POSSIBLE WAYS OF PLASMA HEATING FOR PROCESSING THE METAL-BEARING OXIDIC WASTES

Macoszek M.[1], Brožová S.[2], Kafka V.[3], Bůžek Z.[2]

[1] VÍTKOVICE, a. s., Czech Republic

[2] Department of Metallurgy, FMMI, VŠB - Technical University of Ostrava, Czech Republic

[3] RACIO & RACIO, Orlová, Czech Republic

MOŽNOSTI VYUŽITÍ PLAZMOVÉHO OHŘEVU KE ZPRACOVÁNÍ OXIDICKÝCH KOVONOSNÝCH ODPADŮ

Macoszek M.[1], Brožová S.[2], Kafka V.[3], Bůžek Z.[2]

[1] VÍTKOVICE, a. s., Česká republika

[2] Katedra metalurgie, FMMI, VŠB - Technická Universita Ostrava, Česká republika

[3] RACIO & RACIO, Orlová, Česká republika

ABSTRAKT

V práci se na základě komplexního posouzení pokusných výsledků dokázala metalurgická schůdnost a ekonomická efektivnost aplikace plazmového ohřevu při zpracování oxidických kovonosných odpadů v podmínkách oceláren VÍTKOVICE, a. s.

Výroba železa a oceli je vždy doprovázena vznikem odpadů, které znamenají pro celý výrobní pochod buď vratný, dále použitelný materiál, nebo odpad k další výrobě nepoužitelný, ztrátový. V současné době jsou odpady vysokopecní a ocelářské výroby jen velmi omezeně zpracovávány jako druhotné suroviny nebo jako vratné materiály příslušných výrob.

Prokázalo se, že nízkoteplotní plazma může nahradit dosavadními postupy dosud méně výhodné pyrometalurgické zpracování těchto odpadů, které se proto zpracovávají hydrometalurgicky.

Jestliže metalurgicko-technologické otázky uvažované aplikace jsou zřejmé, pak je třeba vyjasnit její ekonomiku. Ekonomický pohled na efektivnost předpokládaného zpracování kovonosného odpadu je diskutován na příkladu konkrétní situace Divize 200 VÍTKOVIC, a.s.

Ekonomickou efektivnost tohoto pochodu lze v zásadě zjistit porovnáním vykalkulovaných nákladů s cenou hotovního výrobku.

U kovu se zaručeným chemickým složením v tekuté fázi činí zisk 900 Kč/t a rentabilita (zisk vztažený na náklady) bude 20 %. Při výrobě ocelárenského surového železa se dociluje zisku až 900 Kč/t, což odpovídá rentabilitě od 17 do 20 %. U slévárenského surového železa pevného a u Sorelu se možný zisk pohybuje od 2100 do 4100 a rentabilita pak činí od 35 do 51 %.

ABSTRACT

On the basis of a complex examination of trial results this work provided evidence on metallurgical readiness and economical efficiency in implementation of plasma heating at processing of the metal-bearing oxidic wastes under conditions prevailing in the VÍTKOVICE, a. s. Steelworks.

Ironmaking and steelmaking is always associated with origination of waste that presents for the entire metallurgical process either reversible and/or reusable material or lost waste not applicable in further production. At present the waste from iron- and steelmaking finds hardly applicability as secondary raw material.

Evidence has been given that the low-temperature plasma could replace the existing routes of less-suitable pyrometallurgical treatment of such wastes that are therefore processed by hydrometallurgical route.

As the metallurgical and technological features of this application are obvious then more light should be thrown into the economy. The economical insight into efficiency of the assumed processing of the metal-bearing waste is dealt in detail with by example of a concrete situation at VÍTKOVICE, a.s. - Division 200.

The economical efficiency of that route can be in principle determined by comparison of the calculated costs with the price of ready product.

In case of liquid metal with a guaranteed chemical composition the profit would reach 900 Kč/t and the profitability (profit referred to the costs) would be 20%. In case of melting steelmaking hot metal the profit of 900 Kč/t is reached, which refers to a profitability of 17 to 20%. With the foundry hot metal and with Sorel the possible profit varies from 2100 to 4100 Kč/t and the profitability makes 35 up to 51%.

KEY WORDS: metal-bearing oxidic wastes, plasma heating, economical efficiency, calculated and processing costs, profit and profitability

INTRODUCTION

Ironmaking and steelmaking is always associated with origination of waste that presents for the entire metallurgical process either reversible and/or reusable material or lost waste not applicable in further production. At present the waste from iron- and steelmaking finds hardly applicability as secondary raw material. The majority of solid waste is deposited outside of plant as a dumping loss. For the reasons of economy and environmental protection such dumping loss should be recovered as much as possible otherwise such expensive waste depots additionally menace our surrounding world.

