Synopsis

Although conventional agglomerates, such as pellets and sinter, have superior properties for the blast furnace, they also have inferior properties. The purpose of the present investigation was to develop a new iron ore agglomeration process that differs from the conventional ones and thereby to improve the properties of the agglomerates. The main results obtained are as follows:

1. Differing from conventional mini-pellet-bearing sinter, the agglomerates, composed of diffusional bonding structures, are constituted from aggregates of irregularly shaped pellets restricted to between 5 and 10 mm in diameter.

2. Fine ores such as pellet feeds can be used in large quantities as raw materials for this process, differing from the conventional sinter processes, because they are granulated completely.

3. According to an estimation of methods for the addition of fine coke to the raw materials by the mathematical model, it became clear that the method for preferential addition of cokes to the surface of green balls was suitable because of effective coke combustion. This was verified by pot grate furnace tests.

4. The properties of the new experimentally produced agglomerates were found to be superior to those of sinter. The desirable properties were considered dependent mainly on micro- and macro-structures and process characteristics.

Key words: new agglomerate; sinter; coke coating; properties of agglomerate; pot grate furnace; mathematical model.

I. Introduction

It is no exaggeration to say that the pellet and sinter process, after a long history, is almost a completely developed agglomeration processes.1,2) However, the two agglomerates, as blast furnace burdens, have superior, as well as inferior properties, and substantial problems in the production process.3,4)

In the present pelleting process, most iron ores must be ground to less than 44 μm in diameter to reduce gangue minerals in crude ores and to ensure a stable balling operation in spite of the expensive grinding cost. Besides the comparatively expensive operation cost, pellets have inferior properties, when compared to sinter, such as burden distribution in the furnace and high temperature properties. Although it has been evaluated in Japan that sinter is superior to pellets for the reasons described above, further improvements in sinter properties are needed to make blast furnace operation with high efficiency possible. Especially the improvement in reducibility of sinter is one of the most effective methods to diminish the fuel rate at blast furnace.

The reducibility of sinter near 900°C is, in general, less than that of pellets because of the differences in their mineralogical structures. Degradation of sinter occurs during low temperature reduction at a temperature below 600°C, although the mechanism has not been yet clarified in detail, a decrease of the low temperature degradation of sinter is indispensable for a stable blast furnace operation. In spite of the necessity of improvement in these properties, since it is difficult to reduce SiO2 content in sinter in order to maintain productivity and yield, there is a limit in improving the reducibility and the degradation in the sinter process.

Moreover in view of the future trend of iron ore fines there is also a need to develop a process differing from the conventional agglomeration process.5)

Motivated by these concerns the present investigations were aimed at making a distinct improvement in RI (Reduction Index) and RDI (Reduction Degradation Index) of the new agglomerates as compared to those of conventional ones, and basic investigations were also conducted to develop a new agglomeration process.

II. Target Structure and Shape of New Agglomerate

Since there is an obvious demand for reduction of fuel in the blast furnace, we have attempted to find ways of improving the reducibility of sinter in the shaft zone of the furnace. For this purpose the authors have already investigated the relationship between RI and typical sinter structures synthesized by chemical reagents. From the viewpoint of reducibility, it was proved that a diffusion bonded structure with low slag contents was a desirable form of sinter due to the promotion of reduction gas penetration in its porous structure. According to the mineralogical investigation, fine hematites and fine calciumferrites containing micropores were also suited to the structure for the same reason as above.6)

Degradation of sinter at low temperature reduction must be controlled to maintain the permeability of burdens in the shaft zone. By using synthesized samples which were made of typical sinter structures...
and single mineral phases composing these structures, the degradation mechanism was analyzed quantitatively by evaluating the crystal lattice strain which occurred in the samples and crack propagation through the samples caused by this strain.\(^7\) It was clarified from the analysis that it is possible to synthesize a suitable sinter structure having low degradation and high reducibility properties similar to the fine hematites and fine calciumferrites mentioned above.

