COMPOSITE COLD PELLET PRODUCTION AND ITS USE IN SILICO-MANGANESE PRODUCTION

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ABSTRACT

The composite cold pellet of the manganese ore (A) which shows a considerable decrepitation, containing 15 % of fine coke as a reducing agent and 8 % of portland cement as a binder were produced in order to decrease the unit consumption of electricity and substitute the cheaper fine carbon for expensive coke in the manganese ferro-alloy production.

The decrepitation, reduction disintegration, reducibility and resistivity of the produced composite cold pellet were greater in comparison with these of the same lump ore (A).

Composite cold pellets were produced in the plant for the silico-manganese production in order to estimate the decreasing effect of unit consumption of electricity and coke in the two operations of the composite cold pellet and lump ore (A) with a 1250 KVA electric furnace.

40 % of the total manganese input was replaced with the composite cold pellet and the procedure for silico-manganese production was performed. Similarly, 40 % of the total manganese input was replaced with the lump ore (A) in standard operation.

From the operation result, 59 KWH/HMT of the unit electric consumption could be decreased. 115 Kg/HMT of the coke could be replaced by the unexpensive fine coke when using composite cold pellet. The coke efficiency was also improved. The yield of Mn in metal was increased and Mn content in slag was accordingly decreased. These result have shown that the composite cold pellet is an effective burden material for the electric furnace.

INTRDUCTION

In Japan, ferroalloy production requires imported raw materials and costly electricity. Efficient utilization of raw materials and reduction of electricity consumption are therefore of particular concern to Japanese ferroalloy manufacturers.

While the reduction of high grade oxides to MnO is achieved fairly easily, the reduction of MnO to metallic Mn is only possible by direct reduction at high temperatures.[1)]

The authors postulate that direct reduction should proceed effectively when a carbon composite agglomerate is smelted in an electric furnace. Accordingly, a decrease in unit consumption of electricity and also a fine carbon substitute for expensive coke can be achieved.

We have found that the physical properties of manganese ore, i.e., decrepitation, reduction disintegration, reducibility and resistivity were greatly improved by producing composite cold pellet. Our hypothesis was tested by undertaking silico-manganese production using the composite cold pellet in a 1250 KVA electric furnace. Our experiments demonstrated that energy and coke consumption is reduced by this process in comparison to the standard lump ore operation.

PRODUCTION OF COMPOSITE COLD PELLET

1) Row materials

The mixing ratio of raw materials for the composite cold pellet are shown in Table 1. Ore(A) used for composite cold pellet is a high

Table 1. Mixing ratio of raw materials

	Mixing ratio		
	Case 1	Case 2	Case 3
Fine ore (A)	77%	82%	92%
Fine coke	15	10	0
Portland cement	8	8	8

oxidized manganese ore possessing considerable decrepitation. The ore was pulverized and pelletized. Coke was added to the cold pellet in percentages of 0, 10, 15 % in order to investigate the effect of coke content on the compressive strength of product pellet.

The sufficient compressive strength of product pellet for handling was estimated to be approximately 60 kg/pellet, therefore this figure was desired target strength. It required 2 weeks of air curing to reach 60 kg/p with 8 % of portland cement.

The results obtained revealed that even the pellet with 15 % coke had a compressive strength greater than 60 kg/p. This coke content is sufficient to the stoichiometrical amount for the direct reduction in following equations, if the high oxidized manganese and iron were reduced to MnO and FeO before starting direct reduction.

$$3MnO + 4C = Mn_3C + 3CO$$

$$FeO + 2C = Fe_3C + 2CO$$

The size distribution of mixture for composite cold pellet are shown in Fig.1.

