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# Studies Regarding the Elaboration of the Manganese Austenitic Steel in the Induction Electric Furnace with Acid Coating

*The paper forwards a method of elaborating the manganese austenitic steel in induction electric furnaces with a capacity of 250 Kg having an acid furnace coating. Considering the fact that when elaborating the manganese austenitic steel sulphur can be obtained under 0.02% constitutes an additional reason to attempt the elaboration of this steel in the electric furnaces through induction with acid coating, even if the load has over 0.02% S.*

*Keywords: steel, austenitic, induction furnace, acid coating, elaboration, Hadfield steel*

## 1. Introduction

The usual technology is characterised by the fact that elaboration is made in ark alkaline electric furnaces, and the alloying FeMn is entirely given at the end of the oxidation process of the metallic bath and through a continuous oxidation regime of manganese.

This variant leads to the elaboration of a part with defects (cracks) and with poor mechanical characteristics, which can be explained by:

- insufficient dezoxidation of the metallic bath which leads to a high concentration of [FeO] and (FeO) ;
- adding large portions of alloying FeMn leads to the intense oxidation of manganese;
- obtaining a high concentration of ($SiO_2$), which triggers the linkage of (MnO) and the shift of the reaction equilibrium towards the manganese oxidation;
- realisation of the insufficiently alkaline slag with high concentration of $O^{2-}$ anions

In conclusion the elaboration of manganese steel with this technology is not reasonable for the following causes:

- Due to the portions of FeMn added into the bath in a single discharge, the temperature of the bath drops suddenly, which requires the extension of the elaboration duration in order to reach the adequate thermal regime;
- The duration of the discharge is extended also because of very advanced decarburation (under 0.10%C) and of poor dezoxidation methodology. Decarburation at contents under 0.10...0.15% C requires a long time and has as negative effect, besides the extension of the elaboration time, a over-oxidation of steel, which leads to the increase of the percentage of rejects because of the occurrence of cracks after shake out;
- By applying the old technologies one cannot assure the conditions for the manganese regeneration, obtaining final slags with high contents of (FeO) and (MnO). This triggers the following drawbacks:
- Large losses of Mn in the slag under the form of (MnO);
- Extension of the elaboration time, which determines the reduction of furnace productiveness and the increase of the consumption of electric energy, electrodes, materials for the slag formation and labour;
- The obtaining of a high percentage of rejects, because of the heat cracks.

In order to describe in detail the technologies of the elaboration of the manganese austenitic steel one passed to the elaboration of this type of steel in electric furnace with induction with acid coating.

The induction electric furnace is very appropriate for the elaboration of the makes of alloyed steel which contain elements with low vaporisation temperature or strong tendency of segregation in the metallic bath [3] grace to the shortening of the elaboration time, the increase of the elaboration and casting temperature, the reduction of the gas quantity (one can elaborate it in void), unlimited alloying degree, reduced burnings of elements etc.

In view of protecting the acid coating of the induction furnace we use and recommend the periodical spreading of finely grained $SiO_2$. onto the surface of the metallic bath. Along with this, the added $SiO_2$ forms with the oxides exhaled from the metallic bath (FeOMnO) complex formation of the type of silicates (easily fusible) which purify and protect the metallic bath against the atmosphere. For the same reason one may use periodically additions of slags resulted from the elaboration of the aluminium alloys.

The inoculation of aluminium and titanium is beneficial for obtaining a fine structures of manganese austenitic steel an dezoxydation, as the capacity of aluminium is very high.

In a decreasing order, according to the dezoxidation capacity at $1530^0$C:

Zr > Al > Ti > B > Si > V >Mn > Cr

The presence of aluminium on the surface of the metallic bath (macro-additions) will naturally lead to the formation of Fe and Mn silico-aluminates with lower fusion points than the manganese silicate and thus one can obtain a superior purification of the metallic bath grace to the release of these silico-aluminates to the surface of the metallic bath where they can be collected and removed more easily [5], [6], [8].

The possibility to use the additions above is supported also by [7], who showed that for a good dezoxidation one may use synthetic slags with high capacity of absorption of oxygen, inclusions and sulphides. The authors of the treaty show that it is good to use slags according to 1.

