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PROCESSING OF METAL-BEARINGS OXIDIS WASTES, PET-BOTTLES AND WORN TYRES BY PLASMA HEATING

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Abstract
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 EVRAZ VÍTKOVICE STEEL, a.s.
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 EVRAZ VÍTKOVICE STEEL, a.s.
With reference to the previous investigation this paper present evaluation of the possible ways of implementation of the plasma torch at processing refuse from the PET-bottles and worn tyres. Verification of possible processing the PET-bottles and worn tyres with utilization of the plasma technology is performed with original trial facility installed in the working place common of the VŠB-TU Ostrava and Material and Metallurgical Institute, s.r.o.
Keywords: Metal-bearings Oxidis Wastes, PET-Bottles, Plasma Heating

1. 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 .

2. 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:

- At the processes of ladle and tundish metallurgy.

At EVRAZ VÍTKOVICE STEEL, 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) [1].

- 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 - Researeh 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 [2].

- At effective processing of the metal-bearing oxidic waste originating at steel- and ironmaking.

At EVRAZ VÍTKOVICE STEEL, 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 VSB-TU Ostrava and EVRAZ VÍTKOVICE STEEL, 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) [1]. Utilization of the plasma torcb (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 fi1ters (and/or from recyc1ing) can be used as concentrate at the non-ferrous metal works (Figure 1).

Accordingly, this application of plasma heating provides almost a waste-free melting route of iron and steel . On the basis of the achieved encouraging laboratory results the full-scale verification of this teehnological route was run at a 15-ton EAF of Steelworks . 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 EVRAZ VÍTKOVICE STEEL, a.s. [1].

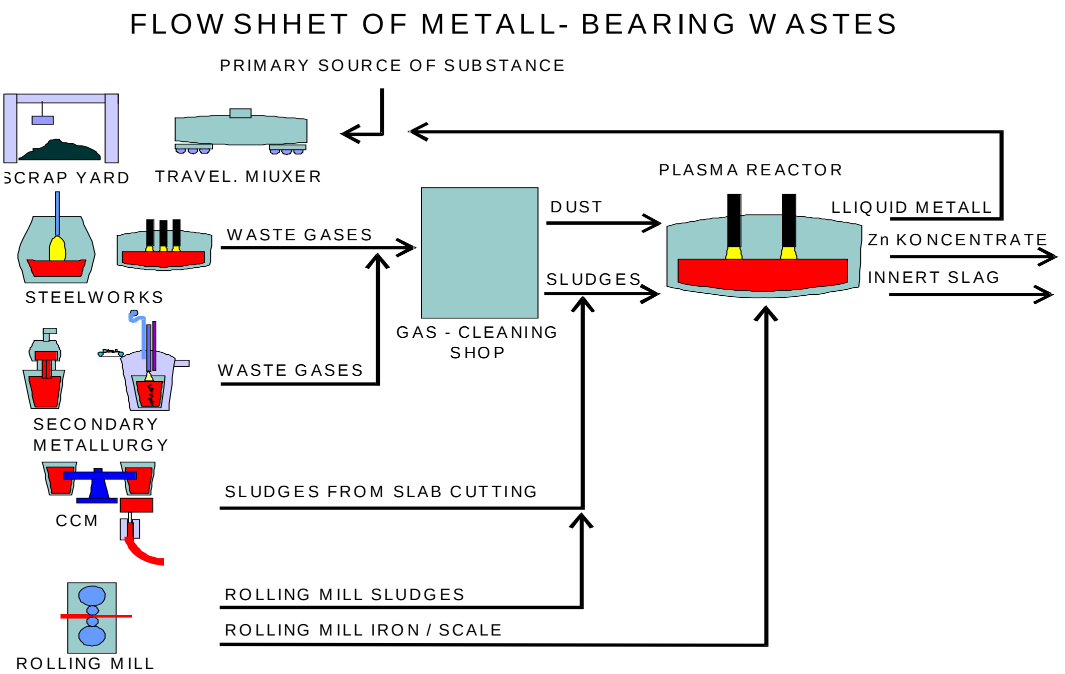

Figure 1: Flowsheet of metal – bearing wastes and plasma reactor in EVRAZ VÍTKOVICE STEEL, a.s

Solution of the problems associated with refuses and their recycling in the framework of utilization of the secondary substances is a challenge of utmost significance in the Czech Republic and even all over the world.

