The Inertinite Influence on Coal Plasticity and on their Behaviour During Carbonization

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The aim of the paper is to elucidate the aspects concerning the behaviour of the inertinite-rich coals used on coke-making charges. Using density gradient centrifugation, some inertinitic coals of different rank have been separated into maceral concentrates. For the inertinite thermoplastic property assessment, a number of established test methods were used as: thermogravimetry, plastometry and optical microscopy. Examination of the results shows that the separation procedure provides interesting information concerning not only the obvious differences between vitrinite and inertinite concentrates, but also within maceral groups. The carbonization behaviour of inertinite macerals has been examined and the ratio between reactive and inert textural components in cokes has been quantified by microscopic techniques and expressed as anisotropic/isotropic quotient.

Keywords: inertinite, density centrifugal separation, thermoplastic properties, coke microtexture

The study of the influence of the inertinitic coals on coke-making represents an important task concerning the production of a high coke quality. That was determined by the increased proportions of inertinite-rich coals from the Southern and Northern Hemisphere which have been used all over the world, in the last decades [1-10]. Thus, it became necessary to elucidate the aspects which involve the selection of coal blends in Romania, for the anticipation and avoiding of some unexpected phenomena during the coking process.

Experimental part

For the present study some inertinitic coals of different rank and their maceral groups concentrates obtained by density gradient centrifugation separation, have been investigated: four Gondwana coals (two low volatile and two medium volatile) and two from North America and Europe. For the present investigation the raw coal samples were ground up to 0.5 mm grain size and then, using heavy liquids and a laboratory centrifuge they were separated on 4 density types, as follows: < 1.25; 1.25-1.35; 1.35-1.45; > 1.45 (g/cm^3). Then, 12 samples were chosen, corresponding to the main fractions in which vitrinite (<1.25 g/cm^3) and inertinite (1.35 – 1.40 g/cm^3) have been concentrated. The rank and petrographic composition were determined for each sample. The information was completed by chemico-technical analyses: thermo-gravimetric, Gieseler plastometry, Koppers coking capacity and coke microscopical structure and composition. The method of preparing coal samples and determining maceral group composition followed ISO 7404-2 and -5 (1994), respectively. The maceral composition followed the recent ICCP classification of inertinite [11].

Results and discussions

Rank and petrographic composition of the parent coals are given in table 1. The coalification range between 1.00 – 1.28% RmVi (Vitrinite Random Reflectance) corresponds

Table 1
RANK (%RmVi) AND PETROGRAPHIC COMPOSITION (vol %) FOR PARENT COALS

Maceral components	Coals					
	1	2	3	4	5	6
Vitrinite	71.1	51.0	60.5	57.1	65.1	64.8
(Pseudovitrinite)	-	(0.7)	-	-	-	(0.5)
Liptinite	2.9	2.0	0.5	1.0	-	-
Inertinite	23.2	43.0	34.1	39.9	31.3	30.6
Semifusinite	18.4	39.3	29.7	37.3	27.9	28.4
Fusinite	0.8	2.1	3.2	0.8	1.4	0.8
Inertodetrinite	2.7	0.9	1.2	1.7	1.8	1.4
Macrinite + micrinite	1.3	0.7	-	-	0.2	-
Mineral matter	3.4	4.0	4.9	2.0	3.9	4.6
Clay	2.7	4.0	4.6	1.5	3.7	4.6
Pyrite	0.7	-	0.3	0.5	0.2	-
Vitrinite random reflectance	1.0	1.01	1.02	1.10	1.24	1.28

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to the "coking coals". The petrographic composition reveals that in the parent coals the inertinite rises over 30% (exception sample no.1) the higher proportion of 80-93% being semifusinite of different rank and textures. Low rank semifusinite belongs to semi-reactive or reactive inertinite that makes difficult the concentrates separation. The low percent of mineral matter has no influence on the technological behaviour of the coals during carbonization.

