THE SIMULATING OF PRODUCTION THE AGGLOMERATE IN LABORATORY SINTERING PAN

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Abstract
The presentation work contains the results, which were attained on the laboratory sintering pan with the simulating of production the agglomerate. On this laboratory sintering pan are sufficiently simulating conditions, which are present in the sinter band. On the basis of the theoretical analyse, analysis measuring data, computing of the balance, production, qualitative and quantitative parameters of the sintering process we can conclude, that in the case of changing under pressure sucking air are influenced main production parameters in the process of agglomerate production (for example recovery, productivity, coefficient of productivity, etc.). This laboratory sintering pan sufficiently simulates conditions present on the sinter belt in relation to the production of CO, CO_2, NO_x, SO_x and solid polluting substances in the sintering process. The significant decrease of emissions can be achieved through minimization of the fuel content in the sintering charge. In connection with high basicity requirements for current agglomerates it is necessary to keep their iron content. This requirement can be met by increasing the content of concentrates in sinter mixtures. For this purpose in view laboratory sintering tests were performed to investigate the effect of sintering ores and concentrates on the agglomeration process and its products. The experiment results were analyzed and summarized in the present paper.

Keywords: sintering, laboratory sintering pan, CO, CO_2 emissions, recovery, productivity.

1 Introduction

Under operational conditions the agglomeration process is performed on agglomeration (sintering) belts which operate on the principle of firing up the agglomeration charge using a burner, creating and applying the sucking air underpressure across the sinter bed (in which the burning of fuel, heat transfer and oxidation-reduction processes take place) and the gradual cooling of the produced agglomerate in the cooling section of the agglomeration belt [1,2]. Under laboratory conditions of Department of Ferrous Metallurgy and Foundry the agglomerate production on the agglomeration belt using a laboratory-scale sintering pan can be simulated. The sintering process under laboratory conditions must be performed in a way which imitates operational conditions to the maximum extent. To meet this requirement the laboratory-scale sintering pan is fitted with the exhauster that creates the sucking air underpressure, thermocouples capable of reading temperatures in the sinter bed, and measuring devices to analyse temperatures and chemical composition of combustion gases. Next in the research in

Japan [1], the movement of the combustion zone from upper to lower during the sintering process was observed using a silica glass tube in the pot test. **Fig. 1** shows the time-dependent change and progress of the movement of the combustion zone during the sintering. When the ratio of inner coke breeze was high, enlargement of the width of the combustion zone and the rise of CO_2 and CO was observed by authors of works [1,3,4,5,6,7].

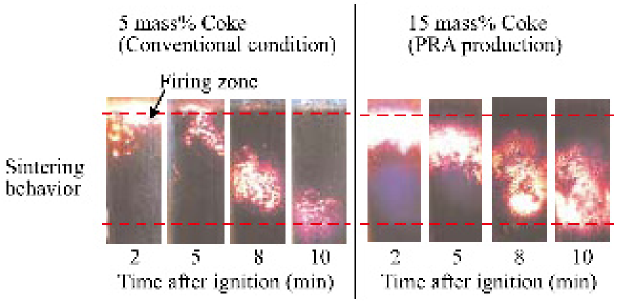

Fig.1 Influence of coke breeze mixing ratio [1]

Fig. 2 shows the relationship between the sinter reduction degree and production ratio. The sinter reduction degree was maximum between −45 μm and −125 μm, and the production ratio also showed its maximum value in the same size range [1,3,6,7]. If the particle size is reduced further, both the reduction degree and the production ratio decrease. Because finer coke burns rapidly and simultaneously with this, the granulated particles are melted excessively, resulting in a lower reduction degree.

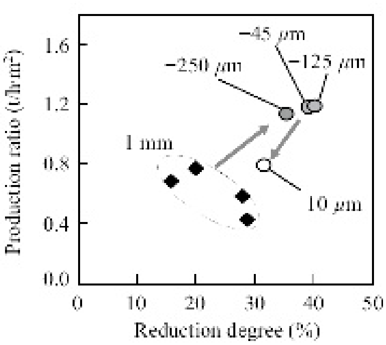

Fig.2 Influence of coke breeze size on productivity and reduction degree [1]

2 Experimental materials and methods

2.1 Materials

Based on the theoretical knowledge of the effects of individual factors on the agglomeration process [2,3,6,8,9], the effect of changing the sucking air underpressure on the parameters of the highly basic agglomerate production process has been preferentially analysed.