Due to the results of the synthesis test, the diffusion bonded structure without unreacted iron ore, which exhibits low reducibility, is desirable for the new agglomerates. Reduction of the pellets is likely to be delayed at high temperature reducing conditions because dense metallic shells restricting reduction gas diffusion are formed around the partially reduced pellets.\(^8\) It is possible to improve the delay considerably by the production of self-fluxed pellets or pellets containing MgO, but the improvement seems to be insufficient for producing the most suitable burdens for blast furnace operation.\(^5\) If pellets are used as the burdens in a large quantity, it is difficult to obtain a desirable burden distribution for blast furnace operation since pellets have the characteristics of low repose angle and high bulk density due to their spherical shape.\(^9\) New agglomerates, therefore, must be composed of the diffusion bonded structure and have a shape which does not change distribution in the blast furnace substantially from that of sinter. Figure 1 shows one possibility of the new agglomerates, which is bonded together with mini-pellets limited to a diameter of less than 10 mm\(^5\).

III. Investigation of the Process

1. Raw Materials

Size distribution of raw materials for conventional agglomeration processes must be controlled respective to their processes. In order to use any kind of raw materials, the new agglomeration process uses a mixture of sinter and pellet feed as raw materials. In addition, for the purpose of improvement in the high temperature properties,\(^10\) blending coarse and fine materials at a proper ratio were considered. However, in order to decrease the unreacted ore in the agglomerate as far as possible, and to improve the reducibility, +5 mm sized ores normally used in the sinter feed were eliminated for this experiment. The new process also aimed at the production of agglomerates with low silica contents. A target level of SiO\(_2\) content in the new agglomerates was set under 5 % to obtain an improvement in reducibility.

2. Process

To produce a new agglomerate having high reducibility and low reduction degradation,\(^6\)\(^7\) and with a shape similar to sinter as shown in Fig. 1, investigations on the fine ores treatment and indurating process differing from those of the conventional agglomeration process are necessary.

As the first step, all raw materials were granulated to produce the mini-pellets block as shown in Fig. 1.

A disc type granulating process, capable of producing green pellets uniformly,\(^11\) was chosen for the new process, because the ore fines are not always granulated completely by the drum type pelletizer used in the conventional sinter process.

The adoption of the conventional traveling grate type induration system was adequate for the sintering of the green pellets taking account the shape of the final product in Fig. 1. However, since the use of the conventional sintering machine without modification is likely to break down green pellets because of rapid vaporization, a drying zone must be provided before an indurating zone.

In order to agglomerate the green pellets by combustion, carbonaceous materials were added in the granulating process, although a relatively long firing zone similar to the pellet process is not always necessary, the conventional sintering machine was utilized here.

In the case of the sinter process, suction pressure in the main blower reaches from \(-1000\) to \(-2000\) mmAq approximately,\(^12\) thus the electric power consumption of the blower accounts for about 50 % of the overall consumption.\(^13\) As the raw materials are completely granulated in the new agglomeration process, permeability in the bed is improved. It is expected that the suction pressure will be in the range of \(-400\) to \(-500\) mmAq,\(^14\) and is similar to the pellet process. Power savings are remarkable when compared with the sinter process.

The productive yield of the conventional sinter process is about 70 to 80 %,\(^15\) In the new process, however, because the agglomerates are in the shape of a mini-pellet block shown in Fig. 1, the productive yield can be expected to be higher than 90 %, the individual pellets which are broken at the bonding part in the handling process, can be used as products as long as each mini-pellet is larger than 5 mm\(^5\) in diameter.