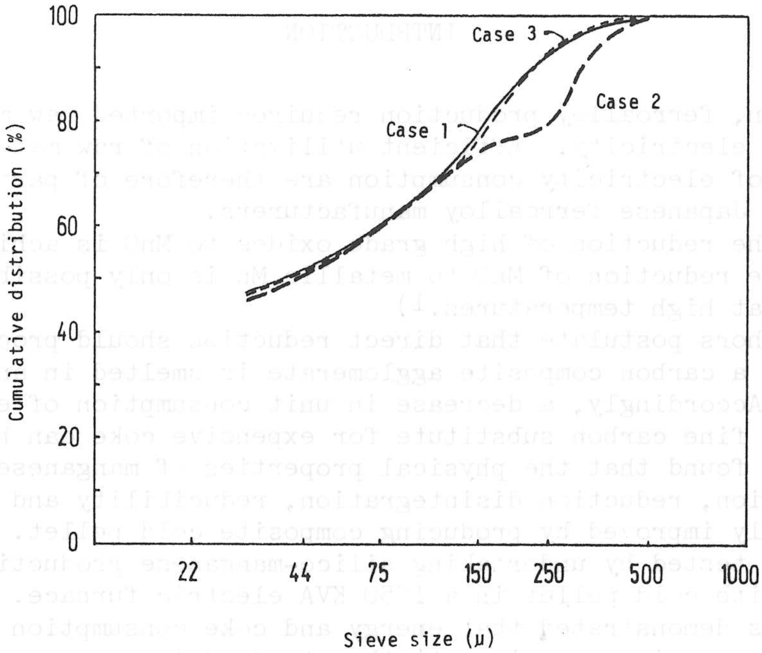


Fig. 1 Size distribution of mixing materials

2) Flow sheet of pelletizing for the composite cold pellet

The flow sheet for composite cold pellet production is shown in Fig.2. The green pellets are sieved in the range of 12.7 - 14.9 mm and cured in the air for hardening. The development of the compressive strength of composite cold pellets in the curing period is illustrated in Fig. 3. The compressive strength of composite cold pellets reached to 60 kg/p after 2 weeks in the forementioned coke content levels.

The chemical compositions of products are shown in Table 2.

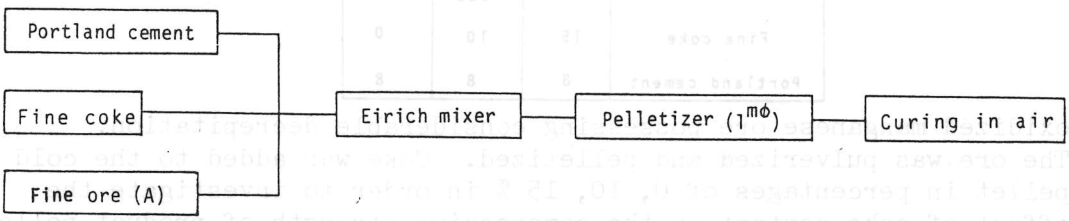


Fig. 2 Pelletizing flow for composite cold pellet

Table 2. Chemical composition of composite pellet and lump ore (A)

	T.Mn	T.Fe	SiO_2	CaO	Al_2O_3	MgO	C	P	S	Na	K	C.W.
Carbon composite cold pellet	36.23	3.35	7.78	5.12	3.77	0.13	11.87	0.06	0.17	0.14	0.95	5.14
Lump ore (A)	49.38	3.74	5.18	0.12	4.69	0.12	0.03	0.06	0.11	0.07	0.78	4.80

PHYSICAL PROPERTIES OF PRODUCT PELLET

Decrepitation, reduction disintegration, reducibility and resistivity tests of composite cold pellet were conducted for comparison of these properties as found in lump ore (A).

The sample sizes for the tests were used in the range of 12.7 - 14.9 mm in composite pellet and lump ore (A).

1) Decrepitation

500 g of samples were heated to 1000°C in a nitrogen atmosphere. After reacing 1000°C the samples were cooled in the furnace. The decrepitation was evaluated with the generation of -5 mm after 900 revolutions using a micro-tumbler. The result is shown in Fig. 4. It is apparent that the decrepitation of composite cold pellet is considerably improved in comparison with that of lump ore (A).

