Fizykochemiczne Problemy Mineralurgii, 27 (1993) 89-98

Jerzy SABLIK*

THE USE OF MDB REAGENT AS A COLLECTOR OR PROMOTER IN THE FLOTATION OF METALLURGICAL COALS

Flotation of metallurgical coals has been examined using maleate dibutyl (MDB) either as collector or promoter. It has been found that MDB improves metallurgical coal flotation when compared with the standard dodecane or Diesel oil used by industry. This effect may be explained by the presence of a double bond in MDB molecule and the effect of the Π electrones on interaction with coal surface.

1. INTRODUCTION

The condition for achieving the optimum technological effect in coal flotation is the correct choice of surface-active substances which in cooperation with each other promote maximum hydrophobicity of the surfaces of the coal grains. This also contributes to the formation of a three-phase froth with the most advantageous properties from the point of view of the flotation process. Apart from the standard collectors and frothers normally used, there exist useful influences on the yield and recovery of combustible substance in the concentrate. This includes also selectivity and frequently also the kinetics of the flotation process. These influences are exerted by surface-active compounds (tensides) known as promoters (stimulators) (Klassen, 1966; Sablik and Makula, 1973; Ivanov et al., 1976; Sablik et al., 1976; Brooks and Bethell, 1979; Holvorsen, 1979; Sablik, 1982, 1984; Nimerick, 1982; Schick and Villa, 1983; Laskowski and Miller, 1984; Stahl, 1985).

The number of substances described in technical and patent literature which are used as promoters has been continually increasing. However, the effectiveness of reagents of this type depends both on their own chemical structure, the structure of the accompanying collectors, frothers, the physicochemical surface structure of the coals and frequently on the properties of the mineral substances found with the coals in the slurries. It may be postulated that the action of the promoters also depends on the pH and on the ionic strength of the solution. Substances used as promoters can exhibit collector properties

*Główny Instytut Górnictwa, 40-951 Katowice, pl. Gwarków 1

independently, however it is more advantageous if they are used in the flotation process as promoters of the apolar collectors action (Sablik 1986).

Physicochemical studies of the surface structure of coals of various types have shown large energy differentiations between the various points (zones) of the coal surfaces (Keller, 1987; Wierzchowski and Sablik, 1991) including coking coals. This is despite the fact that the mean surface hydrophobicity of coals at this degree of coalification is high (Sablik, 1985). Consideration of these circumstances leads to the conclusion that the collectors currently successfully used in industrial coal flotation, i.e. collectors of apolar structure such as kerosene or diesel oil formed principally of aliphatic hydrocarbons, are not, from the theoretical point of view, collectors of optimum effectiveness. This hypothesis was confirmed when introducing FK as a collector for coal flotation (Sablik, 1989) containing no aliphatic hydrocarbons and being simply a certain kind of alkiloarylic hydrocarbon.

Reported here are the results of tests conducted on the flotation of coal slurries using MDB (maleate dibutyl) (Sablik et al.,1989), which is an organic ester with a double bond in the acid radical, as a collector or promoter in the flotation of coking coals.

2. EXPERIMENTAL

2.1. Characteristic parameters of the tested coals

Test material was taken from samples of coal slurry from four mines in which bituminous coking coals occur (type 35 according to Polish classification). A brief compilation of analytical and granulometric parameters of the tested coals is given in Tables 1 and 2. Coals of this kind characteristically exhibit high mean natural hydrophobicity and relatively large flotation response (Sablik 1982, Sablik and Brzezina 1992).

The slurries tested differ considerably in their particle size distribution, particularly in the content of particle size fraction class below 0.06 mm [see Table 2].

2.2. Flotation reagents

Two sets of flotation reagents were used as standards, with two sets being the object of the investigations. The basic reference system was formed by the results obtained when using in the flotation process n-dodecane (DD) as a collector and MIBC as a frother recommended in the

Table 1. Short characteristics of the coal fines evaluated

Coal sample No	Mine	Ash content, A^d, %		Carbon content C^{daf}, %	Mean contact angle deg
		in clean coal rock	in fines below 500 μm		
1	Moszczenica	4.86	28.8	87.36	88
2	Morcinek	4.48	19.0	89.37	86
3	1-Maja	1.75	20.0	87.02	88
4	Borynia	2.95	19.9	86.10	87

Table 2. Granulometric characteristics of the coal fines evaluated

Granulometric analysis, μm	Yield, %			
	Sample No 1	Sample No 2	Sample No 3	Sample No 4
+ 500	2.7	10.5	1.1	0.2
500 - 300	5.4	19.1	7.2	1.3
300 - 200	17.4	17.8	23.8	9.4
200 - 100	14.1	12.0	18.3	24.3
100 - 60	5.4	3.2	11.6	22.6
- 60	55.0	37.4	38.0	42.2

Draft Standard ISO (1987). This was introduced into the suspension in the form of a 9:1 mixture, in a quantity of 1 kg/t of slurry.

