IMPERIAL SMELTING FURNACE CHARGING MODEL

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Abstract

HCM in Miasteczko Śląskie is the only zinc smelter in Europe which use Imperial Smelting Process technology. Paper shows ISF charging model which allows to calculate on-line current state of the furnace batch parameters. The main purpose of the model is predicting of raw Zn, Pb and slag production in the next charging step, which can change depending on thermal demands or new chemical composition of the batch.

Keywords: Zinc and lead production, Imperial Smelting Furnace, batch charging

1. INTRODUCTION

The Imperial Smelting Process (ISP) was developed mid last century in the UK to create a pyrometallurgical continuous zinc winning process. HCM in Miasteczko Śląskie is the only zinc smelter in Europe which uses Imperial Smelting Furnace (ISF). Despite the fact that the ISP technology disappears in the world, it is still very effective thanks to the parallel production of zinc and lead. Thus, in the furnace are not produced lead containing residues like other zinc-making processes do [1]. Beside traditional raw materials as lead and zinc sulphides, at the ISP can be used secondary materials as dust and sludges from steelmaking processes [2]. Before charging as a batch they are lumped in sintering process.

So, the charge to the blast furnace is hot sinter (~300 °C) loaded directly from sinter strand and preheated coke (~800 °C) [3]. Coke is burning in the lower part of the ISF and the heat from this and the carbon monoxide gas produced providing the means to reduce the zinc and lead oxides. Lead oxide is easy reduced in upper part of ISF to metallic state. The lead is tapped from the bottom of the blast furnace, carrying copper, silver and gold with it. With lead also is tapped slag. Zinc vapor leaves furnace from the top side and sprinkled by liquid lead moves to condensed phase. After lead separation, raw zinc is subjected to refining by three lead columns, two cadmium columns, one redistillation column and one baby column. Refining products are zinc SHG (Special High Grade ~99,995 %), GOB (Good Ordinary Brand ~98,5 %) and refined cadmium [4].

Complexity of winning process, where products moves through several phases, does not allow to determine precisely the main product stream mass at the short period [5]. The accuracy of determining the mass of main products in an ISP is the more accurate the longer the time of overhead they are evaluated: shift, day, month. However, for the proper conduct of the process and especially for the control of the heat supply in dependence on its demand, it is necessary to determine the masses in a shorter period such as an hour, even half-hour. The object of present paper is development of ISF charging model which allows to calculate on-line the main product streams as lead, zinc and slag with satisfying precision.

2. MODEL BUILDING

Figure 1 shows materials streams in modelled ISP. From the furnace top are charged sinter, coke and sometime gathered in smelter zinc scrap. These materials are precisely weighted. By-products as scale gathered from condenser well and black sludge from the off-gas filter are estimated daily in kg per tonne of raw zinc (tRZn). Also lead in condenser - sprinkled lead (SPb) - must be supplemented with about 70-80 kg/tRZn. So the unknown parameters in this system are the masses of raw zinc (RZn), raw lead (RPb) and slag.