The change of the sucking air underpressure has been carried out at 3 kPa (sintering No. 7….sign. M7), 5 kPa (sintering No. 6… sign. M6) and 7 kPa (sintering No. 8….. sign. M8), (**Table 1**). To gain knowledge of the effects of agglomeration ores and concentrates on the sintering process and its products, the sintering of major metal bearing components of the agglomeration charge have been performed in certain ratios.

The materials for laboratory experiments were supplied from blast furnace plant. Chemical composition of metalliferous materials is shown in **Table 2**. Supplied materials are commonly used in a sintering process. The sintering ore granularity has been 18.0 % above 8 mm and under 0.5 mm only 2 %. The standard blast-furnace coke under 3mm was used as fuel. Granulometry of limeston and dolomite was in the range of norm for grinding.

Table 1 Structure of the laboratory sintering

Agglomeration mixture….M															
[W%]	M1	M2	M3	M4	M5	M6	M7	M8	-	M10	M11	M12	M13	M14	M15
Fe	41.3	41.3	41.3	41.3	41.3	41.3	40.3	40.3		41.3	40.8	41.9	41.3	40.7	41.3
FeO	10.3	10.3	10.3	10.3	10.3	10.3	9.6	9.6		8.6	8.6	8.2	9.9	10.2	10.1
SiO_2	6.0	6.0	6.0	6.0	6.0	6.0	5.5	5.5		7.1	6.6	6.1	7.5	7.1	7.3
CaO	16.4	16.4	16.4	16.4	16.4	16.4	15.1	15.1		11.7	11.7	11.5	11.3	12.3	11.4
Mn	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4		0.04	0.03	0.03	0.03	0.03	0.03
P	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03		0.03	0.03	0.03	0.03	0.02	0.03
S	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08		0.05	0.07	0.06	0.06	0.06	0.05
C	7.8	7.8	7.8	7.8	7.8	7.8	8.3	8.3		7.4	8.6	8.5	8.6	8.6	8.0
Bas.	2.72	2.72	2.72	2.72	2.72	2.72	2.8	2.8		2	2.1	2.2	1.8	2.1	1.9
	real agglomeration mixtures-optimalization sintering process					agglomeration mixtures-changing underpressure				model mixtures-changing amount of fuel and change ratio **C**oncentrate: **S**intering ore					
						5 kPa	3 kPa	7 kPa							
	Agglomerate….A														
[W%]	A1	A2	A3	A4	A5	A6	A7	A8	-	A10	A11	A12	A13	A14	A15
Fe	49.2	48.7	49.0	49.3	48.8	48.7	48.8	48.4		48.6	48.9	49.7	49.1	48.6	47.9
FeO	7.2	7.0	7.6	8.2	9.5	9.9	9.2	9.8		5.7	6.7	8.05	10.1	8.1	7.5
SiO_2	6.8	7.6	7.1	7.7	6.5	6.7	6.6	6.5		7.5	8.8	8.5	9.4	8.7	9.3
CaO	16.6	16.7	17.1	17.5	18.8	18.8	18.2	18.5		14.9	13.4	13.1	13.3	14.2	14.4
Mn	0.5	0.5	0.4	0.5	0.4	0.4	0.5	0.5		0.1	0.09	0.09	0.08	0.1	0.08
P	0.03	0.03	0.03	0.07	0.03	0.03	0.03	0.03		0.04	0.03	0.03	0.03	0.04	0.03
S	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.06		0.03	0.03	0.02	0.02	0.02	0.02
C	1.4	0.9	0.5				0.4	0.6		0.2	0.3	0.3	0.3	0.3	0.2
Bas.	2.5	2.3	2.5	2.3	2.9	2.8	2.8	2.9		2.4	1.9	1.9	1.7	2.0	1.9

Table 2 Chemical composition of metalliferous materials used in study

[W%]	Sintering ore	Concentrate
Fe	60.70	64.52
FeO	0.14	23.57
Fe_2O_3	86.26	66.44
SiO_2	9.61	8.6
CaO	0.07	0.19
MgO	0.06	0.09
Al_2O_3	1.35	0.06

2.2 Experimental methods

The process of simulating the laboratory production of agglomerate under laboratory conditions of Department of Ferrous Metallurgy and Foundry in Košice has been divided into two stages – a cold stage and a hot stage. The cold stage included the preparation and processing of individual charge components, their agglomeration, formation of test heaps, pre-pelletization and determination of their moisture and air permeability. The hot stage included the heating of the pan, loading the pre-pelletized mixture into the laboratory-scale sintering pan, firing up the surface of the charge using a burner and high temperature sintering. During the sintering process various parameters (e.g. the temperature of the sinter bed, amount and chemical composition of exhaust gasses, underpressure etc.) have been evaluated, (**Fig. 3**).