Table 2 shows the rank and petrographic composition of vitrinite and inertinite concentrates and table 3 the repartition of vitrinite and inertinite fractions reflectance. All the inertinitic densimetric fractions which have been separated show a higher rank than the vitrinitic ones, which reveal the higher rank of the inertinitic maceral types. From the inertinite maceral group, semifusinite represents more than 60-70%, its structure and composition being responsible for the coal behavior during carbonization. The reactives/inerts ratio, higher in some vitrinitic concentrates, reflects a good densimetric separation and high reactive semifusinite content. The results of technological analyses – thermogravimetric and plastometric – reveal interesting relationships between the physico-chemical structure of inertinite and its behaviour on coking.

That is reflected by a wider plasticity domain of all the inertinitic samples [12-17]. The thermogravimetric results show that the rate of devolatilization decreases as the rank and the inertinite content increases. At almost the same rank, the rate of devolatilization is influenced by the type of the inertinitic macerals and the rank of the main inertinitic maceral. Thus, it is higher for the samples that have a higher content of low reflectance semifusinite (fig. 1).

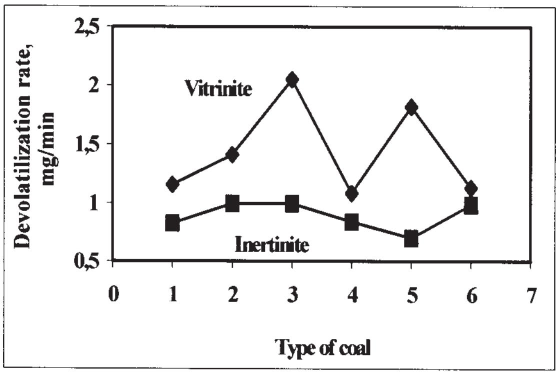

Fig.1. Devolatilization rate for the vitrinite and inertinite concentrates

The influence of the inertinite on thermoplasicity depends on rank, physico-chemical and structural composition of the inertinite type. The results of Gieseler plastometry show that, for the same rank, the maximum fluidity decreases as the inertinite content increases and indifferent of rank, the inertinite fluidity is lower than that of vitrinite (fig. 2).

The influence of inertinite on coals plastic phase, expressed by the decreasing of maximum fluidity, is also

Table 2
RANK (RmVi%) AND PETROGRAPHIC COMPOSITION (vol.%) OF DENSIMETRIC CONCENTRATES

Maceral composition	Coal											
	1		2		3		4		5		6	
	V	I	V	I	V	I	V	I	V	I	V	I
Vitrinite	78.8	69.9	93.4	61.3	71.5	61.7	77.1	51.8	81.0	64.8	96.1	71.0
(pseudo-vitrinite)	-	-	(3.8)	(8.8)	-	-	-	-	-	-	(0.4)	(0.7)
Liptinite	1.3	0.7	1.5	0.3	8.4	2.9	0.6	-	-	-	-	-
Inertinite	18.0	27.2	3.6	35.4	19.8	34.4	21.1	46.4	18.5	33.8	3.5	27.0
Fusinite+ Funginite	0.2	0.9	-	0.3	0.5	1.8	0.6	1.5	-	0.9	-	0.3
Semi-fusinite	16.3	24.1	2.3	31.3[1]	12.8	27.3[1]	19.0	42.6[2]	16.6	31.5[2]	2.3	24.7[1]
Inerto-detrinite	1.1	1.1	1.0	3.3	0.9	0.9	1.5	1.9	1.9	1.2	1.2	2.0
Macrinite + Micrinite	0.4	1.1	0.3	0.5	5.6	4.3	-	-	-	-	-	-
Mineral matter	1.9	2.2	1.5	3.0	0.4	1.0	1.2	1.8	0.5	1.4	0.4	2.0
Reactives/ Inerts[3]	4.45	2.60	25.3	1.49	3.00	1.88	3.70	1.10	4.40	1.91	27.3	2.60
Rank (%RmVi)	0.982	0.998	0.991	1.008	1.053	1.085	1.072	1.107	1.217	1.232	1.269	1.293

[1]Mainly low reflecting semifusinite; [2]Mainly high reflecting semifusinite; [3]Mineral matter free.

reflected by the range of the plastic phase, which is stronger in case of coals having a rank over 1.2%RmVi (fig. 3). The structural higher aromaticity and, consequently lower thermochemical reactivity, extends the duration of mesophase plasticity and facilitates structural interaction elements. For low rank coals that have high percent of low reflectance semifusinite, reactive inertinite content contributes to the increasing of the reactives/inerts ratio, and thus, of the fluidity development.

