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ABSTRACT

In this study we have used wet separation techniques for selective flotation of the low rank Sulcis coal. The investigation has been carried out for cleaning waste coal fines from the Nuraxi Figus treatment plant with a view to using the concentrate in the power industry.
The results of this investigation have shown that the proportion of coal fines recovered ranged between 50 and 60%, depending on desired concentrate quality. Moreover, a market has been identified on the basis of concentrate characteristics.

Key-words : selective flotation, low rank coal, Sulcis coal fines

INTRODUCTION

In the process for beneficiating the low-rank coal from the Sulcis basin in Sardinia (Italy), the fines resulting from preliminary classification by hydrocyclone of the feed material to the spiral concentrator in the gravity separation section and from dewatering the concentrates, are rejected as tailings.
Systematic characterization of these coal waste fines, of which some 75 t are generated hourly, showed them to be composed almost entirely of grains of size smaller than 0.3 mm, and to contain a fair amount of combustible matter, concentrated for the most part in the coarser fractions of the grain size range.
These findings prompted us to carry out an experimental investigation aimed at exploring the possibility of recovering the combustible fractions as a marketable product. As the tailings are currently pumped to a settling pond, it was reasonable to assume that the average grain size characteristics of the coal waste fines were well represented by the several hundreds of tons deposited in the basin.

So a sediment sampling survey was launched, which consisted in drilling 17 holes over the entire area and through the depth of the tailings pond. The main qualitative characteristics of each core were then determined in the laboratory by means of proximate analysis and gross calorific value (GCV) measurement and grain size analysis performed. The results showed that throughout the basin the tailings exhibited fairly uniform grain size and compositional characteristics, on average substantially similar to the values determined for the coal waste fines rejected from the treatment plant. Using the sediment cores, a large representative sample of the tailings ponds as a whole was then prepared for use in the experimental tests. We tested the feasibility of recovering the combustible fraction contained in the tailings pond of the Nuraxi Figus mine, and all the more so in the fines contained in future coal processing waste, by means of selective flotation, a procedure that exploits the surface properties, i.e. the most favourable for fine mineral particle separation.
This paper first describes the main chemical and physical properties as well as grain size characteristics of the sample used in the tests. It then goes on to describe in detail the test conditions and procedure. The results obtained are discussed and some suggestions provided concerning adjustment of the main parameters influencing the technical and economical results of the separation process.

CHEMICAL, PHYSICAL AND GRAIN SIZE CHARACTERISTICS OF THE COAL WASTE FINES

The coal fines deposited in the Nuraxi Figus tailings pond were chemically and physically characterized by determining proximate composition and gross calorific value (GCV).
Proximate analysis was performed using a LECO MAC 400 analyser while gross calorific value (GCV) was determined by means of a Parr adiabatic calorimeter. Grain size analysis was performed wet for grain size classes of up to 37 micrometres. Proximate composition and GCV were then determined for each size class. The results are summed up in Table 1.

Table 1 – Size analysis, proximate analysis and GCV of representative sample of Nuraxi Figus tailings basin.

Size class (mm)	Yield (%)	Moisture (%)	V.M. Dry (%)	Ash Dry (%)	F.C. Dry (%)	Stot Dry (%)	GCV Kcal/kg
+0.210	8.66	5.32	37.82	46.29	15.89	4.87	3640
-0.210+0.150	6.43	6.31	43.49	34.01	22.50	5.23	4592
-0.150+0.105	7.56	6.24	43.23	32.90	23.87	5.42	4728
-0.105+0.075	7.43	6.09	41.85	36.40	21.75	5.41	4443
-0.075+0.045	6.96	5.72	38.88	40.85	20.27	5.20	4092
-0.045+0.037	8.98	4.35	29.68	61.81	8.51	2.94	2045
-0.037	53.97	3.71	23.19	70.85	5.96	2.36	1278
Total reconstituted	100.00	4.58	30.34	58.02	11.64	3.47	2457
Total analysed		4.64	29.97	57.43	12.59	3.58	2399

V.M. = volatile matter; C.F. = fixed carbon; Stot = total sulphur content; GCV = gross calorific value.

As can be observed, the untreated combustible fractions, or in any case those not recovered in the spiral concentrator, tend to concentrate mostly in the +45 micrometre size classes, diminishing drastically in the finer fractions which by contrast contain practically all the clay particles present in the run-of-mine.
The particular distribution of the carbon-containing fractions suggested that it would be beneficial to proceed with classification of the material prior to performing flotation, in order to remove to as much of the clayey constituent as possible, thereby creating more favourable conditions for the beneficiation process.

In this context, as the 0.037-0.045 mm size class was observed to still have a relatively high gross calorific value, we had to assess whether to adjust the classifier cut off size to include this size class or not. The advantages of one or the other option can be weighed up by comparing the technical and economic performance of the separation tests.
Table 2 shows for the 0.037 and 0.045 mm size classes the variations in yield and quality of both the material retained on and the material passing the two sieves. Then it is logical to assume that smaller quantities of potentially recoverable coal will correspond to a superior quality feed and viceversa.

