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ENVIRONMENTAL AND TECHNOLOGICAL PROBLEMS WITH SEPARATION OF "MAXIM" WASTE DUMP MATERIAL

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ABSTRACT

It is well acknowledged fact that solving of certain environmental problems is connected to development of specific technological methods. The liquidation of Maxim dump in the city of Pernik coupled with elimination of the whole spectra of air and water pollution problems linked to that dump is both possible and highly welcome, since dump elimination itself will be self financed via realization of the rejected coal product and its utilization as a fuel in the Thermo power Station. The results from the exploitation testing of Maxim dump material performed in Belgium suggest the technological feasibility for hydrocyclone separation in an autogenous suspension. When tests were performed under 1.44 g/cm^3 suspension density, the dynamic conditions of the media secure real separation density of 1.65 g/cm^3 under which one could obtain coal concentrate with yield 21.43% with 21.5 % ash content. During the course of the industrial trials at the Belgian installation designed for recovery of black coal form local dumps, some negative factors were figured out having influence upon Maxim dump material treatment by which elimination better economic efficiency could be target in the case of hydrocyclone separation of the material in an autogenous suspension. These factors are: the existence of coal particles or intergrowths larger than 40 mm; the high tixotropic features of the clay met in Maxim dump which under increased moisture content of the material tend to form aggregates between coal and shale and their rejecting as 40 mm oversize; coarser dispersion of the clays in comparison to the granulometric characteristic of the autogenous suspension used in the industrial scale testing and others.

Key words: dump, coal, autogenous suspension, hydrocycloning.

INTRODUCTION

During the recent years countries such as UK, Belgium, France and others are allocating appreciable investments for processing of high ash coals and waste materials extracted from past not existing anymore mines. These investments are characterised by high rate of return. Parallel, devastated landscapes are improving and harmful gaseous, dust and liquid emissions are eliminated.

The improvement in the local environment in the city of Pernik is an urgent need, since this region is known as one having heaviest pollutants load on Bulgaria. Great deal of this pollution is due to chemical erosion from the coal dumps as a result of which sulphurous compounds, dust and heavy metals are emitted. During rainfalls these pollutants report into water courses and subsequently enter into soil system.

ENVIRONMENTAL INCENTIVES FOR MAXIM DUMP ELIMINATION

Maxim dump – characteristics

The Maxim waste dump or tip is located in the northern part of Pernik city vicinity, west to Divotinska river and in close proximity with the "St. Ana" coal mine. The outside view of the tip is a non-uniform cut cone having axis dimension 390 x 240 m with 28 m mean height. There are slopes reaching 30-40 % tilt. The upper surface is flattened at 0.5 - 2^o elevation. The dump is characterised by the following physical properties: moisture content – above 30 %, density 2,2 - 2,7 t/m^3, porosity 50 - 65 %. During 1972 the dump with a total area of 76 decars was transferred to Pernik municipal Council for further management. A plantation/biological rehabilitation has been performed in 1974. At the present time young not very well developed plantations remained only at about 30% of the tip surface mainly on its northern part. On the remaining part of the tip the wood plantations are dried as a result of the processes occurring inside the tip.

Up to 1992 six exploration wells were established for convenient for drilling spots however without an exploration grid after which further testing was not carried out. Hence, no sufficient data concerning the energy bearing mass distribution inside the tip is present. Data about ash content from each well differ significantly in a range from 70 % to nil. According to expert estimation about 200000 tones of coal are contained inside the tip.

Environmental problems

Maxim tip is a burning dump. Self ignition of the coal particles results as a result of oxygen contact. As a result of hemisorption oxygen molecules diffuse towards pores and adsorbs onto coal active centres. There compound of peroxide type are formed. These are non-stable compounds and according to chain-radical process theory they dissociate into radicals having high reaction affinity. The later attract coal organic structure and form intermediate compounds which are also non-stable and undergo dissociation. This formation of non-stable compounds is going fast and is accompanied by constant increase in temperature. When temperature reaches coal ignition point, burning takes place accompanied by release of fume gases. They contain CO, CO_2, SO_2, CS_2 and others. Since temperature abstraction from the materials surrounding the burning center is not effective, this is leading to temperature increase as a result of which processes known from gassification occurs leading to release of both HS_2 and other CH containing gasses like ethane, ethylene, acetylene and others. It is possible in some zones an anoxic regime of coal organic matter destruction to be formed which is leading to formation of tar containing various chemical compounds some of which like benzopyrrene are cancerogenic. Oxygen containing compounds like phenols are also emitted as well as amines. These product penetrate under gravity through pit volume, which process is facilitated by the increased porosity of the material. Surface waters coming from rainfalls collect these compounds and dispersed them towards the closest water catchments.

