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COAL DISINTEGRATION USING HIGH PRESSURE WATER JET

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Original scientific paper

The paper presents coal comminution utilizing high-pressure water jet. Prototype of hydrojetting apparatus for coal disintegration with this method is presented. Three different types of coal were examined: hard-, brown-, and charcoal. Obtained results point out that high-pressure water jet usage for such purpose is very effective. Brown coal is more susceptible to this method treatment than the hard one whereas the most intensive disintegration is characteristic for charcoal. Such micronization effect gives even over 100 000 time's increase of its specific surface compared to normal fine coal after traditional comminution. Moreover, charcoal susceptibility for intensive hydro-comminution is the reason why one can get the most comminuted structure, this being a good prognosis for its modification into bio-fuels.

Keywords: *coal, disintegration, high-pressure water jet*

Usitnjavanje ugljena visokotlačnim vodenim mlazom

Izvorni znanstveni članak

U radu se opisuje drobljenje ugljena primjenom vodenog mlaza pod visokim pritiskom. Daje se prototip aparata s vodenim mlazom za usitnjavanje ugljena primjenom te metode. Ispitivane su tri različite vrste ugljena: antracit, lignit i drveni. Dobiveni rezultati ukazuju na veliku učinkovitost primjene visokotlačnog vodenog mlaza u tu svrhu. Lignit je pogodniji za obradu tom metodom nego antracit dok je najintenzivnije usitnjavanje karakteristično za drveni ugljen. Takav efekt mikronizacije daje čak više od 100 000 puta povećanje njegove specifične površine u usporedbi s normalnim finim ugljenom nakon tradicionalnog usitnjavanja. Uz to, pogodnost drvenog ugljena za intenzivno hidro-drobljenje razlog je mogućnosti postizanja najsitnije strukture, a to je dobra prognoza za njegovu modifikaciju u bio-gorivo.

Ključne riječi: *visokotlačni vodeni mlaz, ugljen, usitnjavanje*

1 Introduction

Different methods of coal processing into fuel [1, 6, 12] usually require its intensive comminution. Such situation needs the creation of new technologies for coal micronization [4, 11, 17] that enlarge specific surface of coal micro particles what finally intensifies burning process of such coal dust. Some interesting effects of water-coal mixture ensure waterjetting technology implementation [3, 19]. Such technology enables the production of fuel from powdered coal in water slurry [2, 3, 5] or in energetic fluids (methanol or low viscosity oils) [3, 14].

Traditional mechanical grinders are used for coal grid comminution by means of coal particles crushing and grinding. However such grinders' usage for coal micronization is economically unprofitable because of their low efficiency [6, 10]. It is a result of the coal being much more resistant to pressing stresses than to stretching ones [7, 13, 15].

Taking the above into consideration an alternative technology involving high-pressure water jet can be implemented. Such a jet striking coal surface penetrates inside causing stretching stresses and such water wedge effect leads to easy disintegration of such coal particle. It should be admitted here that hard coal structure is characterized by many cracks [16, 18] and that is the reason why such material is especially susceptible to disintegration during hydrojetting grinding.

2 Research method

A prototype of hydrojetting grinder (Fig. 1) was used for coal disintegration. It was constructed after examining of other types of linear grinders [9, 14, 16]. Such construction work is similar to injector head work that is popularly used for creation of high-pressure abrasive-water jet. However in this particular case, fine coal is processed instead of abrasive material and it is accelerated and initially comminuted inside homogenized nozzle, which is made of sintered carbide. Created this way water-coal jet is directed on a target made of sintered carbide, where final comminution process takes place. Three different types of coal were examined: hard-, brown-, and charcoal.

The machinery used for fine coal comminution was of granularity range 1÷10 mm and process efficiency range 8÷30 g/s. Water output was changed at the range of 0,2÷0,5 dm^3/s and its pressure range of 50÷300 MPa. Hydromonitor based on HDP164 type (p_{max}=300 MPa, Q_{max}=0,5 dm^3/s) pump was used for such water output generation.