The subject of our research was to correlate the different types of inertinite with their higher or lower susceptibility during coke making. The carbonization behaviour of inertinite macerals has been examined and the ratio between reactive and inert textural components in the cokes produced have been quantified by microscopic techniques and expressed as anisotropic/isotropic quotient. The results are presented in table 3. and the structural type in figure 4a-h. The photomicrographs show the typical structures of parent coals macerals and inertinitic concentrates as well as the obtained cokes. Depending on the inertinite type, rank and size (fig. 4 a-e) the resulted vitrinite cokes show a matrix in which the inertinite is more or less well embedded (fig. 4 f-h) .

The small no reactive inertinite grains could be well embedded as inert inclusions in the melted coke matrix, raising its mechanical strength. The weak embedding of big inertinite grains diminishes the coke quality, offering a wider surface for the thermochemical reactions which take place in the blast furnaces.

In coke-making practice the presence of inertinite-rich coals must be a selection criterion not only for the proper

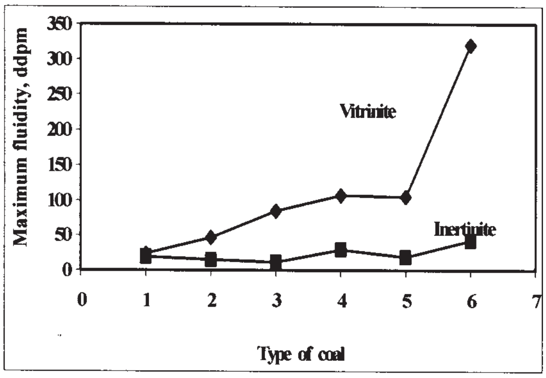

Fig.2. Maximum fluidity of the vitrinite and inertinite concentrates.

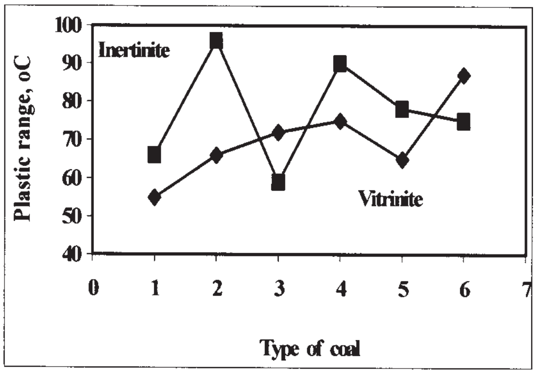

Fig.3. Plastic range of the vitrinite/inertinite concentrates

Table 3
RANK REPARTITION ON VITRINITE SEMI STEPS OF THE DENSIMETRIC CONCENTRATES

Vitrinite type	Type of coal											
	1		2		3		4		5		6	
	V	I	V	I	V	I	V	I	V	I	V	I
0.76-0.80	-	-	1.7	-	-	-	-	-	-	-		-
0.81-0.85	4.5	-	5.0	-	-	-	-	-	-	-	-	-
0.86-0.90	13.3	6.5	10.0	13.4	1.0	-	4.1	-	-	-	-	-
0.91-0.95	20.0	9.6	17.5	11.0	1.0	-	1.4	-	-	-	-	-
0.96-1.00	25.5	46.7	26.6	19.5	16.0	4.0	12.3	-	-	-	-	-
1.01-1.05	12.2	17.7	10.8	20.7	11.0	18.0	17.8	10.0	0.9	-	-	-
1.06-1.10	15.5	11.5	13.3	24.4	38.0	48.0	24.7	36.0	13.2	6.0	6.0	-
1.11-1.15	4.5	4.8	8.4	8.5	17.0	14.0	21.9	34.0	11.5	2.5	3.0	-
1.16-1.20	4.5	3.2	5.9	2.5	10.0	16.0	17.8	20.0	22.8	30.0	14.0	2.0
1.21-1.25	-	-	0.8	-	4.0	-	-	-	14.0	20.5	14.0	20.0
1.26-1.30	-	-	-	-	2.0	-	-	-	15.8	20.0	31.0	36.0
1.31-1.35	-	-	-	-	-	-	-	-	9.6	15.0	11.0	24.0
1.36-1.40	-	-	-	-	-	-	-	-	9.6	6.0	12.0	18.0
1.41-1.45	-	-	-	-	-	-	-	-	2.6	-	7.0	-
1.46-1.50	-	-	-	-	-	-	-	-	-	-	2.0	-
%RmVi	0.982	0.998	0.991	1.008	1.053	1.085	1.072	1.107	1.217	1.232	1.269	1.293

