MINERAL PROCESSING OF A CONVERTER SLAG AND ITS USE IN IRON ORE SINTERING

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Abstract

During the production of steel by a converter process, a slag is produced and stored at slag depots, thus causing serious difficulties through pollution and space requirements. A converter slag is a compact and abrasive raw material containing CaO and Fe. The investigations showed that a multi–stage crushing, classifying and magnetic separation operations influence successful steel recovering from slag, while slag itself is converted into a high–grade fluxing agent which can be used in production of sinter and raw iron. Also, positive economic effects are achieved through a partial substitution of more expensive limestone and a full substitution of Mn–ore and dolomite.

INTRODUCTION

During the LD–process in a steel plant, an important quantity of slag is deposited. Up to now, this slag has not been used as a secondary raw material, except for some invaluable purposes.

In SARTID–1913 (Steel Works–Smederevo) problems of the steel production economy, high energy and raw material consumption, large area occupied by the slag, and by other waste materials, is present. Therefore, solving the problem of

the converter slag by mineral processing has been considered. According to the mineral and chemical composition, the LD slag may be used in the agglomeration and blast furnace processes. These applications of the LD slag require technological operations of grain refinement and magnetic separation. The magnetic fraction, depending on size distribution and on the content of iron, can be applied directly in SARTID–1913, particularly in the extractive blast furnace and agglomeration processes.

The main objective of this study is mineral processing of the non–magnetic fraction of the ore. The ore is obtained on an industrial scale. Furthermore, technological aspects of mineral processing of the LD slag in SARTID–1913 are discussed.

MINERALOGICAL AND CHEMICAL CHARACTERISTICS OF LD SLAG

A converter slag is a heterogeneous system in which the dominating elements are: Ca, Fe and Si, with the presence of Mn, Mg, Al and a few others. Chemical composition of a converter slag is shown in Table I where variations of constituents are given in the range between minimum and maximum values.

Table I   Chemical composition of a converter slag (in mass %)

SiO_2	Al_2O_3	Fe	FeO	MnO	CaO	MgO	P_2O_5
14-22	3-7	10-20	7-20	7-14	43-50	4-8	0.5-4

Chemical composition of the converter slag changes depending on different steel qualities. The converter slag is composed of the mineral phases: iron, calcium ferrite, larnite, rankinite, wustite, periclase, manganosite, Fe and Mn monticellite, Mn–cordierite, melilite and glass. The iron, manganese and magnesium oxides are forming solid solutions of a typical destructive structure.

The mineral composition is variable, i.e. as a function of chemical composition, way of cooling and deposition conditions. The results obtained by X–ray and

microscopic analysis show that the presence of the crystal phase is found to be in the range between 40 to 80 mass per cent.

TECHNOLOGICAL PREPARATION OF THE CONVERTER SLAG

The converter slag preparation, its fragmentation, separation of steel inclusions from the slag and their concentration into a magnetic product is discussed. The convertor slag is a compact and abrasive material of a great compressive resistance. A sample was taken from the converter slag pit in SARTID–1913, and transported to the testing plant by a truck.

The sample comprised of slag lumps without the fines, the top size limit being 400 mm. The particle size distribution of the incoming slag is shown in Figure 1. The slag crushing is depicted by the process flowsheet in Fig. 2.
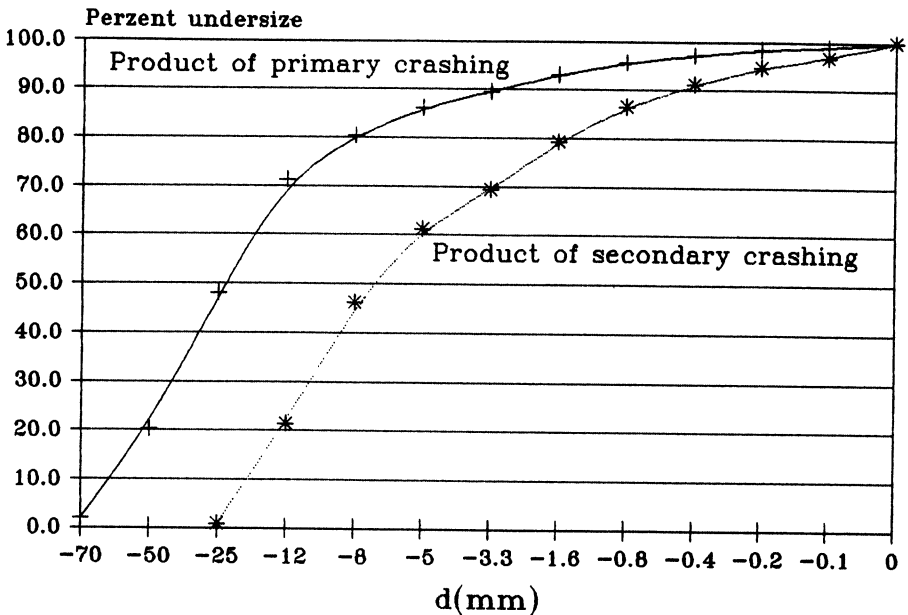

