POSSIBILITIES TO RECYCLE THE BOTTOM ASH FROM COAL FIRED BOILERS. PART II. RESULTS

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Abstract: *A special characteristic of the coal bottom ash is the content of unburned carbon, due to incomplete combustion in the boiler furnace. A special, multi-objective procedure for separation of ash particles containing unburned carbon was developed with the purpose of obtaining synthetic graphite and it was presented in the first part of the paper. In order to achieve full recycling of the ash landfill content, various secondary waste materials resulting from separation and concentration phases of the process flow must be further processed and sorted in order to ensure properties that guarantee recyclability. The process flow presented incorporates the graphitization process flow in such way that all secondary waste fractions can be recycled in various directions. The fix carbon content (FCC) and the mass breakdown weight (MBW) were determined for each separation process in order to choose the optimal process flow.*

Keywords: Bottom Ash, Unburned carbon, Recycle, Synthetic graphite, Particle Size Distribution

1. INTRODUCTION

A process flow has been defined in order to achieve complete recycling of BA (Figure. 1). The ash enters the process flow after the evacuation from the boiler into the main collector. The most significant part of the unburned carbon is present in the grain size fractions larger than 0.5 mm, as the elemental analysis of the raw BA revealed. Consequently, the primary separation process will extract the fraction with grain size >0.5 mm. Although the content of unburned carbon is high in this fraction, it accounts for 16.75 % only from the total amount of raw BA in terms of mass. The separation mechanism (figure 1) employed is the difference between water floatability properties of the two fractions. The efficiency of the separation process is defined in terms of mass percentage that fall in the desired grain size range:

- For grain size fraction >0.5 mm, 16,75 %

For grain size fraction <0.5 mm, 83.25 % The process flow will split from this point as shown in Figure 2 and described in detail in the next sections.

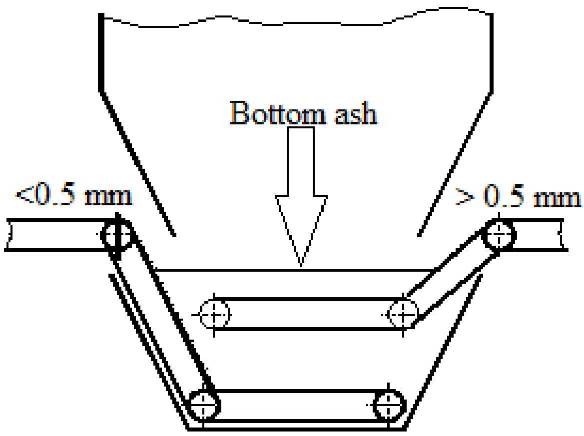

Fig. 1. First stage of separation

2. RESULTS

2.1.1. Dimensional separation

Pre-processing stage of the graphitization process flow requires dimensional sorting of the BA particles using the conventional sieving procedure. This stage is required since elemental analysis reveals that the highest carbon content can be found in particles in the range 2-4 mm. The sieving process will separate the fraction 2-4 mm denoted BP1 (1st stage concentrated) and will produce two by-products denoted BP1.1 and BP1.2, as shown in Table 1.

Table 1. By-products resulting from dimensional separation

Size range	< 2.0 mm	2.0 – 4.0 mm	>4.0 mm
FCC [%]	12.31	**29.31**	0.78
MBW [%]	74.97	18.31	6.72
Notation	BP1.1	BP 1	BP 1.2

2.1.2. Flotation.

BP1 fraction will undergo further concentration being subject to water flotation. Significant density difference of the particles with high carbon content makes this stage possible. Flotation will produce the by-products presented in Table 2.

Table 2. Float/sink separation

Floatability	Float	Sink
FCC [%]	**41.87**	13.89
MBW [%]	55.15	44.85
Notation	BPC.2	BP 2

2.1.3.Magnetic separation

By-product BP.C.2 will be subject to magnetic separation in order to screen out the fraction containing ferromagnetic material. Ferromagnetic material absence in the CCGP is a critical property for the graphitization process. The final results are presented in Table 3.