Table 2 – Yield (wt) and proximate analysis of the 0.045 and 0.037 mm sieve undersize and oversize

Size class (mm)	Product	Yield (%)	Moisture (%)	V.M. Dry (%)	Ash Dry (%)	F.C. Dry (%)	Stot Dry (%)	GCV Kcal/kg
0.045	undersize	37.06	5.91	40.92	38.42	20.66	5.21	4273
	oversize	62.94	3.80	24.12	69.56	6.32	2.44	1388
0.037	undersize	46.03	5.61	38.73	42.98	18.30	4.77	3839
	oversize	53,97	3.71	23.19	70.85	5.96	2.36	1278
	totale	100.00	4.58	30.34	58.02	11.64	3.47	2457

EXPERIMENTAL

In the tests described here the classification stage, which prepares the material for flotation and which in commercial operations is performed using a hydrocyclone, was simulated simply by wet sieving, dividing the sample into the two size classes 0.045 and 0.037 mm. Separation efficiency by means of flotation was then determined using the material retained on both sieves.

The flotation tests were performed in a 1 litre capacity mod. L Denver sub-aeration laboratory flotation cell, setting rotor speed at 1500 revs/minute.

The following reagents were used in the tests:

- sodium hexametaphosphate as dispersant for the residual clay minerals ;
- Dowfroth 1012 as frother ;
- a 50/50 mixture of light (diesel) and heavy (Bunker C) fuel oils as collector.

The findings of earlier studies had in fact demonstrated that the above reagent combination performed well in the flotation of low-rank coals [1-2], especially the light/heavy fuel oil mixture used as collector. Optimal proportions of the two oils depend on the type of coal to be treated, and should be adjusted so as to:

- generate a minor repulsive electric force in the interaction with the surface of the coal particles;
- produce low surface tension and interfacial tension with water;

- be sufficiently viscous to readily emulsify and spread, but not to be excessively adsorbed into the coal pores;

Flotation tests were conducted adopting the following standard procedure:
- 1 litre of pulp with a 10% by weight solids concentration was placed in the flotation cell;
- the pulp was first conditioned for 5 minutes with 1kg of sodium hexametaphosphate per tonne of solid. 200g/t of Dowfroth 1012 frother were then added to the pulp and lastly varying amounts of collector oil;
- after a contact time of 1 minute with the collector, flotation was promoted and allowed to proceed for 4 minutes or in any case until such time as the froth had subsided;
- the rougher flotation concentrate was cleaned to improve quality and the reject, containing minor amounts of combustible matter, was mixed with the rougher tailings;
- the two products, concentrate and reject, were filtered, dried, weighed, and proximate composition and GCV determined [3-4];
- lastly mineral content and recovery of combustible matter were calculated using the following formula

$$\rho = Rc(100-MMc)/(100-MMa)$$

where

Rc = concentrate yield; MMc and MMa = mineral assays of the concentrate and feed respectively.

RESULTS

The results obtained for the flotation tests on the two materials retained on the 0.045 mm and 0.037 mm sieves are shown in Tables 3 and 4 versus amount of collector used and are graphically represented in Figure 1. For ease of consultation, the table only shows the dry ash content, mineral content and GCV while the yields and combustible matter recoveries have been calculated referring both to the feed to the flotation cell and to the total material .

Table 3 – Separation results for flotation of the 0.045 mm sieve oversize versus quantity of collector used.

Collector (kg/t)	Flotation	Yield (%)		Ash dry (%)	Mineral matter (%)	GCV (kcal/kg)	ρ Combustible (%)	
		Feed	Total				Feed	Total
0.570	Product	57.28	21.23	16.17	17.82	6033	76.9	44.3
	Tailings	42.72	15.83	62.39	66.88	2059	23.1	13.3
	Total	100,00	37.06	35.87	38.78	4335	100,0	57.6
1.430	Product	76.62	28.39	23.42	25.53	5414	92.4	53.2
	Tailings	23.38	8.66	74.66	80.04	778	7.6	4.4
	Total	100,00	37.06	35.40	38.28	4330	100,0	57.6
4.280	Product	84.51	31.32	27.93	30.32	5148	96.5	55.6
	Tailings	15.49	5.74	80.52	86.28	276	3.5	2.0
	Total	100,00	37.06	36.07	38.99	4393	100,0	57.6

Table 4 – Separation results for flotation of the 0.037 mm sieve oversize versus quantity of collector used

Collector (kg/t)	Flotation	Yield (%)		Ash dry (%)	Mineral matter (%)	GCV (kcal/kg)	ρ Combustible (%)	
		Feed	Total				Feed	Total
1.430	Product	55.01	25.32	18.87	20.69	5848	78.5	51.5
	Tailings	44.99	20.71	68.47	73.46	1544	21.5	14.1
	Total	100,00	46.03	41.19	44.43	3912	100,0	65.6
2.280	Product	66.76	30.73	24.22	26.38	5407	88.0	57.7
	Tailings	33.24	15.30	74.40	79.77	832	12.0	7.9
	Total	100,00	46.03	40.90	44.13	3886	100,0	65.6
4.280	Product	76.14	35.04	30.09	32.63	4991	92.9	60.9
	Tailings	23.86	10.99	77.91	83.50	401	7.1	4.7
	Total	100,00	46.03	41.50	44.77	3896	100.00	65.6