The fumes released via cracks and caverns coming in contact with atmospheric moisture are leading to acid generation which pollute both surface and underground water courses.

As a result of the erosion occurring in the South-east part of the tip the running near by river which is tributary to Struma river is polluted with non-dissolved solids. In dry seasons surrounding soils are polluted from the dust carried on by the winds carving the tip surface. It is obvious that Maxim tip with its burning features is highly environmentally harmful object. Burning processes are difficult to be forecast since they suddenly seize and start again depending on natural factors. It is not possible to evaluate the duration of complete burning process for the coal contained. It could last for decades. The above mentioned process provide a sound incentive for a search of mitigating options leading to their elimination.

Technological possibilities

Three principle directions are known from practice concerning coal wastes utilisation (Shpirt M.J., 1986):

a) wastes re-processing;
b) development of complex processing flow sheets enabling to use products with low content of burning mass;
c) utilisation of coal wastes in other industrial sectors.

Belgium is among the leading countries in extraction of coals from tips containing mixed materials (cut-off-grade coals and rock mass). Gravity methods aiming for burning mass recovery are widely practised in Belgium. Among the gravity methods the following are employed frequently: heavy media separation, separation in jigs, spirals, concentrating tables, hydrocyclones etc. The Belgian company WAUTELET offers technological flowsheets of installations designed for coal processing in hydrocyclones working with autogenerated suspension. The suspension is generated from the components coming with the raw material – mainly clay, sands and rock mass. From historical prospective coal washing is closely linked with the use of heavy media. Separation in such a media is characterised by not very strongly pronounced dynamic effects. An alternative option to such a heavy media separation is the separation in an autogenous self-generated media which has lower density and significant dynamic effects. The density practically required is compensated by the vortex and centrifugal currents which are generated inside separation devices aiming the recovery of burning components from the rock gangue.

EXPERIMENTAL

In order to prove the practical possibility for processing and utilisation of Maxim dump material an industrial scale trials were needed. Since in Bulgaria there is no installation for processing raw materials of such kind industrial testing was carried out in Belgium at WAUTELET installation in the Charleroi vicinity. The objective of the testing was twofold – first to prove or to reject that possibility and second to evaluate the technical and economic feasibility for the eventual future tip re-processing.

Sample representativeness

Obtaining of a mean representative sample seems a difficult task since waste tip has been formed non-uniformly and under non-constant time intervals. Nevertheless, the quantity of the sample raw material subjected to experimental testing should comply with the granulometric composition of the material inside the tip and with the maximal particle size. Mean sample has been prepared by sampling of six randomly chosen points at tip surface via bucket elevator. From each point about 20 tones were digger out from a depth limited by bucket elevator arm. The material taken out has been stored as cone-shaped on a special site from where after three times joining and dispersion about 60 tones were collected by quart method. Separate sample for laboratory studies has been collected immediately upon material loading onto the railway carriage.

Laboratory studies

Preliminary laboratory tests have proved that the material from Maxim pit has 16 % moisture content and 70 % ash content. Material fractionation (sink/float analysis) in a bromoform as a heavy media was carried out as well. The results obtained are presented at Table 1.

Table 1. Sink/float results for Maxim dump material

Density g /cm^3	Float fractions, %	
	Yield	Cumulative yield
Below 1,6	28,25	28,25
1,6 - 1,7	23,71	51,96
1,7 - 1,8	22,97	74,93
1,8 - 1,9	15,17	90,10
1,9	9,89	100,00

Table 1 analysis data were used for construction of the theoretical processing curves presented at Figure 1 below.