Table 3. Magnetic separation: CCGP

Magnetic properties	Non-magnetic	Magnetic
FCC [%]	61.38	23.97
MBW [%]	47.86	52.14
Notation	CCGP	BP3

The graphitization process flow will thus produce the final concentrated fraction CCGP which will be used in the actual graphitization process and four by-products, BP 1.1, BP 1.2, BP 2 and BP 3.

2.2.By-products recycling

The separation process - aiming to obtain CCGP - will produce the dominant fraction (<0.5 mm) in terms of mass (84.21%) representing a by-product of the main graphitization process. Values of the unburned carbon content suggest that this fraction can be mixed with BP 1.2 and further processed.

The main difference between the two by-products is the PSD. In order to level out the PSD difference, BP 1.2 requires processing by milling. The non-uniform carbon distribution by particle size in this new mix allows separation of the fraction with high unburned carbon content. Thus, a relatively high unburned carbon content by-product with grain size >0.5 mm denoted BP 5 will be separated from the mix, as shown in Table 4.

Table 4. Dimensional separation

Dimensional separation	<0.5 mm	>0.5 mm
FCC [%]	0.28	11.21
MBW [%]	83.97	16.03
Notation	BP4	BP5

2.3.Recycling options for the by-products

The objective of the study was to obtain CCGP - a precursor for the graphitization process. A number of five by-products will result. The by-products differ in the PSD and the unburned carbon content.

The by-products can be categorized based on the unburned carbon content, as follows:

- A. High unburned carbon content: BP 3
- B. Average unburned carbon content: BP 1.1, BP 2 and BP 5
- C. Low unburned carbon content: BP 4

As ash is traditionally used in the construction materials industry, the first consideration is given to this usage. Due to the high organic matter content, A type by-products are not suitable for construction materials. B-type by-products can be used for refractory, thermo-insulating materials. In this case, unburned carbon can replace other conventional pore-former materials such as perlite, diatomite, haydite, lightweight chamotte, lightweight mullite, bubble alumina [1]. Pores presence in thermally insulating material is a key condition for achieving the desired thermo-physical properties of the finite product. Pore-formation results in a low thermal conductivity for thermally insulating materials.