Figure 1 General and detailed view of hydrojetting comminution apparatus prototype

Analysette 22 Micro Tec analyzer (Fig. 2) was used for testing different particles fractions of comminuted coal. It enables fast results valuation of particles size range of 80 nm up to 2 mm. FEI Quanta 200 microscope equipped with chemical analyzer type EDAX Genesis XM 2i was used to

Figure 2 General view of laser measure instrument type Analysette 22 Micro Tec for examining particles size

observe comminuted fine coal surface. Additional software was used for particles shape analysis (Fig. 3). In turn, topography of cut surface and its geometry was measured with spatial surface analyzer type Talysurf CLI 2000 using laser gage as well as confocal gauge working with polarized light.

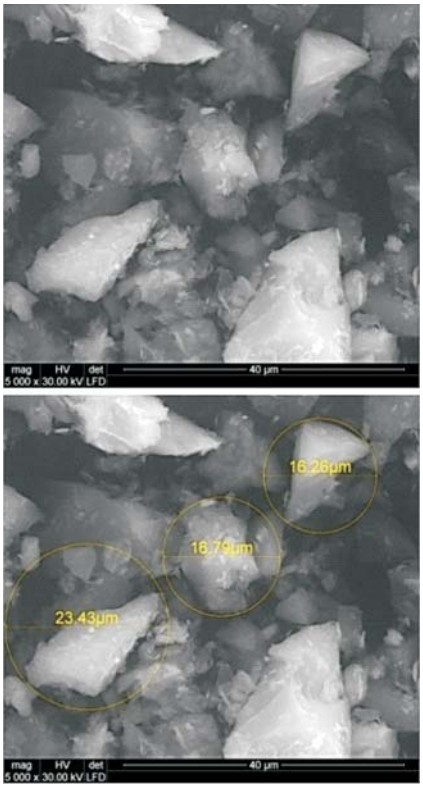

Figure 3 General views of comminuted coal particles

3
Hard coal comminution
3.1
Hard coal particles distribution

In order to achieve high efficiency of coal burning process one should obtain proper particles comminution. Exemplary distributions of hard coal particles are presented in Fig. 4.

However as it occurs the water pressure increase leads to difference in comminution. Examples that illustrate such tendencies are analogical distribution plots obtained for jet pressure of 250 MPa (Fig. 5). Such almost 2 times higher water jet pressure increase leads to distinct comminution of hard coal.

As it comes out from the above research during hydrojetting comminution a few millimeter particles of fine coal become efficiently micronized. The amount of approx.

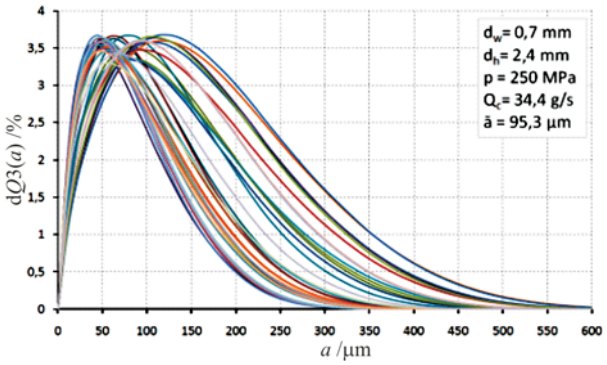

Figure 4 Distributions of hard coal particles fraction comminuted with water pressure of 150 MPa

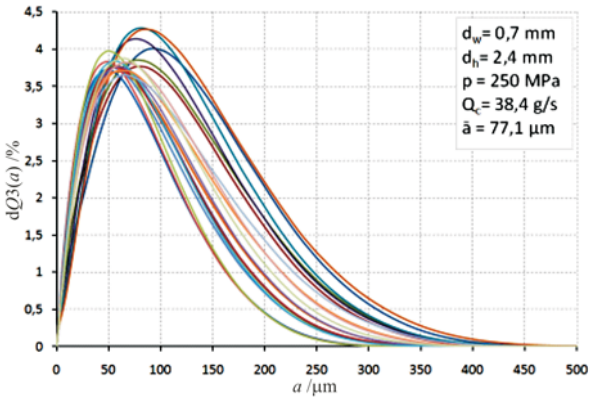

Figure 5 Distributions of hard coal particles fraction comminuted with water pressure of 250 MPa

