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Abdel-hady SALEH*, Jerzy ISKRA**

THE EFFECT OF FEED GRAIN SIZE AND SIZE DISTRIBUTION ON PROMOTING FLOTATION OF LOW RANK COAL

This study investigates the effect of feed grain size and size distribution on the promoting flotation of low rank coal. A natural by-product of oil refinery (pyrolizate) was tested as a promotor. The performance of this natural coal promotor was found to depend on the feed grain size and size distribution. The coal recovery and flotation selectivity were improved as the feed grain size decreased. With a very fine flotation feed material the observed improvement in coal recovery is accompanied by loss in selectivity. Also, within the studied feed size range, it was found that the flotation rate increases as the feed size decreases. The specifications of this natural reagent and its functional groups are still under consideration and will appear later.

1. INTRODUCTION

Recently, interest has aroused in exploiting the large resources of low rank coals. Froth flotation is the well established separation technique. In this respect, it is generally known that the coal floatability varies widely depending on the feed grain size/size distribution, degree of oxidation and the petrographic composition (Sun 1954; Bearse 1961, 1962). Among these factors, the particle size is the most effective and important. This is due to the fact which states that the better understanding of size-recovery performance of the flotation circuit may lead us to selection of an optimum grinding circuit with regard to particle size and/or grinding media (McIvor and Finch 1991; Martin et al. 1991). Also, in modelling the flotation process, it is essential to understand the behaviour of individual size fractions in the feed. It was found that the fineness or the coarseness of the feed affects the performance of flotation process to a large extent (Vanangamudi, Surya and Rad 1989). However, there has been a little agreement between different workers on the form of the relationship between recovery and grain size. It appears, very broadly

*Mining Department, Faculty of Engineering, Alazhar University, Nasr City, Cairo, EGYPT
**Mineral Processing Institute, Faculty of Mining and Geology, Silesian Technical University, Gliwice, POLAND

speaking, that the recovery and/or the rate constant either increases with decreasing size below 500 microns (Banerjee et al. 1962; Pooley 1967; Firth, Swanson and Nicol 1978) or is the greatest in the intermediate range (Sun and Zimmerman 1950; Burdon 1962; Lynch et al. 1981). Trahar (1981) suggested that in mineral flotation there is an interaction between hydrophobicity and grain size whereby larger grains require more hydrophobic surface to be floated to the same degree as smaller grains. The variation of the recovery with size was recently explained in terms of the joint effect of rank and size on the floatability of composite coal grains (Heriberto and Leonard 1984). Consequently, it seems likely that the size distribution of the feed coal influences the strategy to be adopted during the flotation process. Various techniques such as stage-wise addition of reagents (Burdon, Booth and Mishra 1976; Laskowski, Sirois and Moon 1986) and classification of flotation feed prior to flotation (Rajeswara et al. 1985; Pedberge 1987) are commonly suggested.

The promoting effect of a natural refinery by-product (pyrolizat) on low rank coal flotation was observed in previous studies (Sablik 1989 ; Saleh and Iskra 1992). The present work is an attempt to investigate the relationship between such promoting effect and the feed grain size and size distribution.

2. MATERIALS AND METHODS

2.1. Materials

The feed used in this study is of the energetic coal type. It has a rank of 31.1 according to the Polish classification standards (Polish Standards, 1950). It was obtained from Komuna Paryska mine, Silesia, Poland. The feed material contains 27% ash and 3.2% sulphur (experimental values). Throughout the study, diesel oil was used as a collector, aliphal (mixture of aliphatic alcohols) as a frother and pirolizate (a natural refinery by-product) was tested as a collector and promotor. This natural reagent is a mixture of high boiling aliphatic and aromatic hydrocarbons (Sablik 1989).