**Table 1.** Slags used for the dezoxidation of steels

| No. | Steel | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | CaO | MgO | MnO | $CaC_2/CaF_2$ | SLAG |
|---|---|---|---|---|---|---|---|---|---|
| 1 | acid | 47 | 5,0 | 17,0 | 6,0 | 15,0 | 8,0 | - | acid |

*Remark. The slags must have FeO <1%.*

The authors [62] show that by the use of slag no.1 (acid) one may reduce the content of [O] 0 0.05….0.08% to [O] 0 0.01…0.02%. One can remark that the chemical composition of the acid slag no.1 is close to the slags formed in the induction electric furnace used by us, except $TiO_2$ and MgO not introduced specially, in exchange (MnO) appears grace to the reaction taking place in the case of this steel:

$$[FeO]+[Mn]\rightarrow[Fe]+(MnO) \tag{1}$$

When choosing the refractory materials for the coating of the induction electric furnaces [2] one takes into consideration first of all the refractivity of the coating that must assure the operation of the furnace at a temperature higher than the melting temperature of the alloys we work with.

The materials must be characterised by thermal stability to the sudden variations of temperature, good resistance against the intrusion of metals, oxides and flows. Other required properties: it must be chemically inert in relation with the molten metal, with its oxides and with slag, to have the lowest possible thermal and electric conductivity, a good capacity of synthesis, low cost.

The induction electric furnace can be used also grace to the fact that the manganese austenitic steel requires only the temperature of $1360^0$C for elaboration, and the temperature of the slags formed remains anyway below the temperature of the elaborated steel. These aspects are favourable for the braking of the reaction between the acid coating of the furnace and the products of the slags formed, by using the aforementioned additions.

The acid coating of an induction electric furnace with quartzite generally has the following chemical composition: 98% $SiO_2$ maximum; 0.6 % $Fe_2O_3$; 1 % $Al_2O_3$;

The acid coating is preferred to the alkaline one as it conducts heat better, can be found on the Romanian market and is much cheaper.

The chemical reactions with the coating may be of reduction between the silica of the coating and the elements contained in the liquid steel (whose oxides have the dissociation tension lower than that of the $SiO_2$ of the coating); of neutralisation, between the acid silica of the coating and the alkaline suspensions of slag existing in the liquid steel which possesses a dissociation tension close to that of $SiO_2$.

These reactions take place at temperatures usually exceeding $1470^0$C and are related to carbon, manganese and iron, and the elaboration of the steel in cause need only $1360^0$C due to the high fluidity.

The steel chosen to be elaborated in the induction electric furnace is a manganese austenitic steel make T120CrMn130 different from the make elaborated in the alkaline coating ark electric furnace i.e. T130Mn135. One considered the presence in the chemical composition of the steel of certain carburigene elements able to help the formation of complex carbide and create favourable conditions for obtain healthy cast parts due to the higher fineness degree of the structure after casting.

By alloying the manganese austenitic steel with a percentage of 1.5-2.5% Cr one significantly reduces the quality of rejected parts, by the formation in the steel structure of complex carbides, resistance to heat cracks. [1], [7].

This make of steel called Hadfield manganese steel with chromium apud [8], [9], [10] has the advantage of a higher elasticity limit, this characteristic lacking to he classic austenitic steel; besides the elasticity characteristics, the chromium additions increase the resistance to abrasion.

## 2. Determining the temperatures of elaboration – casting of the manganese austenitic steel.

Keeping in mind that the manganese austenitic steel has a good fluidity and the fact that thick-walled parts are cast, we can use a casting temperature close to the liquidus line for the steel with the ratio $\frac{Mn}{C} \cong 10$, in which C is over 1%, i.e. an inferior temperature, which should not favour the cooling reaction after casting $\gamma \rightarrow \alpha + carbures$ and to avoid the occurrence of chemical reaction between the furnace coating and the metallic bath.

The chemical composition of the steel chosen for elaboration in the induction electric furnace is the following:

**Table 2.** Chemical composition of the manganese austenitic steel alloyed with chromium

| Make | Chemical composition [%] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T120CrMn130 STAS 3718-88 | C | Mn | Si max. | P max. | S max. | Ni max | Cr | Mo |
| | 1.05-1.35 | 11.50-14.00 | 1.00 | 0.11 | 0.05 | 0.80 | 1.50-2.50 | - |

That is why it is necessary to calculate the liquidus temperature for the steel in cause.

For the calculation of the liquidus temperature of the proposed chemical composition, one uses the following relation [7], [8]:

$$T_l(^0F) = T_{lFe} - \Sigma\Delta T_{el} \qquad (2)$$

where:

$$\Sigma\Delta T_{el} = \Sigma K_{el} a_{el} \qquad (3)$$

$a_{el}$ = average percentage of the chemical elements;
$K_{el}$ = coefficient of influence of the element upon the liquidus temperature.