In the Czech Republic we have considerable delay in this field if compared with other countries, especially the U.S.A. and some advanced European countries.

In our previous work there have been verified and evidenced in a convincing manner both the possible way of processing the metal-bearing refuse by means of plasma heating [3] and the routes of thermal processing of refuses by utilization of plasma decomposition. [2]

When considering other possible ways of application of plasma heating we have focused our attention at processing the PET-bottles and the worn tyres that both represent significant sources of industrial refuse.

3. THE PET-BOTTLES

We shall deal first of all with the non-returnable PET-bottles covering significant volume of the refuse stream.

At present the Czech Republic has available a rather limited capacity for recycling the PET-bottles, namely at the SILON Works, a.s. at Planá n. Lužnici.

The PET is a polyethylenereftalate as the most significant thermoplastic polyester. The PET is raw material especially for production of fibres and in a smaller volume also for production of foils. Perhaps the most widespread utilization of the PET is as packing material in form of the PET-bottles for packing liquids and especially drinks.

What is the recycling route of the worn PET-bottles?

The first step of recycling is collection of the waste bottles. At present the majority of European towns have implemented collecting systems for reclaiming materials to be recycled such as the PET-bottles.

The PET is reclaimed by mechanical recycling or by depolymerization.

In the case of mechanical recycling the bottles accumulated by collection are subjected to chipping to get floccules. These floccules are washed and further prepared or admixed into a mixture together with a virginal polymer. The depolymerization process provides decomposition of the molecules of polymer. The final product is as clean as a virginal resin.

4. WORN TYRES

The development of the automobile industry is intimately associated with worn tyres surrounding the world. Some 1 billion waste tyres are originating every year. However, in the meantime utilization of such tyres is rather limited.

At present the approach to solution of the problems of worn tyres is changing. They are more frequently considered to be a suitable source of material and energy than an unwanted burden. In spite of this a great amount of worn tyres are deposited at dumping areas impairing so the environmental conditions.

In this respect the present-day situation in the Czech Republic is not quite good. The annual occurrence of worn tyres is constantly increasing and the volume of waste is enhanced by importing used tyres with declared purpose for re-usage.

Before we start to deal with the recycling of worn tyres let us say a few words about their material composition.

The composition of mixture varies with the purpose for which it will be used. The rubber compounds contain sorts of rubber such as the natural and synthetic forming the main part of mixture. Such a mixture should contain a certain proportion of carbon black (used as a filling agent), the antioxidants (hard rubbers against ageing), various softening agents, some cross-linking agents such as sulphur and the vulcanisation accelerators.

At present there are available several possible ways of utilization of worn tyres such as:

- retreading (from the viewpoint of safety and ageing process it cannot be carried out permanently)
- power-generating usage
- chemical processing – production of regenerate
- pyrolysis
- physical and mechanical processing
- disposal

- material utilization – in the building industry, in agriculture, in mechanical engineering, in household and in other industrial branches

5. PREPARATION OF EXPERIMENTS

One of the possible ways of processing of the waste PET-bottles and worn tyres with the help of a plasma torch is experimentally verified in the Material and Metallurgical Institute, s.r.o..

The experiments were prepared at the trial plasma equipment installed at the working place common of the VŠB-TU and Material and Metallurgical Institute, s.r.o.

The plasma working place has a reaction vessel (with a reaction volume for 15 – 20 kg), made of steel plate, lined with refractory concrete and in the bottom with graphite electrode. The reaction vessel is equipped with two pivots enabling slight turning in the carrying frame and pouring out of melt into fireclay moulds. The removable cover is also lined with refractory concrete and it enables sliding the graphite burner into the reaction vessel, exhaustion of waste gases through a “chimney” and additional pouring of the processed material through a tube into the burning plasma torch. Prior to teeming the melt the cover should be manually removed.

The graphite plasma torch, developed at the Material and Metallurgical Institute, s.r.o. is clamped in a holder enabling supply of gases and pouring of processed material through the middle orifice of the torch. The graphite torch is handled manually (high-speed travel) with possible electric drive for the voltage regulation of the plasma arc whose DC-feeding is provided by 2 cable-terminal boxes TRT 1000 enabling to realize a wide extent voltage-current data, see Figure 2.