2.2. Methods

The coarse coal lumps were crushed in a jaw crusher to a size of 1 mm and then dry ground in a ball mill to -0.5 mm. In each run, the fraction -0.5 mm was separated while the fraction +0.5 mm was returned to the mill. Other two flotation feeds -0.2 mm(A) and -0.2 mm(B) were also prepared by following the same technique. In the first, 20% of the

TABLE I. The size distribution of flotation feeds

-0.5mm	size*	+0.3	+0.2	+0.102	+0.075	+0.060	-0.060	Total
	Wt.%	24.24	19.11	16.97	3.98	0.92	34.78	100%
	Ash %	17.63	19.46	21.03	27.13	25.18	48.75	29.80
-0.2mm A	size		+0.15	+0.102	+0.075	+0.060	-0.060	Total
	wt.%		26.99	27.28	16.93	11.28	17.51	100%
	Ash %		23.00	24.53	27.28	30.38	29.26	26.06
-0.2mm B	size		+0.15	+0.102	+0.075	+0.060	-0.060	Total
	wt.%		08.04	20.32	10.69	07.48	53.47	100%
	Ash%		18.86	18.10	17.90	18.61	33.27	26.29

* Size in mm.

feed material is -60 microns while in the second this fraction represents about 50% of the feed material. The size distribution of these samples is shown in Table 1. Sizing of the ground material was carried out using a set of laboratory sieves and a Ro-Tap shaker. Flotation tests were carried out in a 1-litre subaeration machine. During all tests, the pulp density (10% by wt.), aeration rate, rpm of the impeller and the speed of the paddle were kept constant. The coal sample was agitated for 5 min to ensure the complete wetting of the coal surface. Diesel oil collector and the aliphal frother were contacted for 5 min and 1 min, respectively. Pyrolizate was mixed for 1 min before adding the diesel oil collector in the promoting tests and contacted for 5 min in the tests designed to check its collecting ability. In the kinetic tests, the concentrate was collected after 0.15, 0.25, 0.50, 1.00, 2.00 and 4.00 min. Otherwise, one concentrate was collected after 4.00 min flotation time. The concentrate as well as the flotation tailings were filtered, dried, weighed and analyzed for ash content.

3. RESULTS AND DISCUSSION

It is worth mentioning here that the coal recovery and the concentrate ash always refer to the recovery of organic matter and the concentrate ash content, respectively. A comparative picture of performance of diesel oil, pyrolizate and a combination of both are presented in Fig. 1 and Fig. 2. The mentioned total reagent dosage in these figures does not include frother dosage. Also, 4 min flotation time (F.T.) was considered. Inspection of these figures gives rise to a number of trends that have been found to be true. To begin with, the

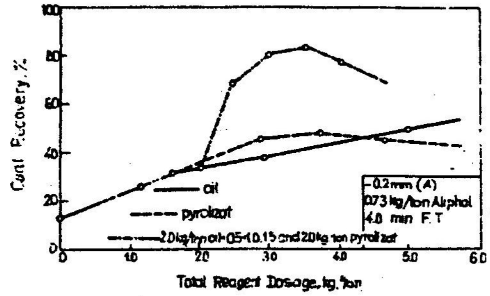

Fig. 1. Comparative picture of performance of diesel oil, pyrolizate and a combination of both - coal recovery

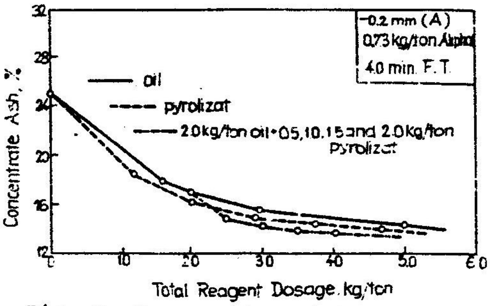

Fig. 2. Comparative picture of performance of diesel oil, pyrolizate and a combination of both - concentrate ash content

coal feed among the coals is characterized by a poor flotation response which may result from the surface oxidation of the coal particles and/or from the disseminated mineral matter in the flotation feed which do not liberate even with high degree of grinding. Second, while pyrolizate and diesel oil have, more or less, the same collecting action, the first is a little bit more selective for coal particles. Third, the promoting effect of pyrolizate is clear, in particular, if we notice that while the coal recovery increases as the pyrolizate dosage increases, the concentrate ash content is still, more or less, constant or sometimes decreases. Fourth, there is an optimum ratio of pyrolizate promotor to diesel oil collector below which the coal recovery begins to decrease. Fifth, the concentrate high ash content in all cases may result from the mechanical carry-over flotation of fine ash particles. Fig. 3 and Fig. 4 illustrate the relation between the promoting effect of pyrolizat and the feed grain size. It is clear that the performance of pyrolizate promotor depends, to a great extent, on the feed grain size and becomes more remarkable with relatively fine flotation feeds.

The order of flotation recovery is -0.2mm(B) > -0.2mm(A) > -0.5mm. This consequence may be due to the better degree of liberation as the feed grain size becomes finer. It is obvious that, with a feed material characterized by a very fine size distribution, the improvement in coal recovery is accompanied by loss in selectivity. The effect of pyrolizate on the kinetics of coal flotation is shown in Fig. 5. It is worth mentioning here that, within an acceptable approximation, the two parameter modified first order model of the form,

$$r = R\ [1 - (1\ /\ (kt))\ (1 - \exp\ (-kt))], \qquad (1)$$

was chosen to estimate the flotation rate constants. In Eq. (1), r is the cumulative recovery, t is the flotation time, R is the equilibrium

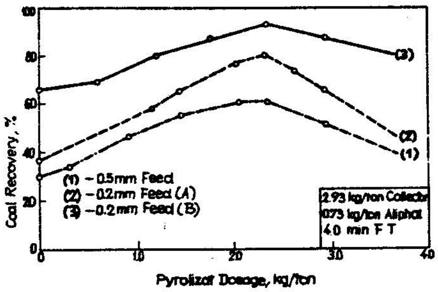

Fig. 3. The promoting effect of pyrolizate as a function of feed grain size - coal recovery

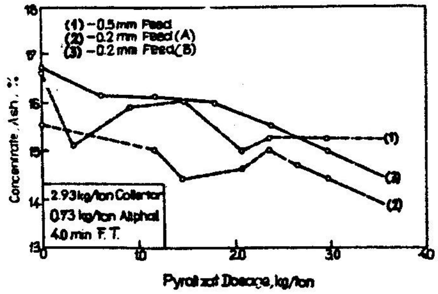

Fig. 4. The promoting effect of pyrolizate as a function of feed grain size - concentrate ash content.

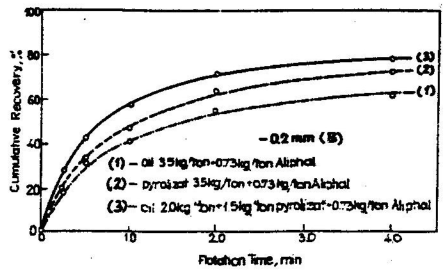

Fig. 5. Recovery-time profile of diesel oil, pyrolizate and a combination of both

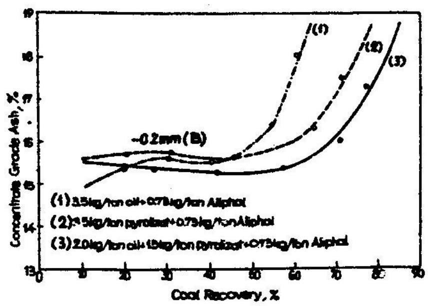

Fig. 6. Grade-recovery profile of diesel oil, pyrolizate and a combination of both

recovery at long flotation times and k is the flotation rate constant min^{-1}. This particular model has been shown to have more flexibility to describe the experimental flotation data than the simple classical first order model (Dowling, Klimpel and Aplan 1985). Table 2 summarizes the results obtained. It is clear that while pyrolizat and diesel oil show, more or less, equal flotation rates, higher ultimate recovery was obtained with pyrolizat. The highest ultimate recovery and flotation rate were obtained in the promoting flotation (a combination of pyrolizat promotor and diesel oil collector). Also, the promoting flotation showed a little bit higher selectivity than that of pyrolizat or diesel oil flotation. This fact is clearly observed from Fig. 6 which represents concentrate ash content (concentrate grade) versus organic matter recovery. Fig. 7 along with Table 2 show the effect of feed grain size on the promoting flotation kinetics. It is clear that the flotation rate as well as the ultimate recovery follow the order -0.2mm(B) > -0.2mm(A) > -0.5mm The best flotation selectivity was obtained with -0.2mm(A) flotation feed as indicated in Fig. 8. The above

