Foaming of the slag and recycling of stainless steel dusts by injection into the electric arc furnace for stainless steels

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Abstract

In Europe about 600.000 tonnes of dusts are generated during steel production in the electric arc furnace. Valuable metals like zinc and lead from the production of carbon steels as well as chromium and nickel, respectively, from the production of high-alloy steels are recovered from these dusts by external processors, usually.

In the past, only few attempts on the internal recycling of dusts have been made. Within a Brite EuRam II project the technology of dust recycling has been developed and the economical and ecological benefits of the internal recycling of EAF dusts from the production of carbon steels have been documented

Recent investigations supported by ECSC, however, are dealing with the recycling of EAF dust from high-alloy steel production, aiming at the recovery of chromium and nickel from the dusts and to improve the foaming behaviour of the slag.

At Edelstahlwerke Südwestfalen (EWS), formerly Krupp Edelstahlprofile a wide range of different steel grades from high performance construction steels up to stainless steel products, mostly as billets, are produced.

The melting shop is running an electric arc furnace with a capacity of 140 t. The furnace was furnished with a 75 MVA transformer station. Melting practice is characterised by a tap-to-tap time of about 80 minutes in average, but a longer melting time for stainless steels has to be considered. Following in the production line there is a ladle furnace and RH type vacuum degassing for the production of the various construction steel grades and VOD (Vacuum Oxygen Decarburisation) unit for the production of high alloy steels.

At Ugine-Savoie Imphy (USI) only stainless steel qualities are produced. The melting shop is running two electric arc furnaces of 42 t each which are furnished with a 19 MW transformer station. The tap-to-tap time of the furnaces is 2 hours. The furnaces are running alternatively, sending one melt every hour to the AOD (Argon-Oxygen-Decarburisation) converter. The AOD-converter has a capacity of 47 t. The tap-to-tap time is about 55 min. After AOD-treatment the final composition of the steel is adjusted by ladle treatment.

At EWS the dust recycling has been developed. The injection of dust during the production of construction steels is state of the art. The total amount of generated dust of about 1.5 t per heat is recycled, starting just after having the first melt in the furnace. The dust is transported pneumatically to the injection lance which is mounted on a BSE manipulator. The outlet of the lance is placed preferably into the boundary of slag and steel.

By the injection of the dust the contents of Zn and Pb are increased in the newly generated dust, which leads to a more economical recovery of these metals. A distinct reduction of the amount of dust which has to be shipped for recovery of Zn and Pb by external processors is another economical and ecological effect.

The recycling of dust from stainless steelmaking aims at the recovering of Cr and Ni into the steel melt. This is achieved by the reduction of the slag at the same time as dust is injected. Additionally a stable foaming slag practice shall be realised.

Due to the different secondary metallurgical treatment lines of both the steel works, ways and means of the dust recycling had to be defined for each steel work, separately.

At EWS high performance construction and stainless steel qualities are produced periodically in defined campaigns. The dusts generated in these campaigns are collected in one gas cleaning system. Changing from the production of stainless steels to construction steels the composition of dust alters continuously for about 8 hours, corresponding to 5 heats. The same is found when starting with construction steel campaigns. This delay is due to the layout of EWS's dedusting system.

Aiming at the recovery of chromium by recycling dust, an improved reduction of the slag is of importance at EWS. The input of carbon in the furnace is limited by the following VOD treatment for high alloy steels. Consequently the reduction of chrome from the slag in the furnace is carried out mainly by FeSi.

To improve the reduction of chrome a system for the additional injection of up to 500 kg FeSi per melt has been installed at the EAF. FeSi is injected with air or nitrogen as transport gas. The injection lance is mounted on a three lance manipulator. Today the injection rate and the injected amount of coal, FeSi and oxygen are adjusted independent of each other. In this way optimised conditions can be adjusted to meet the metallurgical requirements.

In several campaigns the benefits from the co-injection of FeSi were tested. Dust was injected in a range from 0 to 2400 kg per melt. Within each campaign reference melts with injection of dust but without co-injection of FeSi were included.

The chrome content in the slag has been reduced as a result of the co-injected FeSi. Nevertheless, slag samples of these campaigns showed a wide scatter in the concentration of chrome oxide. This scatter must be seen in correlation to the broad range of steel qualities, i.e. the broad range of chrome in the raw steels that are produced at EWS. The benefits from the co-injection of FeSi are clearly shown by the distribution of chrome between slag and metal, expressed as $(Cr_2O_3)/[Cr]$. By co-injection of FeSi with air, the coefficient $(Cr_2O_3)/[Cr]$ is decreased by 18 %, relatively. A decrease of 31 %, relatively, is achieved by taking nitrogen as transport gas.

USI has tested the injection into one of their electric arc furnaces. Contrary to EWS, USI injected a mixture of coal and dust, containing about 70 % of dust. About 800 kg/heat of the carbon/dust blend was injected during the refining period.

Industrial trials at USI have shown that the quality of carbon/dust blend has an important impact on its fluidity and on the success of the injection process.

Due to the dust grain size and dust moisture at USI, it is impossible to inject dust alone. To perform the dust injection, a certain quantity of carbon is needed to prevent clogging. Best results in term of fluidity have been obtained with similar grain size of carbon and dust.

But the most important parameter is the blend ratio carbon/dust. The carbon content of the blend has to > 25 %, preferentially > 30 %, to maintain a good fluidity. For metallurgical reasons it is impossible to adjust this ratio at USI as the quantity of carbon injected may sometimes be too high and induce variability on silicon and carbon content of the heat.

After first trials at USI, the operational conditions have been improved and a rather good control of dust injection and slag foaming has been achieved.

Quality controls confirmed that dust injection has no negative influence on the steel quality.

An evaluation of the investigations reveals significant benefits of dust recycling in EAF steelmaking.

At EWS the recycling of dust has reached a high standard. Benefits are given by higher concentrations of zinc in the dust and by the decreased amounts of dust given to external processors. Further progress has been achieved by recycling dust from stainless steelmaking combined with the co-injection of FeSi. The distribution of chrome between slag and metal, expressed as $(Cr_2O_3)/[Cr]$, is decreased by 18 to 31 %, relatively. The better yield of chrome will reduce the consumption of expensive alloying materials.

At USI additional costs due to blend manufacturing and delivery, depreciation of invest costs for the injection unit, necessary energy for melting the blend (+ 7kWh/t), additional oxygen and operation costs, slight increase of the slag amount, increase of electrode consumption (+0,08 kg/t) and the costs for carbon are balanced by Cr and Ni recovery, melting time (-1 min), benefits due to less dust amounts to be processed, decrease of Cr_2O_3 in slag, saving of energy due to the foaming of slag and less refractory consumption. The balance leads to a decrease of about 6 % on the melting costs due to the foaming practice.

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