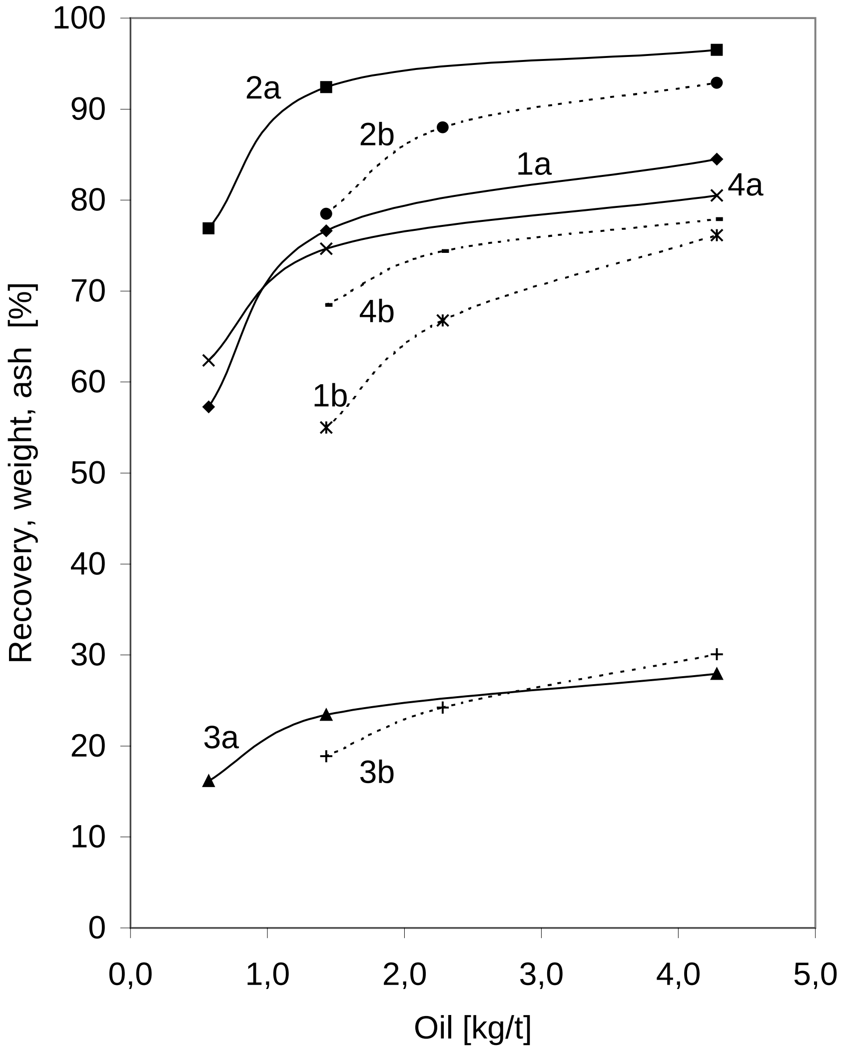

Figure 1 – Influence of amount of oil collector used in flotation of oversize particles retained on 0.045 mm (a) and 0.037 mm (b) sieves. 1) Yield; 2) Recovery of combustible matter in flotation product; 3) Ash content of flotation product; 4) Ash content of tailings.

CONCLUSIONS

Laboratory investigations conducted for the purpose of assessing the possibility of recovering the coal from the waste fines rejected from the treatment plant at the Nuraxi Figus coal mine in Sardinia have demonstrated the feasibility of their separation using flotation techniques.

Characterization analyses conducted on a representative sample of the waste fines obtained from systematic sampling of the material deposited in the tailings basin, showed that the size classes finer than 37- 45 micrometres, which contain little coal matter, need to be removed prior to proceeding with the flotation process..

The flotation tests were in any case performed on the two products deslimed by wet screening at 45 and 37 micrometres.

The flotation technique employed here, which had been tested in earlier experiments on coals of similar rank to the Sulcis coal, uses a 50/50 mixture of heavy and light fuel oils as collector.

The qualitative characteristics of the flotation products depend to a large extent on the amount of oil employed, in other words on the desired yield and combustible matter recoveries. On average it should be possible to obtain concentrates with an ash content of between 20 and 30%, corresponding to a GCV in the order of 5800 and 5000 kcal/kg respectively, with yields, referred to the total amount of waste fines generated by the coal processing plant, ranging from 25 to 35% and coal recoveries of between 50 and 60%.

Concerning the marketability of these concentrates, potential areas of commercial application lie in the power industry for example in subcritical PCC (Powder Coal Combustion) or FBC (Fluidized Bed Combustion) plants .

Lastly, regarding optimum adjustment of the cut point (d_{90}) in the hydrocyclone desliming section, to prepare the material for the flotation process, comparison of the experimental results obtained shows that working with higher cut sizes offers some advantage in terms of collector consumption, while at the finer sizes there is some improvement in overall performance. The choice between the two will thus be dictated by reagent costs and the market price of coal products.

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