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RECYCLING OF OXYGEN CONVERTER FLUE DUST INTO OXYGEN CONVERTER CHARGE

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The paper deals with aspects and effects of oxygen converter flue dust recycling into the oxygen converter charge. Flue dust was recycled when solidificated into form of briquettes. No significant effects of the recycling on process of hot metal refining and on quality of produced steel were recorded. Recycling of flue dust briquettes influenced composition and structure of steel making slag, namely its zinc contents and composition of oxygen converter flue dust. Recommendation on recycling of up to 4 000 kg of flue dust briquettes into the 160 t charge of oxygen converter was suggested.

Key words: *oxygen converter, flue dust, recycling*

Recikliranje prašine kisikovog konvertora u talinu kisikovog konvertora. Članak se bavi aspektima recikliranja prašine kisikovog konvertora u talinu konvertora i posljedicama tog recikliranja nakon skrućivanja u brikete. Nisu zapažene nikakve značajnije posljedice recikliranja na proces vrućeg rafiniranja metala kao ni na kakvoću proizvedenog čelika. Recikliranje prašine u brikete utiče na sastav i strukturu troske, tj. na sadržaj cinka u njoj i na sastav visokopećne prašine konvertora. Preporuča se recikliranje do 4 000 kg visokopećne briketirane prašine u konvertoroske taline od 160 t.

Ključne riječi: *kisikov konvertor, visokopećna prašina, recikliranje*

INTRODUCTION

Flue dusts, by - products of oxygen converter process, are together with mill scales the most valuable secondary raw materials produced in steelmaking [1, 2]. The converter flue dusts contains up to 70 wt % of iron, this kind utilization of this material in integrated steelworks is duty of any steel producer. Recycling of the converter flue dust into the sintering process, the most suitable from the physical characteristics point of view, is restricted by zinc and lead contents, that are harmful for blast furnace process. Zn and Pb contents in flue dust are directly related to contents of these elements in steel scrap, part of the oxygen converter charge. Part of the converter flue dust is formed by vaporization, about 17 % of flue dust in the first part of oxygen blowing and about 32 % of flue dust in the second one. Easily vaporized elements Zn and Pb are concentrated mostly in the flue dust formed in the first part of the blowing [3, 4].

Acceptable way of the flue dust utilization, preferred in present, is recycling of the converter flue dust into the charge of oxygen converter. First plant trials of this method started in eighties and converter flue dust was charged in packages. In present, converter flue dust in dry state is solidificated by briquetting and charged into the converter together with steel scrap. Mechanic properties of the briquettes can by improved by hot briquetting in atmosphere of the inert gas [5-7].

Zinc and lead enter the flue dust, formed in the refining process. By this way concentrations of zinc and lead continuously increase. When the zinc concentration reaches 20 % or more, the whole amount of the flue dust is removed from the process and utilized in the non-ferrous metals industry.

DESCRIPTION OF EXPERIMENTS

The research of influence of converter flue dust briquettes additions on refining regime and composition of oxygen converter products was realized in two stages. In the first one the oxygen converter heats produced with intentional additions of the flue dust briquettes were sampled. Five heats were produced with addition of 1 000 kg of briquettes, the next five ones with addition of 2 000kg of briquettes, the last five ones with addition of 3 000 kg of

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briquettes. The briquettes were added at the beginning of the blowing together with the first portion of lime. All fifteen heats were produced in the same 190 t oxygen converter with combined blowing during production of the same grade of deep drawn.

The converter flue dust briquettes had oval shape with dimensions 75 mm x 45 mm x 25 x mm. Typical example of chemical composition of the briquettes is: 36.70 wt % Fe metallic, 68.75 wt % Fe total, 30.32 wt % FeO, 12.15 wt % Fe_2O_3, 1.42 % wt SiO_2, 7.75 % CaO, 2.50 wt % MgO, 0.14 wt % Al_2O_3, 0.53 wt% Mn, 0.064 wt % P, 0.047 wt % S, 2.35 wt % C, 0.131 wt % Pb, 0.585 wt % Zn, 0.50 wt % Na, 0.364 wt % K.