TABLE 2 The influence of reagent type and feed size on flotation kinetics of coal

Reagent	Rc	kc	Ra	Rc/Ra	Remarks
Diesel oil	0.58	5.60	0.32	1.81	
Pyrolizate	0.67	5.70	0.37	1.81	-0.2mm(B)
Diesel oil + Pyrolizate	0.75	6.34	0.40	1.87	*
feed size	**Rc**	**kc**	**Ra**	**Rc/Ra**	**Remarks**
-0.5mm F.F	0.62	3.68	0.30	2.06	2.9kg/tOil +
-0.2mm (A)	0.83	4.07	0.38	2.18	2.3kg/tPyr +
-0.2mm (B)	0.92	6.12	0.45	2.04	0.7kg/tAlf **

* 3.5 kg/t Total reagent dosage excluding frother.
** 5.2 kg/t Total reagent dosage excluding frother.
Rc and *Ra* Ultimate recoveries of coal and ash.
kc and *ka* Flotation rate constants of coal and ash.

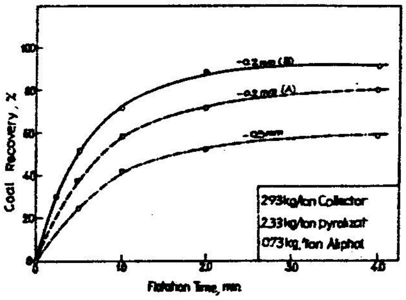

Fig. 7 Recovery-time profile of various flotation feeds in the presence of pyrolizate

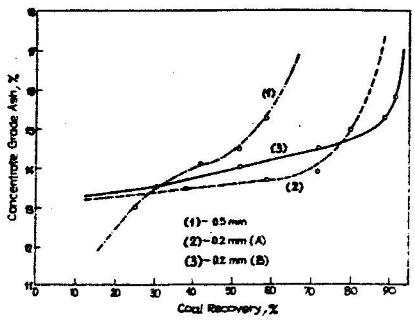

Fig. 8. Grade-recovery profile of various flotation feeds in the presence of pyrolizate

experimental findings illustrate the great effect of pyrolizate promotor in coal flotation. It combines the properties of collector and promoter. Its performance depends, to a large extent, on the feed grain size and size distribution. The specifications of this natural reagent and its effective functional groups are still under consideration and will appear later.

4. CONCLUSION

In this work, the influence of feed grain size and size distribution on the promoting flotation of low rank coal was investigated. Pyrolizate, a natural refinery by-product was tested as a promoter. The experimental results showed that pyrolizate has a remarkable effect whether used as a collector or promoter. Its promoting effect was observed from increasing ultimate coal recovery, flotation rate and flotation selectivity. It was found that the performance of pyrolizate depends on the feed grain size and feed size distribution. There is a trend towards improving the coal recovery as the feed particle size decreases but, with overground feed such improvement is accompanied by loss in selectivity. Further studies are needed to specify the effective functional groups of this natural product.

REFERENCES

Banerjee, A., et al., (1962), Kinetics of coal flotation, J. Inst. Fuel, Vol. 35, pp. 298-302.

Bearse, W.A., (1961), Mechanics and control in coal flotation, Colorado School of Mines Quarterly, Vol. 56, pp. 371.

Brown, D.J.,(1962), Coal flotation [in:] Froth Flotation-50th Ann. Vol., D.W. Fuerstenau (ed.), AIME, New York, pp. 518-538.

Burdon, R.G., (1962), Some factors influencing the rate of flotation of coal, Fourth Inter. Coal Prep. Cong., Harrogate-U K, pp. 273-285.

Burdon, R.G., Booth, R.W. and Mishra, S.K., (1976), Factors influencing the selective processes for the beneficiation of fine coal , Proceed. 7th Int. Coal Prep. Congr., A.C. Partridge (ed.), Sydney-Australia, pp. 25.

