The Use of Ironless Industrial Wastes in Steelmaking

PUTAN ADRIANA, PUTAN VASILE, VILCEANU LUCIA, SOCALICI ANA
Engineering and Management Department
University Politehnica Timisoara
Revolutiei street, no 5 Hunedoara, cod 331128
ROAMANIA
{adriana.putan,vasile.putan, lucia.vilceanu, virginia.socalici}@fih.upt.ro

Abstract: - The paper introduces the results of industrial experiments on the use of synthetic slags resulted from melting mechanical mixtures of industrial wastes, used in steelmaking in order to refine steel inside the ladle. The industrial experiments we performed consisted in adding the waste mechanical mixture at the bottom of the ladle, its melting leading to the formation of synthetic slag. The use of such industrial wastes in order to form slag has metallurgical, economical, as well as ecological effects.

Key-Words: waste, slag, steel, ladle, recovery

1. Introduction
The large scale introduction of liquid steel refining with synthetic slags inside the ladle is conditioned by the high costs and the lack of technical alumina, obtained from bauxite, a component of the synthetic slag.

The possibility of improving steel purity by refining with synthetic slags is based on [1]:
- the achieving – during the steel and slag mixing process – of a contact, interaction surface about 300 times larger than in the electric arc furnace;
- the physical-chemical properties of the slags adequate to the simultaneous reduction of the sulphur and oxide inclusions;
- in order to meet these requirements it is mandatory to know the physical and chemical reactions in the system metal-slag, under the conditions of an intense overlapping of the two phases.

The degree of steel mixing with the synthetic slag is determined by the possibility of its turning into the smallest possible particles, by the physical and chemical properties of the slag and steel, as well as by the hydrodynamic process taking place during steel tapping.

The contact surface increases significantly up to a certain value of the jet falling height, after which it practically stays constant. Usually, the falling height is 5 - 7 m.

As to the quantity of synthetic slag, its magnitude goes hand in hand with the growth of the quantity of emulsion slag in the steel and with the specific contact area, while the average dimensions of the slag particles stay practically unchanged. Normally, the quantity of synthetic slag is 30…50 kg/t of steel. Synthetic slag, as mechanical mixture has a composition of the type CaO : SiO₂ : Al₂O₃ = 40:40:20, and is characterized by a low melting temperature, a high fluidity and a high absorption capacity [2].

Steel refining with synthetic slag represents a possibility of diminishing steel impurification with non-metallic inclusions, due to the fact that, under certain conditions, the drops of slag emulsion in the steel can assimilate non-metallic suspensions, being decanted alongside with them.

Steel processing with synthetic slags leads to low-sulphur steel, low impurification (particularly) with sulphidic, oxidic inclusions, and with a lower content of oxygen.

On steel elaboration in electric arc furnaces and treating it with synthetic slags, the content of sulphur is 1,5-2 times lower than in steel obtained by the usual technology.

The data in reference literature [3-6] show that the use of synthetic slags with 52-55% CaO and 38-42% Al₂O₃ overheated to 1680-1750 °C, in a quantity of 10-60kg/t leads to desulphurizing degrees of 40-60%.

The use of synthetic slags corresponding to the ternary system CaO-Al₂O₃-SiO₂, with up to 15% SiO₂ is widely used as it grants a high fluidity at the temperature of the molten steel. These slags are used in quantities of 40-50 kg/t, which make for desulphurizing degrees of 45-70 %.

Sulphur removal by means of synthetic slag depends, besides the charge deoxidizing degree, on the chemical composition, on the grain size and on the quantity of desulphurizing agent, as well as on the degree of steel-slag mixing.
2. Problem Formulation

These slags can be added to the steel into the ladle both under a liquid state or a solid one. During our industrial experiments we opted for the latter variant, as there was no slag melting furnace on the work platform. The variant of choice is more economical and simpler from the point of view of the technological flux.

On synthetic slag formation, we chose two types of waste: aluminous slag (resulted in the process of aluminum elaboration) and lime powder and, in order to increase the fluidity of the newly formed slag, we added fluorine. The chemical composition of the aluminous slag is shown in fig.1. The synthetic slag results from the melting of the mechanical mixtures of industrial wastes (lime dust and aluminous slag) according to the recipe shown in fig.2.

![Fig.1. Chemical composition of aluminous slag](image1)

![Fig.2. Recipe for synthetic slag formation](image2)

The industrial experiments were done on 16 steel charges (4 charges/recipe) elaborated into a 100 ton electric arc furnace, steel to be used in the production of pipes. Steel secondary treatment with synthetic slag is done inside the ladle. In this case, considering that steel tapping is done into a single pot, the comparison was drawn with other charges of steel having the same grade and being elaborated under similar conditions.