The second flotation reagent taken as the standard for comparison of results was formed of diesel oil (ON) and higher alcohols (AC) mixed in a ratio of 9:1. This reagent is used on an industrial scale for the flotation process. The earlier determined unit additions of this reagent differed for the various tested slurries as follows:

1,5 kg/t slurry, Moszczenica mine,
1,5 kg/t slurry, Morcinek mine,
0,9 kg/t slurry, 1-Maja mine,
0,5 kg/t slurry, Borynia mine.

During the course of the tests the MDB substance (manufactured by Erg Boryszew in Sochaczew) was employed both as a collector in the mixture with higher alcohols (AC) in a ratio of 9:1, and also as a

Table 3. Flotation results of the coals evaluated at various reagent conditions

Coal sample No Tab.1	Reagent composition	Reagent dose g/kg	Flotation preformace	Combustible matter recovery
1	DD(90%);MIBC(10%)	1.0	Fig.1a curve 1	15.4
1	ON(90%):AC(10%)	1.5	Fig.1a curve 2	76.6
1	MDB(90%);AC(10%)	1.5	Fig.1a curve 3	87.4
1	ON(85%);AC(10%);MDB(5%)	1.5	Fig.1a curve 4	82.3
2	DD(90%);MIBC(10%)	1.0	Fig.2a curve 1	85.8
2	ON(90%);AC(10%)	1.5	Fig.2a curve 2	87.1
2	MDB(90%);AC(10%)	1.5	Fig.2a curve 3	92.6
2	ON(85%);AC(10%0);MDB(5%)	1.5	Fig.2a curve 4	96.2
3	DD(90%);MIBC(10%)	1.0	Fig.3a curve 1	92.4
3	ON(90%);AC(10%)	0.9	Fig.3a curve 2	89.0
3	MDB(90%);AC(10%)	0.9	Fig.3a curve 3	95.5
3	ON(85%);AC(10%);MDB(5%)	0.9	Fig.3a curve 4	92.9
4	DD(90%);MIBC(10%)	1.0	Fig.4a curve 1	96.7
4	ON(90%);AC(10%)	0.5	Fig.4a curve 2	86.3
4	MDB(90%);AC(10%)	0.5	Fig.4a curve 3	94.6
4	ON(85%);AC(10%);MDB(5%)	0.5	Fig.4a curve 4	94.5

promoter in the mixture with diesel oil (ON 85%), alcohols AC (10%) and MDB (5%). The unit additions for slurries from the individual mines were the same as for the standard reagent (ON+AC).

2.3. Test procedure

Experiments were conducted in a mechanical type laboratory flotation machine of capacity of the chamber 1dm^3. Impeller speed was 1200 r.p.m. All experiments were carried out using the fractionated flotation method making it possible to follow the kinetics of the process. In each case the concentration of solids in the mixture was 100 g/dm^3. The reagent was added to the feed, with a calibrated dropper, in portions up to a quantity of 70% of the planned dose at the beginning of the experiment, and 15% after abstracting both the I and II concentrate fractions. The suspension already with the introduced reagent was seasoned for 30 s with air access shut off. The yield and also ash content in the flotation products were determined.

3. RESULTS AND DISCUSSION

Experimental results are shown graphically in Figs.1-4 and given in Table 3. In the Figures marked a) the experimental results are presented by means of kinetics curves, and in those marked b) in the form of M-curves of mean values.

The influence of MDB, in the form of a collector or promoter, on the flotation response of coal from the Moszczenica mine is quite apparent, while results obtained in both cases are adequate. The reagent comprising ON+AC has substantially less effect, while the standard reagent (DD+MIBC) in a quantity of 1 kg/t of slurry provokes only a very slight flotation response (Fig. 1 a). The flotation kinetics are clearly better in the cases in which the flotation reagent contains MDB.

Analysis of M-curves (Fig. 1 b) also shows that for coal from the Moszczenica mine, flotation response in conditions close to standard conditions is very small, from the technological point of view of no practical significance (curve M1). The application of the reagent MDB in the form of a collector or promoter together with an increased addition of reagent (Table 3) gives advantageous results (curve M3) which are better than when the collector is diesel oil (curve M2).

