PRODUCTION OF MEDIUM CARBON FERRO-MANGANESE BY SHAKING LADLE PROCESS

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ABSTRACT

In December 1978, our company started production of medium carbon ferromanganese by the Shaking Ladle process. This process consists of quick desiliconization of silicon manganese using manganese ore. Efficient utilization of the heat of reaction in this process makes replenishment of energy unnecessary.

The shaking and agitating effect in this shaking ladle process increases manganese recovery rate and reduces vapor loss.

Under the conventional shaking ladle method, utilization of that manganese ore most suited for desiliconization is one of the requirements, thus, making it difficult to produce low phosphorous medium carbon ferro-manganese. After the production technology, was established, limitations of manganese ore have been reduced, thus making it possible to produce it at a low price.

Our shaking ladle process is featured by:

(1) No additional energy required
(2) High productivity, and
(3) Low equipment cost.

1. INTRODUCTION

The shaking ladle process, which was invented in 1959 by Mr. Kalling (Sweden) and G.H.W. A/G (West Germany), in its chief practical use, was utilized for desulfurization purposes. Afterwards, application of this process to other metallurgical reactions was considered by reason of its remarkable shaking and agitating effect. As far as the production of medium carbon ferro-manganese is concerned, the technique of applying the shaking ladle process was first developed in 1970 by a Japanese Company, Pacific Metals Co., Ltd.

We had noticed this energy-saving process, and in December 1978, we started production of medium carbon ferro-manganese utilizing it. It is to be emphasized that our equipment was the sole one developed specifically for that purpose. Medium carbon ferro-manganese, thus produced, is low phosphorous for the most part, and there is a restriction relating to the manganese ore used for desiliconization. Realizing however a low-cost production, it is gaining a favorable reputation by its user, Kawasaki Steel Corporation.

2. THEORETICAL BACKGROUND OF SHAKING LADLE PROCESS

The desiliconizing reaction in the production of medium carbon ferro-manganese from silico-manganese is exothermic. If we are successful in profitably employing the heat of the reaction produced in this process, we can get the medium carbon ferro-manganese aimed at, without compensating for any energy.

$$MnO_2 + Si = Mn + SiO_2 + 80.2\ Kcal$$
$$2Mn_2O_3 + 3Si = 4Mn + 3SiO_2 + 53.2\ Kcal$$
$$Mn_3O_4 + 2Si = 3Mn + 2SiO_2 + 40.1\ Kcal$$
$$2MnO + Si = 2Mn + SiO_2 + 25.3\ Kcal$$

In the regular electric furnace process, the desiliconizing reaction is slow, and processing time is long. Therefore, energy loss is great and this requires to make energy up. While, in shaking ladle process, shaking and agitating effect reduces time of desiliconizing reaction, and energy loss is small. Therefore, energy make-up is not required except for sensible heat generated from silico-manganese.

3. PRODUCTION EQUIPMENT

Production facilities used under the shaking ladle method can be roughly divided into two categories: ore treatment facilities where manganese ore is pretreated for desiliconization, and shaking ladle facilities where the desiliconizing reaction takes place.

(1) Ore Treatment Facilities

In the shaking ladle process, since molten silico-manganese is used, the high content of water adhering to the ore and crystallized water in the ore will cause a boiling phenomenon which poses a risk to life and at the same time, reduces the yield of manganese. Exothermic reaction is greater if MnO_2 ore is used, and MnO ore is more desirable from a Mn yield point of view. It is therefore necessary to realize a lower degree of oxidation within a range where the heat balance can be dealt with, taking into account Mn yield and damages to refractories. Ore treatment facilities are meant not only to eliminate water adhering to the ore and crystallized water, but also to control oxidation.

In these facilities, we have efficiently used the electric furnace gas by adopting a hot blast recycling type shaft furnace which has high thermal efficiency and allows for the easy automatic control of temperature. Fig. 1 represents ore treatment facilities. Capacity thereof is 5 t x 2 sets.

(2) Shaking Ladle Facilities

Since the ladle, which is a reactor, is set on a rocking device, we have adopted the U type tilting version which is convenient for the tapping of hot metal and slag. The maximum ladle capacity is 26 t (metal + slag) and the effective inner volume is 13.02 m^3.