In order to obtain the reducing slag, we introduced at the bottom of the ladle, 30 min before tapping, a mixture of 4-14,5 kg/t steel, made of: 68-75% lime dust (grain size below 40mm), 14-17% calcium fluoride (grain size below 35mm) and 11-20% aluminum slag (grain size below 25mm). In order to compensate the heat loss resulting from the melting of the mixture, the tapping temperature was 20-40°C higher than the normal one. The average chemical composition of the resulting synthetic slag is shown in fig.3.

![Fig.3. Average chemical composition of synthetic slag](image3)

For all the experimental variants we collected samples from the tapped steel jet and also from the ladle, 15 min after it was filled up, as well as slag samples, right after the filling of the ladle. The analysis of the samples helped us determine the chemical composition of the steel and slag and, implicitly, we could calculate the desulphurizing degree.

In order to calculate the desulphurizing degree when treating with synthetic slags into the ladle ($\eta_{S\ ladle}$), we used the relation:

$$\eta_{S\ ladle} = \frac{S_{initial\ ladle} - S_{final\ ladle}}{S_{initial\ ladle}} \times 100, \ [%] \quad (1)$$

$\eta_{S\ ladle}$ - steel desulphurizing degree inside the ladle, %

$S_{initial\ ladle}$ - the sulphur content in the ladle before treatment, %

$S_{final\ ladle}$ - the sulphur content in the ladle at the end of the treatment, %

The total desulphurizing degree when treating with synthetic slags inside the ladle ($\eta_S$) is calculated by means of the relation:
\[ \eta_S = \frac{S_{\text{melting-furnace}} - S_{\text{final-ladle}}}{S_{\text{melting-furnace}}} \times 100, \% \] 

(2)

\( \eta_S \) - total steel desulphurizing degree, %

\( S_{\text{melting-furnace}} \) - the content of sulphur in the furnace at the end of steel smelting, %

\( S_{\text{final-ladle}} \) - the content of sulphur in the ladle at the end of the treatment, %.

3. Problem Solution

The data obtained as a result of industrial experiments were processed in EXCEL and thus we obtained the variation of the desulphurizing degree with synthetic slags inside the ladle (fig.4) respectively the variation of the total desulphurizing degree on experimental charges (fig. 5).

The analysis of the diagrams shows that the degree of desulphurizing in the ladle with synthetic slags ranged within the limits 30@60%, respectively the total desulphurizing degree varied within the limits 60@80%, so the sulphur content at the end of the treatment was about 0,015%S.

4. Conclusion

The data obtained as a result of industrial experiments were processed in EXCEL and thus we obtained the variation of the desulphurizing degree with synthetic slags inside the ladle (fig.4) respectively the variation of the total desulphurizing degree on experimental charges (fig. 5).

The analysis of the diagrams shows that the degree of desulphurizing in the ladle with synthetic slags ranged within the limits 30-60%, respectively the total desulphurizing degree varied within the limits 60-80%, so the sulphur content at the end of the treatment was about 0,015%S.

Reintroducing small size and powdery industrial wastes in the economical flux, preferably if they have a low content of iron, whether they come from current technological fluxes or from waste dumps, may lead to a reduction of pollution in the air, soil and water in areas adjacent to the generators of such wastes.

Industrial implementation of the solution we suggested, consisting in using wastes in the secondary treatment of steel, leads to the following technological, economical and ecological advantages:

- the additives used to desulphurize steel allow us to obtain slag with high desulphurizing power, an important part being played by fluorides which grant a good fluidity, a highly important parameter in the slag deoxidizing capacity;

- desulphurization with synthetic slags is efficient, both in the case of using slags corresponding to the ternary system CaO – Al₂O₃ – MeₓF, and in the binary one: CaO - MeₓF;

- the quantity of slag positively influences the desulphurizing degree; thus, its increase from 4kg/t to 15kg/t leads to an increase of the desulphurizing degree by 6-9% for the electric arc furnace steel;

- the use of aluminous slag (resulting from the aluminum production lines) in the desulphurizing mixture used in the formation of the synthetic slag grants the turning into account and reintroduction in the economical circuit of dumped wastes and returning the respective area to the natural habitat.

The implementation of this technology and the use of the products we suggested leads to technological benefits (the recovery of useful elements from the wastes, the intensifying of the siderurgical processes), economical benefits (cutting down the costs with raw materials, financial benefits for the processing plants) and ecological ones.
(reducing the degree of pollution in the soil, air and water).

References: