of coal particles. It turned out that apart from the increased specific surface there is a whole range of physical and chemical phenomena: breach of chemical connections of organic substances of coal, change of

molecular and mass propagation, formation of soluble products and volatiles, free radicals and uprise of intense electric fields, and electronic emission [8].

Electric phenomena at mechanical influence onto coals undoubtedly take place, however, they are usually considered as side processes. Core practically important phenomena at mechanically treatment of coal are associated with chemical transformations [9, 10].

Pressure from 1.2 to 2.4 MPa applied to the coal sample is accompanied by intense gas emission. Additional mechanical variable field with the frequency of 1-2 Hz gives 3-8 times acceleration of the gas emission process. Especially growing is hydrogen and hydrocarbon generation. Among hydrocarbon gases obtained from brown coals there is methane and its homologues up to pentane inclusively.

Experimentally we have proved possible change of coal reaction capacity in the process of thermal dilution resulted from preliminary mechanical activation. Conversion degree of mechanical activation increases in the low temperature area 2.5-3 times. It is believed that mechanical and chemical processes cause change of reaction capacity of the coal organic substance. Increased portion of phenol hydroxide, alcohol and alkyl groups and changing character of substitution of C-H bonds of aromatic rings in the mechanical activated coal have been demonstrated. Among obtained liquid low molecular compounds – alkaline, starting from C₁₅-C₁₆ and higher have been identified.

Thus, mechanical and chemical treatment of coal becomes important not only at combustion but in the whole range of technologies: in hard coal liquefaction or in the medium of paste former at the stage of coal preparation and sludge treatment aiming at augmented transformation of organic coal mass and extra target production; for thermal oxidation of hydrogen production at reduction of oxide-metallic contacts on the basis of ferrum oxide by mechanically activated coal; for preparation of heavy fuel oil and water-coal suspensions fit for further piping and combustion in the boilers.

Size of combusted coal particles turns out to be important for all conditions of heating and mass transfer: when a limiting stage appears to be the heat supply to the fuel particle, transfer of heat inside the fuel particle, mass transfer of volatiles from the particle volume to its surface. Structural and chemical transformations at the stage of mechanical treatment can be especially significant for highly dispersed coal combustion.

Influence of mechanical and chemical effects on the activation energy of micro-ground coals for their inflammation and combustion

Studies were carried out with the use of thermal analyzer STA 449C, Netzsch, Germany, in the air flow. Temperature increased from 28 to 800 °C with the velocity of 10 °C/min. With the increase of the warming up period we registered: reactor temperature, sample weight (TG), heat flow (DSC). Heat flux from the sample is written in the units “microvolt to milligram”, which is conditioned by the construction of the measuring cell of standard line assigned for the thermal analysis. Walls of the measuring cell are equipped with thermocouples measuring thermo-electric driving force, arising at absorption or emission of heat from the sample. Heat fluxes and effects of the processes in the sample can be expressed by absolute units as well however the required information on heat capacity of reagents and reaction products is often absent therefore we use the unit “microvolt to milligram” proportionate to the absolute value of the heat flux.

Samples were pretreated in the disintegrator (disk rotation velocity 6000 revolutions per min.) and vibrocentrifugal activating mill VCM-7 (acceleration of affecting solids – balls 120 m/s², diameter of steel balls – 12 mm). Treatment in both units resulted in coal grinding to the average size of the particles of 30-40 μm.

The following types of coal have been studied: anthracite seed culm (Listvianskoye deposit of Novosibirsk region) and brown coal of B-2 grade.

It has been discovered that thermoanalytical data for the samples with close distribution of particles according to their sizes, analyzed in 48 hours after mechanical treatment in all cases are close to each other.

We find significant differences in thermal analysis of samples carried out short after mechanical treatment. Figure 6 demonstrates results of analysis of brown coal sample after 2 hours and 48 hours of treatment in the ball-tube vibrocentrifugal mill.