The shaking ladle itself is not moved rotationally. However it may be moved eccentrically with the ladle drawing small circles, thus rotating its contents as it shakes and agitates them. The shaking ladle is therefore designed so that as optimal agitating effect may be obtained by adopting the eccentricity and rotational numbers which are most suited to the capacity of ladle.

Fig. 2 shows shaking ladle.

4. OPERATIONAL METHOD

Quicklime and pretreated ore are charged into the ladle, over which then, molten silico-manganese is poured. At the moment of this pouring, 70% of the desiliconizing reaction occurs and 30% takes place after shaking has begun. Charging is administered at 25.5 t (metal + slag). With silico-manganese used, hot ore occupies 75 to 80%, and cold ore, 20 to 25%. Ore and quicklime that are lacking are additionally charged as soon as shaking commences. A microcomputer control system has been adopted for administering ladle capacity, ingredients of metal and slag, etc., thereby making it possible to take the necessary measures quickly. Shaking time is about 18 minutes for every 13.5 t of metal produced. Fig. 3 shows production process.

5. RESULTS

Two types of medium carbon ferro-manganese are now produced, (according to the needs of the customer) one containing 0.120% or less of P, and the other containing 0.080% or less of P. Since no particular dephosphorization is being carried out, the quality of ore depends on P content rather than on the characteristics of the desiliconizing reaction. With the development of operational techniques, there remain no problems in a desiliconizing reaction. An example of the operation results is given below.

(1) Medium carbon ferro-manganese with 0.120% or less of P content

Charged Silicon Manganese:

Molten Silicon Manganese	75%
Cold Silicon Manganese	25%

Mn Recovery in the Metal	79.8%
Shaking Time	17 min/Heat
Metal Product	13.5 t/Heat
Slag Product	12.1 t/Heat

Metal Analysis :

Mn %	C %	Si %	P %	S %
76.9	1.80	1.42	0.097	0.002

Slag Analysis :

Mn %	MnO%	SiO_2%	CaO%	MgO%	Al_2O_3%
19.8	25.5	35.0	33.7	2.3	1.7

(2) Medium carbon ferro-manganese with 0.080% or less of P content

Charged Silicon Manganese :

Molten Silicon Manganese	85%
Cold Silicon Manganese	15%

(No problem from a thermal point of view. Since procurement of cold silicon manganese is difficult, is proportion limited to 15%.)

Mn Recovery in the Metal	76.5%
Shaking Time	20 min/Heat
Metal Product	12.7 t/Heat
Slag Product	12.8 t/Heat

Metal Analysis :

Mn %	C %	Si %	P %	S %
78.0	1.35	1.31	0.075	0.002

Slag Analysis :

Mn %	MnO%	SiO_2%	CaO%	MgO%	Al_2O_3%
20.5	26.4	34.9	32.7	2.1	1.4

6. HEAT BALANCE

In the table below, we indicate the heat balances of medium carbon ferro-manganese with a P content of 0.120% and of that with a P content of 0.08%, calculated according to the most standard operation results we had. We can conclude from the figures that there remains a considerable thermal margin. Page 6 shows heat balance.

7. REFRACTORIES

What are problematic in the shaking ladle process are the refractories. Damage of refractories is thought to come from thermal spalling, structural spalling, as well as from wear caused by shaking. The shaking ladle is operated on the basis of 4 charges/day thus widening the temperature difference of the refractories with the passage of time. This serves as the cause of thermal spalling. Structural spalling is caused by the penetration of slag into the refractories, but what is characteristic in the case of the shaking ladle method is a deterioration of refractories by wear. That damage caused by shaking and agitating is inevitable.

As the result of joint research and improvement with Kawasaki Refractories Co., Ltd., the price of refractories used in the shaking ladle process has been reduced to about 1/3 of that foreseen at the time of designing. However the basic unit quantity of refractories used remains too high when compared with the quantity used for a steelmaking converter, therefore, further study is required.

8. CONCLUSION

A smooth operation of the shaking ladle can be realized by establishing its production technology. The most remarkable features of this production method are that it does not require any compensation of energy and also that it has a high productivity rate. Moreover it can be utilized not solely for the production of medium carbon ferro-mananese but also for that of low carbon ferro-manganese without any problems. Thus the same method of exploitation can be widely applied.