Coal from the Morcinek mine reacts to the presence of the substance MDB similar to the coal from the Moszczenica mine. However, differences occur in the details. Reagents containing tested MDB promote a greater flotation response and cause a greater flotation rate for this coal in comparison with reagents in which the collector is diesel oil or dodecane (Fig. 2a). In the case of coal from the Morcinek mine a characteristic feature is that points determined from various experiments tend to concentrate, in practice, around one M-curve. However the points determined under the influence of ON and DD collectors correspond to a smaller yield of concentrate (Fig. 2b). Hence, it would appear to be probable that the yield of concentrate for cases in which the collectors are ON and DD could be increased by increasing the addition of these reagents. It is also noteworthy that the greatest yield of combustible substance is found when the substance MDB is used as a stimulator (Table 3).

Similarly as in the flotation of coal from the Moszczenica mine, conclusions may be drawn from the results obtained both for coal from the 1-Maja mine (Fig.3, Table 3) and for coal from the Borynia mine (Fig.4, Table 3). In both these cases the unit additions of flotation reagent necessary to obtain technologically acceptable results are relatively small, which means that the standard addition (1 kg/t) is

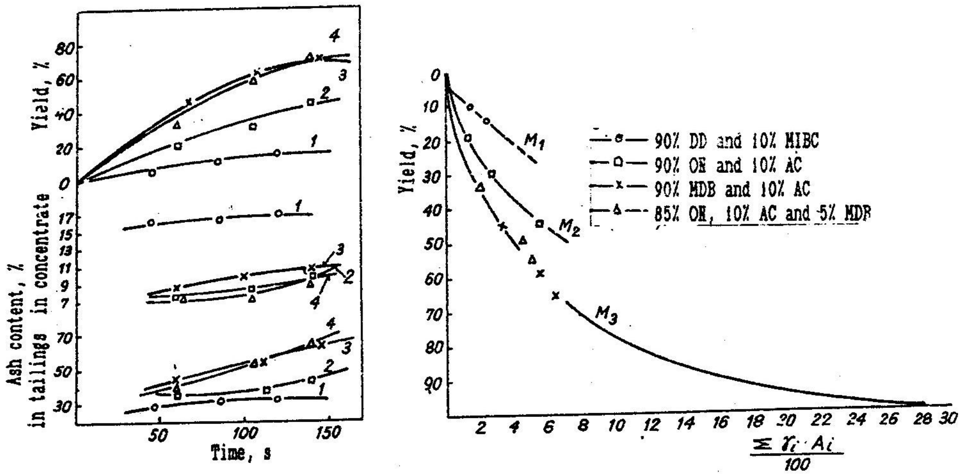

Fig.1. Influence of the MDB reagent on the Moszczenica coal flotation process, (a) kinetic curves, (b) M-curves (Table 3, sample No.1)

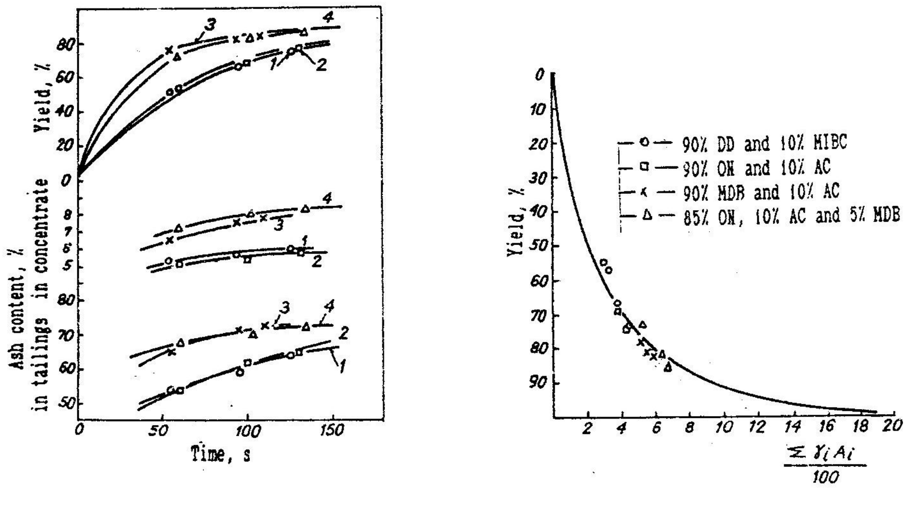

Fig.2. Influence of the MDB reagent on the Morcinek coal flotation process, (a) kinetic curves, (b) M-curve (Table 3, sample No.2)