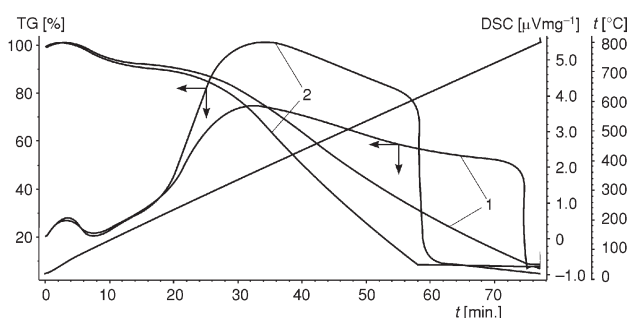


Figure 6. Thermoanalytical data (loss of the sample weight at air heating – TG and heat flux, microvolt per milligram – DSC) for brown coal

1 – in 2 hours after mechanically treatment, 2 – in 48 hours; straight line – temperature change, velocity change 10 °C/min.

more evident exoeffect at the thirty fourth minute of decomposition. Low temperature exoeffects usually are associated with eduction of various gases from coal, exoeffect at high temperatures – with coal oxidation.

The discovered unusual phenomenon can be formulated as follows. Treatment of brown coal in the ball planetary mill with constrained impact unlike treatment in the disintegrator – the mill with free impact results in the increase of combustion time and the decrease of maximum combustion temperature. The phenomenon turns out to be temporary and in 48 hours after the coal treatment after storage is not observed.

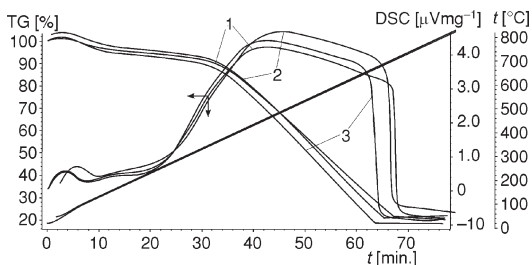


Figure 7. Thermoanalytical data (decrease of the sample weight at air heating – TG and heat flux, microvolt per milligram – DSC) for the anthracite 1 – in 5 hours after mechanical treatment, 2 – in 76 hours, 3 – in 245 hours; straight line – changing temperature, change velocity 10 °C/min.

It is clear that the newly treated sample loses weight slower than the sample in 48 hours after the treatment. Minimum weight is obtained for 75 and 59 minutes accordingly. Limit of samples weight correlates with the ash content – inorganic substances. Maximum temperature of the samples in the air oxidation by oxygen is 560 and 780 °C.

Overall view of the weight change curves indicates that decomposition occurs in 2 stages: low temperature decomposition characterized by heat absorption and endoeffect minimum at the eight minutes of decomposition at the temperature about 140 °C, and

In case with anthracite the phenomenon is less expressed (fig.7).

The discovered phenomenon should be considered during the construction of the units for gasification and combustion of fine-dispersed coal.

Increase of coal combustion time after mechanical treatment in the device with constrained impact can be explained on the basis of the contemporary ideas on combustion mechanisms of coal combustion and gasification.

Structure of organic coal substance has been widely discussed to date. Until recently coal structure has been divided into two

parts. The first part consists of “condensed aromatic nuclei” usually presented by 3–4–5 aromatic rings, analogous to rings in the structure of graphite planes. Nuclei are flat and can form laminated “clusters” similar to the laminate structure of graphite. Nuclei and clusters are disoriented in relation to each other and bound with each other by “seams” from aliphatic molecules to get solid frameworks. Within the nuclei composition as substitutes in the “seams” there can be oxygen containing functional groups: phenol, carbonyl, ether, and acidic. Both in the nuclei and in the “seam” composition there can be heteroatoms – sulfur and nitrogen. Fragment of the hypothetical structure of coal is presented in fig. 8.

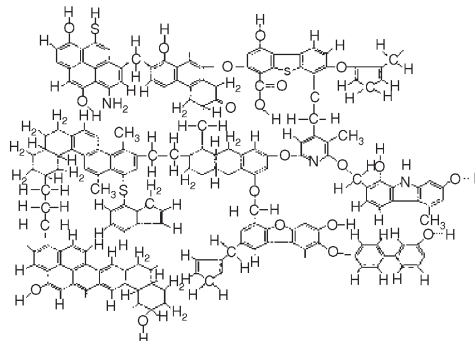


Figure 8. Fragment of the hypothetical structure of coal

In the coal structure there are pores that can be filled by low molecular compounds.