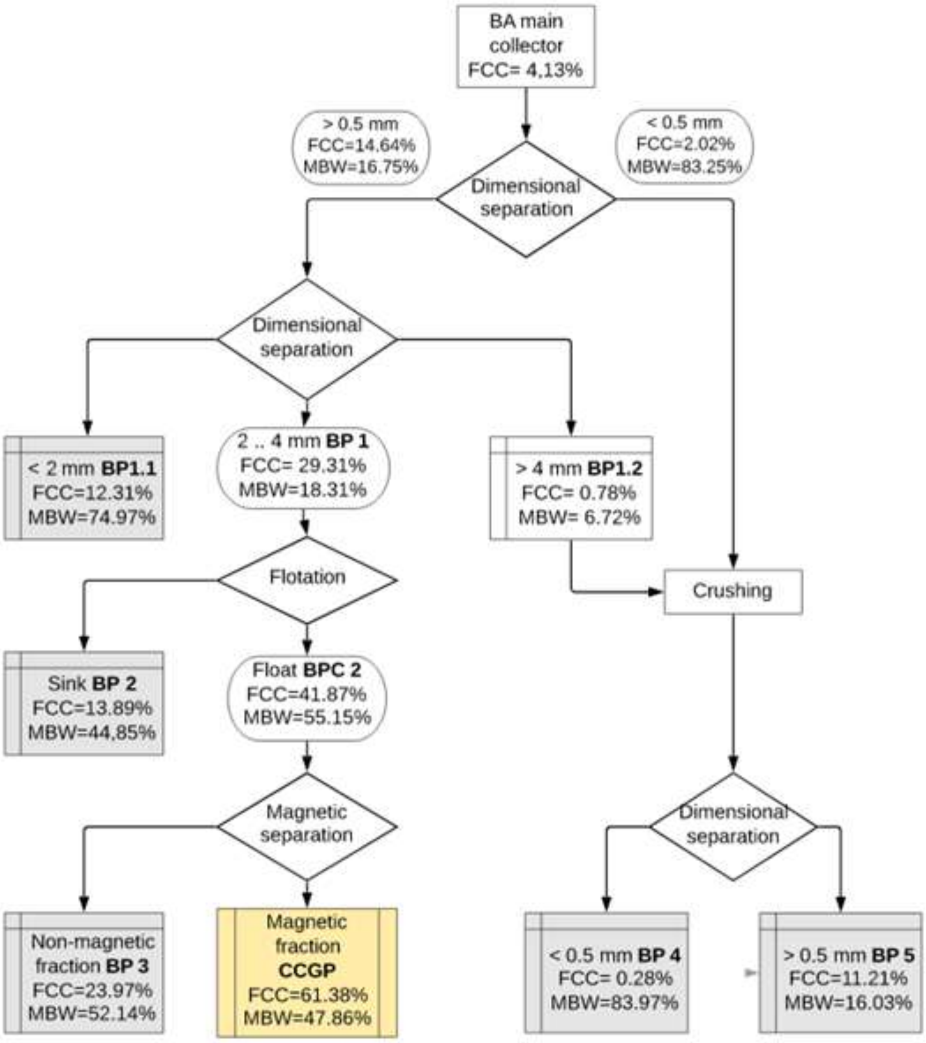

Figure 2. Overall process flow for complete BA recycling

Pore-former agents must have characteristics adequate to the application. Currently, the following techniques are employed to achieve thermal insulation properties through pore formation for construction elements:

- sawdust addition [2] for refractory construction elements with high thermal insulation
- expandable polystyrene [1] for insulating bricks

Another pore-forming agent is wood ash. It creates a more complex reaction during the heat treatment of the element with several factors influencing the pore density [3]. The presence of unburned carbon in the secondary waste BP1.1, BP2 and BP4 suggest that the unburned carbon can be employed as pore-formation agent in manufacturing of lightweight insulating construction elements [5]. High temperature heat treatment of the construction element will cause combustion and pyrolysis of the unburned carbon and will create a porous structure, which will contribute to increasing significantly the thermal insulation properties. On the other hand, a porous structure will lead to less satisfactory mechanical strength properties.

The directions of use for recycling the by products resulting during various stages of the process flow are presented in Table 5.

Table 5. By-products recycling options

SW	FCC [%]	Recycling options
BP1.1	12.31	Additive for lightweight construction materials [5]
BP 2	13.89	
BP 5	11.21	
BP 3	23.97	Briquettes [4], [2] Co-combustion [3]
BP 4	0.28	Substituent for concrete aggregates [6..9]

3. CONCLUSIONS

Complete recycling of BA is a challenging process due to the inconstant nature of the physical and chemical properties. Existing recycling technologies employ usually one specific property of the BA resulting in a small recycling percentage.

A complex recycling process flow targeted on several recycling directions with the purpose of achieving complete recycling of BA deposited in ash landfills is presented. The principle on which the process flow is based is fractions separation with the purpose of obtaining uniform properties (either physical or chemical). Uniform distribution of properties renders each fraction suitable for a specific recycling direction and use.

The primary purpose of the process flow presented is obtaining synthetic graphite from unburned carbon present in the BA. The by-products resulting from various phases are further processed, sorted and mixed based on similarity of chemical and physical properties. A number of five by-products fractions with little dispersion of the chemical and physical properties are finally obtained and three recycling directions are identified for each, thus achieving full recycling of BA.

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