Moreover since, Mn loss caused by vapor and dust is less than 1%, this process is excellent from the production cost point of view as well.

CALCULATION RESULTS OF HEAT BALANCE

Item	P Content, 0.120% or less	P content, 0.08% or less
Heat Input SiMn (Sensible Heat)	% 32.9	% 33.0
Mn-Ore (Sensible Heat)	8.5	8.7
(Sub Total)	(41.4)	(41.7)
$Fe_2O_3 \rightarrow FeO$	Δ 3.4	Δ 4.4
$FeO \rightarrow Fe$	Δ 6.0	Δ 7.9
$MnO_2 \rightarrow MnO$	Δ20.2	Δ19.4
$MnO \rightarrow Mn$	Δ34.6	Δ30.6
$H_2O \rightarrow H_2$	Δ 4.8	Δ 5.0
$Si \rightarrow SiO_2$	127.6	125.6
(Sub Total)	(58.6)	(58.3)
Total	100.0	100.0
Heat Output Metal (Sensible Heat)	36.3	32.5
Slag (Sensible Heat)	36.0	38.5
Exhaust Gas/Dust (Sensible Heat)	1.3	1.4
(Sub Total)	(73.6)	(72.4)
SiMn (Heat of Decomposition)	8.5	8.4
Slag (Heat of Formation)	Δ13.4	Δ13.8
C.W. (Heat of Decomposition)	0.2	0.2
Moisture (Heat of Vaporization)	0.8	0.8
Carbonate (Heat of Decomposition)	1.2	1.3
(Sub Total)	(Δ 2.7)	(Δ 3.1)
Loss of Heat	29.1	30.7
Total	100.0	100.0