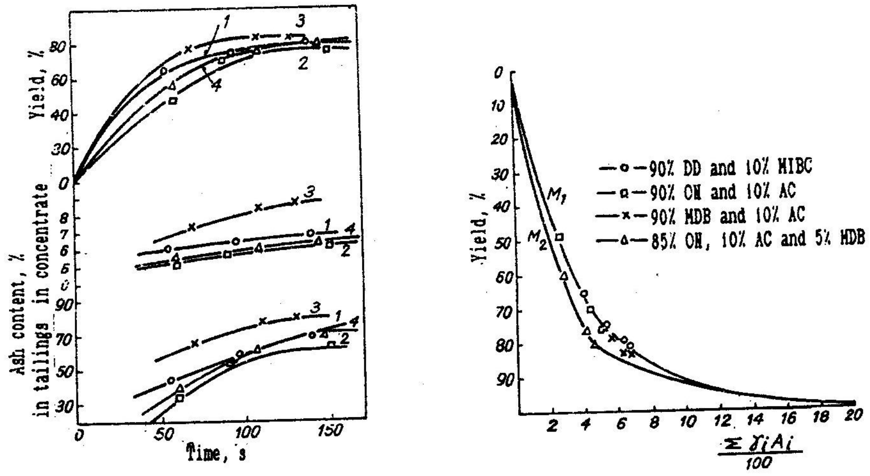

Fig.3. Influence of the MDB reagent on the 1-Maj coal flotation process, (a) kinetic curves, (b) M-curves (Table 3, sample No.4)

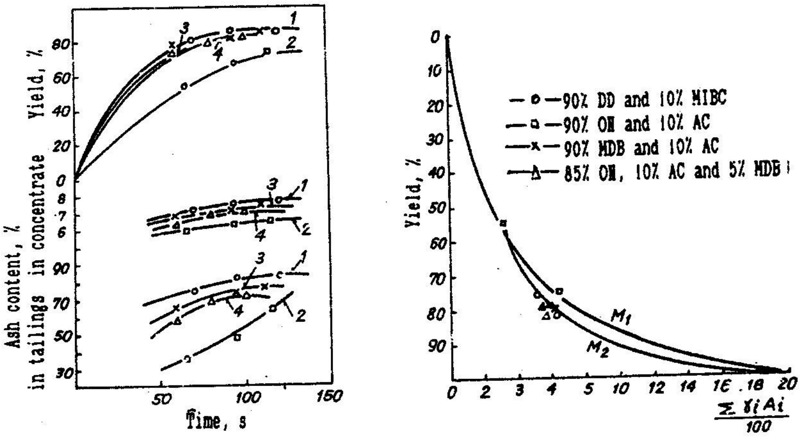

Fig.4. Influence of the MDB reagent on the Borynia coal flotation process, (a) kinetic curves, (b) M-curves (Table 3, sample No.4)

greater than they are. Results found under the influence of a reagent formed of dodecane (90%) and MIBC (10%) are more advantageous than when the reagent is ON and AC, particularly in the case of coal from the Borynia mine. In this case the unit addition to ensure technological significance is only half of the standard addition. Despite such a difference in the quantity of reagent in the flotation process, results obtained when the reagent contained MDB were virtually equivalent to results obtained in standard conditions (Table 3). From the coefficients of the M-curves it is possible to plot the derived curves of M 1 (Fig. 4b) illustrating the poorer concentration effects achieved under the influence of the reagent formed of ON and AC.

The flotation of coal from the 1-Maja mine, where the technological unit addition of flotation reagent is only slightly less than the standard (Table 3), showed that the process takes place most advantageously when MDB is used as promoter (Fig. 3b, curve M 2). This result is supported both by the large yield of concentrate and its relatively good quality.

The experimental results presented indicate that MDB is not only a very good collecting reagent for coking coals, better than diesel oil alone, but also that used as a promoter it causes the highest flotation response. In the cases analyzed, the three-component reagent, including MDB as a promoter, makes it possible not only to obtain a high yield of concentrate but also a high selectivity in the separation of the coal from the waste parts, i.e. high quality of this concentrate. This reagent also causes a substantial improvement of the flotation rate in comparison with the process in which diesel oil is used.

The tests conducted earlier (Sablik and Wierzchowski, 1990) indicated that from among several substances of chemical structure similar to MDB, only MDB itself exhibits properties of a collector substance in the process of flotation of coking coal better than those of diesel oil. A characteristic feature, distinguishing MDB from the aspect of chemical structure, is the presence of a double bond in the acid radical. It may be assumed that this substance having a pair of Π electrons in every molecule may undergo specific adsorption at points of higher polarity on the coal surface, due to its hydrocarbon chains increasing the hydrophobicity of the coal surface. Hence the MDB substance may act as a collector or assist the apolar collectors in wetting the surface of the coal grains. In blocking the polar centers on the coal surface this substance can improve the kinetics of the coal surface, wetting with apolar substances, and also increasing the number of active collisions of coal grains with air bubbles in unit time. This is a possible explanation of the observed increase in coal flotation rate when MDB is used as collector or promoter.