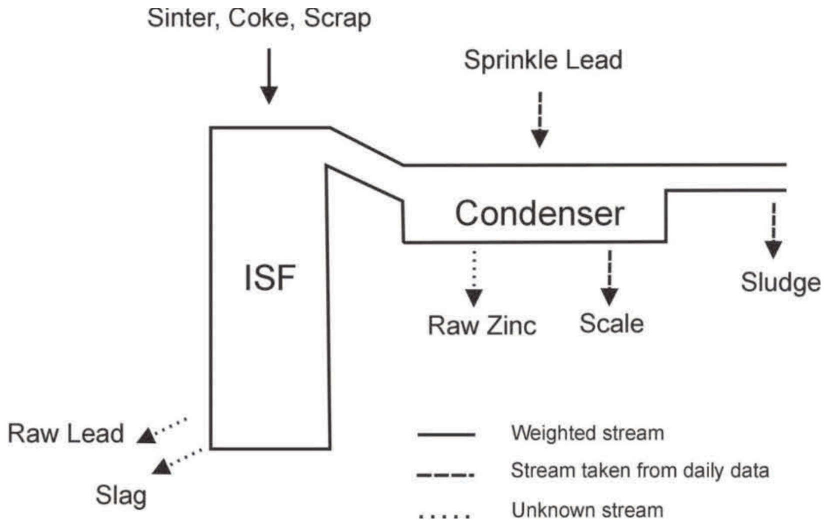

Figure 1 Materials streams in ISP

These unknowns can be found by solution of a system of three linear equations describing the material balance for Zn, Pb and SiO_2.

Zinc balance:

$$\%Zn_{sinter} \cdot M_{sinter} + \%Zn_{scrap} \cdot M_{scrap} = \%Zn_{slag} \cdot M_{slag} + \%Zn_{RZn} \cdot M_{RZn} + \%Zn_{RPb} \cdot M_{RPb} + + \%Zn_{scale} \cdot M_{scale} + \%Zn_{sludge} \cdot M_{sludge} \quad (1)$$

Lead balance:

$$\%Pb_{sinter} \cdot M_{sinter} + \%Pb_{scrap} \cdot M_{scrap} + 100\ \% \cdot M_{SPb} = \%Pb_{slag} \cdot M_{slag} + \%Pb_{RZn} \cdot M_{RZn} + \%Pb_{RPb} \cdot M_{RPb} + + \%Pb_{scale} \cdot M_{scale} + \%Pb_{sludge} \cdot M_{sludge} \quad (2)$$

SiO_2 balance:

$$\%SiO_{2\ sinter} \cdot M_{sinter} + \%SiO_{2\ scrap} \cdot M_{scrap} + \%SiO_{2\ coke} \cdot M_{coke} = \%SiO_{2\ slag} \cdot M_{slag} + + \%SiO_{2\ scale} \cdot M_{scale} + \%SiO_{2\ sludge} \cdot M_{sludge} \quad (3)$$

where:

%Zn, %Pb, $\%SiO_2$ - weigh percent of element or substance (wt.%)

M - mass of stream per charge (kg)

Bold parameters in equations (1-3) are unknown.

Another parameter, calculated by application is C/Zn which reflects heat input to the furnace and can be adjusted:

$$\frac{C}{Zn} = \frac{M_{coke}}{(\%Zn_{sinter} + 0.1\,\%Pb_{sinter})\,0.01\,M_{sinter} + (\%Zn_{scrap} + 0.1\,\%Pb_{scrap})\,0.01\,M_{scrap}} \quad (4)$$

From equation (4) can be derived the mass of sinter necessary to adjust demanded C/Zn parameter:

$$M_{sinter} = \frac{\frac{100\,M_{coke}}{\frac{C}{Zn}} - M_{scrap}\,(\%Zn_{scrap} + 0.1\,\%Pb_{scrap})}{\%Zn_{scrap} + 0.1\,\%Pb_{scrap}} \quad (5)$$

3. APPLICATION OVERVIEW

Figure 2 shows the main window of developed application. Left side of form presents data of measured actual charge. Masses of materials are weighted hourly and converted to kg per charge, taking into account that coke charge is always weighted 2000 kg/charge. Slag basicity is calculated from the last tap chemical analysis. Left bottom quarter of form shows daily data from the previous day. The main role of previous day data is estimation of secondary materials production such as scale from condenser well and black sludge from top gas filter.