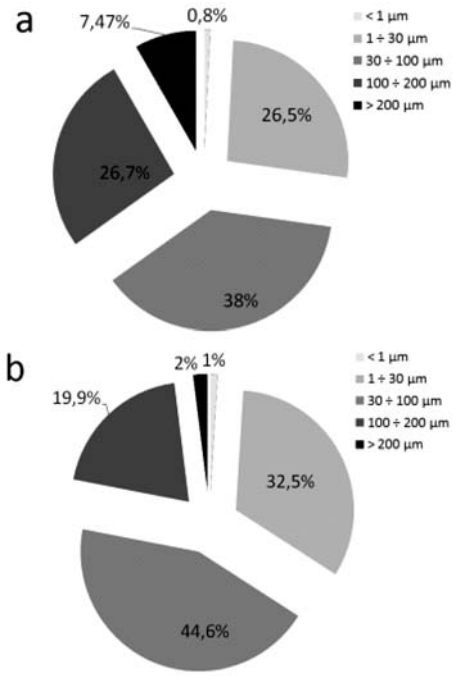

Figure 6 Quantitative contents of hard coal different fractions comminuted with high-pressure water jet (a - 150 MPa, b - 250 MPa)

65 % of hard coal is processed after the first stage and such material becomes range of 1÷100 µm for processing water pressure of 150 MPa while higher level of 250 MPa causes such percentage to reach the level of 77 %. Detailed contents of chosen particles fractions of the hard coal comminuted with high-pressure water jet are exemplified in Fig. 6.

3.2
Hard coal particles surface

Fine granularity of coal particles is limited by their specific surface increase what intensifies burning process. However, as it comes out from microscopic analysis hydrojetting micronization of coal causes specific development of created particles. Such a surface looks like shredded lamella additionally enlarging total work surface of these particles. Morphology examples of such particles being a part of new fuel type made of hard coal are presented in Fig. 7.

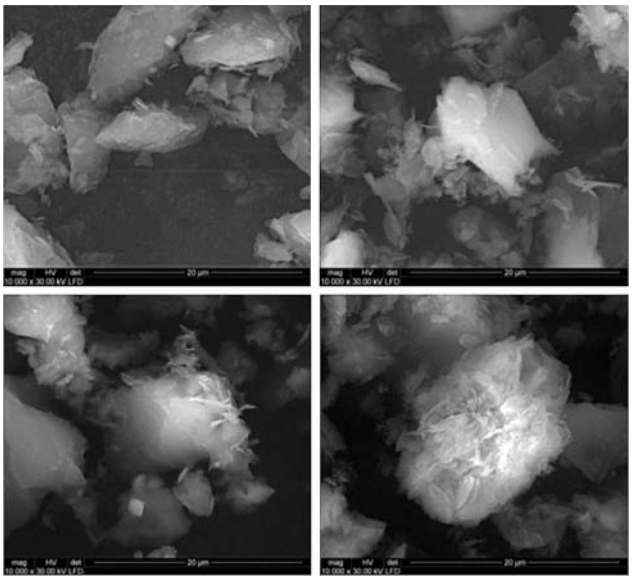

Figure 7 SEM pictures of hard coal showing different stages of their specific surface development

Estimated simulation results realized for lamellar morphology of coal particles created during water jet comminution point out that their real surface increases even up to 100 000 times compared to specific surface of usual fine coal. Such feature is very important taking into account efficiency of bio-chemical coal conversion into new generation fuel [8].

4
Brown coal comminution
4.1
Brown coal particles distribution

As it comes out from the experiments, the comminution of brown coal during high-pressure water jet grinding is much more intensive than that of the hard one. Evidence for that can be exemplary distributions of brown coal particles which are presented in Fig. 8.