choosing of the blend components but also for the adequate operations of the charge preparation by the type and number of the grinding equipment and operations.

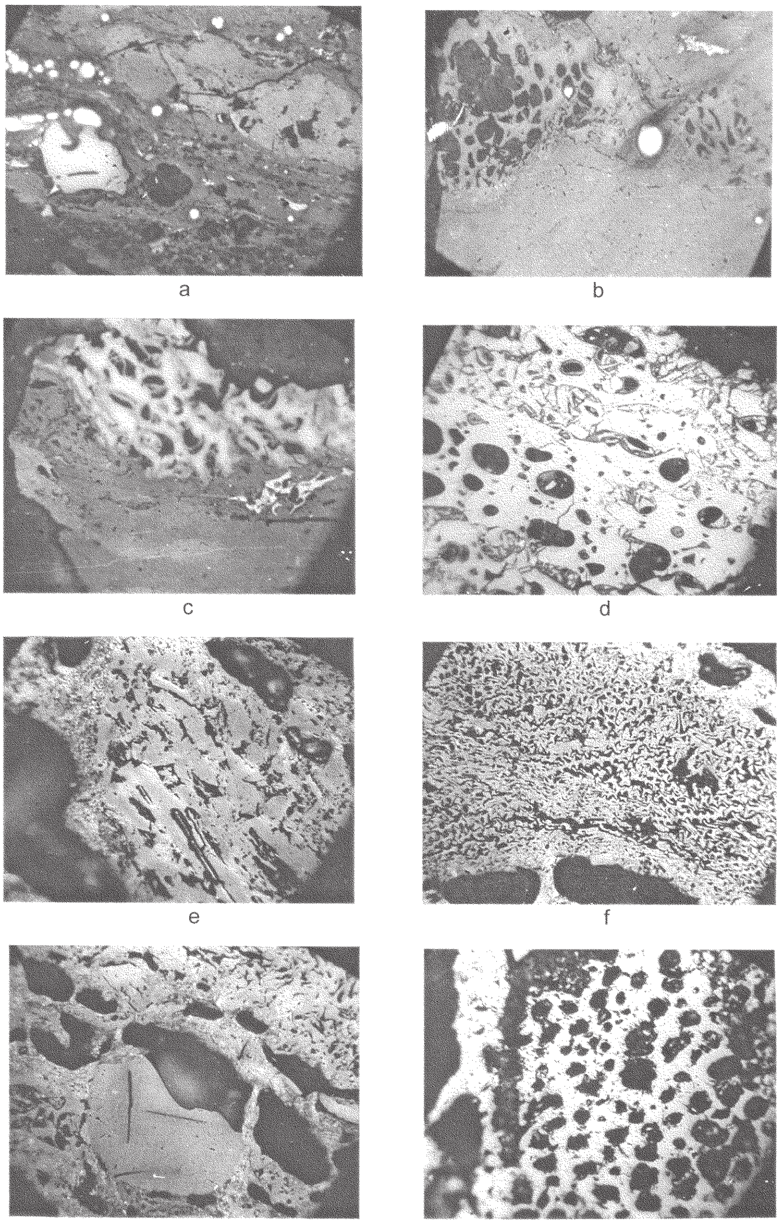

Fig. 4. Photomicrographs of inertinite macerals in raw coals, in densimetric concentrates, and in coke, under reflected light, oil immersion, 250x: a – Carbominerite (clay+pyrite) in vitrinertite (organic matter). Inertinite is presented as low reflectance semifusinite (top) and fusinite (secretinite) middle. b – Fusinite of low reflectance as the associated semifusinite and vitrinite. c – Vitrinertite with partial gelified fusinite (top) and semifusinite of different types and reflectance (bottom). d – Cellular high rank, low reactive fusinite embedded in a detritic fusinite mass. e – Inertinite coke from no reactive but small anisotropic semifusinite in an anisotropic punctiform matrix, polarized light, crossed nicols. f – semifusinite partial melted on the edge in contact with plastified anisotropic matrix, polarized light, crossed nicols. g – inertinites (top and bottom) embedded in a degassed anisotropic matrix (mosaic); no degassed and isotropic secretinite (middle), polarized light, crossed nicols. h – High reflectant fusinite coke grain, with partially mineral infilled cells, polarized light, crossed nicols.

Table 4
COKE PETROGRAFIC COMPOSITION, VOL.%

Structural characteris-tics	Type of coal											
	1		2		3		4		5		6	
	V	I	V	I	V	I	V	I	V	I	V	I
Isotropic	1.4	2.4	11.7	13.0	7.0	0.8	-	-	3.2	2.0	2.8	-
Fused	1.4	2.4	8.0	6.3	5.8	0.8	-	-	2.5	1.0	2.8	-
Unfused	-	-3.7	6.7	1.2	-	-	-	-	0.7	1.0	-	-

Anisotropic	59.4	50.5	77.3	35.0	65.0	50.0	65.4	44.0	71.2	50.2	87.0	63.5
very fine (punctiform)	16.6	16.5	75.8	17.1	30.0	25.9	15.1	10.0	23.6	0.2	46.3	16.7
very fine(flow)	3.7	4.5	-	-	-	-	9.1	7.0	37.6	30.9	18.3	10.9
fine grained	8.5	11.5	1.5	5.0	6.0	5.3	7.2	3.7	1.1	6.0	5.2	13.8