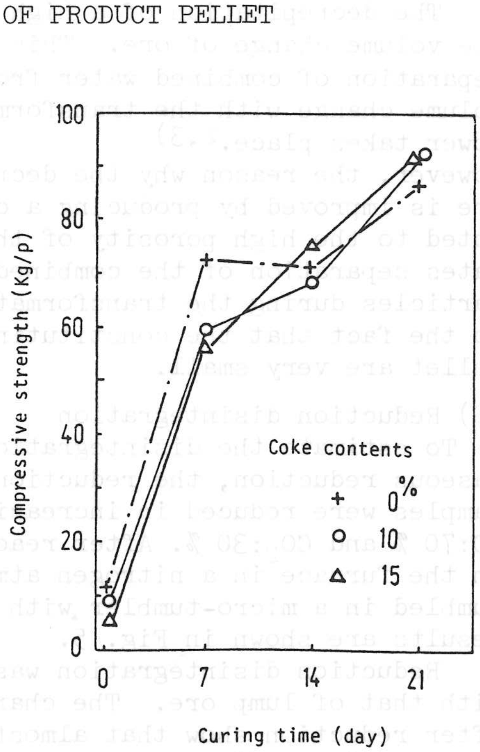


Fig. 3 Strength development of composite cold pellet

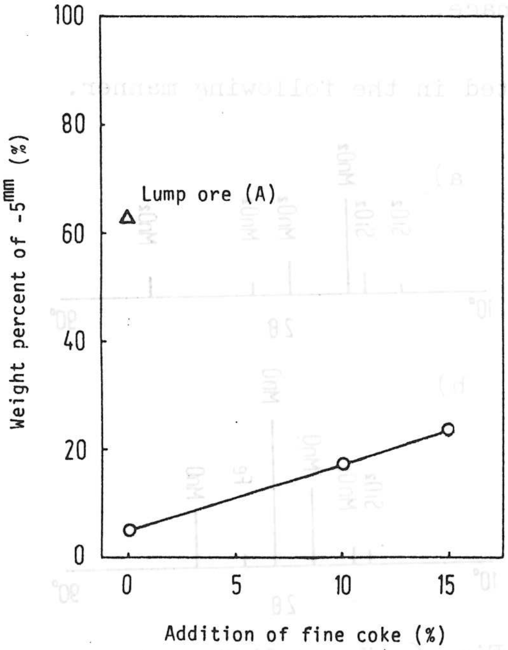


Fig. 4 Decrepitation of composite cold pellet

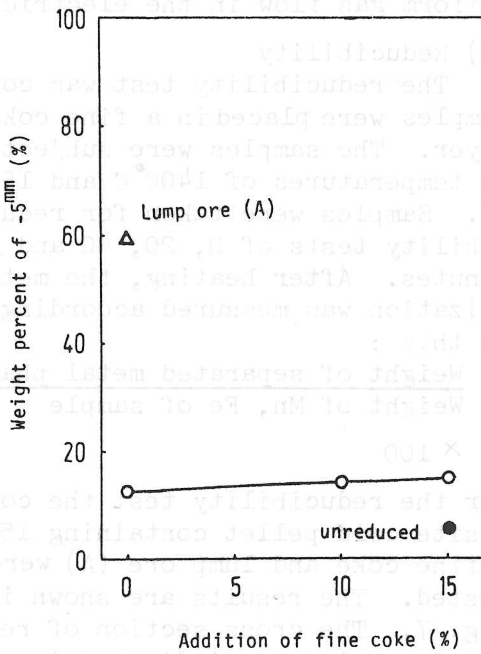


Fig. 5 Reduction disintegration of composite cold pellet

The decrepitation of a high oxidized manganese ore is a result of the volume change of ore. This volume change occurs when a radical separation of combined water from ore particles, heat strain and volume change with the transformation from higher oxide phase to the lower takes place.[2,3)]
However, the reason why the decrepitation of high oxidized manganese ore is improved by producing a composite cold pellet can be attributed to the high porosity of the composite cold pellet which facilitates separation of the combined water. Stress and strain in ore particles during the transformation of oxide phase is dispersed owing to the fact that the constituting particles of a composite cold pellet are very small.