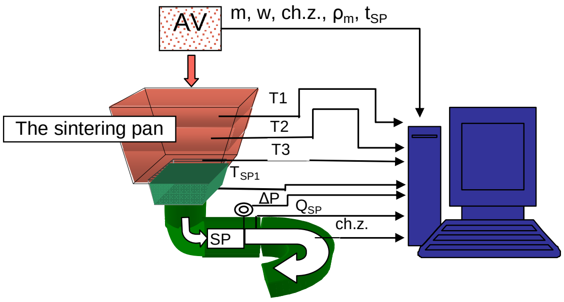

Fig.3 The laboratory sintering pan
Legend: m – amount of agglomeration mixture, w – moisture of agglomeration mixture, ch.z. – chemical composition of agglomeration mixture, p_m – specific weight of agglomeration mixture, t_{SP} – time of sintering, T_1, T_2, T_3 – temperatures in the sinter bed, T_{SP1} – temperatures of outgoing combustion gases, Δp – underpressure, Q_{SP} – amount of combustion gases, ch.z. – chemical composition of combustion gases

3 Experimental results

3.1 Effect of the sucking air underpressure on the production parameters of the sintering process

The evaluation of the laboratory experiments shows that the reduced underpressure (3 kPa) extends the total sintering time, which has a direct impact on the decrease of the vertical speed of sintering and the reduction of production of agglomerate **(Fig. 4)**. For particular values compared with the underpressure of 5 kPa and 7 kPa the vertical speed of sintering is lower by 2.72 mm/min. or 4.76 mm/min. In terms of production it is the drop by 32.55 kg/hour or 39.24 kg/hour.

In case of the highest experimental underpressure of 7 kPa the factor which gives the occurrence of solid polluting substances had a very negative impact (compared with the underpressure of 3 kPa the increase of solid polluting substances was 7.7%; and compared with the underpressure of 5 kPa the increase was 9.9%).

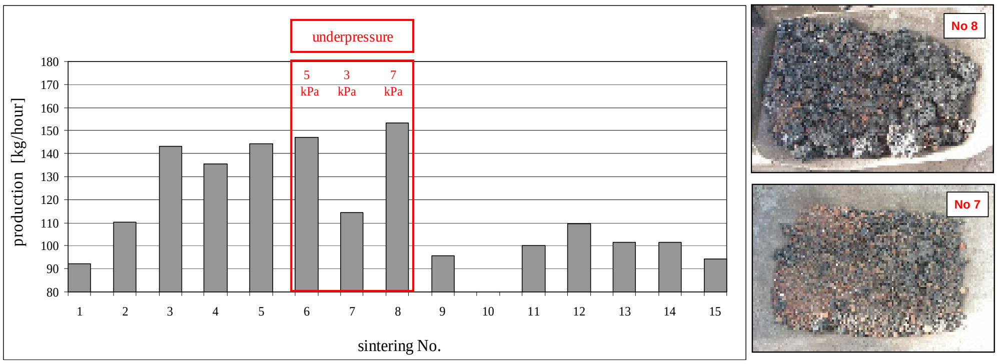

Fig.4 Production of agglomerate in the laboratory process

3.2 Effect of the sucking air underpressure on CO and CO_2 emissions

The theory of the dependence between the amount of fuel and the rise of CO_2 and CO is generally well known. As the burning of solid fuels is a heterogeneous process, the speed of its course depends also on the velocity of the oxygen supply to the reaction surface as well as on the speed of the chemical process of CO and CO_2 formation [2,10,11,12,13]. Within the framework of modelling the sintering process by means of a laboratory-scale sintering pan very close dependencies between the carbon content in the agglomeration mixtures and arising amounts of CO_2 and CO have been confirmed (**Fig. 5**).