Evidence has been given that the low-temperature plasma could replace the existing routes of less-suitable pyrometallurgical treatment of such wastes that are therefore processed by hydrometallurgical route [1].

1. THE METALLURGICAL ISSUE OF IMPLEMENTATION OF PLASMA HEATING INTO IRON- AND STEELMAKING

A profound investigation into literature allowed to draw the following conclusions on application of plasma heating in melting iron and steel:

1.1 ***At the processes of ladle and tundish metallurgy.*** At VÍTKOVICE, a.s. the plasma applications with original own torch are under preparation both for heating-up of liquid steel in ladle and for the metallurgical processes in integrated system of the secondary metallurgy (ISSM) [2].

1.2 ***At elimination of undesirable non-ferrous metals from the iron-based melts.*** Accomplishment of the laboratory heats in the common plasma-working site of the FMMI VSB-TU Ostrava and the

Division 940 - Research and Development has confirmed the preconditions for possible elimination of such deleterious elements by evaporation from the melts. The effect of plasma heating on composition of the anode metal, as-melted down, has been examined with some 24 trial heats whereby the results have confirmed here the phenomena of removal of the non-ferrous metals such as Cu, Sn, As and Sb and brought some new data on the possible routes of reduction especially of lead and zinc by plasma heating [3].

1.3 ***At effective processing of the metal-bearing oxidic waste originating at steel- and ironmaking.*** At VÍTKOVICE, a.s. the laboratory experiments have been carried out by using a gas torch to verify the possible ways of processing the waste (iron scales and sludges from oxivite route) available at Division 200. The experiments were run with the original testing facility installed in cooperation with the FMMI VŠB-TU Ostrava and VÍTKOVICE, a.s. The product of processing is metal whose chemical composition can be governed by reasonable selection of materials and/or additives to be charged (C-bearing materials, lime) [4]. Utilization of the plasma torch (reactor) seems to be suitable even from the viewpoint of environmental protection as the waste processing route provides both metal of desirable chemical composition and also inert slag to be used in building industry. Moreover, lead and zinc caught-up in the filters (and/or from recycling) can be used as concentrate at the non-ferrous metal works (Fig.1).

Fig.1 Flowsheet of metal - bearing wastes and plasma reactor in the VÍTKOVICICE,a.s.

Accordingly, this application of plasma heating provides almost a waste-free melting route of iron and steel [4]. On the basis of the achieved encouraging laboratory results the full-scale verification of this technological route was run at a 15-ton EAF of Steelworks II [5]. At present full-scale introduction is under preparation at a redesigned 15-ton melting unit equipped with 15 MW plasma torch.

As the metallurgical and technological features of this application are obvious then more light should be thrown into the economy. The economical insight into efficiency of the assumed processing of the metal-bearing waste is dealt in detail with by example of a concrete situation at VÍTKOVICE, a.s. - Division 200 [6].

2. EVALUATION OF THE ECONOMICAL EFFICIENCY [7]

2.0 Technical and technological sources

We assume all the occurrence of metal-bearing waste available at the Division 200 to be subjected to "plasma" processing in the modified melting unit with some 15-ton capacity. The field of charged waste is assumed some 60% which means that about 9 tons of melt would be acquired from each heat. Processing of the metal-bearing waste in this furnace would last for about 60 minutes. Here, four products are the possible outcome of melting, i.e.

metal with guaranteed chemical composition in liquid and solid state

liquid or solid steelmaking hot metal

solid foundry hot metal

solid special foundry hot metal called Sorel

The different qualities of melt are reached by reasonable selection of the metal-bearing waste.

2.1 Procedure of economical evaluation

For the sake of proper economical evaluation the assumed calculation of the own expenses of the ready product should be compiled first. The assumed sum of the own expenses for ready product is then compared with its assumed market price. The obtained difference (profit or loss) shows the economical attractive feature of processing the metal-bearing oxidic waste.

2.2 Proper evaluation of the economical benefit from waste processing

The entire average volume of the metal-bearing waste at the Division 200 (as per the actual occurrence in 1998 and 1999) is reaching some 50 000 tons a year. The dust separated from the units such as the LF, the SL and the DH and/or the sludge from oxyvit route and from rolling mill cannot be economically processed by the orthodox technological procedures and thus, it is deposited. From the available documents is obvious that the relevant lump sum for "deposition" attains 420 up to 900 Kč/t and is of considerable significance in the economy of plant. The average "price" of the metal-bearing waste makes 162.4 Kč/t and the potentional customer of the Divison 200 has to pay for it.