Contemporary ideas on the coal structure arose from the necessity to consider of spectroscopic data on coal structure with various degree of metamorphism. Intensity in infrared spectrum of absorption stripes, responsible for C–C oscillations in aromatic ring (1600/cm) with the increase of the level of metamorphism does not increase but goes down. Reduction alkylation of some coals does not result in the aromatic compounds but long aliphatic chains.

On this basis contemporary hypotheses on the coal structure concede low content or absence of condensed aromatic nuclei in coal. However, these hypotheses also consider such nuclei as formed in the process of thermal coal decomposition. Organic coal mass is presented as “the set of macromolecules of different chemical composition bound by electronic donor-acceptor and hydrogen boundaries”. The set includes: condensed aromatic rings, cycloalkane fragments, functional groups, alkyl substitutes, and bridge connections.

Thermochemical transformations of so complex structures in coals with various level of metamorphism differ from each other. However, in all cases at gasification and combustion volatiles exude, part of them can be condensed at cooling; and solid residue is formed. It is considered that volatiles are formed from “seams” and other low molecular components. Rigid-joint framework from condensed aromatic nuclei is transformed into solid product of thermal decomposition or interim product of combustion.

In the experiments we can also observe vicissitude of coal transformation. Especially it is demonstrative in the experiments with anthracite. Major exothermal peak furcated as it is shown in fig. 7 (exoeffects at 44th and 72nd minutes). First part of exopeak may be formed by heat generation at combustion reaction relative to low molecular molecules from seams and the second part of exopeak reflects aromatic nuclei framework combustion.

Thus, physical and chemical gist of the discovered phenomenon clears up, namely, increase of coal combustion time after mechanically treatment in the mills with constrained impact. As it was shown earlier mechanical treatment of coal results in eduction of low molecular substances and formation of more solid framework from aromatic nuclei. In this case exothermal effect changes owing to substitution of heat generation to the longer combustion time: fig. 9 from 59 to 75 minutes. It is typical that position of low temperature endopeak connected with eduction of volatiles (at the 7th minute) and position of major exopeak (at the 42nd minute) visibly are not changed since they have no relation to the changing solidity of the framework.

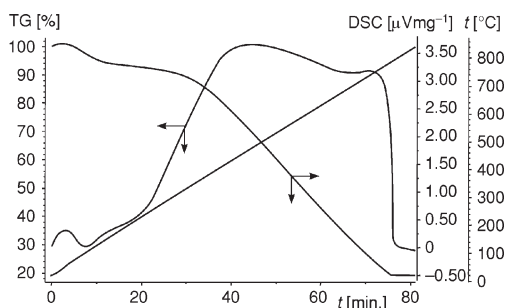


Figure 9. Thermoanalytical data (loss of sample weight at air heating – TG and heat flux, microvolt per milligram – DSC) for anthracite in 311 hours after the treatment; straight line – change of temperature, velocity change 10 °C/min.

water and 50-60% of volatiles and decompose faster than solid grades containing 30-40% of water and 45-50% of volatiles [7].

Stand (1 MW_t) for the study of inflammation, autothermal combustion, and direct gasification of microground coal

The stand is made for and in accordance with the complete technological cycle of dust and coal fuel combustion (fig. 10). It is equipped with grinding mills of two types VCM with the capacity up to 100 kg per hour and disintegrator – to 150 kg per hour (capacity), prechamber with furnace extension, coal afterburning shaft, and scrubber. Main idea taken into account in the technological scheme consists in microgrinding of coals (development of reaction surface of coals and their mechanical activation) with subsequent thermal gas preparation (partial gasification) furnace extension space of the stand. The stand is equipped with photometric, multicomponent gas analytical, and temperature equipment that serves to diagnose the process state in real time scale. As the fuel lighting we use standard fuse spark device in particular for methane which is used during ~1 minute. Afterwards fuse device is disabled and combustion of dust and coal fuel goes within the autothermal mode. The stand is also equipped with plasmatron with the capacity up to 15 kW_t. The

stand purpose and function is to elaborate and test technology and design of the transition to autothermal combustion mode with partial gasification of wide range of coals at dry slag removal.