3. Preliminary Investigation of the Production Conditions

1. Investigation of the Production Condition by Simulation

Investigations were carried out on the method of adding carbonaceous materials, drying of agglomerates on the grate, ignition, and indurating conditions by using a simulation model. On the basis of the mathematical model previously presented,\(^16\) a new simulation model considering phenomena of raw ma-
terial melting and solidification of the melt was developed for analyzing the new process. The heat wave profile in the bed influencing the properties of the agglomerate is closely dependent on the combustion rate of the cokes. Conventional simulation models have indicated that the combustion is regarded as that of a single independent coke particle, hence only gas-film mass transfer and chemical reactions at unreacted interface were considered as an elementary reaction process.

As the carbonaceous materials are distributed in the green pellets granulated by the new agglomeration process, consideration was given to
1) mass transfer resistance of gas-film around the surface of the pellet
2) diffusion resistance of the intraparticle of the pellet
3) chemical reaction resistance at the interface in the pellet.

Detailed mathematical equations, various parameters, physical constants and numerical methods for use in the model were presented in the previous paper.

Simulation results obtained from this model are shown in Fig. 2, which (1) shows a pellet with 2.8% coke fines uniformly added in the process of granulation. Figure 2 (2) shows the case of preferential coke addition, that is 3.0% in surface layer, 0.9% in core, and the overall content is adjusted to 2.8%.

Results shown in Fig. 2 indicate that the temperature of (2) in the bed, compared to (1), is higher in all zones of the bed, where other conditions are the same except in the method of coke addition. As in the case of (1) where fine coke content is uniform in the pellet, efficient combustion of fine coke is restrained by the oxygen diffusion into the pellet.

The case of (2) indicates that the combustion of fine coke is considerably efficient, concerning the oxygen diffusion rate-determining step, compared with (1), because of the preferential addition of fine coke. This can be assumed from the linear variation of the combustion \((R_m, R_b)\) shown in Fig. 2 (2).

From the results mentioned above it seems to be an effective method for the new process, differing from the pellet process, to apply a preferential fine coke coating on the surface of the green pellets in consideration of fine coke combustion within a short ignition time of about 1 min similar to the case of the sinter process.

As to the drying process, the method of down draft drying for 3 min was adopted by taking into consideration the following:

1) thermal shocks in the drying process are reduced as compared to conventional pellets due to the small sizes of the green balls;
2) decrease in bursting during the drying process because of using a relatively coarse size of raw materials in the new process as compared to that of the pellet process;
3) the necessity for a shorter drying zone to maintain high productivity.

On the basis of simulation results given in Fig. 2, drying of the green pellets was not accomplished under the conditions as mentioned above however the surface layer of the bed was dried. Conversely, the mois-
ture content of the pellet was increased by condensation of moisture originating from the upper zone of the bed. Under this situation, it is difficult to evaluate only by simulation results whether the operation can be carried out smoothly or not, it must be demonstrated experimentally.

2. Verification of Operation Conditions by Pot Grate Furnace

The new process was verified by the use of a pot grate furnace, which allows experiments under the same operating conditions as the new agglomeration process. A pot grate system made up of drying, indurating and cooling zones was set up in order to simulate the commercial plant operation. New agglomerates are produced when a green ball charged in the pot with dimension of 300 mm in diameter and 400 mm in height is transferred on a railway line through the respective zone.17)

Australian iron ore, screened to under 5 mm in size, and South American pellet feed were used as the raw materials for the experiments. The raw materials were blended at a ratio of 60 to 40 %. Fine coke obtained from the Coke Dry Quenching Plant (CDQ) was used as fuel. The blended raw materials and burnt lime as binder and basicity control (−5 mm in size, additional rate of 6 to 7 %) were charged into a V-type blender and mixed for 6 min. The mixed materials were granulated to between 5 and 10 mm φ with a 1.3 m φ in diameter disc pelletizer (revolution speed of 11 to 14 rpm, and tilting angle of 44°) by adding 8 to 10 % moisture.

In the case of uniform coke addition, fine coke (3.0 %) is mixed together with other raw materials in the V-type blender. On the other hand, in the preferential addition to green pellet surfaces, after the granulation without addition of fine coke, the green pellets were coated with fine coke by using the disc pelletizer.