The waste in an amount of rd. l kg was placed in a small steel vessel into electrically reheated furnace. Argon was supplied into the bottom part of the reaction vessel. The temperature of outside mantle of the steel vessel was kept on 500 C.

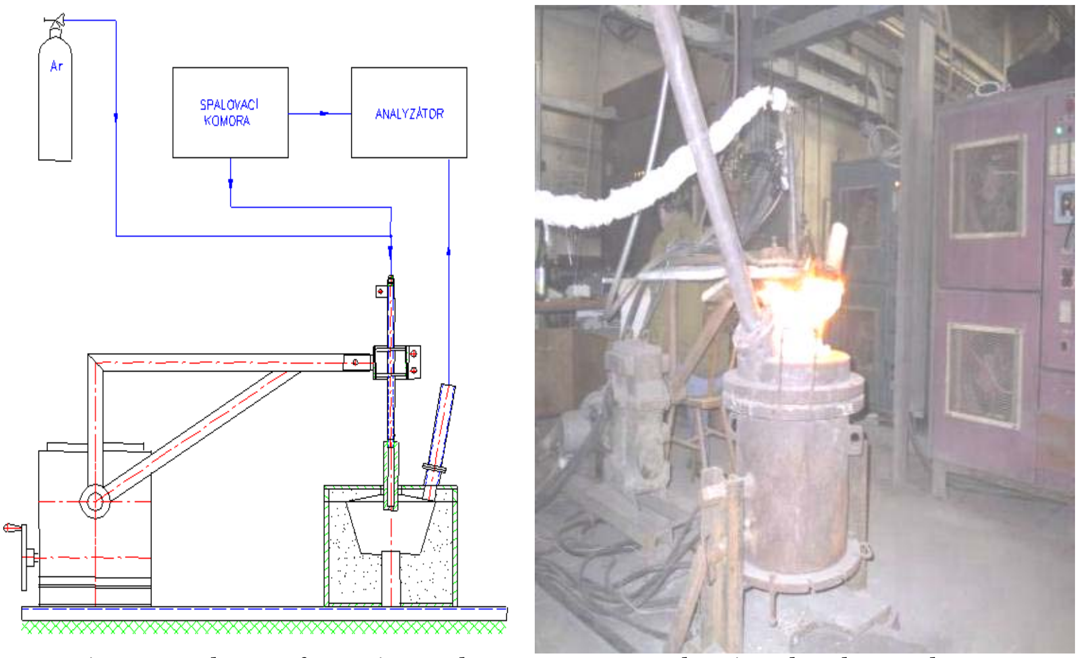

Figure 2: Scheme of experimental arrangement combustion chamber analyser

The products of decompasition were partially returned into the steel vessel – similar to the reflex of a rectifying column – this route provided a longer dwell of the products in the reactor and so an effective decomposition of the liquid products. The surplus of gases was cooled down to a temperature of 60 C. The condensate was entrapped for the needs of further analysing. The gas cooled down was supplied directly to the plasma.

Then, the decomposition of the PET-bottles and worm tyres has been carried out step by step.

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6. RESULTS

The illustrative spectra of the thermolysis gases, always without plasma, with decompostion in plasma and with decomposition in plasma in presence of Fe-melt are shown in Figure 3 (the spectrum of decomposition of the PET-bottles and in Figure 4 (the spectrum of decomposition of tyres).

Table 1. Marking of experiments

Marking	Description
1	PET-bottles, without Fe-melt
2	PET-bottles, n presence of the Fe-melt
3	Worn tyre, without Fe-melt
4	Worn tyre, in presence of the Fe-melt

Table 2. The average concentration of substances in the waste of decomposition

Marking	CO_2 %	CO ppm	CH_4 %	CnH_{2n-2} ppm	H_2 %
1.	0.085	580	0.48	18.8	2.45
2.	0.12	3250	0.08	11.6	2.94
3.	0.69	1960	0.96	18.3	3.55
4.	1.21	6280	0.11	8.8	4.28