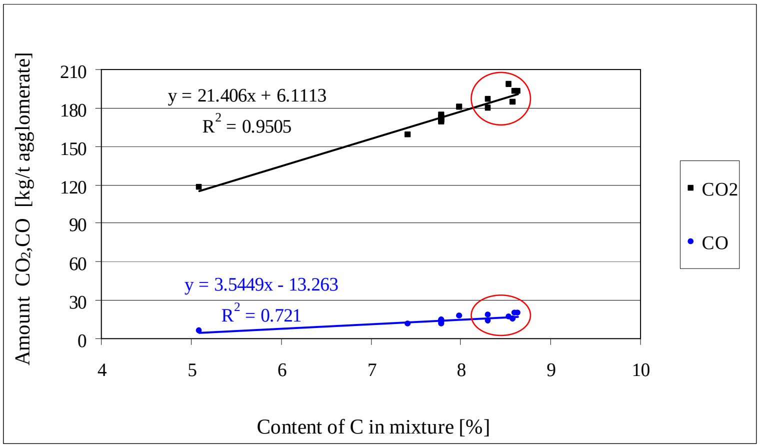

Fig.5 Influence of the carbon content on the amount of CO_2 and CO

The analysis of the effect of the sucking air underpressure on the occurrence of CO_2 and CO reveals that the increase of the underpressure to the level of 7 kPa results in the increase of the CO content in combustion gases. This fact is documented also in **Table 3**.

Table 3 The amount CO_2 a CO with various underpressure sucking air

Underpressure value [kPa]	CO			CO_2		
	[%]	[kg/t agl.]	[g/m^3 combust. gases]	[%]	[kg/t agl.]	[g/m^3 combust. gases]
3	1.02	13.82	10.38	8.78	186.81	140.28
5	1.13	14.08	11.28	8.74	170.36	136.43
7	1.28	18.20	13.86	8.05	179.93	137.08

Theoretical knowledge which implies that the increased underpressure increases the linear velocity of the air stream passing through the sintering bed, when a relatively fast air stream drifts CO produced on the surface of the burning fuel into the cold zone so quickly that the oxidation by atmospheric oxygen is not complete, has been explicitly proved [2,11,14]. A reduced underpressure and lower vertical speed of the sintering process result in a slower and gradual heating of the pre-pelletized charge with a longer tenacity at maximum temperatures and subsequent slower cooling. At the lowest underpressure of 3 kPa also the amount of heat absorbed by combustion gases decreased and a relatively even distribution of temperatures across the sinter bed occurred, **(Fig. 6, 7)**.

3.3 Increase of iron content in current sinter

The use of agglomeration ores and concentrates in agglomeration processes is a standard procedure used by a majority of agglomeration plants. Their mutual ratio in an agglomeration charge affects not only the agglomerate richness but also the course of the agglomeration charge preparation process as well as technological conditions of sintering.