Under these experimental conditions, whichever addition method of fine coke was employed, the granulation was possible in all cases. The green ball size distribution obtained in this experiment was as follows: −5 mm: 3 to 5 %, 5~10 mm: 93 to 95 %, and +10 mm: 2 to 3 %.

On the basis of the experimental results, it was clarified that granulation with the disc pelletizer can be accomplished without any problems using relatively coarse size raw materials (−44 μm=30 %) as compared with the pellet feed. The green pellet properties in the granulation process indicated a considerable drop strength of 5 to 7 times, and of the compressive strength of 0.8 to 1.0 kg/p because of using raw materials containing coarse sized ore considerably. As compared to the ordinary pellet properties,19) these are lower, but it was determined that there will be no problem since a degradation of green pellets was allowable to some extent because of the characteristics of the new process.

Figure 3 indicates the difference in the heat pattern in the bed between the uniform coke addition and the preferential addition from the pot grate furnace tests. In the case of uniform coke addition, the tempera-

![Fig. 3. Influence of method for coke addition to green ball on heating pattern of the new agglomeration process.](image-url)
as the coarse raw material. The mixing ratios and size distributions are shown in Table 1. CDQ fine coke was used as coating carbonaceous material. Burnt lime sieved to under 5 mm was used as the binder and basicity control, and the adding rate was determined at 6.5 to 7.5%.

On the basis of conditions as mentioned in Sec. 111.3.2 and indicated in Fig. 2, the following granulating and sintering conditions were determined using experimental disc pelletizer and pot grate furnace:

- Primary granulation time by 1.3 m\(^2\) in diameter disc-pelletizer: 15 to 20 min
- Coke coating time by the same pelletizer: 2 to 3 min
- Drying time and temperature: 3 min at 200 to 250°C
- Suction pressure in drying zone: 200 to 250 mm Aq
- Ignition time and temperature: 1 min at 1 000 to 1 100°C
- Suction pressure in indurating zone: 350 to 400 mm Aq

The products of the new agglomerates were subjected to shatter (SI), RI, and RDI tests in accordance with the property evaluation test for sinter. A typical chemical composition of the product is given in Table 2.

As can be seen from Fig. 4, RI and RDI, compared to commercial sinter, are superior and the influence of coke addition on them was not obvious under the present experimental conditions. Shatter index, SI (+5 mm), which indicates the strength at room temperature, was practically the same as that of the pot test sinter.

On the other hand, high temperature reduction tests under-load was performed on the new agglomerates, commercial sinter, and basic pellets to evaluate the softening and melting properties. The test conditions are as follows:

- Size of agglomerates tested: 4.97 to 7.5 mm
- Heating rate: 5°C/min
- Gas composition and flow rate: CO 30% + N\(_2\), 15 Nl/min

Test results and dimensions of the apparatus are given in Fig. 5.

Figure 5 shows that the high temperature properties of the new agglomerate are superior to pellets, concerning melting temperature and pressure drop and approximately equivalent to sinter. The new agglomerate is characterized particularly by indicating a lower value of pressure drop during the melting period.

Judging from the investigations of the properties of the new agglomerates using the raw materials as shown in Table 1, it is clear that the properties of the new agglomerates were superior to those of sinter and pellets. It is expected that the new agglomerates will make drastic improvements in the reducibility and low temperature reduction degradation as compared to the conventional ones.