2.3 Compilation of the calculation of costs from processing the metal-bearing waste

The first item of cost of this calculation is the proper metal-bearing waste whose utilization is assumed for some 60%. Accordingly, one ton of product would require some 1666.7 kg waste. Then, the cost of waste with a price of 162.4 Kč/t would be 270.7 Kč/t.

2.3.1 Determination of the cost items arranged into processing costs

Calculation of costs for the electric energy for "melting" is going out from the assumption that a plasma torch of an output of 15 MW would be installed at the melting furnace. With a melting time of 60 minutes and the weight of ready product the consumption of energy would reach some 1666.7 kWh/t. When considering the present-day´s price of electric energy of 1.6 kWh/Kč then the relevant specific cost would be 2666.72 Kč/t. (When determining the costs for electric energy there is to note that under actual working conditions a considerale drop in consumption should be taken into account. In this respect the first experimental verifications show a consumption of some 1100 to 1300 kWh/t only.) The costs for the plasma-forming gas (nitrogen) are going out from an hour´s input of 36 Nm^3, which with a price of 0.43 Kč/Nm^3, attain some 1.7 Kč/t. The occurrence of waste gas is assumed to be some 537 Nm^3/t of ready product. The gas will be entrapped and utilized in the power-energy system. Then, such a credit note would attain 221.2 Kč/t.

The total power system costs attain some 2447.2 Kč/t. To determine the expenses for the furnace lining one is going out from the costs for lining and from the average lifetime of lining of some 300 heats. The resultant cost will then reach 111.1 Kč/t. Calculation of expanses for ladle lining is going out from similar considerations. Thus, the relevant cost would reach some 182.5 Kč/t. In this respect the total lining expenses attain 293.6 Kč/t.

The costs of graphite melting electrode are considered to be 100 Kč/t due to its negligible consumption.

The calculation of expenses for direct wages is going out from the assumption that in total 7 workers are attending the melting unit with the necessary handling operations, whereby the rough wage of a person would be 15000 Kč/month. Thus, the expenses for direct wages attain 989.4 Kč/t.

For the sake of calculation of the depreciation allowances one has assumed the modification of the melting unit would require some 25 Mill. Kč. The building work should consume 4 Mill. Kč, the aspiration would need some 6 Mill. Kč and the proper installation work would consume some 2 Mill. Kč. The total capital expenses would so reach some 37 Mill. Kč. With a depreciation time of 15 years and with assumed annual production of 28020 tons the depreciation allowances would attain some 90.4 Kč/t.

The total non-specified costs were assumed for 300 Kč/t. The total value of the s.-c. other costs (electrodes, wages, depreciation allowances and non-specified costs) would then reach some 499.5 Kč/t

2.4 Evaluation of the calculation of costs compiled for ready product

The calculated processing costs would reach 3329.6 Kč/t., the own expenses in total would attain 3600.3 Kč/t. Thus, the processing costs refer to 92%. The costs for the charging material attains 8% only. The most significant item of the processing costs refers to the energy, i.e. 78%, the other costs refer to 16% and that for lining and for charge 8% each (Table 1, Fig.2).

Table I Calculation of costs for processing metal-bearing waste

Fig.2 Structure of expenses for processing of metal-bearing waste

2.5 Economical efficiency of processing the metal-bearing waste with application of plasma

The economical efficiency of that route can be in principle determined by comparison of the calculated costs with the price of ready product.

As mentioned above various sorts of ready products will be provided by reasonable selection of the metal-bearing waste to be charged.

When determining the price for which the ready product will be sold to the customers, one has gone out from the existing price relations. From the viewpoint of production and economy metal with a guaranteed chemical composition in liquid state presents reasonable ready product, as its utilization for steelmaking seems to be rather attractive. This is due especially to its possible usage in a LF-unit or its usage as liquid charge for the EAF, the BOF and induction furnace. In all the examples cite here the economical effect would be favourable due to "acquisition" of the sensible heat of metal. If the liquid charge will be used at an EAF, then the economical effect will consists of the price of scrap (3200 to 3600 Kč/t) and at least of 50% of the processing costs required for metal melting at an EOP (about 1000 Kč/t). Then, the selling price of metal will be 4500 Kč/t at least, see Table II.

Table II Economical effectivness of processing metal-bearing waste

2.6 Possible achieved profit with the individual sorts of ready products

In case of liquid metal with a guaranteed chemical composition the profit would reach 900 Kč/t and the profitability (profit referred to the costs) would be 20%. In case of melting steelmaking hot metal the profit of 900 Kč/t is reached, which refers to a profitability of 17 to 20%. With the foundry hot metal and with Sorel the possible profit varies from 2100 to 4100 Kč/t and the profitability makes 35 up to 51%, see Fig.3.