Industrial testing method

The method used for industrial scale testing is comparatively-simulative. It presumes subjecting the Maxim tip material by interruption of a working installation with parameters optimised in advanced for processing of black coal tips. It was decide to envisage 5 minutes time interval in order to precisely delineate between start-up and finishing for the two materials – the one originally processed at the installation and the Maxim dump material. However, the originally generated suspension is used for the Maxim materials well, since the quantity of the material and its residence time inside installation are both enough for generation of self-suspension. Suspension density has been monitored every 2 minutes. Same time interval was used for sampling, when two equal samples from the suspension were taken, and were joined by the end of the experiments. In a 4 minute intervals samples from concentrate and collective tails were taken by means of pulp sectioning. In order to satisfy data compilation the following items were additionally estimated:

- overall quantity of treated material;
- quantity of coal concentrate yielded;
- ash and moisture content of the coal concentrate.

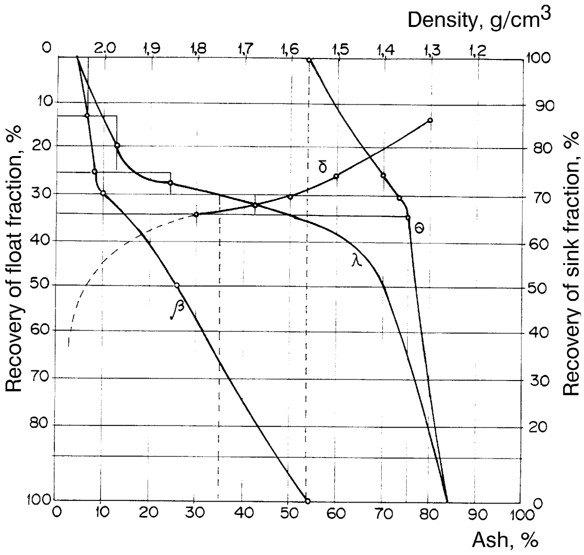

Figure 1. Theoretical processing curves for Maxim dump material

Industrial installation

The principal sequence of the industrial installation is shown at Fig. 2

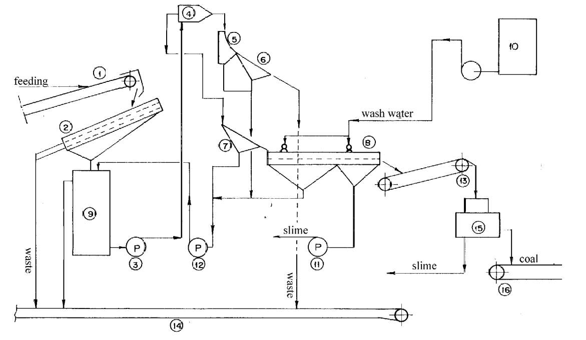

Figure 2.. Black coal waste separation flow-sheet- unit sequence

1- feeding belt; 2- double deck vibration screen; 3- pump; 4- hydrocyclone; 5- arc screen; 6- drainage screen for waste; 7- drainage screen for hydrocyclone overflow; 8- wash screen; 9- washing drum "Barrel"; 10- wash water tank; 11- slime pump; 12- recycled water pump; 13- rubber transportation belt for washed coal; 14- rubber transportation belt for waste material; 15- drainage centrifuge; 16- rubber transportation belt for coal concentrate to storage.

Experimental results

The experimental testing has followed an initially agreed routine for and established technological regime. Experimental start-up has coincide with hour four after initial installation running. The Maxim dump material has been processed on one of both modules. Total test duration has been set to 24 minutes. The total amount of material processed was 56 tonnes with an ash content of 70 % and 18 % moisture. 12 tonnes of concentrate were obtained having ash content of 21,5 % and 15,3 % moisture. Representative samples from the following products were collected – autogenous suspension, coal concentrate, tail. They were subjected to lab studies at the UMG in Sofia. The suspension density measured with aerometer ranging form 1,0 - 1,5 g/ cm^3 at 18 ^0C has indicated 1,44 g/ cm^3. Its granulometric composition was obtained by means of a laser particle sizer Analyzzette 22 and is given ate Figure 3 .