2) Reduction disintegration

To estimate the disintegration of the composite cold pellet after gaseous reduction, the reduction disintegration test performed. The samples were reduced in increasing temperatures in atmosphere of CO:70 % and CO_2:30 %. After reacing 1000°C, the samples were cooled in the furnace in a nitrogen atmosphere. The reduced samples were tumbled in a micro-tumbler with 900 revolutions and sieved. The results are shown in Fig. 5.

Reduction disintegration was considerably improved in comparison with that of lump ore. The charts of X-ray diffraction of the sample after reduction show that almost all the MnO_2 is converted to MnO by reduction(Fig. 6). These results indicate that the transformation from the high oxidized manganese phase to the lower has a very small effect on the reduction disintegration when producing the composite cold pellet. Therefore,to make the composite cold pellet from high oxidized manganese ore is an effective method for improving decrepitation and reduction disintegration, which is effective for achieving uniform gas flow in the electric furnace.

3) Reducibility

The reducibility test was conducted in the following manner. Samples were placed in a fine coke layer. The samples were subjected to temperatures of 1400°C and 1500 °C. Samples were taken for reducibility tests of 0, 20, 40 and 60 minutes. After heating, the metallization was measured according to this :

$$\frac{\text{Weight of separated metal phase}}{\text{Weight of Mn, Fe of sample}} \times 100$$

For the reducibility test the composite cold pellet containing 15 % fine coke and lump ore (A) were tested. The results are shown in Fig. 7. The cross section of reduced samples are indicated in Photo 1.

Fig. 7 shows that the reduci-

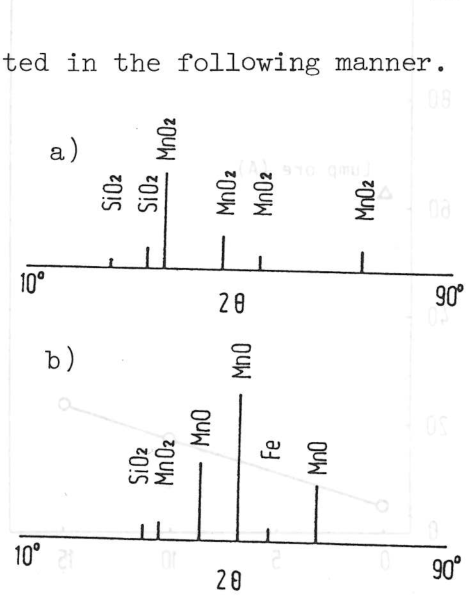


Fig. 6 X-ray diffraction pattern
a) before reduction
b) after reduction

bility of composite cold pellet is extremely improved when compared to that of lump ore at 1400°C and 1500°C.

In the composite cold pellet, metallization takes place through the whole cross section of pellet, but in a lump ore small metallic particles are observed only on the outer surface of ore which comes into contact with the coke. Accordingly it is evident that the improvement of reducibility of the composite cold pellet is caused by the increase in the contact areas between ore particles and reducing agents. In Fig. 7, furthermore, metallization of composite cold pellet at 0 minute means that the metallization occurs during preheating at temperatures considerably below 1400°C.