Fig.3 Profitability of processing of metal-bearing waste

2.7 Evaluation of economical efficiency of processing a metal bearing waste providing that new processing line would be commissioned

For the sake of completnes there are given data of economical efficiency of processing a metal-bearing waste in an assumed new processing line [8].

In comparison with preconditions given in this analysis there is newly taken into consideration commission of new processing line installed in a "green meadow". A difference consists here in the extent of construction of a drying and preheating chamber and in the extent of aspiration and filtering. The total capital costs would then vary within 120 and 145 Mill. Kč [9]. In further consideration the sum of 145 Mill. Kč will be assumed. In the calculation of costs for ready product there will be altered especially the depreciation allowances. With the capital costs of 145 Mill. Kč and with annual production of 28020 t of ready product the depreciation costs reach 345 Kč/t. The modified calculation to the own costs of the ready product would reach 3854.9 Kč/t (Table III, Fig.4).

Table III Calculation of costs for processing metal-bearing waste at commissioning of a new plant

Fig.4 Structure of expenses for processing of metal-bearing waste at commissioning of new production line

The costs for production of the individual sorts of ready product were recalculated with the identical principles. Thus, the calculated costs for a ready product have risen with solid foundry hot metal by 300 Kč/t. Again, high economical efficiency is reached with the adopted measure and with possible commisioning of a new line for 145 Mill. Kč.

With production of steelmaking hot metal there are reached a profit of 545 Kč/t and a profitability of 12%. In case of solid foundry iron and of the Sorel the possible profit varies from 1845 to 3845 Kč/t and the profitability attains some 31 to 48%, see Table IV, Fig.5.

Table IV Economical effectivness of processing metal-bearing waste with construction of new plant

Fig.5 Profitability of processing of metal-bearing waste at commissioning of a new production line

2.8 Evaluation of the achieved profitability and of profit

The achieved profit varies within 545 and 4100 Kč/t and the profitability from 12 up to 51%. These results provide explicitly positive answer about the economical suitability of processing the metal-bearing waste with the help of plasma heating.

CONCLUSION

On the basis of a complex examination of wide trial results this work provided evidence on the metallurgical applicability and economical efficiency in implementation of plasma heating at processing the metal-bearing oxidic wastes under conditions prevailing in the steelworks of VÍTKOVICE, a.s.

ACKNOWLEDGEMENT

The result of the project LN00B029 were supplied with subvention by The Ministry of Education of Czech Republic.

Literature

[1] BROŽOVÁ S.: Some theoretical issues of low-temperature plasma. Seminary of plasma metallurgy, VÍTKOVICE, a.s., 4/1997 (not published). Actual questions of diminishing content of non-ferrous metals in steel with utilization of the plasma-metallurgy routes. In: Proceedings of the Day of internal doctorants of the FMMI.VŠB-TU Ostrava, 1997, pp. 9-12

[2] MACOSZEK M. et al.: Aplication of plasma technology. Concluding report of 1998, VÍTKOVICE, a. s. Division 940 - Research and Development, 1999. Some possible ways of plasma utilization in metallurgy. In : International Scientific Conference, Maschinery Technology - production technology 99, Súlov,1 999, pp.177-180

[3] BROŽOVÁ S.: Utilization of plasma for improvement of steel cleanness. In: Proceedings Day of internal doctorants of the FMMI.VŠB-TU Ostrava, 1998, pp.7 - 8

[4] BROŽOVÁ S., RACLAVSKÝ M., BŮŽEK Z., MACOSZEK M.: Processing of metal-bearing oxidic wastes with utilization of the plasma. In: XIV. Conference of EA-Steelmakers and of secondary metallurgy of steel. Rožnov pod Radhoštěm, 2000, pp.169 - 177. Processing of metal-bearing wastes with utilization of plasma technology. In: 9. International metallurgical conference METAL 2000, Ostrava, 2000, post 161, ISBN 80-85988-48-8 Possible ways of wasteless steelmaking. Hutnické listy, No. 4-7/2000, Vol. 55, pp.50-55

[5] Macoszek M., Krayzel M.: Non-published report on the results of full-scale verification. VÍTKOVICE, a.s., 10/2000

[6] Kafka V., Brožová S., Bůžek Z., Macoszek M.: Evaluation of economical efficiency of processing of the metal-bearing oxidic waste with utilization of plasma heating. In: X. Internat. scientific conference iron and steelmaking, Szczyrk, Poland, 2000

[7] Kafka V.: Issue of economical evaluation of efficiency of plasma processing of the metal-bearing oxidic waste. Study, manuscript ,Orlová, September 2000

[8] Kafka V.: Supplement to the study. Manuscript, Orlová, September 2000

[9] Moravecký D.: Processing of oxidic waste. Technical report, VÍTKOVICE, a.s., September 2000