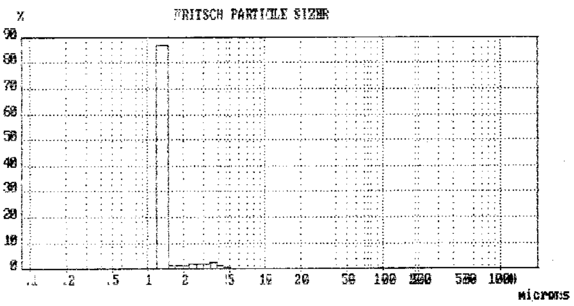

Figure 3. Granulometric characteristic of autogenous suspension used for black coal waste tips hydrocycloning in Belgium

Table 2. Size analysis for washed onto 0,063 mm sieve coal concentrate obtained during an industrial testing in Belgium

Size class mm	Yield %	Ash content %	Cumulative mass "+", %	
			Yield, %	Ash content, %
+ 20,0	2,59	24,5	2,59	24,80
- 20,0 + 9,0	16,05	11,0	18,64	12,87
- 9,0 + 5,0	22,33	10,7	40,97	11,69
- 5,0 + 2,5	24,25	14,1	65,22	12,58
- 2,5 + 1,25	20,50	16,4	85,72	13,50
- 1,25 + 0,5	9,13	25,8	94,85	14,68
- 0,5 + 0,63	5,15	42,2	100,00	16,10
Total	100,0	16,1	-	-

For the coal concentrate sample as taken from the installation moisture content after drying at 105 ^0C, has been estimated as 5,3 %. After further concentrate washing with tap water on 0,063 mm sieve a granulometric analysis of the oversized dry product has been done. Data from that analysis are presented ate Table 2. During concentrate washing a clayey-slime products was collected which was settled and dried. Its mass yield was 8,05 % and ash content 67,6 %.

The tailing sample was wet sieved on 40 mm screen. It was found out that size class + 40 mm encompasses two groups of particles:

a) massive lumps;

b) aggregates consisting of coal and loamy marl particles glued by wet clay.

Table 3 presents the granulometric composition of class 40 mm undersize with the respective ash content for each class.

Table 3. Granulometric composition of class 40 mm undersize for the tailing obtained during industrial testing in Belgium

Size class mm	Yield %	Ash content %	Cumulative results "+", %	
			Yield, %	Ash content, %
+ 20,0	7,34	84,60	7,34	84,60
- 20,0 + 9,0	2,60	79,10	9,94	83,10
- 9,0 + 5,0	10,53	83,30	20,47	83,23
- 5,0 + 2,5	13,85	81,60	34,32	82,57
- 2,5 + 1,25	16,21	85,20	50,53	83,42
- 1,25 + 0,5	20,36	88,70	70,89	84,93
- 0,5 + 0,63	15,03	89,10	85,92	85,66
- 0,063	14,08	88,20	100,00	86,02
Total	100,00	86,02	-	-

By means of hand sorting massive lumps were separated from the aggregates of + 40 mm class after which loamy marl particles were separated from the coal particles. The aggregates between loamy marl and coal particles are glued by the clay. After disintegration and washing of this fraction the results shown ate Table 4 were obtained.

Table 4. Granulometric composition of class 40 mm oversize for the tailing obtained during industrial testing in Belgium

Size class, mm	Yield, %	Ash content, %	Cumulative yield, "+"	
			Mass, %	Ash content, %
above 40 mm shales	14,70	90,80	-	-
> 40	6,48	34,10	53,83	73,45
40 - 0,5	12,92	69,30	86,68	71,88
< 0,5	5,24	81,30	100,00	73,13
Total + 40	39,34	81,30	-	-

From the clayey product (- 0,063 mm) shown at Table 3 a sample for sieve analysis has been taken. It was subjected to Analyzzette 22 particle sizer. Figure 4 presents the result form that analysis. This class was generally responsible for autosuspension formation during Maxim dump material processing.

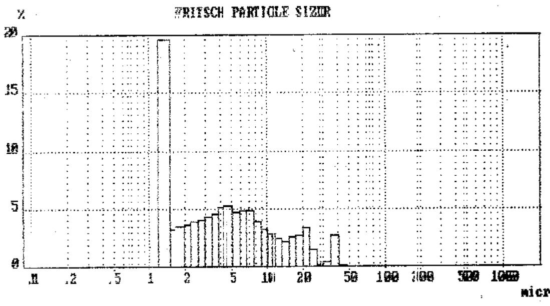

Figure 4. Granulometric characteristic of clayey product - 0,063 mm from Maxim dump

DISCUSSION

Maxim dump material is suitable for separation by means of autogenous suspension which itself presents the finest part of clayey-sandy fraction of the material. Data at Figure 3 support the fact that the Belgian suspension consists predominately of fine particles – about 90 % under 2 micrometers. These are fine loamy particles, since there is no clay in the host rocks. In contrast, the finest part of Maxim tip material is presented predominately by clay and fine rock (mostly marl) particles. Owing to data at Figure 4 the fraction 2 micrometers undersize is around 30 %, and the maximal grain size exceeds 40 microns. Particles in the range 2 - 20 microns are characterised by relatively random distribution. The clay found in Maxim dump is sticky and has high plasticity. These features of the material are additionally supported by the fact that significant aggregates are present in class + 40 mm consisting of fine coal and loamy marl particles coated with clay.

The analysis of the gangue obtained during the industrial testing suggests that definite reserves for improving separation efficiency exist. Coal particles are found in class + 40 mm, which is not subjected to treatment. These particles have low ash content which makes them suitable as power plant fuel. This class consists of two groups:

a) monolithic coal and loamy marl lumps;

b) aggregates.

Coal fractions having 16,48 % mass and A^d - 34,1 % has been separated from the class + 40 mm during hand sorting based on colour and blister. This material could not be treated via hydrocycloning according to the flow sheet tested , but it could be successfully separated by the means of Barrel washing drum and joined the concentrate obtained after hydrocycloning. The other option for utilisation of this product is to subject it to size reduction down to - 40 mm and to processed it according to the flowsheet given at Figure 2, however with lower recovery anticipated.

The aggregates rejected in class + 40 mm present also an interesting reserve. Based on distribution, size and ash content, the aggregates which form this class are similar to the particles met in the coal concentrate and in the tailing - 40 mm. Obviously, if a conditions under which clay does not manifest its plasticity and adhesives are maintained, they will report in the concentrate and in the tails in ratio estimated during the experiments, which will lead to overall increase in concentrate yield. The unwanted effects of clay could be eliminated also either by initial increase in its moisture content or by its preliminary drying.

These reserves are proving the relatively large difference in the quality and amount of the obtained concentrate compared to the data suggested by the theoretical processing curves.

The autogenous suspension density during experimental test was 1,44 g/cm^3 demonstrating strong dynamic effects, which is equal to separation density of 1,6 - 1,65 g/cm^3 for calm media. The shape of the (λ) curve (elementary fractions curve) suggests that the Maxim dump coals are easily beneficiated. The theoretically possible yield is 33,2 % with A^d - 42,8 %.

The experimental results, however are indicating yield of 21,43 % for A^d - 21,50 %, which are fairly below those suggested by the curves. Provided some correction in the flowsheet are taken into consideration, accounting some of the reserves mentioned above, yield could be increased above 30 % for A^d lower than 40 %. These results are approaching those suggested by the theoretical curves. Density of 1,6 - 1,65 g/cm^3 is a suitable one for recovery of energy material from brown coals such as those met in Maxim dump, while such a density does not work effectively for black coals where concentrate with low ash content suitable for the coke industry could be recovered only. Gives this issue, the choice of the industrial testing installation for the material coming from Maxim dump seems the right one.

CONCLUSION

The industrial testing performed with the Maxim tip material with objective of recovery of burning fraction suitable for Thermo Power Stations fuel, provide a positive answer to the problem of tip liquidation. By means of extraction of the burning-prone fractions from the tip, the potential source of environmental pollution are eliminated. Qualitative and quantitative characteristics of the concentrate obtained are quite convincing, while the economic estimations suggest that the costs associated with material re-processing are entirely covered by realisation of the concentrate with about 15 – 40 % profit depending upon installation capacity.

The separation of Maxim dump material via installation working with hydrocyclone scalping is a suitable method. A special emphasis should be placed on the following technological peculiarities during the course of operation:

a) clay met in Maxim dump material possess high plasticity and adhesives when moisture is above 15 %;
b) coal lumps are present in the fraction rejected ahead of the separation, i.e. + 40 mm;
c) thin (1 - 2 mm) coal layers are met inside loamy marl particles.

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