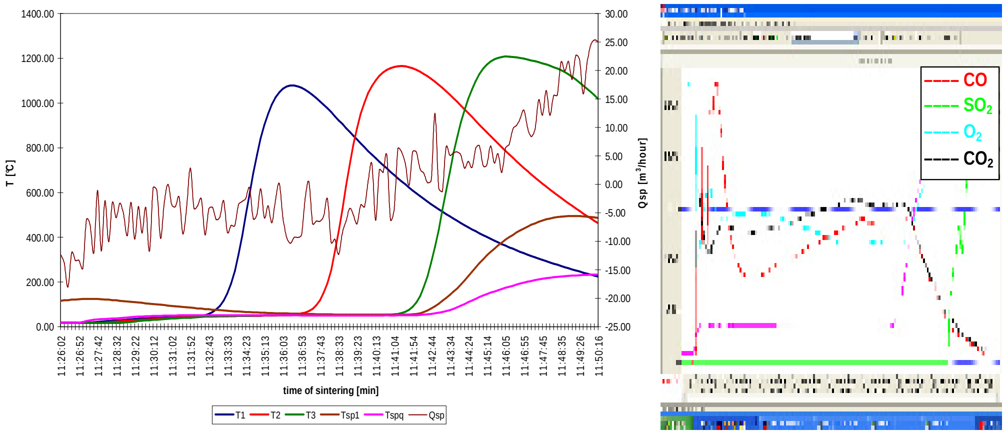

Fig.6 The sintering process with minimum underpressure sucking air - 3 kPa

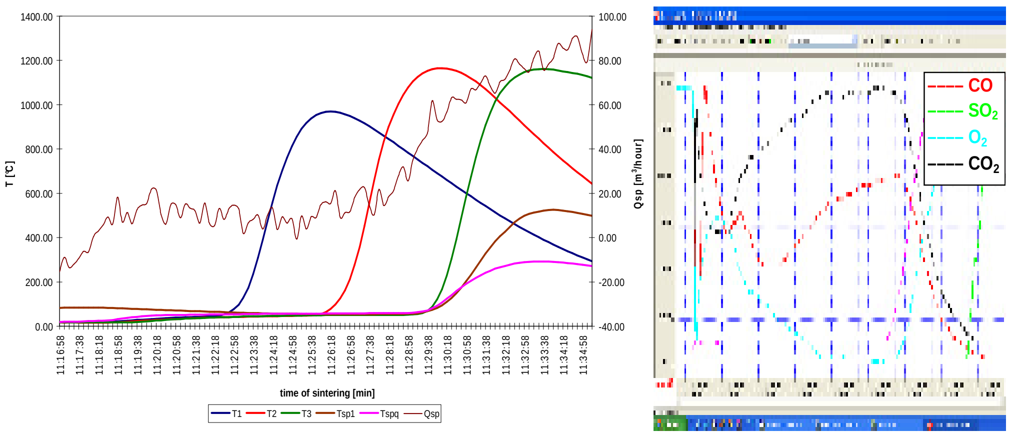

Fig.7 The sintering process with maximum underpressure sucking air - 7 kPa

To gain knowledge of the effects of agglomeration ores and concentrates on the sintering process and its products [2,8,15], the sintering of major metal bearing components of the agglomeration charge have been performed in certain ratios. Six test heaps have been created with two Concentrate:Sintering ore ratios (Conc:SintOre), namely 1.2:1 and 1.8:1. Fuel additions of 55, 65 and 70 kg.t^{-1} of agglomerate have been set for test heaps. All sintering processes have been carried out while maintaining the constant underpressure of 5 kPa. With respect to the results of the first sintering using the fuel quantity of 55 kg.t^{-1} of agglomerate, when the thermal effect sufficient for the sintering of the agglomeration charge column has not been achieved, the fuel additions for the increased Conc:SintOre ratio of 1.8:1 have been set to 65 and 70 kg.t^{-1} of agglomerate. The sintering results are summarised in the following **Table 4**.

Amount of coke fuel in agglomerate mixture affects temperature in sintering layers – is influencing on content FeO in agglomerates. Content of FeO in agglomerate is illustrated in **Fig. 8**.

Table 4 Sintering parameters of model stacks

Technological parameters		Conc:SintOre 1,2:1			Conc:SintOre 1,8:1		
		SP10	SP11	SP12	SP13	SP14	SP15
bulk density	$kg.m^{-3}$	1870.12	1909.18	1899.41	1835.94	1843.26	1857.91
sintering time	min.	34:14	26:43	27:03	23:22	24:02	27:43
sintering rate	$mm.min^{-1}$	-	11.64	11.69	12.88	12.85	11.21
medium grain	mm	-	16.30	16.41	12.27	12.47	13.23
index of strenght	+ 6.3mm, %	-	57.33	60.67	62.67	64.00	65.07
index of abrasion	- 0.5mm, %	-	6.67	6.00	6.00	6.67	6.73
specific output	$t.m^{-2}/24h$	-	23.48	25.63	23.83	23.81	22.12
coefficient of productivity	%	-	73.36	80.16	69.96	69.81	73.77
$T1_{max}$	°C	484	829	757	915	671	770
$T2_{max}$	°C	634	1090	1199	1054	1199	763
$T3_{max}$	°C	839	1152	1317	1294	1275	1240
Tsp_{max}	°C	382	492	532	546	569	515

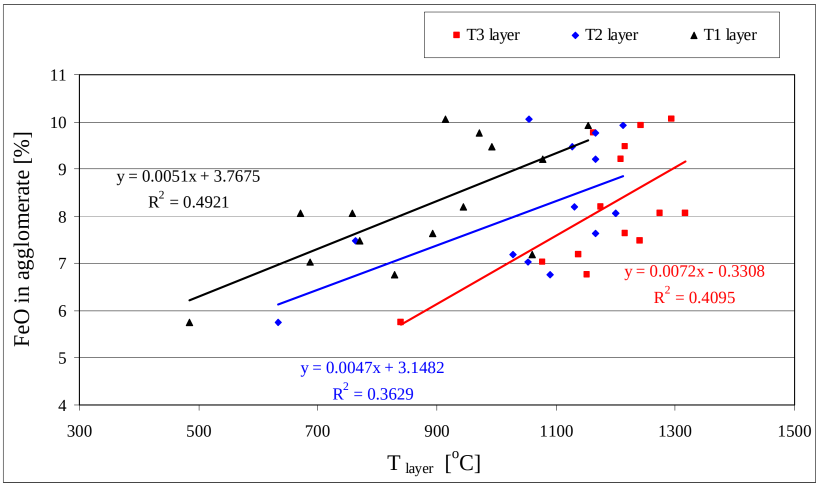

Fig.8 Influence of temperature in sintering layers on FeO in agglomerate

Based on the comparison of the course and results of laboratory sintering with the identical quantity of fuel, the following can be stated:

- The monitored production indicators are in many cases similar or identical.
- Significant differences have been observed at granulometric scatter. In case of SP15 sintering the +25 mm fraction represented only 45% amount of this fraction value compared to SP11 sintering, which has been proved also by the D_{str} value from the overall scatter.
- From the above it results that the enriched agglomerate with the increased Conc:SintOre ratio reduces the +25 mm fraction. It can be explained by the fact that from the viewpoint of the pelletizing mechanism a higher content of concentrate provides fine-grained micro-pellets.

4 Conclusions

1. The process of simulating the production of agglomerate in the laboratory sintering pan introduce new approach and new course in simulation of the technological processes, because during the sintering process various parameters (e.g. the temperature of the sinter bed, the temperature, amount and chemical composition of exhaust gasses, underpressure etc.) have been evaluated.
2. The increase of the sucking air underpressure resulted in the reduction of the total sintering time and the increase of the vertical speed of sintering. This process leads to the increase of the production agglomerate, and contributes to gaining required qualitative parameters of the produced agglomerate.
3. Based on the theoretical analysis and balance calculations the fuel (coke dust) has been defined as the major source of CO and CO_2 gaseous emissions in combustion gases resulting from the agglomeration process.
4. It has been discovered that the increase of the underpressure results in the increase of the CO content in combustion gases.
5. By increasing the amount of the concentrate the average grain size of the produced agglomerate decreases, mainly due to the increase of undersize particles and the reduction of the granulometric fraction +25 mm.
6. The increase of the amount of the concentrate deteriorates pelletizing conditions and pre-pelletization of the agglomeration charge, as well as its quality in terms of air permeability.

Acknowledgements

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References

[1] R. Findorák , M. Fröhlichová, J. Legemza, F. Bakaj, M. Džupková: Acta Metallurgica Slovaca, Vol. 17, 2011, No. 3, p. 186-192.
[2] A. Łedzki et al.: Hutnik, Vol.7, 2007, p. 344-347.
[3] J. Mitterlehner et al.: ISIJ International, Vol. 44, 2004, No. 1, p. 11-20.
[4] R. Budzik: Metalurgija, Vol. 46, 2007, No. 2, p. 145-147.
[5] S. N. Misra, C. Gupta: ISIJ International, Vol. 33, 1994, p. 468.
[6] H. Sato, S. Machida, K. Nushiro, K. Ichikawa, N. Ooyama: ISIJ International, Vol.10, 2003, No. 10, p. 52-55.
[7] S. Machida, H. Sato, K. Nushiro, T. Ariyama: ISIJ International, Vol. 17, 2004, No. 5, p. 810-816.
[8] R. Benesch, M. Wyderkoand A. Ledzki: Hutnické listy, Vol. 42, 1987, No. 8, p. 533-538.
[9] J. T. Chao, J. Cookand A. E. Grau: Ironmaking Processing, Vol. 48, 1989, No. 1, p. 383.
[10] R. Budzik: Stal', Vol. 10, 1987, No. 8, p. 125 – 132.
[11] M. Budayová, A. Varga: Acta Metallurgica Slovaca, Vol. 15, 2009, No. 2, p. 126-130.
[12] S.K. Kawatra, S. J. Ripke: International Journal of Mineral Processing, Vol. 72, 2003, No. 1, p. 429-441.
[13] R. Budzik: Hutnik, Vol. 54, 1987, No. 5, p. 132-138.
[14] R. Benesch, M. Wyderko-Delekta, A. Ledzki: Hutnik, Vol. 56, 1989, No. 5, p. 170-176.
[15] S.J. Ripke, S.K. Kawatra: *Effect of Cations on Iron Ore Pellet Strength*, In.: Proceedings of the 2002 Annual Meeting, SME, Phoenix, 2002, p. 1-12.