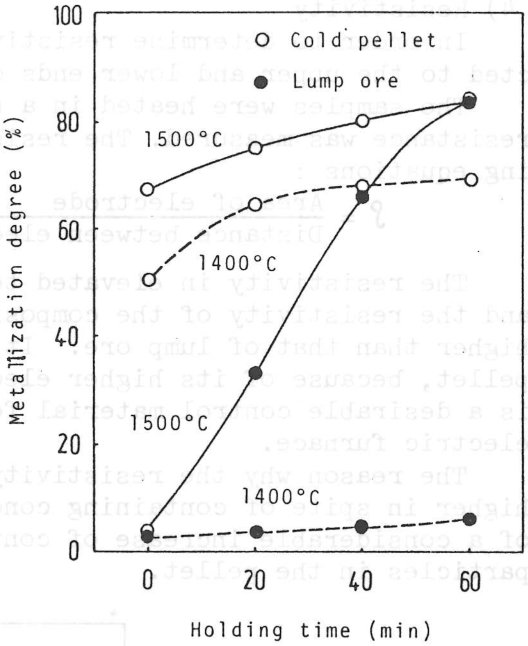
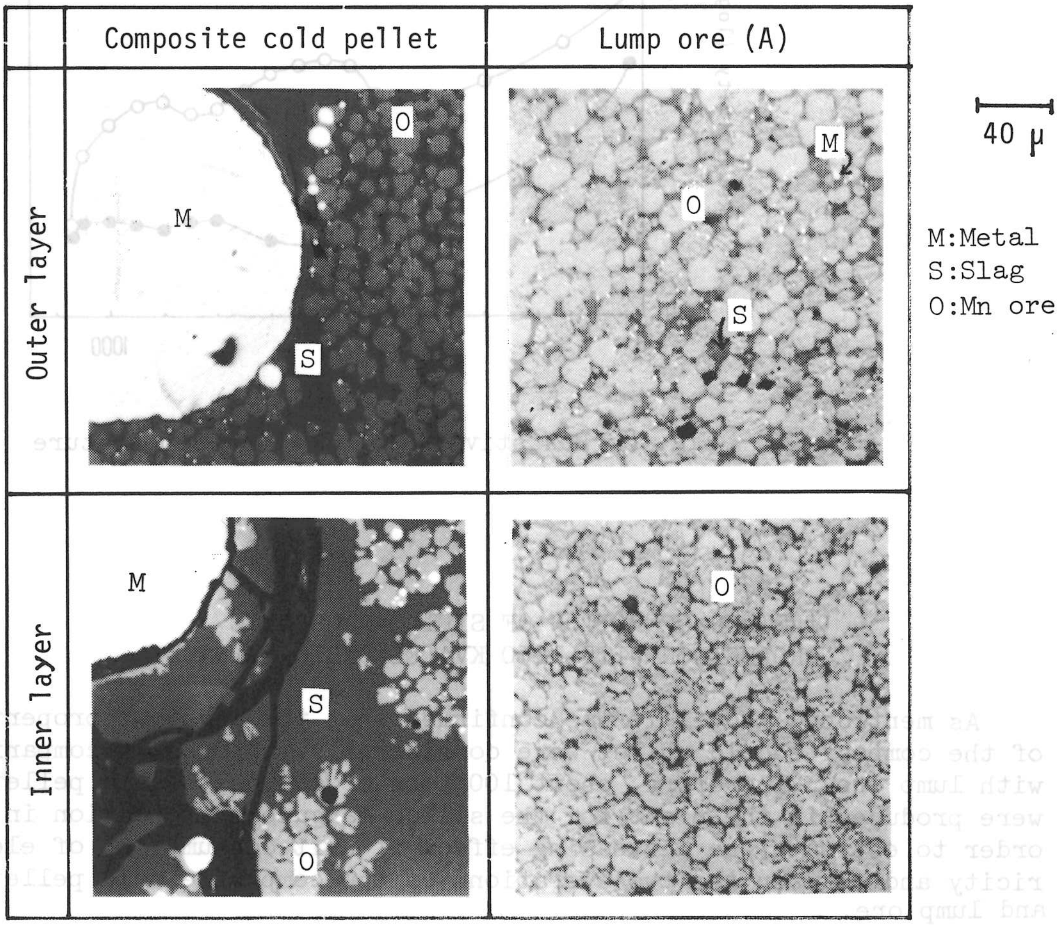


Fig. 7 Reducibility in high temperature

Photo.1 Structure of reduced sample in 1400°C (holding time: 0 min)



4) Resistivity

In order to determine resistivity, a Wheatstone bridge was cennected to the upper and lower ends of a packed layer of samples.

The samples were heated in a nitrogen atmosphere and the electric resistance was measured. The resistivity ρ was calculated by following equations :

$$\rho = \frac{\text{Area of electrode}}{\text{Distance between electrodes}} \times \text{Electric resistance}$$

The resistivity in elevated temperatures is indicated in Fig. 8 and the resistivity of the composite cold pellet is considerably higher than that of lump ore. It is apparent that the composite cold pellet, because of its higher electric resistance and material shape, is a desirable control material for submerging electrodes in an electric furnace.