In the second stage statistic set of heats was studied, based on the heats records from the steel plant. Analysed set contained the heats without briquettes additions, the heats with briquettes additions up to 1 000 kg, the heats with briquettes additions from 1 000 kg to 2 000 kg, the heats with briquettes additions from 2 000 kg to 3 000 kg, and the heats with briquettes additions more than 3 000 kg. The statistic set contained 9 123 heats. The histograms, that were complemented by distribution curves, were constructed from analysed values.

EVALUATION AND DISCUSSION OF EXPERIMENTS RESULTS

The goal of the research in the first stage was to study the effect of flue dust briquettes additions on desulphuration and dephosphoration processes in oxygen converter, composition and cleanness of the steel, chemical and structural composition of the oxygen converter slag, chemical composition of the converter flue dust. To do it, the samples of metal and slag were taken during interruption of oxygen blowing, after finishing of oxygen blowing and after reblow from each heat. Also samples of flue dust were taken in the 8^{th} minute of oxygen blowing, after finishing of oxygen blowing and after reblow from each heat.

Normal changes in converter slag composition, that are intrinsic of oxygen converter process, were found by slags analysis. No changes specific to the flue dust briquettes were found except of zinc contents. No significant values of lead and tin contents in slag were recorded. Contents of zinc in slag increased significantly with increasing additions of the flue dust briquettes in the converter charge, Figure 1. From this fact it follows that multiple recycling of converter flue dust with growing zinc contents can effect the utilization of demetallized converter slag in road building because of penetration of soluble zinc compounds into the underground water sources.

Structural composition of the slag samples, taken from the all fifteen heats, was studied with the help of microscopic analysis. The slag samples taken during blowing interruptions had structure of primary converter slag consisted

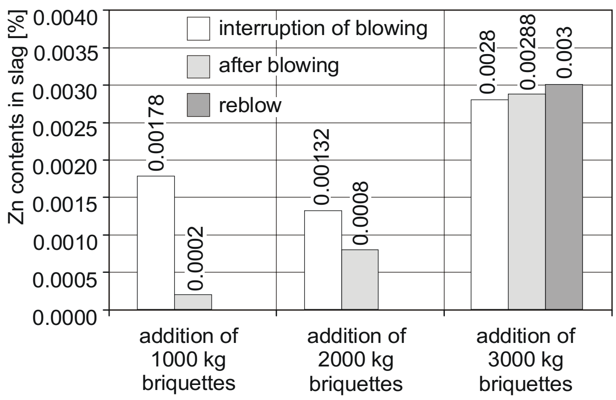

Figure 1. **Relation between mean contents of zinc in slag and amount of flue dust briquettes added into the charge**

Slika 1. **Omjer srednjeg sadržaja cinka u troski i količini briketirane visokopećne prašine dodane u talinu**

of dicalcium silicate 2CaO·SiO_2 and complex "RO" phase (Ca, Mn, Mg, Fe) O. Also non-assimilated lime was frequently found in the structure. No relation between the structure of slag and amount of added flue dust briquettes was found in the samples taken during blowing interruptions.

This statement was not fully valid for the slags taken after oxygen blowing. The final structure of the slags contained also tricalcium silicate 3CaO·SiO_2 in the form of needle-like particles. The slags taken from the heats produced with additions of 1 000 kg and 2 000 kg of flue dust briquettes consisted of both dicalcium silicate particles and tricalcium silicate needles, Figure 2. In all slag samples taken from the heats produced with additions of 3000 kg

