SUSTAINABLE UTILISATION OF EAF SLAG BY SUCCESSFUL RESEARCH AND OPTIMISED OPERATIONAL PRACTICE

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Introduction

Meanwhile slags from metallurgical processes are widely used in Europe and worldwide in different fields of application, *e.g.* in the building industry, road and waterway construction or as fertilisers. About 90% of ferrous slags produced in Europe are used for building purposes. Nevertheless, also these by-products have to be improved to ensure their sustainable use. A prerequisite for the use of these slags is that they meet the requirements for technical and environmental aspects given in the standards. So, for the future use of *e.g.* EAF-slags, targets such as preservation and protection of the environment, protection of human health as well as sustainable use of natural resources have to be taken into account. The treatment of *e.g.* liquid EAF-slags by changing their chemical and mineralogical composition during or outside of the steel production process, will lead to interesting new properties of the newly formed products and thus guarantee their sustainable use in the future.

Therefore, the paper describes as example for by-product research the engineering of some methods and devices for tapping, handling, optimisation and processing of liquid and solidified EAF-slag. The work is still in progress by the steel work of Lech-Stahlwerke GmbH and the research and development department of Max Aicher Umwelt GmbH, the slag and residue processor and marketing company. At the location in Bavaria/Southern Germany (Meitingen) more than 1 mio. tons of steel[1] and more than 200,000 tons per year of by-products and residues are produced, processed and recycled, internal and external.

Electric Arc Furnace Slag

EAF-slag is an important material for use in civil application (Figure 1 and Figure 2), but the utilisation rate depends from the quality and also from the regulations which are unfortunately different from country to country. Slag utilisation saves natural resources and decreases the amount of slag disposed in landfills.
In order to utilise EAF-slag, mechanical and chemical properties (in terms of composition and leaching tests) must be satisfied. In the case of utilisation of EAF-slag, the results of leaching tests play an important role. Leachable substances in the slag, *e.g.* chromium or vanadium determine the possibility to use the EAF-slag in further

applications, as for concrete, road construction as asphaltic or unbound layer. For this purpose, in Germany so-called slag classes are defined. Among these critical elements, vanadium is one with complex and with not yet totally understood behaviour. Most of the researches carried out up to now were devoted to the study of the chromium immobilisation in slag.

Figure 1: application of EAF-slag in asphaltic layer by BSW Stahl-Nebenprodukte GmbH[2]

Figure 2: application of EAF-slag as waterway construction material by BSW Stahl-Nebenprodukte GmbH[2]

The results of laboratory tests and operational daily business show that the chrome leaching (Cr in eluate) decreases with the increase of the sum of the most important spinel forming compounds in the slag (MgO, Al_2O_3 and FeO_x) and obviously increases with the increase of chrome oxide content in the slag. But even if the slag contains remaining chrome contents, the leaching of chrome is suppressed.

Vanadium is a metal which exists in oxidation states ranging from 0+ to 5+ and the most common valence states are 3+, 4+ and 5+. The condition of oxidation of vanadium in slag depends on the composition of the slag, particularly its basicity. Investigation of CaO-SiO_2-VO_x-slags at 1600°C showed, that the ion with high valence, V^{5+}, is stabilised by a high po_2 and high basicity[3]. However, under powerful reducing condition (p_{O2}<10^{-9} atm) V^{3+} predominantly occurs. The interaction with oxides can best be assessed, when the V oxides are assumed to be ionic VO^{2+}. While VO^{2+} appears in acid and VO^{2-}, VO_3^{2-} and VO_4^{3-} in basic slag. In terms of water solubility, the most stable oxide is the only soluble (V_2O_5). The solubility decrease in this order: V_2O_3, VO_2 and VO. The adding of reducing agent in slag can reduce the amount of V_2O_5 versus the other vanadium oxides, less soluble. Vanadium, as chromium, can form spinels[4], α-type (formula AB_2O_4), with iron, zinc, magnesium and manganese, where the tripositive ions B are V^{3+} and the dipositive ions A are Fe^{2+}, Mg^{2+}, Mn^{2+} and Zn^{2+}. Cations like Ca^{2+}, Sr^{2+}, and Ba^{2+} cannot form spinels with vanadium due to a large ionic radius. Investigations have showed that the most stable V-phase during selective oxidation of vanadium most probably is V-spinels[5].