The reason why the resistivity of the composite cold pellet is higher in spite of containing conductors such as coke may be a result of a considerable increase of contact resistance among constituent particles in the pellet.

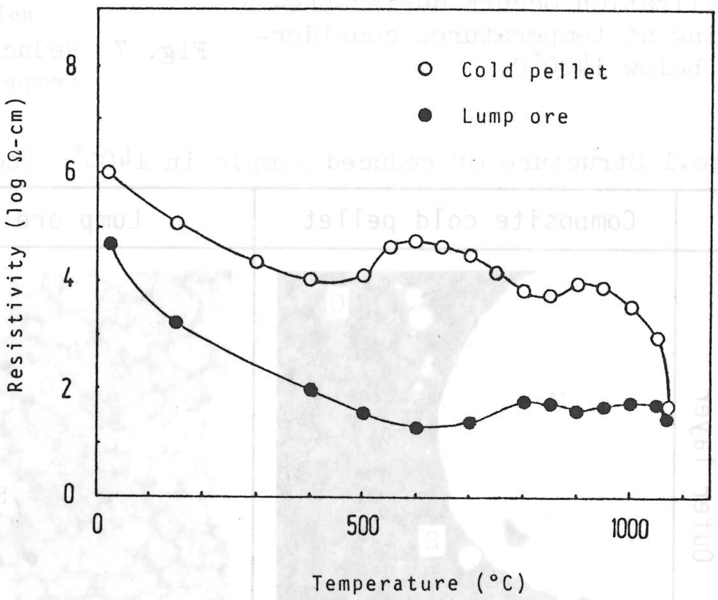


Fig. 8 Resistivity in elevated temperature

TESTING OPERATION OF SILICO-MANGANESE PRODUCTION WITH 1250 KVA ELECTRIC FURNACE

As mentioned above, it was confirmed that the physical properties of the composite cold pellet were considerably improved in comparison with lump ore. Therefore, about 100 tons of composite cold pellets were produced in the plant for the silico-manganese production in order to estimate the decreasing effect of unit consumption of electricity and coke in the two operations of the composite cold pellet and lump ore.

1) Installations for pelletization and silico-manganese operation

The process flow and specification of pelletization and electric furnace are shown in Fig. 9 and Table 3 respectively.

The mixing ratio of raw materials and compositions are the same those produced in the laboratory. The mixing and kneading of raw materials such as fine manganese ore, fine coke and portland cement were carried out in a rod mill. The mixed materials were pelletized in a pelletizer.