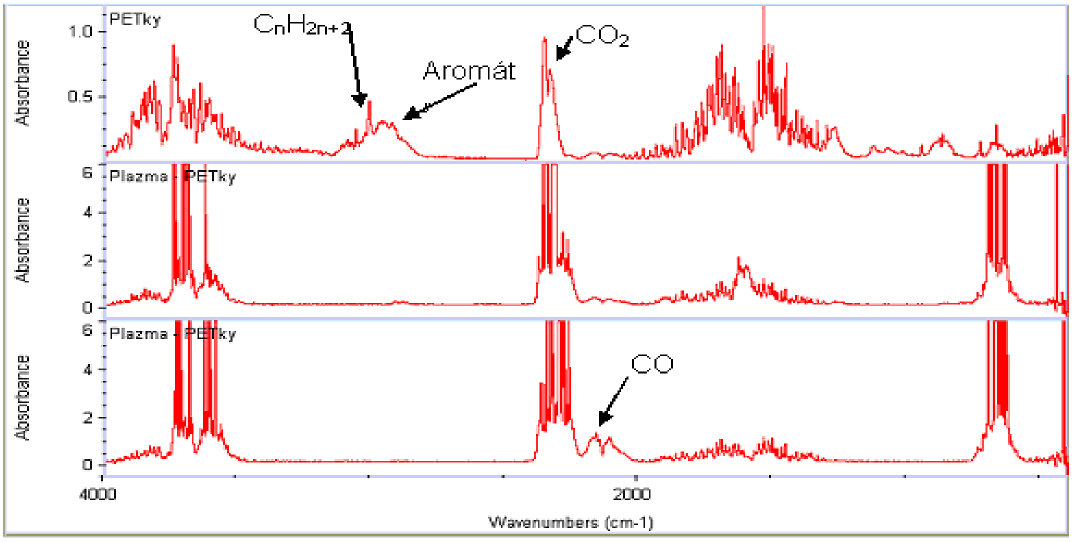

Figure 3: The spectra of gases from the PET-bottles – without plasma, the plasma and plasma with Fe

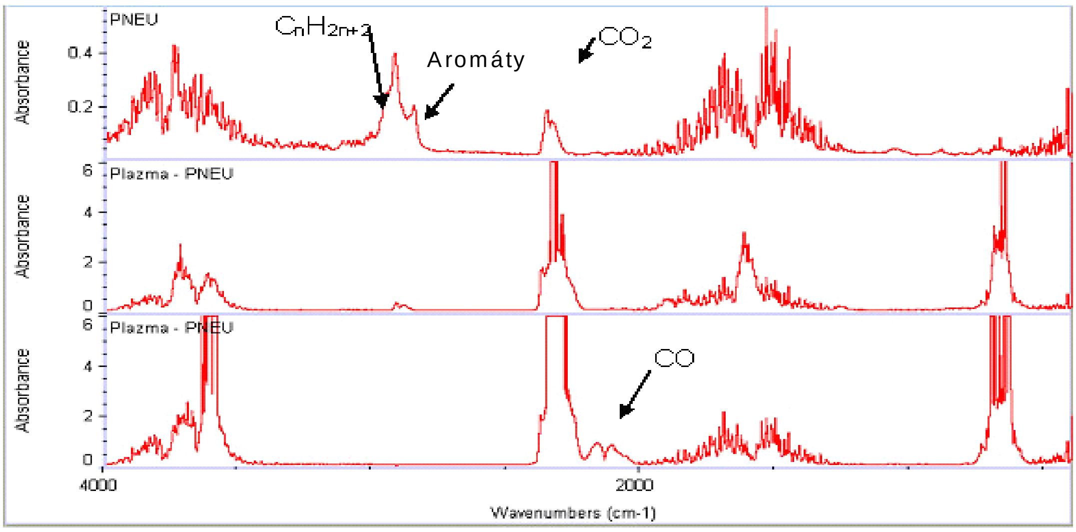

Figure 4: The spectra of gases from tyres – without plasma, the plasma and plasma with Fe

7. DISCUSSION

From Figures 3 and 4 is obvious that in either case the crude thermolysis gas contains carbon dioxide, water steam, higher aliphatic hydrocarbons and aromatic hydrocarbons. In the course of plasma decomposition the hydrocarbons are in practice completely decomposed. The efficiency of decomposition is further enhanced in presence of the Fe-melt, see Table 2. At assessment of the picture there should be reckoned with the modification of the scale of graphs as required for the needs of illustration. The data in table are calculated from non-modified spectra.

8. CONCLUSION

The proposed combination of the thermolysis decomposition with plasma processing of gas is an example of successful combination of the projects focused on waste processing. The outcome of combination of the two routes is the new prospective route of processing the municipal refuse. The acquired data will be further used for preparation of the design of the pilot-plant unit.

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