### Table 1. Size distribution of raw mixtures used for the new agglomeration process. (%)

<table>
<thead>
<tr>
<th>Blended material</th>
<th>+4.76 mm</th>
<th>~2.83</th>
<th>~2.00</th>
<th>~1.00</th>
<th>~0.50</th>
<th>~0.125</th>
<th>~0.044</th>
<th>~0.044</th>
</tr>
</thead>
<tbody>
<tr>
<td>A ore (−3 mm)+P. F (40%)</td>
<td>—</td>
<td>0.44</td>
<td>4.11</td>
<td>19.06</td>
<td>12.86</td>
<td>17.07</td>
<td>17.07</td>
<td>29.44</td>
</tr>
<tr>
<td>A ore (−5 mm)+P. F (40%)</td>
<td>0.10</td>
<td>4.89</td>
<td>7.44</td>
<td>15.16</td>
<td>11.86</td>
<td>15.39</td>
<td>20.16</td>
<td>25.00</td>
</tr>
<tr>
<td>Bedding ore (−5 mm)+P. F (50%)</td>
<td>0.02</td>
<td>5.98</td>
<td>6.47</td>
<td>13.01</td>
<td>8.83</td>
<td>17.37</td>
<td>19.30</td>
<td>29.02</td>
</tr>
</tbody>
</table>

### Table 2. Chemical composition (%) of new agglomerate.

<table>
<thead>
<tr>
<th>Material</th>
<th>T. Fe</th>
<th>FeO</th>
<th>SiO(_2)</th>
<th>CaO</th>
<th>Al(_2)O(_3)</th>
<th>CaO/SiO(_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A ore (−3 mm)+P. F (40%)</td>
<td>60.23</td>
<td>0.43</td>
<td>4.10</td>
<td>6.86</td>
<td>1.99</td>
<td>1.67</td>
</tr>
<tr>
<td>A ore (−5 mm)+P. F (40%)</td>
<td>60.32</td>
<td>1.29</td>
<td>3.87</td>
<td>6.63</td>
<td>1.94</td>
<td>1.71</td>
</tr>
<tr>
<td>Bedding ore (−5 mm)+P. F (50%)</td>
<td>60.37</td>
<td>4.31</td>
<td>3.29</td>
<td>6.79</td>
<td>1.65</td>
<td>2.06</td>
</tr>
</tbody>
</table>

### Fig. 4. Comparison of qualities between new agglomerate and sinter.

### V. Discussion

#### 1. Coating Process on Green Balls with Fine Coke

The properties of agglomerates are severely affected by the heat patterns in the sintering process. The heat patterns are dependent mainly on the ignition condition, amount of fine coke, and the distribution of fine coke in the raw materials. Furui et al. reported that the combustion of fine coke was restrained as in-
crease in the finer raw mixes in sinter process. In order to improve the combustion, they propose the method of preferential addition of fine coke to the surface of quasi-particles.

A comparison of heat patterns between the new agglomeration process and sinter process by the pot tests is shown in Fig. 6. Despite the relatively small amounts of fine coke addition, the results indicate that the maximum temperature in the bed by the new agglomeration process is higher than that of the sinter process. This is partially based on the large amounts of gangue minerals in the raw sinter mixes compared to the new agglomerates, which cause endothermic reaction during melting and the use of limestone as flux which cause endothermic reaction during its thermal decomposition. However, the major cause is as reported by Furui et al.20

The new process permits coating with fine coke in the secondary granulation. The coke coating method, therefore, enables an effective combustion due to an adequate supply of oxygen to the coke on the green ball surface. In the case of the new process when using relatively large sized green balls compared to the quasi-particles in the conventional sintering process, the oxygen diffusion into the pellets containing fine coke is uniformly restrained as described in Sec. III.3.2. For this reason, a fine coke coating process is important for the new agglomeration process.

As shown in Fig. 6, a comparison in cooling rate of the new process and the sintering process in the temperature range from 1 000 to 300°C, indicates that the cooling rate for the agglomeration process is about 240 to 290°C/min and for the conventional sintering process is 165 to 280°C/min. The faster cooling rate in the new process is mainly attributed to the faster combustion of fine coke on the green balls, in addition to the total granulation and therefore improving the permeability in the bed.