Fig. 1   The particle size distribution of the slag

The primary crushing was done using a jaw crusher type UCD–30–YU (60 kW). The grain–size distribution in the primary crushed product is shown in Fig. 1. The secondary crushing was done with a cone crusher type A–750–Yu (55 kW). The grain size distribution of the secondary crushing is shown in Fig. 1.

Legend:

1. Ore storage bunker
2. Raw mineral feeder
3. Jaw crusher
4. Conveying belt
5. Cone crusher
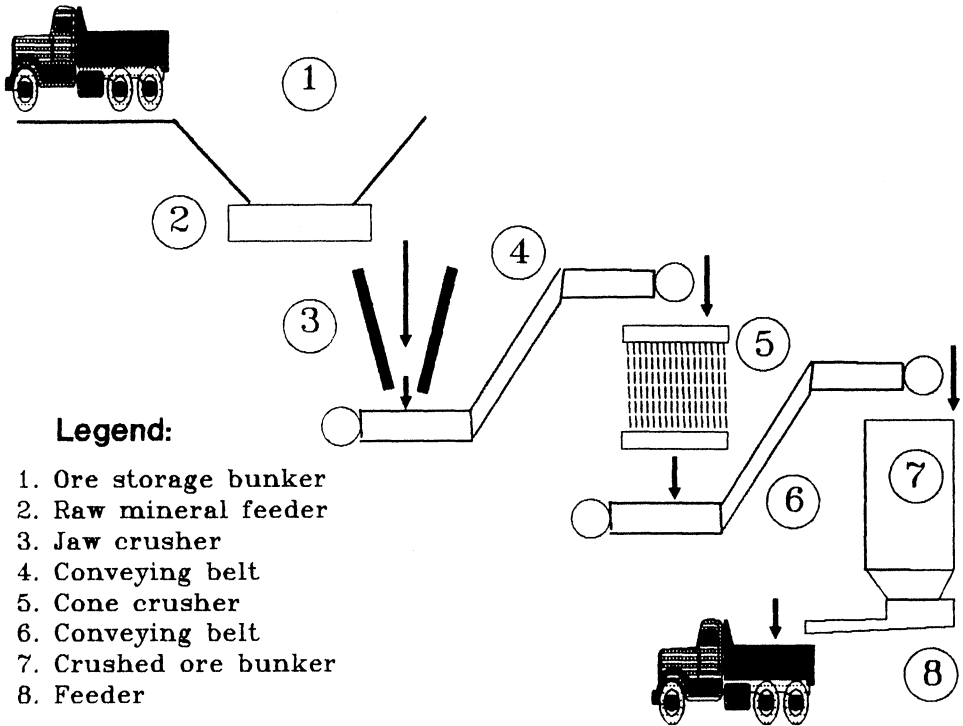6. Conveying belt
7. Crushed ore bunker
8. Feeder

Fig. 2   The crushing slag flowsheet

Samples for magnetic cleaning of the slag particles were taken from quantity of the crushed slag on the conveyors (Fig. 2, points 4 and 6). Two samples were formed:

1. The slag produced by primary crushing
2. The slag produced by secondary crushing.

The slag was separated into size classes and each one was cleaned with a magnet. The size classes with grains below 5 mm were cleaned using a band Dings magnet with a magnetic field of 0.08 T. Finer classes were cleaned with a disc Dings

Grain size (in mm)

Legend:	
Magnetic	(shaded)
Non-magnetic	(white)
Fe	Iron in wt-%
M	Mass in wt-%

1. −70 +50
2. −50 +40
3. −40 +25
4. −25 +12
5. −12 +8
6. −8 +5
7. −5 +3.35
8. −3.35 +1.6
9. −1.6 +0.8
10. −0.8 +0.4
11. −0.4 +0.2
12. −0.2 +0.1
13. −0.1 +0