The presented research proves that during hydrojetting comminution a few millimeter particles of fine brown coal become efficiently micronized (Fig. 9). The amount of approx. 90 % of brown coal is comminuted after the first stage and such material becomes of range 1÷100 μm for processing water pressure of 250 MPa.

4.2
Brown coal particles surface

Brown coal micronization during the high-pressure water jet process causes intensive comminution as well as

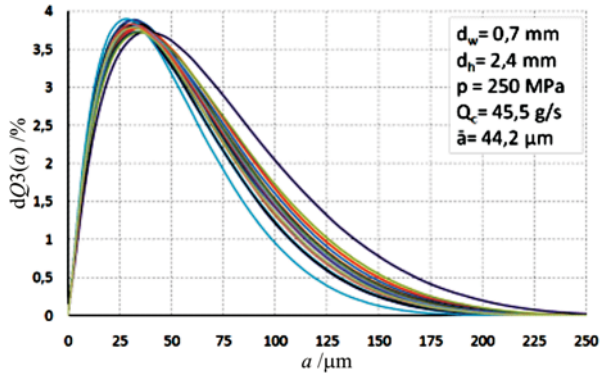

Figure 8 Distributions of brown coal particles fraction comminuted with water pressure of 250 MPa

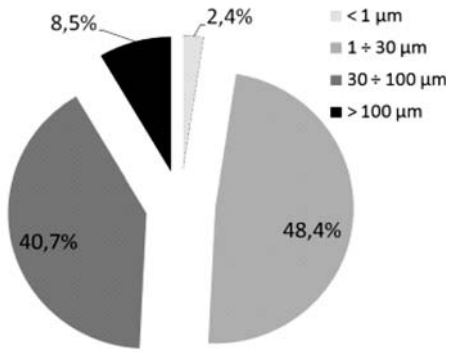

Figure 9 Quantitative contents of brown coal different fractions comminuted with high-pressure water jet (p= 250 MPa)

considerable growth of the created particles' surface. Diversification of its size and shape is illustrated in SEM images (Fig. 10).

Shredded form of comminuted particles of brown coal greatly multiplies their total surface. It is very profitable for efficiency of their burning process. Some exemplary morphologies of such particles are illustrated in SEM

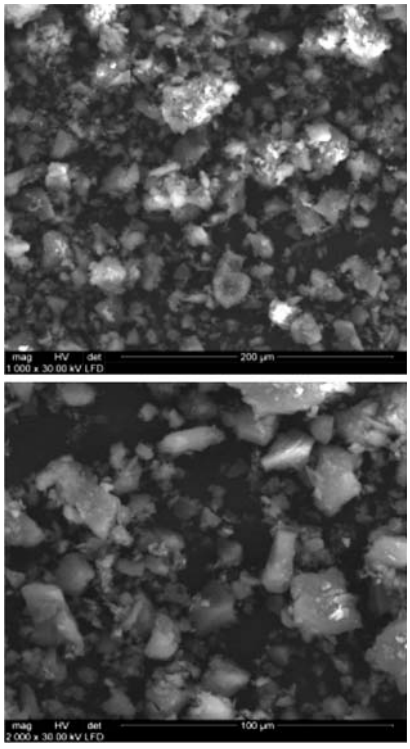

Figure 10 SEM images illustrating diversification of brown coal size and shape after high-pressure water jet comminution (p= 250 MPa)