Furthermore, from the view points of an improved reducibility, bonding of the agglomerates was designed.
to form calcium ferrite with relatively high reducibility in this new process, as shown in Fig. 7. In order to obtain a rigid agglomeration among the pellets by calcium ferrite bonding, the fine coke was coated so that the rapid combustion of coke on the green pellets surface can partially form calcium ferrite liquids. According to the microstructural analyses of bonding part, hematite and calcium silicate slag have been observed as mineral phases. But since SiO₂ content of product, as shown in Table 2, is low at 3.3 to 4.1 %, it was found that desirable needle type calcium ferrite partially accompanied with secondary hematite and magnetite, as shown in Fig. 7, was mainly formed.


In this section, the reason why the properties of new agglomerates were superior compared to the conventional ones was discussed from the viewpoints of microstructure and shape. Typical microstructures of the new agglomerates are shown in (a) and (b) of Fig. 8. Figure 8(a) shows a case of coke addition in relatively small amounts. It can be seen that the agglomerates are proved to be composed of diffusion bonded structures, which were established as the initial design target. As a result, production of the new agglomerates with high reducibility of RI (=87 %) was accomplished.

On the other hand, since the amount of fine coke addition is relatively increased so that the bonding of pellet blocks is strengthened to obtain a shape as similar as possible to that of the sinter, a melting type microstructure composed of columnar calcium ferrite, magnetite and secondary hematite is formed as shown in Fig. 8(b). In spite of the melting type structure, 76 % of RI can be maintained. This is because of the small amount of slag formation and pore distribution in the mineral structures. Concerning this Maeda and Ono reported that in the case of sinter, the presence of macropores enables the passing of the reduction gas and improves the reducibility.

In order to clarify the results, a mercury intrusion type porosity meter was used to measure the pore diameter distribution of agglomerates. Figure 9 shows that there were much more macropores of 10 to 100 µm in the new agglomerate as compared to the others. Moreover, pore diameter higher than 1 µm was scarcely observed in the pellet. Also, pores larger than 10 µm in the sinter were less than half of the new agglomerate. It was therefore assumed that besides mineral phases, a large number of macropores has a close relation in attaining a high reducibility in the new agglomerates.

Figure 10 indicates that the size of unreacted iron...
ore in the new agglomerates is smaller than that of the sinter, as the size of raw materials in the new agglomerates is smaller than that of the sinter. Furthermore, the attainment of high reducibility of the new agglomerates in Fig. 4 is attributed to the distribution of macropores and size of unreacted ores. Also, the unit particle size of the product is smaller than that of the conventional agglomerates. It is considered that the effects of a proper mixing rate of coarse and fine raw materials under the conditions of the present experiments as well as the firing conditions enabled the distribution of micro and macropores in the structure of the new agglomerates.

As shown in Fig. 1, the mini-pellets are bonded together in the new agglomerates. A continuous shatter strength test similar to the JIS standards was conducted to evaluate degradation during transportation. For comparison of the new agglomerates (3.5 % coke), pot test sinter (3.8 % coke) was used. Figure 11 shows that both SI plus 5 and SI plus 10 indices of the new agglomerates have lower degradation values than the sinter. It was further assumed that the sinter containing a large amount of brittle silicate slag, which weakens the structure, shows a higher degradation rate than the new agglomerates.

It can be seen from Fig. 4 that the RDI value of the new agglomerates is superior to that of the sinter. However, the phenomenon of low temperature reduction degradation of sinter, which is influenced by many factors, has not been clearly analyzed. The authors have suggested the possibility of maintaining the RDI at a low level by decreasing the formation of Al₂O₃ dissolved secondary hematite and glassy slag which is a crack propagating media in the sintering process.³³

Inazumi et al.²² indicated that the secondary hematite can be restrained by accelerating the cooling rate of the liquid phase formed in the sintering process. Shibuya et al.²³ conducted an operational analysis of the sintering process using a commercial sintering machine and pointed out that the RDI is improved when the cooling rate is accelerated by increasing the gas volume suctioned in the last half of the grate.