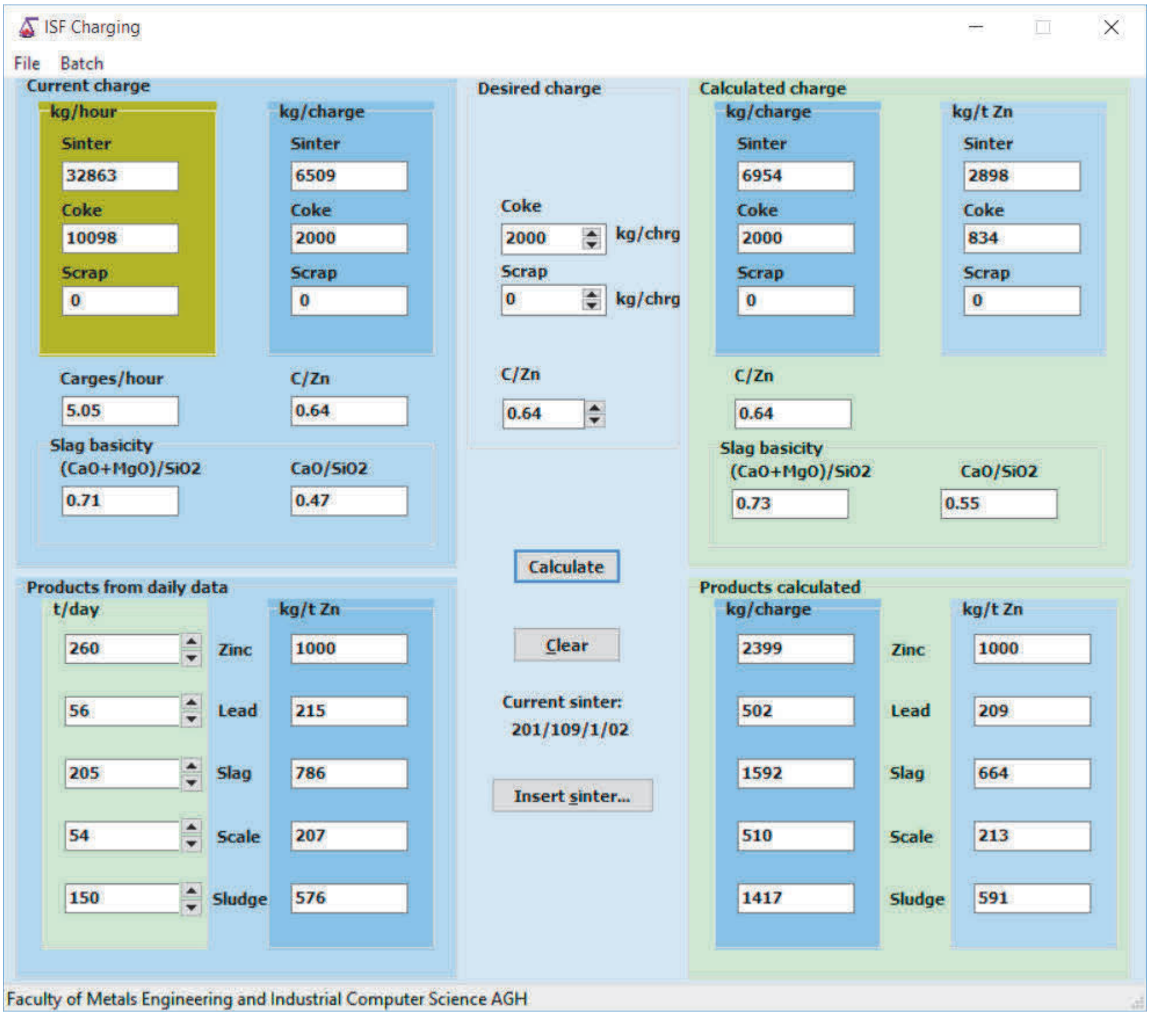

Figure 2 The main window of charging application

Central part of form is designed for steering of next charge. Operator or technologist can change masses of coke or scrap. As mentioned before, the scrap is loaded into furnace only occasionally, when gathered enough to fill charging container. However, mass of sinter is calculated according to set parameter of C/Zn. Important possibility in steering is setting of sinter batch. Sinter is produced in HCM continuously in sinter plant. Thanks to using currently of waste materials in form of zinc oxide instead traditional raw materials in form of zinc sulphide, the zinc content in sinter can significantly change during even few hours. So, every two hour sinter batch is analyzed and marked in database.