Grain size	1	2	3	4	5	6	7	8	9	10	11	12	13
Primary crushed Slag													
M	2.0	18.3	0.7	0.2	0.3	0.4	0.5	1.3	0.7	0.6	0.6	0.3	0.6
Fe	15.1	15.5	32.4	40.1	36.8	37.8	28.7	24.3	21.3	21.2	19.0	18.8	15.0
M			26.9	23.2	8.7	5.5	2.8	2.3	1.8	1.0	0.6	0.3	0.3
Fe			16.5	18.5	18.0	16.8	16.4	15.0	14.7	13.3	12.6	12.3	11.6
Secondary crushed Slag													
M			0.9	0.3	0.3	0.6	0.8	2.3	2.3	1.9	2.3	1.4	1.5
Fe			15.9	63.6	37.5	51.7	46.4	26.5	21.1	19.2	16.5	14.8	14.1
M				20.4	24.5	14.4	7.4	7.8	4.9	2.7	1.4	0.6	1.3
Fe				19.2	24.1	16.0	15.4	14.5	13.4	11.9	7.5	4.0	8.9

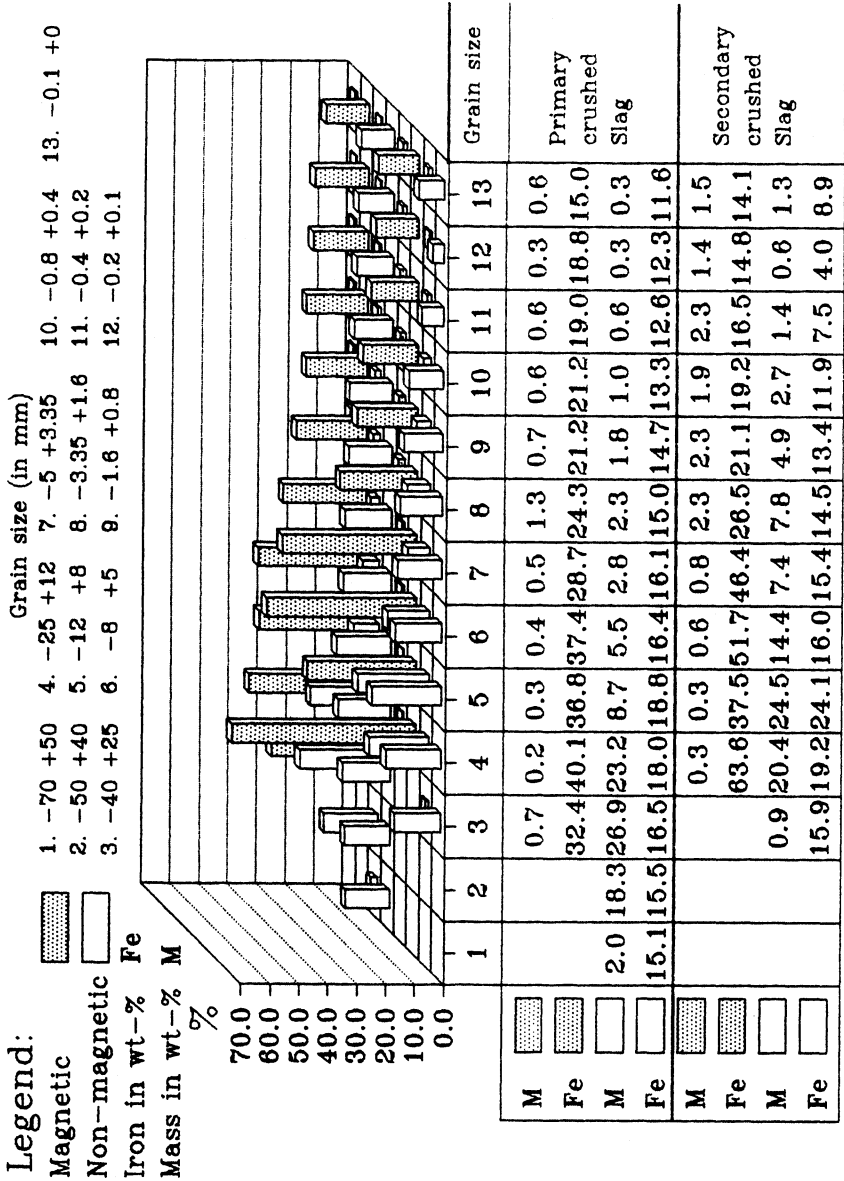Y-axis (%): 0.0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0

Fig. 3   A summary of the results of magnetic separation of the primary and secondary crushed slag

electromagnetic separator with a magnetic field of 0.14 T. The results are summarised in Fig. 3.