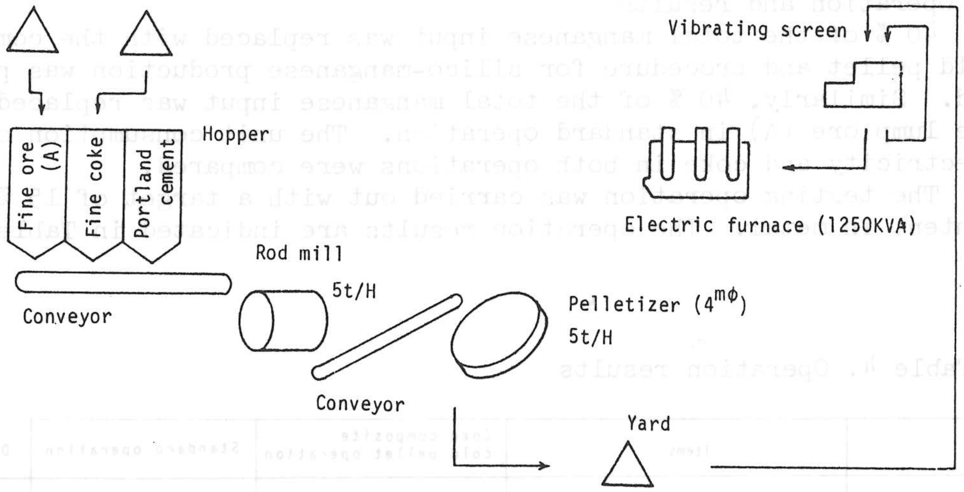


Fig. 9 Pelletizing flow in plant

Table 3. Specification of pelletizing plant and electric furnace

	Equipments	Specification of pelletizing plant and electric furnace
Pelletization	Rod mill	$2.4^m \times 1.5^{m\phi}$ (5t/H)
	Pelletizer	$4^{m\phi}$ (5t/H)
Electric furnace	Height of furnace	1200^{mm}
	Area of hearth	5.72^{m^2}
	Diameter of electrodes	460^{mm}
	Distance among the surface of electrodes	1520^{mm}
	Capacity of transformer	1250kVA
	Secondary voltage	104 ~ 150V
	Rated secondary current	4800A

The mean particle size of produced green pellets was 15 mm. The pellets were cured in the air for 2 weeks for hardening. Some of pellets sticked during curing period. The sticked pieces were separated by a vibrating screen, and charged to the electric furnace.

The compressive strength of product pellets after 2 weeks curing was in the range of 50 - 70 kg/p, which was satisfactory for handling for the electric furnace without crushing.

The electric furnace used for silico-manganese production was an open type furnace with 3 electrodes.

2) Operation and results

40 % of the total manganese input was replaced with the composite cold pellet and procedure for silico-manganese production was performed. Similarly, 40 % of the total manganese input was replaced with the lump ore (A) in standard operation. The unit consumption of electricity and coke in both operations were compared.

The testing operation was carried out with a target of 15 % Si content in metal. The operation results are indicated in Table 4.

Table 4. Operation results

	Items	Coke composite cold pellet operation	Standard operation	Difference
Metal contents	Mn	62.4%	62.7%	
	Si	15.3	15.2	
	C	1.81	1.85	
Slag contents	Mn	11.74%	13.03%	
	SiO_2	36.88	37.89	
	Al_2O_3	14.00	12.49	
	CaO/SiO_2	0.51	0.49	
Results	Unit electricity consumption	3880kWh/HMT	3939kWh/HMT	-59kWh/HMT
	Unit coke consumption	489kg/HMT *	490kg/HMT	-1kg/HMT
	Coke efficiency	90%	86%	+4%
	Yield of Mn in Metal	80.2%	78.5%	+1.7%

* Added the coke 115 kg/HMT in composite cold pellet

Results verify that the unit consumption of electricity decreased to 59 KWH/HMT in the operation with composite cold pellet as compared to 3939 KWH/HMT in the standard operation. The sum of coke and fine coke contained in the composite cold pellet operation is equal to the amount of the coke in standard operation. From this fact, it was proved that expensive coke can be replaced with cheaper fine coke. The coke efficiency (i.e, rate of input coke quantity to the theoretically required coke quantity) was increased from 86 % to 90 %. The yield of manganese in metal was also increased from 78.5 % to 80.2 % and the manganese content in slag was decreased from 13.03 % to 11.74 %.

From above results it is confirmed that the composite cold pellet is sufficiently effective as a burden material in the ferroalloy electric furnace.

CONCLUSIONS

1) The composite cold pellet of the manganese ore (A) which shows a considerable decrepitation, containing 15 % of fine coke as a reducing agent and 8 % of portland cement as a binder were produced.
2) The decrepitation, reduction disintegration, reducibility and resistivity of the composite cold pellet were greater in comparison with these of the same lump ore (A).

The following were proven from the operation in which the silico-manganese was produced with the composite cold pellet replacing 40 % of the total manganese input.
1) 59 KWH/HMT of the unit electricity consumption could be decreased.
2) 115 kg/HMT of the coke could be replaced by the unexpensive fine coke when using composite cold pellet. The coke efficiency was also improved.
3) The yield of manganese in metal was increased and manganese content in slag was accordingly decreased.

From these results it has been recognized that the composite cold pellet is an effective burden material for the manganese ferroalloy electric furnace.

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