Fig. 1 RAW MATERIAL TREATMENT FACILITIES

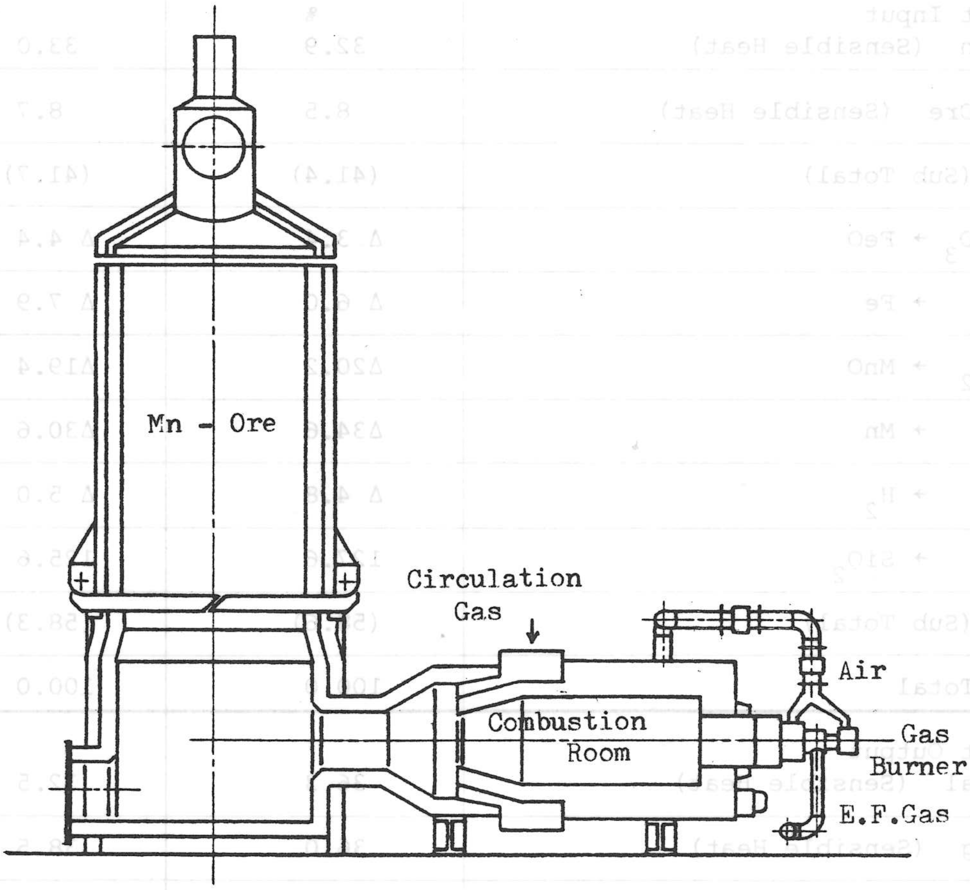

Fig. 2 SHAKING LADLE EQUIPMENT

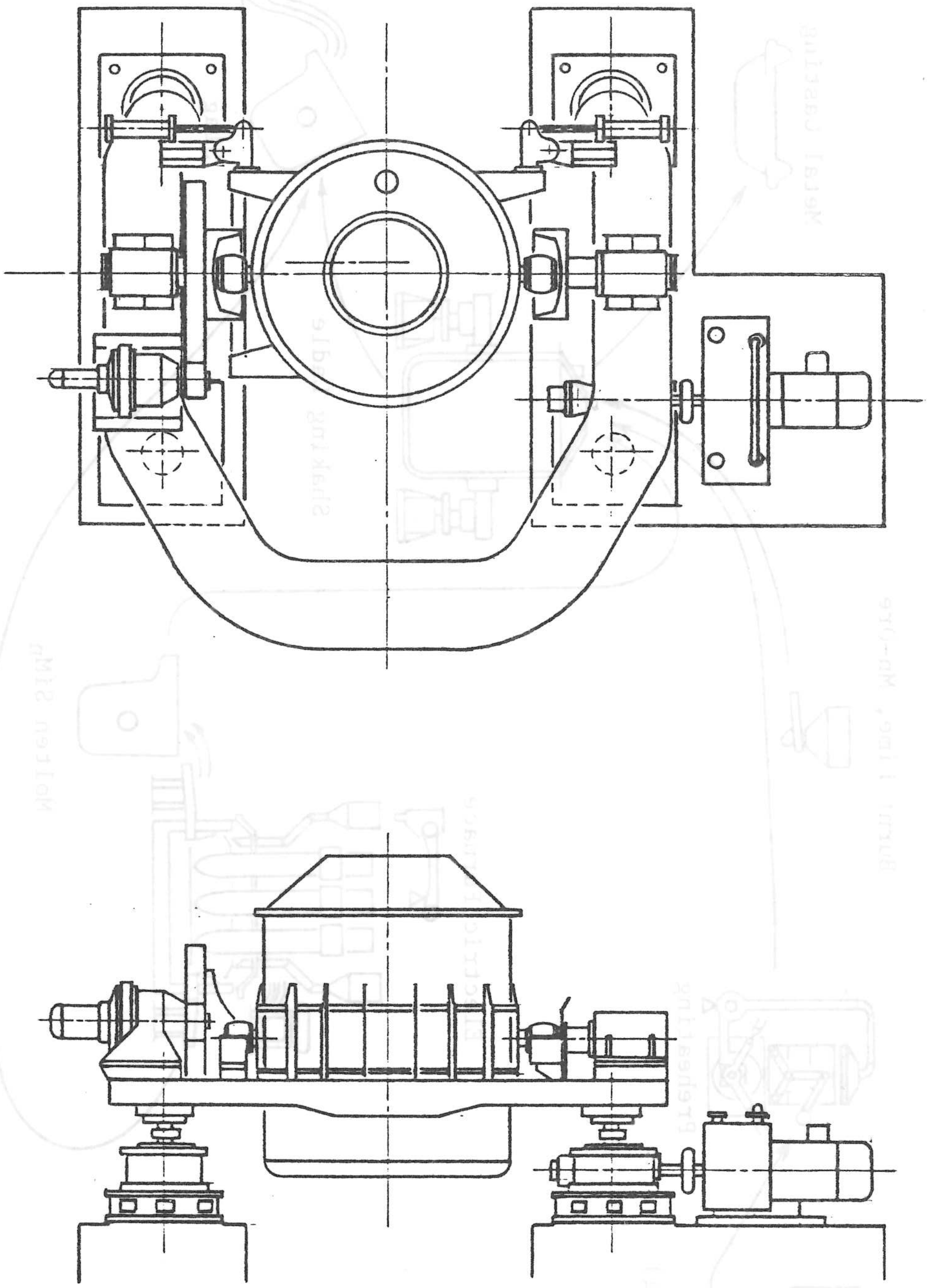

Fig. 3 PRODUCTION PROCESS