The magnetic product of a large–size class contained steel inclusions up to 40 mm and steel balls with 95 to 99.5 % Fe. The mass content of steel in the magnetic product by size classes was 20 to 60 % by mass. The non–magnetic fraction in various size classes was treated for metallurgical purposes.

THE SLAG UTILISATION IN THE MANUFACTURE OF SINTER IN SARTID–1913

In view of its favourable chemical and mineral composition, the LD slag represents a useful material for application in a steelmaking process. This pertains especially to its application in sinter manufacture, i.e. iron, where the slag, apart from cost reduction of manufacturing, also improves certain process parameters, as well as qualities of the sinter to some extent.

Cost reduction of the manufacturing results from substitution of a part of limestone, dolomites and manganese ore by a cheaper slag. larger number of minerals in the slag contained in the sinter reduces quantities of solid fuel for sintering.

The non–magnetic slag improves aggregations of small–sized fractions of the sinter mixture which consequently improves its gas permeability and other process parameters, and especially productivity of the sinter plants. These parameters also improve quality of the sinter. It should be emphasized that the slag quantity which is to be added to a sinter mixture for manufacture of the sinter is limited, as a result of a high content of phosphorus. This is of high importance since the production programmes of a steel–making industry rely increasingly upon high–quality steels. The content of these elements in steels manufactured in SARTID–1913 must not exceed 0.02% by mass.

SARTID–1913 manufactured several sinter materials with various contents of the LD slag in an ore mixture (30, 50, 80 kg/t of sinter). Also, a possibility of full replacement of limestone by slag as a flux material has been examined.

Optimum sintering conditions for the sinter basicity of 1 and FeO content in the sinter of 11.5% by mass were achieved by calculating the material and heat balance of the sintering process, following a method of E.F. Vegman. The sinter material was manufactured following the results of the calculation. Necessary quantities of the ore mixture of limestone and coke, for a manufacture of 100 kg of sinter, are graphically presented in Figure 4.
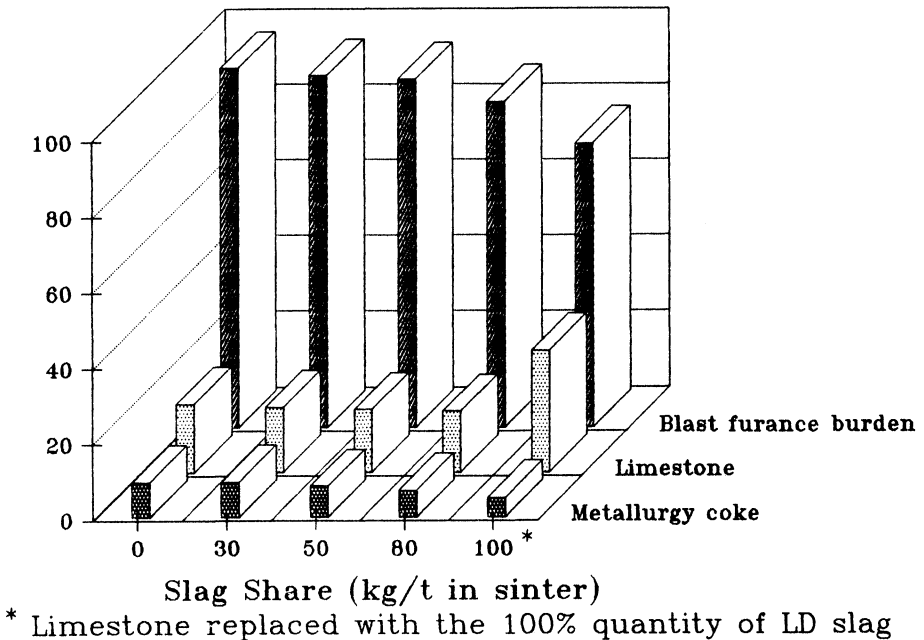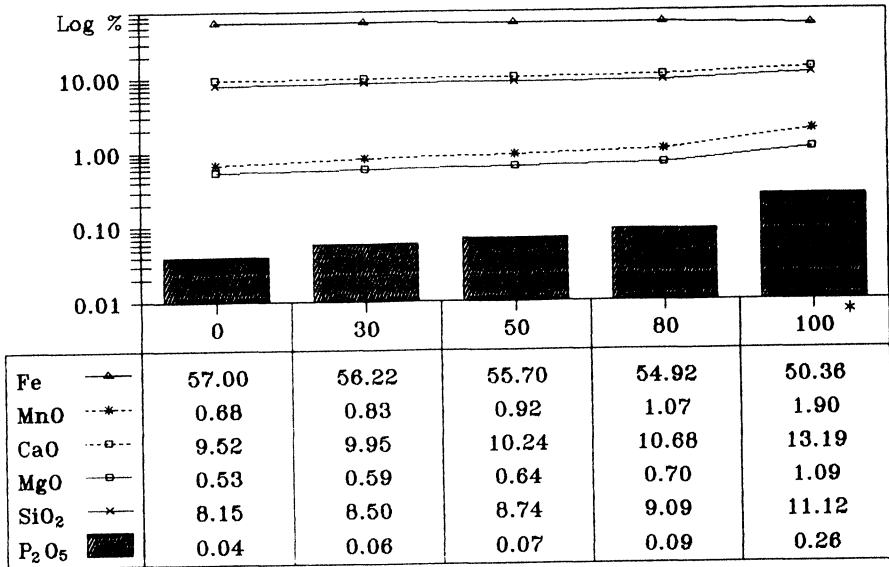