Results of air gasification of non-coked microground coals

First experiments on air gasification of mechanically activated microground coal (grade B-2) were held in the stand (fig. 10) at the following parameters: fuel consumption – 19 kg per hour, primary air consumption – 36 m³ per hour,

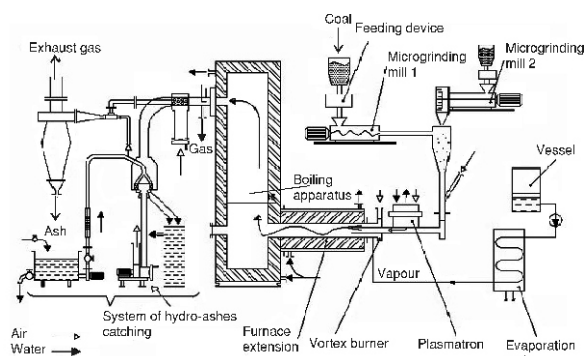


Figure 10. Desk for combustion and vapor and air gasification of microground coals

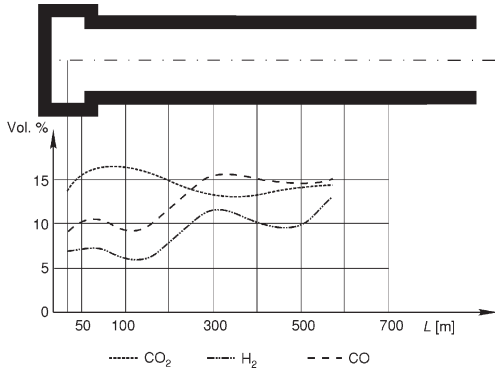


Figure 11. Distribution of appropriate components of gasification of coal of grade B-2 over the furnace extension length

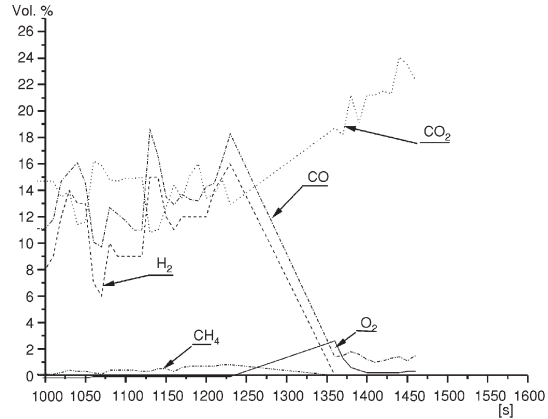


Figure 12. Distribution of components in the afterburner

secondary – 55 m³ per hour, at the average temperature over the axis of furnace extension ~1100-12000 °C.

Distribution of the appropriate components of gasification over the furnace extension length is shown in fig. 11. Experiments have proved that for the given thermotechnical and structural conditions there is significant volume content of CO and H₂ in the flux at practically complete burn out of oxygen.

The noticeable is equidistant character of CO and H₂ changes. It may be connected with the similar mechanism of their gasification.

After the supply of secondary air (into the afterburner) volume distribution of 5 components in time is presented in fig. 12.

Analysis of material balance of air gasification of carbon over the furnace extension length 150 mm and 450 mm from the vortex chamber face is presented in fig. 13 and 14. It is clear that with the increase of furnace extension length carbon quantity in solid phase decreases and the quantity of gasified carbon increases.

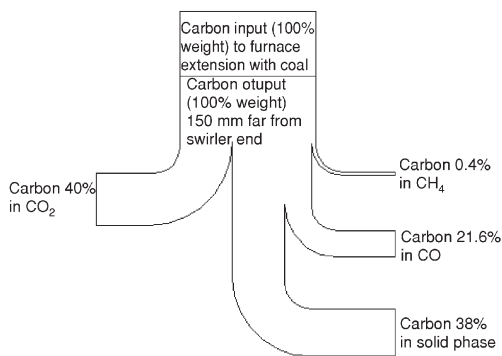


Figure 13. Scheme of material balance of air gasification of carbon in the furnace extension with the overall length of 150 mm from the vortex chamber face