medium, coarse	15.9	12.0	-	12.9	18.0	5.8	25.8	20.1	8.9	11.3	17.2	19.5
banded, flow	4.7	6.0	-	-	11.0	13.0	8.2	2.4	-	1.8	-	2.6
Coke matrix	60.8	52.9	89.0	48.0	72.0	50.8	65.4	44.0	74.4	52.2	89.8	63.5
Melting degree,%	100	100	96	86	98	100	100	100	99	98	100	100
Anisotropic/ isotropic	98/2	95/5	87/13	73/27	90/10	98/2	100/0	100/0	96/4	96/4	97/3	100/0
Inertinite coke	28.0	37.8	8.8	50.0	26.0	45.0	30.2	54.6	24.1	40.0	7.7	32.1
Isotropic (degassed)	12.7	35.1	7.3	23.2	12.0	26.5	14.0	33.3	15.2	12.7	16.5	10.5
Isotropic no degassed	1.3	9.3	0.7	15.9	2.5	9.5	4.8	8.2	5.9	15.0	7.0	4.7
Isotropic high degassed	9.4	17.6	0.8	2.1	8.0	7.4	7.6	9.4	-	4.8	1.7	8.7
Anisotropic	4.6	5.8	-	8.8	3.5	1.6	3.8	3.7	3.0	7.5	2.5	8.2
Carbargilite	5.6	2.5	-	-	-	1.1	2.2	0.7	0.7	3.9	0.8	0.7
Mineral matter (clay)	5.6	6.8	2.2	2.0	2.0	3.1	2.2	0.7	0.7	3.9	1.7	3.7

Conclusions

The inertinite influence on coal thermoplasticity depends on rank and the physico-chemical and structural composition of inertinite type.

The high proportions of inertinite determine the diminishing of the plastic phase maximum fluidity by the softening temperatures, higher than that of the associated vitrinite, and the extension of the plastic phase.

The devolatilization rate decreases as rank and inertinite content increase and, at the same time, by the absorption of the plastic phase into inertinite tissue like structure.

On carbonization, the type, grain size and amount of the inertinite are decisive. The low reflecting semifusinite, by a softening and melting process similar to that of vitrinite, becomes more orientated which permits its complete assimilation into the coke matrix.

The results show that the used investigation techniques for characterization of inertinite thermoplastic behaviour and coke microtexture, can provide a more detailed insight into the nature and behaviour of coal macerals with regard to coke manufacturing.

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