4. CONCLUSIONS

Because of its specific structure, the MDB acts very effectively as a collector (promoter) in the metallurgical coal flotation. This substance improves coal flotation more than Diesel oil which is commonly utilized by industry.

MDB increases concentrate yield and recovery of combustible matter, it also improves flotation rate. When used as a promoter, it improves selectivity at relatively high yield. The consumption of MDB at which good flotation results are obtained is lower than the consumption of Diesel oil (when used without MDB).

It may be postulated that the observed effects result from a double bond in the MDB molecule, and hence, from the role the Π electrons play in the process of rendering coal surface hydrophobic.

ACKNOWLEDGEMENTS
The author is very grateful to Prof. J.S. Laskowski of the University of British Columbia (Vancouver, Canada) for his useful advice.

REFERENCES

Brooks B.F.,Bethell J.P., (1979), The development of a flotation-filtration reagent system for coal. *VIII International Coal Preparation Congress*, Donieck.

Draft International Standard ISO (DIS 8858) Hard Coal Froth Flotation Testing, Part 1, Laboratory Procedure 1987.

Halworsen W.I., (1979), New developments in Froth Flotation. *VIII International Coal Preparation Congress*, Donieck.

Iwanov G.V., Turnikova V.J., Antipenko L.A., (1976), *Obogascenije i ispolzovanije uglia*. Wyp. IX, Moscow (Russian text).

Keller D.W., (1987), *Colloids, Surfaces*, 22,21.

Klassen W.I., (1966), *Flotacja węgla*, wyd. Śląsk.

Laskowski J.S.,Miller J.D., (1984), New reagents in coal flotation. Paper presented at the Reagents in the Minerals Industry Conference (IMM), Rome, September.

Nimerick K.M., (1982), Characterization of coal responding to froth conditioning. Paper presented at SME-AIME Fall Meeting, Honolulu, September, Reprint 82-377.

Sablik J., Makula K., (1973), *Wzbogacanie i Utylizacja Kopalin, nr 6* (Polish text).

Sablik J. et al., (1977), Polish Patent, No 104 569.

Sablik J., (1982), *International Journal of Mineral Processing*,V 9 p.245.

Sablik J., (1984), *Archiwum Górnictwa*, Vol.29, 11-23.

Sablik J., (1985), *Polish J. Chem.*, 59, 433.

Sablik J. (1986), Własności powierzchniowe węgli kamiennych i stymulatory ich aktywności flotacyjnej. Prace GIG, Katowice.

Sablik J., (1989), *Polish Techn.*, Rev.1.

Sablik J. et al, (1989), Polish patent No 152 703.

Sablik J., Wierzchowski K., (1990), *Przemysł Chemiczny*, 2.

Sablik J., (1990), Relation between flotation response of coal and presence of double bonding (Π electrons) in the chemical structure of collectors and promoters. Proceedings of the VII International Annual Pittsburgh Coal Conference.

Sablik J.,Brzezina R. (1992), *Przegląd Górniczy*, 48,4 (22-28).

Stahl H., (1985), *Erzmetall*, 38, nr 11 (German text).

Schick M.J.,Villa J.L., (1983), JAOCS Vol. 60, No 7.

Wierzchowski K.,Sablik J.,(1991), *Fizykochemiczne Problemy Mineralurgii*, 24, (173-178).

SABLIK J., (1993), Substancja MDB jako kolektor lub promoter w procesie flotacji węgli koksowych, *Fizykochemiczne Problemy Mineralurgii*, 27, 89-98 (English text)

Przedstawiono wyniki badań flotacji węgli koksowych, jeżeli jako kolektor lub stymulator zastosowany został maleinian dwubutylu (MDB). Stwierdzono, że substancja ta wzbudza większą aktywność flotacyjną węgla koksowego zarówno z punktu widzenia efektów technologicznych, jak i kinetyki procesu, niż stosowany w przemyśle olej napędowy lub wzorcowy dodekan. Działania takie można tłumaczyć obecnością podwójnego wiązania w rodniku kwasowym cząsteczki MDB, a więc promującym wpływem elektronów Π na adsorpcję substancji hydrofobizujących powierzchnię węgla.