4. CALCULATIONS AND DISCUSSION

To verifying charging model and application, were carried out passive calculation (without connection of the model with furnace). It was taken into account ten samples of sinter plant daily production which consequently was loaded into ISF. **Table 1** shows the main substances of sinter in ten samples. As mentioned before, the values of main substances may change in wide range rapidly when waste materials are used. However **Table 2** shows calculated charge characteristics for different values of C/Zn parameter. B2 and B1 are slag basicities showed in **Figure 2** as '(CaO+MgO)/SiO_2' and 'CaO/SiO_2' respectively. It can be seen from **Table 2**, that for various sinter samples with fixed C/Zn parameters, masses of coke and sinter per tonne of raw zinc are similar. But mass of slag can change in range of 0-40 kg/t RZn. So it confirms necessity of precise determination of slag mass for next charge calculation. It may also reduce coke consumption in so heat-demanding process.

Table 1 Chemical composition of sinter

Sinter sample	Main substances of sinter (wt. %)					
	Zn	Pb	CaO	SiO_2	Al_2O_3	S
1	43.50	13.47	2.91	4.18	1.08	1.99
2	44.01	13.03	2.94	4.22	1.03	1.77
3	43.83	13.11	2.89	4.27	1.24	1.62
4	43.87	13.05	2.98	4.11	1.01	2.28
5	44.10	12.78	3.22	4.27	1.64	2.20
6	43.60	12.86	3.16	4.11	1.49	2.22
7	42.82	13.64	3.28	4.26	1.09	2.10
8	44.14	12.63	3.20	4.29	1.07	1.78
9	43.63	12.85	3.19	4.14	1.04	2.02
10	43.75	12.68	3.09	4.35	1.05	1.81

Table 2 Calculated charge characteristics for different values of C/Zn parameter

C/Zn (-)	Charge characteristic	Sinter sample									
		1	2	3	4	5	6	7	8	9	10
0.64	Sinter (kg/t RZn)	2898	2866	2880	2873	2861	2891	2949	2859	2890	2887
	Coke (kg/t RZn)	834	833	834	832	833	832	836	832	832	833
	Slag (kg/t RZn)	664	662	672	648	668	652	685	670	656	684
	B2 (-)	0.73	0.73	0.72	0.75	0.79	0.79	0.78	0.76	0.78	0.74
	B1 (-)	0.55	0.55	0.54	0.57	0.6	0.61	0.62	0.6	0.62	0.57
0.74	Sinter (kg/t RZN)	2904	2869	2882	2876	2863	2894	2951	2861	2892	2889
	Coke (kg/t RZn)	965	964	965	963	963	963	967	963	963	964
	Slag (kg/t RZn)	690	689	698	675	694	679	712	697	682	711
	B2 (-)	0.71	0.72	0.71	0.73	0.77	0.77	0.76	0.74	0.76	0.72
	B1 (-)	0.54	0.54	0.52	0.56	0.59	0.6	0.61	0.58	0.6	0.56
0.84	Sinter (kg/t RZN)	2906	2871	2885	2881	2869	2900	2956	2867	2898	2891
	Coke (kg/t RZn)	1096	1094	1096	1095	1095	1095	1099	1095	1095	1095
	Slag (kg/t RZn)	717	715	725	702	721	706	739	724	709	737
	B2 (-)	0.69	0.7	0.69	0.72	0.75	0.75	0.75	0.72	0.74	0.71
	B1 (-)	0.53	0.53	0.51	0.54	0.57	0.58	0.59	0.57	0.58	0.54

5. CONCLUSION

The paper reflects implementation progress of the project financed by European Funds, Operational Programme Smart Growth 2014-2020. Part of the project is improving of ISF charging. Developed model uses the newest data as possible. These data are gathered on-line, eventually for secondary material streams are taken daily data. Charging model allows to calculate demanded masses of batch materials depending on heat state of ISF. There is also possibility of the main products masses calculation obtained after actual charging.

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