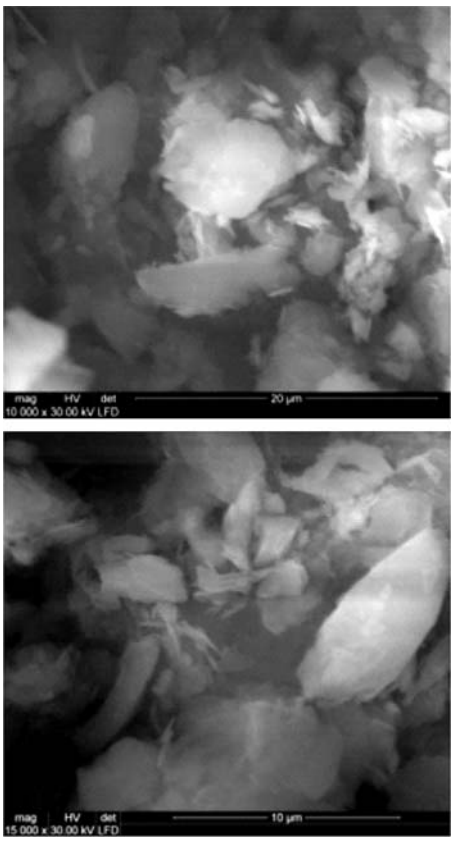

Figure 11 SEM pictures of brown coal comminuted with high-pressure water jet of 250 MPa showing different stage of their specific surface development

images presented in Fig. 11.

5
Charcoal comminution
5.1
Charcoal particles distribution

More intensive comminution is characteristic for charcoal grinding utilizing high-pressure water jet. Evidence for this can be observed in exemplary distribution of charcoal particles, which are presented in Fig. 12.

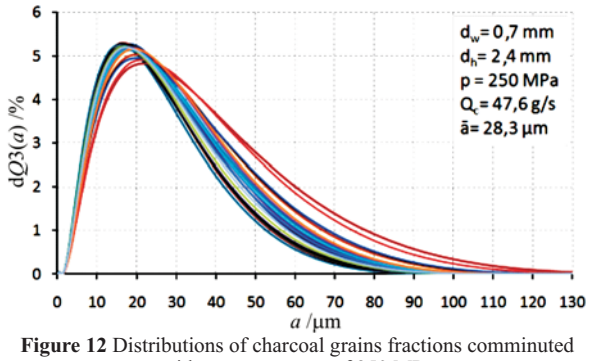

Figure 12 Distributions of charcoal grains fractions comminuted with water pressure of 250 MPa

Hydrojetting comminution of fine charcoal gives high-efficient micronization. Only the first stage of processing gives the range from approx. 65 % to over 83 % of charcoal comminuted with 250 MPa water jet to the range of 1÷30 µm. Detailed information on that results from the graph presented in Fig. 13.

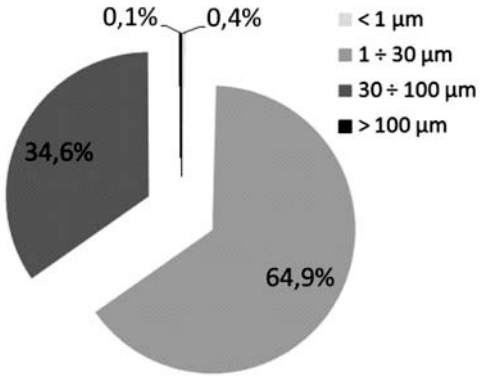

Figure 13 Quantitative contents of charcoal different fractions comminuted with high-pressure water jet (p= 250 MPa)

5.2.
Charcoal particles surface

Charcoal susceptibility for intensive hydro-jetting comminution is the reason why one can process the particles of the finest granularity structure what makes good prognosis for such coal usage as a bio-fuel. Thanks to hydro-jetting micronization method of charcoal one can observe that the most dominant part of after-processing material usually accumulates on the water surface in the form of foam. After drying such coal foam consistency is very porous (Fig. 14).