$$T_l(^0C) = \frac{5[T_l(^0F) - 32]}{9} \qquad (4)$$

$T_{lFe} = 2795^0F$

**Table 3.** Value of the $K_{el}$ coefficient

| Chemical element | C | Si | Mn | Cr | Al |
|---|---|---|---|---|---|
| $K_{el}$ | 141 | 22 | 7,2 | 4,2 | 9 |

$$T_l^0F = 2795 - [(1.50)141 + (0.70)22 + (14.00) + (0.03)9 + (1.6)4.2] \quad [^0F]$$

$$T_l\ ^0F = 2460{,}1\ ^0F \qquad (5)$$

$$T_l^0C = \frac{5(2460.1 - 32)}{9}$$

*$T_l\ ^0C = 1348.94\ ^0C$*

Theoretically it results a value of the liquidus temperature of the manganese austenitic steel of $1349^0$C. Adding an overheating of about $80^0$C, the cooling temperature may be considered $1430^0$C , $10^0$C under the value of the starting temperature of the reactions between the components of the metallic bath and the furnace coating.

### 2.1. Technology of elaboration in the 250-kg induction electric furnace

The elaboration of this make of steel was done in an induction electric furnace with acid coating with the capacity of 250 Kg. All the necessary quantity of FeMn was introduced since the beginning along with the load

During elaboration, which lasted for 65 minutes, the melting took 37 minutes. In the remaining interval until discharge, i.e. 28 minutes, measurements were done with the thermo-couple by immersion, the measured values being of $1395^0$C, and $1432^0$C. The last measurement of temperature was done before discharge after the correction of the chemical composition and it had the values of $1450^0$C. The relatively short contact time with the furnace coating, 4-5 minutes, does not raise problems as regards the start of a chemical reaction between the liquid metal and the coating of the electric furnace. The temperature of steel in the ladle measured with thermo-coupe by immersion was of $1400^0$C.

In order to highlight the advantages of alloying manganese austenitic steel with chromium, Table 4 shows the results of the mechanical tests in the thermally treated state. In the manganese austenitic steel the chromium has the role of stabiliser of carbides by forming complex carbides. By alloying with chromium within the ranged indicated STAS 3718 – 88, one found also an increase of toughness and resilience of the manganese austenitic (Table 4).

**Table 4.** Average variation of the mechanical characteristics.

| Mechanical and chemical characteristics | Symbol | M.U. | STAS 3718-88 | Samples prepared according to new technologies | |
|---|---|---|---|---|---|
| | | | | Ark alkaline electric furnace | Induction electric furnace |
| Flowing limit | $R_{p0,2}$ | [N/mm$^2$] | 245-390 | 320-360 | 410-480 |
| Breaking resistance | $R_m$ | [N /mm$^2$] | 790-980 | 850-950 | 840-860 |
| Brinell toughness | HB | HB | 180-220 | 185-190 | 215-235 |
| Resilience | KCU | [J/cm$^2$] | 20-30 | 22-24 | 29-33 |

## 3. Conclusions to the elaboration of the Mn – Cr alloyed steel in the induction electric furnace with acid coating

1. The elaboration of the manganese austenitic steel T120CrMn130 was done in an induction electric furnace with acid coating.

One chose this elaboration procedure as one considered that the temperature of the metallic bath during the elaboration does not require exceeding the temperature of 1440$^0$C, from which the components of the metallic bath start chemical reactions with the acid coating of the furnace. The ark alkaline electric furnace can be replaced by the induction electric furnace if one assures a load with the chemical composition as close as possible to that of the elaborated steel and the casting plant does not have large manufacture capacities.

2. As the liquidus temperature of the solution of 1450 $^0$C is below the equilibrium temperature, the following reaction takes place:

$$[FeS] + [Mn] = ]MnS] + [Fe ] \qquad (6)$$

and it is known that the melting temperature of MnS is of 1610 $^0$C and does not influence negatively the properties of heat fragility of steel;

3. As long as the temperature of the metallic bath does not exceed the equilibrium temperature (1450$^0$C), the reaction of chemical linkage of S by Mn is efficient.

4. This procedure allows the elaboration of manganese austenitic steels at low temperatures and its casting in the casting mould at temperatures below 1400$^0$C grace to its high fluidity. [11], [12];

5. The casting of the manganese austenitic steel at these temperatures is in fact highly advisable, as these steels have a high shrinkage coefficient, which has an unfavourable influence, leading to the occurrence of the heat cracks due to the separation of carbides after casting, which increase along with temperature;

6. Although this furnace has a reduced capacity , i.e. [250 kg] it gives the possibility of obtaining a high productiveness as one uses only preheated materials at temperatures higher than 900$^0$C;

7. The addition of $SiO_2$ and of aluminium leads to the deployment of dezoxidation reactions through diffusion with beneficial effect on purity and on the properties of the manganese austenitic steel without destroying the furnace coating.

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