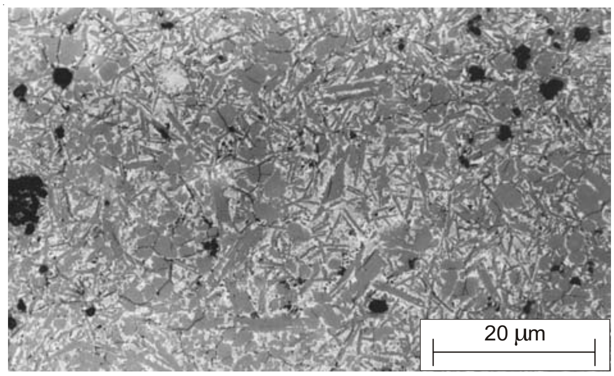

Figure 2. **Structure of slag with di-and tricalcium silicates in needle-like, globular and irregular forms**

Slika2. **Struktura troske s dikalcijumskim i trikalcijumskim silikatima u igličastim, globularnim i nepravilnim oblicima**

of flue dust briquettes their structure contained mostly tricalcium needle-like particles, RO phase matrix and calcium ferrite particles, Figure 3. No relation between quantitative composition of the slag structure and flue dust briquettes additions was found.

The distribution coefficients of sulphur and phosphorus were evaluated. The state after oxygen blowing into the converter was used for the calculations. From analysis results and calculations followed the highest distribution coefficients both for sulphur and phosphorus related to

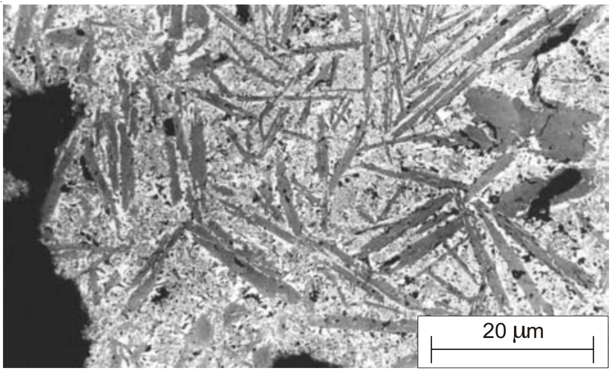

Figure 3. **Structure of slag with needles of tricalcium silicate, RO phase and calcium ferrites**
Slika 3. **Struktura troske s iglicama trikatcijum silikata, RO faze i kalcijum ferita**

the group of heats produced with additions of 3 000 kg of flue dust briquettes. This fact is illustrated in Figure 4. showing mean values of the distribution coefficients for all three groups of heat. Kinetics of both desulphuration and dephosphoration processes were fully regular, characteristic for oxygen converter process.

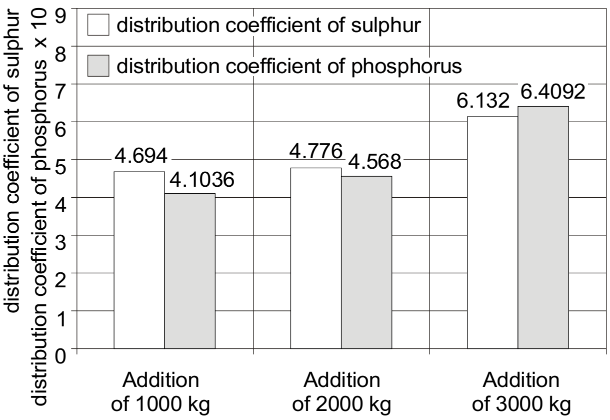

Figure 4. **Relation between mean values of sulphur and phosphorus distribution coefficients and amount of flue dust briquettes added into the charge**
Slika 4. **Omjer srednjih vrijednosti koeficijenata distribucije sumpora i fosfora te količine briketirane visokopećne prašine dodane u talinu**

Nitrogen contents values in all steel samples had very stabile level, not influenced by the flue dust briquettes additions. Also nearly all contents of Zn, Sn and Pb in steel samples were under the sensitivity limits of the optic quantometer used for analysis.