Slag Share (kg/t in sinter)
* Limestone replaced with the 100% quantity of LD slag

Fig. 4   Consumption of the ore burden with increasing content of LD slag in a sinter mixture

During the sinter preparation, an attempt was made to accomplish all sintering conditions anticipated in the calculation. After accomplishing these properties, the sinter manufacture with a given quantity of the LD slag in the mixture was completed. Figure 5 shows chemical composition of the manufactured sinter material.

Log %	0	30	50	80	100 *
Fe ——▲——	57.00	56.22	55.70	54.92	50.36
MnO ⋯*⋯	0.68	0.83	0.92	1.07	1.90
CaO ⋯▫⋯	9.52	9.95	10.24	10.68	13.19
MgO ——▫——	0.53	0.59	0.64	0.70	1.09
SiO$_2$ ——×——	8.15	8.50	8.74	9.09	11.12
P$_2$O$_5$ ▓▓	0.04	0.06	0.07	0.09	0.26

Amountal slag (kg/t of sinter)

* Limestone replaced the 100% quantity of LD slag

Fig. 5   Chemical composition of the sinter

Based on the results thus obtained, some parameters of the blast furnace process have been analysed, during the blast furnace operation with 70% by mass of sinter, and with properties obtained by manufacturing a sinter material with various content of the LD slag and 30% by mass of pellets. The blast furnace performance is analysed in Figure 6.

Figure 7 depicts the difference between the material cost of a sinter and iron manufacture, by using the converter slag as an addition to the sinter mixture, i.e. as a component which has completely replaced limestone as a flux material.

Based on the results thus obtained, it can be seen that the optimum slag quantity in the sinter mixture is 50 kg/t of sinter, under the SARTID–1913 sintering plant conditions. It follows from Fig. 5 that by adding 50 kg of slag per tonne of the sinter the Fe content in the sinter is reduced to the value of 2.3% by mass, while
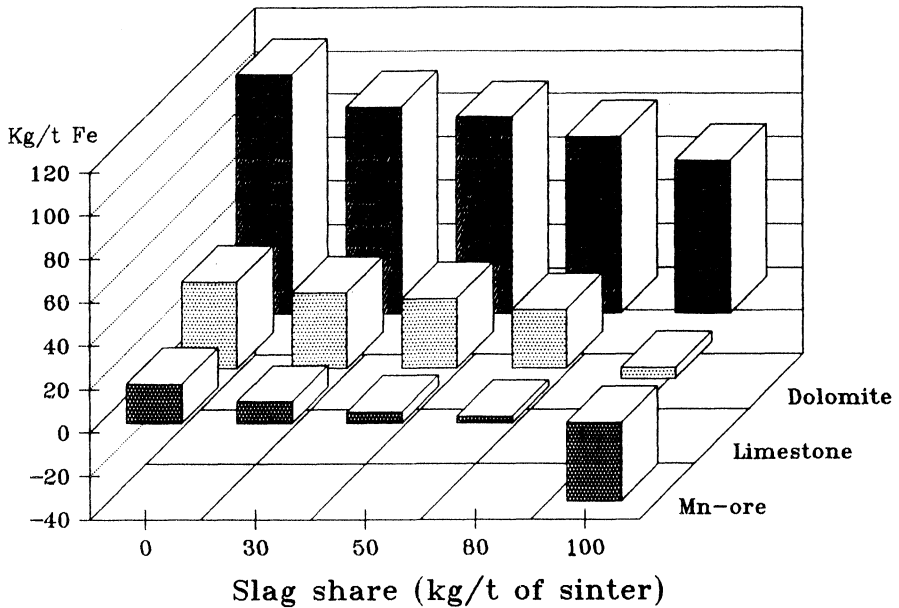
Fig. 6   Parameters of the blast furnace processes for various concentrations

an increase of the Mn concentration is 35.3% by mass. The degree of increase in the Mg content is 20.7% by mass.

Concentration of phosphorus is increased from 0.038% to 0.069% by mass, which is within permitted limits for conditions prevailing in SARTID–1913. Complete replacement of limestone with the converter slag as a flux material is not possible because of high concentration of phosphorus in the slag. Material cost of the sinter manufacture is reduced by US$1.98 per tonne of sinter (Fig. 7). Parameters of the blast furnace process are not distorted at this quantity of the converter slag where the material costs of manufacture are reduced by US$11.8 per tonne of the manufactured material.
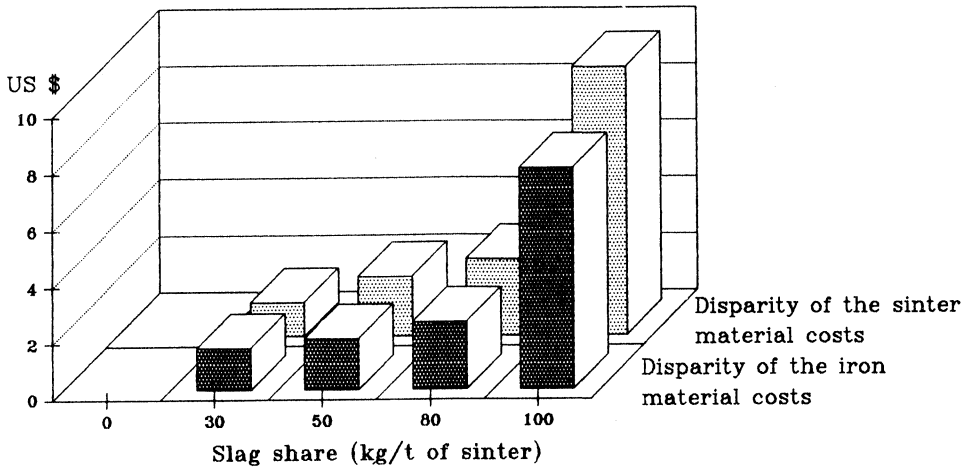
Fig. 7   Reduction of the material costs of the sinter and iron production,
         in a sinter mixture, depending of the slag quantity.

CONCLUSIONS

1.   The converter slag can be disintegrated for industrial needs in jaw crushers
      and cone crushers. Considering its high strength, the slag is crushed in
      modified conditions the crushers operation.

2.   The results obtained in magnetic separation of the disintegrated slag show
      that steel is successfully separated from the slag, as is shown in Fig. 3.

3.   Adding the converter stag to a sinter mixture reduces the material costs of
      the sinter manufacture, on the account of reduced quantities of ore mixture,
      limestone, dolomites and sintering coke.

4.   Analysis of the blast furnace process based on the sinter melting shows a
      reduction of the materials costs of iron manufacture, on the account of
      lower cost of the sinter, without disrupting the operating parameters of the

blast furnace.

5.   The optimum quantity of the added slag regarding the most favourable techno—economic effects of the sintering and blast furnace process is 50 kg/t of sinter. This quantity is limited by a high content of phosphorus in the slag.

Slobodan Radosavljevic (47) is presently employed at the Institute for Technology of Nuclear and Other Raw Materials in Belgrade, Yugoslavia. Before joining ITNMS, he was a professor at the Mining and Geological Faculty of the Belgrade University. Professor S. Radosavljevic is the author of a book and of more than 40 papers.