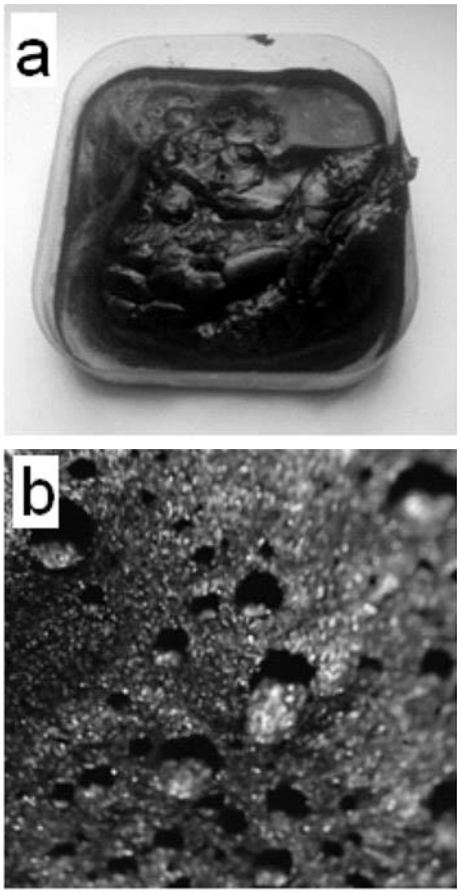

Figure 14 Air-dried charcoal mass (a) of great porosity (b), comminuted with high-pressure water jet (p= 250 MPa)

However, in reality the charcoal particles created in this way are grainy in structure and characterized with regular edges and surface. Typical examples of their shape and

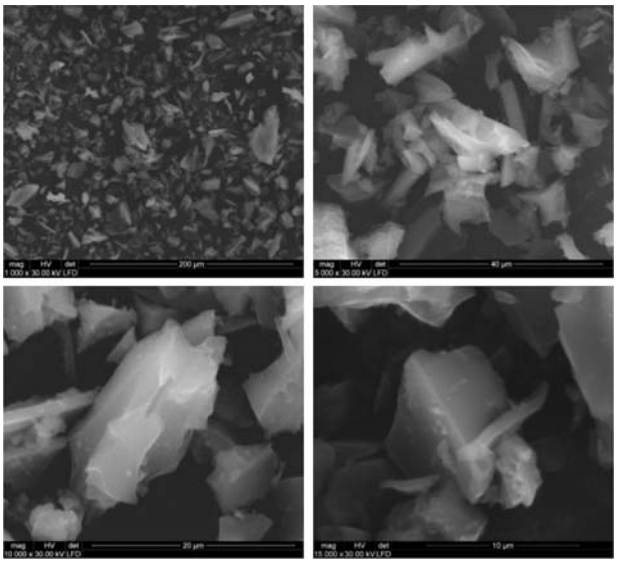

Figure 15 SEM pictures of charcoal showing different stages of their specific surface development

morphology, being a part of new generation charcoal fuel, are presented in Fig. 15.

6
Conclusions

The presented results of fine coal comminution with high-pressure water jet technique make it possible to formulate the following important conclusions of general character:

- Owing to small coal resistance to stretch stresses water jet technique usage for comminution is very effective. Moreover brown coal is much more susceptible for such processing than the hard one whereas the most intensive comminution is characteristic for charcoal.
- Amount of approx. 65 % of hard coal is processed after first stage and such material becomes of range 1÷100 μm for processing water pressure of 150 MPa while higher level of 250 MPa causes such percentage to reach the level of 77 %.
- Analogically approx. 90 % particles of brown coal's mining give the following results: 1÷100 μm for water pressure of 250 MPa.
- For charcoal comminuted with high-pressure water jet of 250 MPa, approx. 65 % to over 83 % of its particles size achieve the level of barely 1÷30 μm.
- Hydrojetting coal micronization causes the created particles surface to very often have a shredded lamellar form and thanks to that their real surface increases even up to 100 000 times comparing to the specific surface of usual fine coal.
- Charcoal susceptibility for intensive hydro-jetting comminution is responsible for causes that one can get particles of the most fine-grained structure giving the same good prognosis for its processing into bio-fuel.

Taking into account above results one should evaluate developed apparatus and method as very effective technique for high-pressure water jet coal comminution.

7
Nomenclature

a, $\bar{a}$ – unitary, mean size of coal particle, mm
d_h – homogenizing nozzle diameter, mm
dQ3 – frequency of unitary value occurrence of coal particle size, %
d_w – water nozzle diameter, mm
p – water jet pressure, MPa
Q_c – efficiency of hydro-jetting coal comminution, g/s.

8
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