PROEOS

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Figure 3: sampling of EAF-slag direct after tapping to control the slag quality after treatment during PROEOS[6]

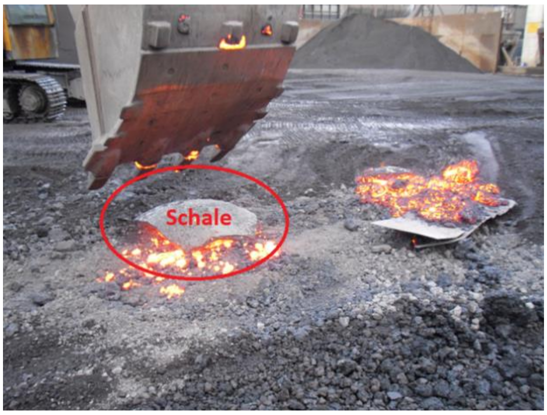

Figure 4: two different parts of EAF- slags: "Schale" (left) and "liquid" (right) of the same charge

The research project PROEOS is still in progress[7], but until now a lot of results had been transferred in operational practice at Lech-Stahlwerke GmbH, Figure 3. For example, a worst-case scenario with the first metallurgical slag in the melting process (Figure 4: "Schale" which solidifies first in the slag pot as "shell") with low reduction rate has shown the correlation between the scrap quality and the leaching behaviour of the electric arc furnace slag, Figure 5.

Conclusions

The high costs for the treatment of electric arc furnace slag to improve the quality of this industrial building material should be rewarded by premium applications. Unfortunately, the authorities prefer until now natural stones despite electric arc furnace slags have even better properties as natural building materials.

Therefore, the claim of research and development for better slag quality and sustainable utilisation by the development of methods and devices for tapping, handling, optimisation and processing of liquid and solidified slags is in a conflict with the reality. Reality is the discrimination of iron and steel slags in general comparing to

natural stones and sometimes also against other recycling materials, especially for the electric arc furnace slag in Bavaria.

The main target of research and development for slag production and sustainable utilisation is to close the circle economy and to protect thereby the environment. Therefore, the same politicians who preach circle economy should also push the utilisation of metallurgical slags and therefore also of EAF-slag in Bavaria, Germany and Europe.

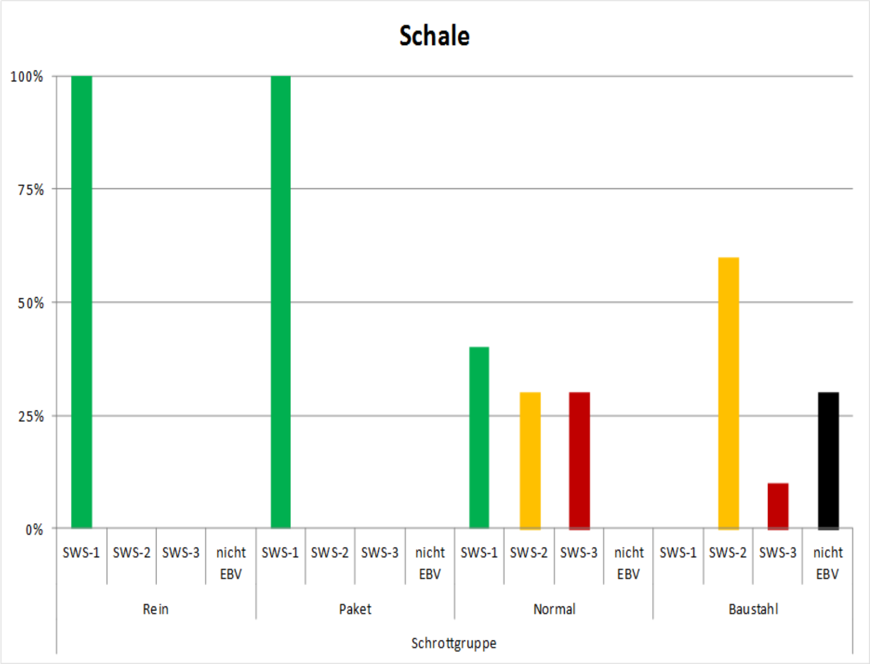

Figure 5: slag quality (environmental behaviour in leachate with water-slag-ratio: 2:1) as function of the scrap quality for the production of quality steel in the electric arc furnace during PROEOS ("**SWS-1**" means best and "**nicht EBV**" means bad quality)

References

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7. AiF-research project 18812N: PROEOS - Nachhaltige Produktion, Aufbereitung und Nutzung von Elektroofenschlacken aus dem Stahlherstellungsprozess durch metallurgische Maßnahmen und einen neuartigen, geschlossenen Waschprozess (partners: FEhS, BFI, LSW, MAU).