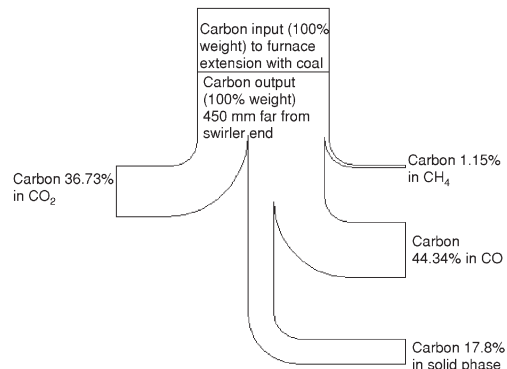


Figure 14. Scheme of material balance of air gasification of carbon in the furnace extension with the overall length of 450 mm from the vortex chamber face

Conclusions

The potential of mechanically activated processes at coal microgrinding have been studied. Experiments on ground coals and air gasification have been carried out. Intense mechanoactivation of coals increases their chemical activeness that may be used at the development of highly efficient power units.

Nomenclature

A	– ash content, [%]	p	– pressure, [Pa]
D	– diffusion coefficient, [m^2s^{-1}]	T	– temperature, [$^{\circ}\text{C}$]
d	– diameter [m]	t	– time, [s]
h	– convective heat transfer coefficient, [$\text{Wm}^{-2}\text{K}^{-1}$]	V	– volatiles content, [%]
K	– linear chemical reaction rate, [ms^{-1}]	W	– water content, [%]
K^{\dagger}	– combined reaction rate, [ms^{-1}]	$1/K$	– is chemical (it kinetic) resistance, [sm^{-1}]
k	– thermal conductivity, [$\text{Wm}^{-1}\text{K}^{-1}$]	$1/K^{\dagger}$	– combined drag transition of oxidizer to reacting particle, [sm^{-1}]
Nu	– Nusselt number, ($= hD/k$)	$1/\beta = d/\text{Nu}D$	– diffusion resistance, [sm^{-1}]

References

- [1] Chukhanova, Z. F., Problems of Fuel and Energy, AS USSR, Moscow, 1961
- [2] Kantorovich, B. V., Fundamentals of Solid Fuel Combustion and Gasification Theory, AS USSR, Moscow, 1958
- [3] Lavrov, N. V., Physical and Chemical Basis of Fuel Combustion, Nauka, Moscow, 1971
- [4] Baramboin, N. B., Mechanochemistry of High Molecular Compounds, *Khimia*, Moscow, 1971
- [5] Cherkinskaya, K. T., Khrenkova, T. M., Shterenberg, L. E., Changing Physical and Chemical Properties of Coals at Dispersion (in Russian), *Khimia tverdogo topliva (RUS)*, (1974), 2, pp. 48-52
- [6] Zharova, M. N., *et al.*, Influence of Microgrinding Conditions onto the Properties of Coal Oxidation Products (in Russian), *Khimia tverdogo topliva, (RUS)*, (1977), 2, pp. 65-70
- [7] Ekaterinina, L. N., Khrenkova, T. M., Motovilova, L. M., Chemical Transformation of Coals at Grinding (in Russian), *Khimia tverdogo topliva (RUS)*, (1974), 4, pp. 36-37
- [8] Khrenkova, T. M., Mechanochemical Activation of Coals. Nedra, Moscow, 1993
- [9] Soroko, Y. I., Low Temperature Generation of Carbon Gases by Sapropelic Coal under the Effect of Resiliency, 11th Russian Symposium on Mechanochemistry and Mechanoemission of Solids, Chernigov, Russia, 1990, Theses, Vol. 1, pp. 101-103
- [10] Kirda, V. S., Physical and Chemical Transformations at Mechanically Effect onto the Residual Coal, 11th Russian Symposium on Mechanochemistry and Mechanoemission of Solids, Chernigov, Russia, 1990, Theses, Vol. 1, p. 106

Author's affiliations:

A. P. Burdukov (corresponding author)

Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences
1, Prospect Lavrentyeva
630090 Novosibirsk, Russia
E-mail: burdukov@itp.nsc.ru

V. I. Popov, V. A. Faleev

Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences
Novosibirsk, Russia

Paper submitted: August 29, 2008

Paper revised: October 24, 2008

Paper accepted: December 26, 2008