In the new process, it is assumed that the low RDI is attributed to the small amount of glassy slag, and the relatively high cooling rate, as compared to the sintering process caused by the improved coke addition method and the improvement of permeability in the bed.

In spite of the fact that the individual particle of the new agglomerates is shaped into pellets, Fig. 5 represents that the high temperature properties of the new agglomerate is superior to the basic pellet. Table 2 shows that the basicity of the new agglomerate, which is similar to the sinter, is higher than compared to the basic pellets. In addition to the formation of a slag with a high temperature melting point during the reduction process as mentioned above, the most important reason for the superior high temperature properties is considered to be in the shape.

In the high temperature reduction under load a dense metallic shell is likely to be formed around the surface of the conventional pellet, and the high temperature properties are deteriorated²⁴ by the low melting point slag composed mainly of wustite which is forming the core.

In contrast, it is considered that high temperature properties of the new agglomerate are superior because of the following reasons,

1. As shown in Fig. 10, the size of a single pellet is smaller (5~10 mm) compared to the conventional pellet. For this reason, the new agglomerate is reduced completely before the formation of a metallic shell.

2. Because of the coarse particles in the raw materials, volumetric shrinkage of the agglomerate is restrained as pointed out by Sugiyama et al.¹¹. As a result, large sized pores are maintained. Furthermore, the softening and shrinking behavior is equivalent to sinter, and moreover, as the low slag volume due to low SiO₂ content, the pressure drop has been kept to a low level. From the results described above it was concluded that the new agglomerates were desirable agglomerates for blast furnace.

It seems that new agglomerate blocks are broken down and separated into each pellet during the transportation process. In this case, if the burden distribution behavior in the blast furnace is similar to that of the pellet, the blast furnace operation might be deteriorated.

The repose angle between the new agglomerates and conventional ones was compared to evaluate the burden distribution. The results indicated that the repose angle of the new agglomerate was 35.8° at 5 to 10 mm, and 37.2° at a pellet block of 10 to 50 mm. The values were equivalent to those of the sinter (35.8°), showing that the repose angle was larger than for pellets (32.7°).

The difference of the repose angle is due to the shape of each unit pellet of the new agglomerates differing from the conventional pellets.

Consequently, it seems that the blast furnace operation is not deteriorated because the burden distribution behavior is nearly equal to that using of the sinter even if the new agglomerates are broken down and separated into single pellets during handling.
IV. Conclusions

In order to solve the various problems existing in the conventional agglomeration process and properties of agglomerates, a new agglomeration process was developed. Properties of the new agglomerates obtained from the process were also evaluated. The main results obtained were summarized as follows:

1) From the viewpoint of the improvement of the quality of the conventional agglomerates, a new type of agglomerates has been introduced and the burden distribution in the blast furnace has been evaluated. The structure of the new agglomerates mainly consisting of a porous microstructure with a low silica content and the product is constituted by an aggregate composed of irregularly shaped pellets limited to 5 and 10 mm in size.

2) In order to produce the new agglomerates as mentioned above, large amounts of finer iron ore, which are difficult to use in the conventional sintering process, were applied for the new process. Granulation of raw materials, coating with fine coke, drying on the grate, ignition, and indurating process were evaluated by the simulation model. In addition to this evaluation, it was verified by a pot grate furnace test that the process is commercially feasible. As compared to the conventional agglomeration processes, the new process showed that it is superior in production yield and energy consumption.

3) The new process is clearly capable of producing agglomerates with superior qualities compared to those of the conventional pellets and sinter which have essential deficiencies. These qualities are mainly based on raw material properties and production conditions.

REFERENCES

14) A. Ishimitsu: Pellet, Tatara Shobo, Tonago, (1977), 34.

Research Article