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Simulation for Obtaining Mild Steels from a Cast Iron Rich in Manganese

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Abstract: The converter is a reactor which can eliminate to a very low rate oxydable elements from the cast iron (C, Mn…). However, in spite of great progress having allowed a better approach of physical and chemical balances, the results obtained remain inefficient. The quality from the chemical point of view of the cast iron is one of the main causes of this dispersion. It is currently the case of oxygen steel-works of Arcelor-Mittal-Annaba-Algeria, which have enormous difficulties in producing tinplate from a cast iron very rich in Manganese, around 2.36%. In fact 42% of the fusions elaborated with oxygen steel-works their concentration in Manganese at the end of the blowing is higher than that of the concerned steel and thus, have to be subjected to an additional blowing. This operation involves an increase in production cycle (approximately 7 mn) leading to a significant loss of production. The conditions of oxidation of carbon, the temperature of the bath, the alkalinity of the slag and particularly the initial content of Manganese in the cast iron, have a direct influence on the residual Manganese content in steel. In order to improve the working conditions of the steel-works, it is proposed in this work to carry out partial demanganization of the cast iron outside the reactor using the process of the gas-lift. In the first step of this study, a gas-lift experimental set up is designed containing air compression machine, a column to rise of the Gas-liquid mixture and various control devices as well as a complete procedure of experimentation is developed. This experimental set up has made possible the simulation at the laboratory the conditions of the cast iron treatment. The analysis of the obtained results have allowed the establishment hus of the relation: liquid flow and gas-flow. Finally, the design characteristics of the industrial plant were fixed and a calculation model is established in order to determine the procedure which allows easy and fast extension of the model for each cast iron chemical composition.

Key words: Gas-lif, mild iron, manganese, simulation, gas-liquid

INTRODUCTION

The thermodynamic and kinetic study of Manganese oxidation have shown that at the end of the refining, the residual content in steel depends mainly on that of the cast iron liquide (Matchekin *et al*., 1983; Osztani, 1982; Yavoski and Krakousky, 1983). In the plant of iron and steel (Arcelor-Mittal-Annaba-Algeria), it is noticed that it was particularly difficult to work out nuances with low carbon and low manganese, intended to manufacture tinplate from a cast iron rich in manganese (2.36%). A gradual substitution of Algerian ore with high-grade in manganese by a low-grade Brazilian ore have increased the rate of manganese in blowing from 58% in 2001 to 98.4% in 2006 for manganese contents in the cast iron of 2.36 and 1.17%, respectively (R.A.P, 2007). Thus, confirming the theory of Kritvtchenko *et al*. (1985) which says that contents higher than the value of 1.2%, manganese change strongly the process of refining in the L.D. converter. In order to avoid additional plowings and consequently all the inherent nuisances (an additional blowing of afew seconds can extend the cycle around seven minutes) by carrying out the pretreatment of cast iron to eliminate the surplus of manganese. A gas-lift experimental set up is designed at the laboratory to simulate, using the mixture water-air, the behavior of the mixture cast iron-oxidizing gas. Finally, by using similarity law to establish the relation between cast iron flow to be treated and air flow to be insufflated in the reaction column.

Experimental procedure

Processes of pretreatment of cast iron: The future trend and development of the iron and steel industry from the quantitative and especially qualitative point of view is based on the treatment outside the furnace of the cast iron. Several processes were tested throughout the world (Gueyer; 1982; Raguin and Husson, 1981; Sokolov and Domensky, 1976). Their study have shown nevertheless that the gas-lift is the equipment the most

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advantageous because is inexpensive and can be inserted easily since the principle is based on the treatment of the metal jet that can be carried out during the transfer cast iron.

Gas-lift: The gas-lift is a gas elevator of liquides (Delhaye, 2001 ; Gueyer, 1982). The rise of the liquid

01 : Recipient
02 : Reaction column
03 : Nozzles
04 : Deferential manometer mixture
05 : Jet outflow
06 : Van
07 : Compressor
08 : Cover
09 : Water
10 : Manometer
11 : Water-air

is done by a gas compressed and mixed with this liquid. It is in USA (Pennsylvania) that the first installations of gas-lift is appeared but their adaptation in metallurgy was in the institute of Donetsk for the treatment of cast iron in Makeevka plant (Efimenko *et al.*., 1986). It should be noted that in gas-lift installations, the liquid movement is very intense which favorise the increase in the interaction surfaces.