Dowling, E.C., Klimpel, R.R. and Aplan, F.F., (1985), Model discrimination in the flotation of coal, AIME Annual Meeting, New York.

Firth, B.A., Swanson, A.R. and Nicol, S.K., (1978), The influence of feed size distribution on the staged flotation of poorly floating coals, Trans. Austral. Inst. Min. Metall., Vol. 267, pp. 49-61.

Heriberto, B. and Leonard, J., (1984), The joint effect of rank and grain size on the flotation of Australian bituminous coals, Inter. J. Min. Process., Vol. 13, pp. 13-28.

Laskowski, J.S., Sirois, L.L. and Moon, K.S., (1986), Effect of humic acids on coal flotation. I. Coal flotation selectivity in the presence of humic acids, Coal Prep., Vol. 3, pp. 133-154.

Lynch, A.J., Johnson, N.W., Manlapig, E.V. and Thorne, C.G., (1981), Mineral and coal flotation circuits - their simulation and control, Elsevier, Amsterdam, pp. 46-48.

Martin, C.J., McIvor, R.E., Finch, J.A. and Rao, S.R., (1991), Review of the effect of grinding media on flotation of sulphide minerals , Minerals Eng., Vol. 4, No 2, pp. 121-132.

McIvor, R.E. and Finch, J.A (1991), A guide to interfacing of plant grinding and flotation operation Minerals Eng., Vol. 4, No 1, pp. 9-23.

Pedberge, W., (1987), Fractional flotation of coal, Aufbere. Tech., March, No. 3, pp. 136-142.

POLISH STANDARDS, Pn/G 97002, (1950), Classification of coals - Coal ranks, 1950.

Pooley, F.D., (1967), Some aspects of the flotation behaviour of coals with an insoluble collector, Trans. IMM,Vol. 67(1967), pp. C282-C284.

Rajeswara, M.R., Konar, M.M., Vanangamudi, M. and Rao, T.C., (1985), J. Mines, Metals and Fuels, Vol. 23, pp. 247.

Sablik, J., (1989), Physicochemical Problems of Mineral Processing, Wroclaw Technical University - Poland, Vol. 21, pp. 171.

Saleh, A.M. and Iskra, J., (1992), The promoting effect in the flotation of low rank coal, Proceed. conference on functioning of polish coals - mining under conditions of market economy and ecological restrictions. Faculty of Mining and Geology, Silesian Tech. Univ., Gliwice, 26-27 Nov., pp. 231-237.

Sun, S. C. and Zimmerman, R.E., (1950), The mechanism of coarse coal and mineral froth flotation, Min. Eng., Vol. 2, pp. 616-622.

Sun, S.C., (1954), Effects of oxidation of coals on their flotation properties, Trans. AIME, Vol. 199, pp. 395-401.

Trahar, W.J., (1981), A rational interaction of the role of particle size in flotation, Inter. J. Min. Process., Vol. 8, pp. 289-327.

Vanangamudi, M., Surya, K. and Rad, T.C., (1989), Effect of fines content on the froth flotation of coal, Powder Tech., Vol. 58, pp. 99-105.

Saleh A., Iskra J., (1993), Wpływ składu ziarnowego nadawy na flotację węgla niskouwęglonego, *Fizykochemiczne Problemy Mineralurgii*, 27, 99-106 (English text)

Badano wpływ wielkości górnej granicy ziarn oraz składu ziarnowego nadawy na wyniki flotacji węgla niskouwęglonego. W badaniach tych jako promotor flotacji zastosowano pirolizat, który jest frakcją destylacyjną ropy naftowej. Zaobserwowano, że działanie aktywujące pirolizatu zależy od wielkości górnej granicy ziarn nadawy i jej składu ziarnowego. Uzysk koncentratu oraz jego jakość poprawiły się z obniżeniem wielkości górnej granicy ziarn. Dla nadawy z dużą ilością drobnych ziarn następował wzrost uzysku koncentratu, jednak przy obniżeniu jego jakości. Zauważono również wzrost kinetyki flotacji z obniżeniem górnej granicy ziarn nadawy.