To study the non-metallic inclusions contents in steel the metallographic surfaces were prepared on all steel samples taken during and after oxygen blowing. Quantitative microscopy methods revealed very low contents of sulfidic inclusions - 0.005 % of area or less. Oxidic inclusions, observed in samples taken after oxygen blowing, were mostly alumina inclusions occurring in spacious clusters. They resulted from Al-killing of steel samples. Because of low oxygen contents in refined hot metal during blowing interruption, the steel samples, taken in this stage, were not killed and no alumina clusters were formed. The samples contained mostly silicate inclusions, globular and glassy and also slag particles trapped in the hot metal. Cleanness of steel in all three groups of heats was similar, no influence of flue dust briquettes additions on steel cleanness was found.

Because of increased contents of tin and lead in the converter flue dust the study of possible segregations of those elements on grain boundaries of solid steel was performed. From the steel samples, taken from heats produced with additions of 1 000 kg, 2 000 kg and 3 000 kg of flue dust briquettes into the converter charge, testing bars were prepared and subsequently broken. Surfaces of fractures were observed under scanning electron microscope, next some spots on grain boundaries and the particles occurring on fractured surfaces were analysed by energy dispersive microanalysis. None of the analysed spots showed presence of Zn, or Pb.

Chemical analysis of the flue dust samples taken from the heats produced with addition of flue dust briquettes showed that total iron content was not influenced by the additions. The lime contents were higher in the samples taken in the 8th minute of blowing than in the samples taken after finishing of blowing. It was connected with the presence of the non-assimilated lime in the oxygen converter charge after 8 minutes of oxygen blowing.

Figure 5. shows relation between mean values of zinc and lead contents in the flue dust and amounts of flue dust briquettes added into the converter charge. The flue dust samples taken after finishing of oxygen blowing were used. Important increase of zinc contents related to increased amount of flue dust briquettes in the charge was found.

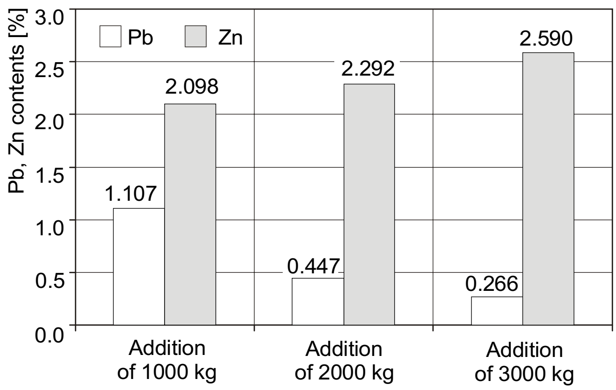

Figure 5. **Relation between mean values of Pb and Zn contents in flue dust and amount of flue dust briquettes added into the charge**
Slika 5. **Omjer srednjih vrijednosti sadržaj Pb i Zn u visokopećnoj prašini te količine briketirane prašine dodane talini**

This find necessitates the control of Zn contents in flue dust when recycling of flue dust briquettes into charge of oxygen converter and elimination of flue dust from recycling after reaching 20 % of zinc. Reverse relation was found in lead contents. It can by explained by the fact, that samples of flue dust were taken after oxygen blowing, but lead was eliminated from the charge in the first stage of the oxygen blowing.

Table 1. **Mean values of normal distribution**
Tabela 1. **Srednje vrijednosti normalne raspodjele**

		Steel shop I top blowing mean value	Steel shop I combined blowing mean value	Steel shop II top blowing mean value
Without briquettes addition	Basicity	3.9281	3.9491	4.0626
	Fe total in slag [%]	19.3050	18.8696	16.7936
	Distribut. coeff. of P	34.6726	36.2626	40.4813
	Distribut. coeff. of S	6.2562	6.8115	6.1438
With addition of up to 1000 kg of briquettes	Basicity	3.9756	3.8833	-
	Fe total in slag [%]	20.0219	17.8364	-
	Distribut. coeff. of P	31.2690	36.7782	-
	Distribut. coeff. of S	6.8113	6.6266	-
With addition of 1000 kg to 2000 kg of briquettes	Basicity	4.0268	3.9888	3.8865
	Fe total in slag [%]	18.4270	18.0313	17.0833
	Distribut. coeff. of P	37.9577	37.1124	41.7765
	Distribut. coeff. of S	6.8558	6.6783	6.3294
With addition of 2000 kg to 3000 kg of briquettes	Basicity	3.8718	4.0335	4.0041
	Fe total in slag [%]	17.7461	18.1306	17.9061
	Distribut. coeff. of P	38.7161	36.8474	41.4703
	Distribut. coeff. of S	6.7551	6.7219	6.3001
With addition more than 3000 kg of briquettes	Basicity	3.8942	4.0366	3.9762
	Fe total in slag [%]	17.0504	17.1038	17.6473
	Distribut. coeff. of P	38.7726	37.1330	44.0172
	Distribut. coeff. of S	7.1325	6.8697	6.5404

STATISTIC EVALUATION OF FLUE DUST BRIQUETTES RECYCLING

Statistic set contained 9 123 heats:
- 8 679 heats without briquettes additions,
- 122 heats with additions up to 1 000 kg of briquettes,
- 100 heats with additions up to 1 000 kg to 2 000 kg of briquettes,
- 128 heats with additions up to 2 000 kg to 3 000 kg of briquettes,
- 94 heats with additions more than 3 000 kg of briquettes.

Four parameters were evaluated in the statistic set:
- basicity of slag,
- iron content in slag,
- distribution coefficient of phosphorus,
- distribution coefficient of sulphur.

The heats were produced in both steel shops in the steel plant. The steel shop I used both converter with top blowing and converter with combined blowing, the steel shop II used the top blowed converters.

Table 1. shows mean values of normal distribution of analysed parameters for both steel shops and for different refining ways. From analysed values it follows, that additions of flue dust briquettes into oxygen converter charge effect the values of slag basicity and iron contents in slag only by insignificant way. Distribution coefficients of phosphorus were positively influenced by briquettes additions, when increased portion of briquettes resulted in increased value of distribution coefficient. Distribution coefficients of sulphur slightly increased with increased portion of flue dust briquettes in the converter charge. Positive effects of briquettes additions on the distribution coefficients of both P and S were more intensive in top blowed oxygen converters. It is necessary to note that the mean values of both coefficients from the set of heats produced without briquettes additions were higher. This broad set of heats related to different ways of steel making practice, e.g. different charge composition, when producing different grades of steel.

CONCLUSIONS

The paper presents results of study related to recycling of converter flue dust briquettes into the oxygen converter charge. The most important items are as follows:
- it was found by study of the dephosphorisation and desulphurisation processes in the experimental part of the work and by statistic analysis that the highest values of the distribution coefficient of both P and S were recorded in the heats produced with the highest portion of the flue dust briquettes. This positive effect was more intensive in top blowed oxygen converters;
- the briquettes additions had not any significant effect on chemical composition of slag: iron contents in slag, basicity of slag and free lime contents. Only zinc contents in slag were effected, they increased with increasing portion of briquettes in the converter charge;
- final structure of slag was influenced by the briquettes additions. The slags from heats, produced with the high-

est portion (3 000 kg) of briquettes, had structure that contained both dicalcium silicates and tricalcium silicates components.

- the most pronounced effect of briquettes additions was observed in the composition of converter flue dust, mainly in the contents of zinc and lead;
- from presented study follows that additions of converter flue dust briquettes into oxygen converter charge have no negative influence on stability of refining regime in the converter, nor on quality of produced steel. The addition up to 4000 kg briquettes into 160 t charge of oxygen converter are recommended.

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