Metallurgic gas-lift hydrodynamique: Many research work were carried out in the field of gas-lift and their method of calculation (Delhaye, 2001; Mamaiev and Simenov, 1969; Wolly, 1972). Unfortunately no study have lead to the establishment of a fundamental mode of calculation, because of complexity in the two-phase system, but it is possible thanks to the experiment and to the law of similarity, to solve many problems involved in the movement of two-phase currents (Efiminko *et al.*., 1986). These results can be used for the construction of metallurgical gas-lift.

Simulation of the set up at the laboratory: By taking in consideration the working conditions of N°1 steel-works, a laboratory set up is designed and is illustrated in Fig. 1.

The laboratory apparatus is designed from a sheet of 2 mm thickness. The reaction column (2) has two lateral faces made from Plexiglas of 3 mm thickness in order to observe the behavior of water-air mixture during the experiments. At the column reaction base five holes were made to fixe the nozzles of 4mm thickness for air insufflation. The necessary compressed air is provided by a compressor. Control apparatus used are: a manometer to measure the insufflated in reaction column, a scaled burette to control water level and a chronometer. The air flow is defined by the organs of diaphragm type allowing by the use of Bernoulli equation to find the air flow from the pressure difference (Grichko, 1984).

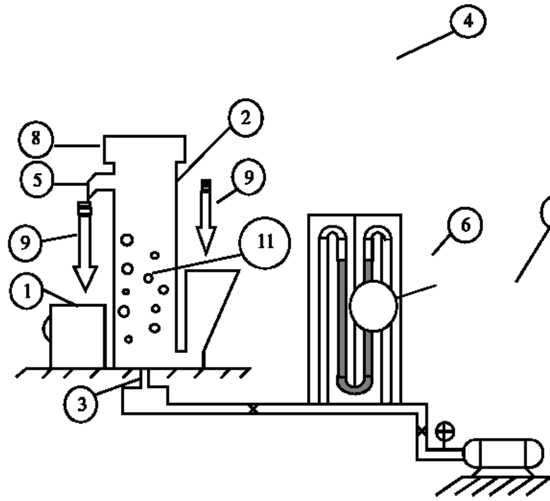

Fig. 1: Experimental set up designed at the laboratory

RESULTS AND DISCUSSION

Laboratory tests description: A series of tests were undertaken to measure the water flow poured in the recipient (1) for a given pressure. Then, the pressure is increased by 0.5 Kgf cm^{-2} and the operation is repeated several times.

The results obtained from this simulation have allowed plotting the curve illustrated in Fig. 2.

Point A_0, A_1, A_2 and A_3 are the arithmetic mean values obtained for each class of experiment. It is noticed according to this curve that the dependence between the air flow and the water flow is almost linear up to the point A_1. From point A_1, it is observed a reduction in the water flow up to the point A_0, which represents a maximum with values: 2,41 10^3 m^3/mn for water and 0.865 m^3/mn for the air, from this point water flow decreases while air pressure increases. It can be concluded, that the gas jet crosses the column of liquid without rising and thus, loses his effectiveness. It is noted that at this point the mixing of the liquid is intense. To carry on calculations the average values is 0.619 m^3/mn for the air flow and 1,409.10^{-3} m^2/mn for the water flow corresponding to point A_2.

Calculation of simulation: The essential characteristics of the gas-lift which is projected to build for the treatment of the cast iron of Arcelor-Mittal-Algeria were specified by the laboratory apparatus. It only remains to determine the

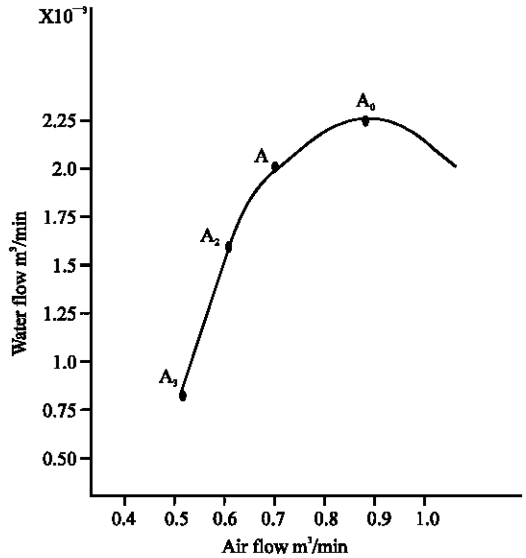

Fig. 2: Variation of water flow according to air flow

necessary air flow to be injected into the column of reaction to obtain a cast iron flow equal to 8t min^{-1}, (flow defined by the technological requirements of Arcelor-Mittal). For this the criterion of Froude is used for the liquid-air mixture. The criterion of Weber allow to define the diameter of the tubes necessary to air insufflation (Efimenko *et al.*, 1986). Air-water mixture in column reaction can be simulated to a two phase system. Froude criterion can be simulated as follows:

$$Fr^{lab}_{m} = \frac{W^{2\ lab}_{m}}{g.\ l_{lab}}$$

Fr_m^{lab} : Criterion of Froude of the mixture at the laboratory

$W^{2\ lab}_{m}$: Speed rise of the mixture at the laboratory, m s^{-1}

L_{lab} : Determining length for

$$Fr^{ind}_{m} = \frac{W^{2\ ind}_{m}}{g.\ l_{ind}}$$

Fr^{ind}_{m} : Criterion of Froude for the mixture under the industrial conditions.

$W^{2\ ind}_{m}$: Speed rise of the mixture under the real conditions; m/s.

g : Force N/m^2 gravity.

l_{ind} : Determining length (m).

$$Fr^{ind}_{m} = \frac{W^{2\ ind}_{m}}{g.\ l_{ind}}$$

$$V_g^{moy} + V_l^{moy}$$

$$W_m^{lab} = \frac{V_g^{moy} + V_l^{moy}}{F}$$

Where, V_g^{moy} and V_l^{moy} are the average flows of the liquid and gas, m^3/mn and F, the section of the reaction column, m^2.

To make the similarity between the real conditions of laboratory and those the following equation is proposed;

$$Fr^{ind}_{m} = \frac{W^{2\ ind}_{m}}{g.\ l_{ind}} = Fr^{lab}_{m} = \frac{W^{2\ lab}_{m}}{g.\ l_{lab}}$$

The criterion of Weber can be formulated according to:

$$We_m = \frac{\sigma}{g(\delta_l - \delta_2)d^2}$$

σ : Tension superficielle.

g : Force de pesanteur.

δ_I : Density of liquid.

δ_G : Density of gas.

d : Diameter of the tube.

After calculation, it is determined that in order to treat a cast iron flow of 8t mn^{-1}, air of 18.07 m^3/mn with a tube of 19.2 mm is needed.

This mode of calculation makes it possible to define the air flow necessary to treat any liquid cast iron flow.

Process of refining in the gas-lift: The treatment of the cast iron in the installation of gas-lift occurs in a three-phase system: gas oxidizing-dross-metal. For calculations this system can be assimilted to a two-phase system gas-liquid (Delhaye, 2001; Efimenko *et al.*, 1986).

If, it is supposed that the oxidation of Manganese proceeds according to the reaction

$$[Mn] + (Fr0) \rightarrow (Mn0) + [Fe]$$

and it is necessary to eliminate 2.36-1.2 = 1.14 % that is to say approximately 48% Manganese of the cast iron. Therefore, it is necessary to inject 20.52 m^3/mn of oxygen to treat 8t mn^{-1} of cast iron. Moreover, recording to Matchekin *et al.* (1983) and Osztani (1982), one considers that a small quantity of oxygen takes part in the oxidation of carbon and that it is necessary to have almost the same proportion as Manganese to oxidize Silicon, one takes account of the purity of technical oxygen then it is necessary to insufflate approximately 41.3 m^3/mn oxygen and 23 m^3/mn of air. It is necessary to note that oxygen injected does not take part in rising mixture gas-liquid, Efimenko (1986) affirms that as of its entry in the column of reaction, oxygen between almost instantaneously in reaction with the chemical elements contained in the liquid cast iron.

CONCLUSION

This study have showed that the steel making, for low carbon and low Manganese intends for the manufacture of tinplate, starting from a cast iron rich in Manganese, poses a major problem of success at the end of the refining. Thus, to improve productivity of the steel-works the treatment, outside of the reactor of the cast iron to eliminate the surplus of Manganese is essential. For this, the processes of gas-lift are in our opinion very adequate. This end simulation, with the installation assistance of laboratory, enabled us to define the essential characteristics of the projected industrial facility. In this research a mode of calculation based on the relation between the flow insufflated air and the water flow obtained have made possible to define exactly the quantity of oxided gas to be injected into the column of reaction for demanganise a quantity of desired cast iron.

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