ISSN 2176-3135

EFFECT OF MICRO-PARTICLES IN IRON ORE ON THE GRANULE GROWTH AND STRENGTH[1]

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Abstract

Pelletization tests were conducted using pulverized iron ore to record changes in pellet strength by changing the volume of micro-particles and ore types. The strength of pellets when completely dried can be explained by the volume of micro-particles in ore, and the greater the volume of micro-particles, the higher the strength of pellets. The rate of increase in pellet strength by micro-particles when completely dried varies depending on the ore type of micro-particles and the strength increases in the order of pisolite, Marramamba, and hematite. Regarding the generation of pellet strength during the moisture drying process, there are two different mechanisms at work at the early stage and the last stage before complete dryness. The rise in strength at the early stage of drying is considered attributable to the increase in liquid viscosity due to the condensation of micro-particles and APD in the liquid, and the increase in strength just before complete dryness is considered attributable to the formation of solid bridges caused by the movement and rearrangement of micro-particles.

Keywords: Granulation; Moisture; Micro-particle; Anionic-polymer-dispersant.

1 *Technical contribution to the 6th International Congress on the Science and Technology of Ironmaking – ICSTI, 42nd International Meeting on Ironmaking and 13th International Symposium on Iron Ore, October 14th to 18th, 2012, Rio de Janeiro, RJ, Brazil.*

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ISSN 2176-3135

1 INTRODUCTION

Sinter is agglomerate made of fine iron ore that is cheaper than pellets and lump iron ore and is superior in terms of reducibility and dropping characteristics. For the two reasons of better production cost performance and stable operation of blast furnaces, sinter has been used in Japan as one of the main sources for blast furnace operation.

Recently in the research project on "Sintering through Designing of Composite Granulation & Bed Structure" undertaken by a group led by Kasai, MEBIOS (mosaic embedding iron ore sintering)(1-3) is under study. The main objectives of the MEBIOS sintering method are to find measures for the effective utilization of Marramamba iron ore and measures to improve sinter productivity, and by embedding pellets made mainly of Marramamba iron ore, ventilation routes are effectively formed in the sintering structure, improving the productivity of sinter. To realize this MEBIOS method, a granulation technology for producing solid pellets that do not break during transportation and on the sintering bed is sought.

We(4) conducted iron ore granulation tests using anionic polymer dispersant (hereinafter abbreviated to APD) and reported that the addition of APD increases micro-particles in granulation moisture, improving granulation. This improvement in granulation is also maintained with the dried granulated product, suggesting that the effective utilization of micro-particles using APD would produce very strong granules.

In this report, in order to clarify the mechanism whereby the use of micro-particles improves granulation, pelletization tests were conducted using pulverized iron ore to record changes in pellet strength by changing the amount of micro-particles and ore types. Furthermore, in order to clarify the mechanism of producing strength when dried, a characteristic of APD, changes in the strength of pellets in the drying process were investigated to examine the behavior of micro-particles.

2 EXPERIMENT

2.1 Specimens

The types of iron ore used for the tests are shown in Table 1. Ores A to C are Australian iron ore; ore A is alumina pisolite iron ore, ore B is low-alumina pisolite iron ore, and ore C is Marramamba iron ore. Ore D is Brazilian hematite pellet feed.

Ores A, C, and D were completely dried and sieved to achieve fine particles of smaller than 0.25 mm, and then the fine particles were pulverized to be smaller than 10 μm using a fluidized bed opposite jet mill. Furthermore, in order to achieve pulverized fine particles with different size distribution, for ore C, specimens were also prepared by pulverizing for thirty minutes using a planetary ball mill. The particle size distribution of each specimen after adjustment of its particle size and amount of micro-particles to smaller than 10 μm are shown in Table 2. Particle size distribution

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was measured using a laser light diffraction particle size analyzer, and the amount of micro-particles was measured by the Andreasen pipette method.(4)

Table 1 Chemical composition of sample ores

(mass%)

	T.Fe	Al_2O_3	SiO_2	MgO	C.W
Ore A	56.8	2.75	6.01	0.21	7.80
Ore B	58.2	1.45	5.11	0.06	9.31
Ore C	61.2	2.35	3.50	0.10	5.80
Ore D	68.17	0.42	1.09	0.10	0.53
Serpentine	5.21	2.12	53.26	34.18	12.61

Table 2 Size distribution of iron ores for granulation test.

Ore	Pulvarized method	250～100μm	100～10μm	10～1μm	-1μm	Micro-particle
A	No pulvarization	25.4	31.8	22.0	20.8	19.8
A	Jet Mill	0.0	0.0	92.8	7.2	96.7
B	No pulvarization	25.6	33.1	21.4	19.9	18.6
C	No pulvarization	18.5	26.9	22.4	32.2	20.9
C	Ball mill	8.9	24.3	32.5	34.3	37.3
C	Jet Mill	0.0	1.4	70.7	28.9	89.1
D	No pulvarization	11.9	88.1	0.0	0.0	2.2
D	Jet Mill	0.0	0.0	100.0	0.0	99.8
SP	No pulvarization	47.6	52.4	4.8	5.2	8.2

2.2 Granulation Evaluation Tests of Micro-particle Blended Pellets

In order to investigate the influence of the amount of micro-particles on the granulation of pellets and on their strength, a pellet feed with lower granulation performance, which was ore D, and various pulverized iron ore types were blended to produce pellets.

3 kg of a blended specimen was blended for one minute with a kneading machine, and then with water and APD added, it was kneaded for 4minutes. The specimen thus kneaded was then granulated for 4minutes in a drum mixer with an inner diameter of 1000 mm. The amount of APD added was a constant of 0.5 mass % as converted to weight of ore solid, and the water added varied from 7 to 15 mass %. In order to evaluate the granulation yield of adjusted pellets, the produced 600g pellets were dried up to 3.0 mass % moisture and the + 5mm yield was measured with a hand sieve. Then, to evaluate the strength of the pellets, 20 pellets of 4.75 to 6.3 mm in diameter were selected and the compressive strength was measured when they were completely dried. The fracture faces of the pellets after the compressive

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strength testing were observed using a scanning electron microscope (hereinafter abbreviated to SEM), and the distribution of micro-particles inside the pellets was directly examined.

2.3 Pellet Strength Evaluation Testing During the Drying Process

By changing the drying time of the pellets, and therefore changing the residual moisture in the pellets, the relationship between the residual moisture in the pellets and the strength of the pellets was investigated. Here, 3kinds of blending were set up.

The blended specimens were mixed for one minute each with a shearing mixer, then water and 0.2 mass % APD were added, and the specimens were kneaded for a further 2minutes. The specimens thus kneaded were then granulated for four minutes in a drum mixer with an inner diameter of 1000 mm. 200g of the pellets produced were dried at a temperature of 105ºC. The drying time was changed from 0 to 30 minutes, the residual moisture in the pellets was adjusted, and then 20 pellets of 4.75 to 6.3 mm in size were selected and their compressive strength measured.

2.4 Observation of the Behavior of Micro-particles During the Drying Process

In order to check the behavior of micro-particles in suspension during the drying process, observation was made using a transmission digital microscope. A pattern diagram of the tests is shown in Fig. 1. A suspension of 1 mass % jet-milled pulverized iron ore C was prepared and 50 μL of it was dropped onto a glass plate and spread thinly to 5 mm. By heating this suspension using a halogen lamp, the behavior of micro-particles in the drying process was observed using a transmission digital microscope. In order to check the influence of APD on the behavior of micro-particles, an observational comparison of two levels was made, one where APD was not added to the suspension, and the other to which was added 5 mass % APD.

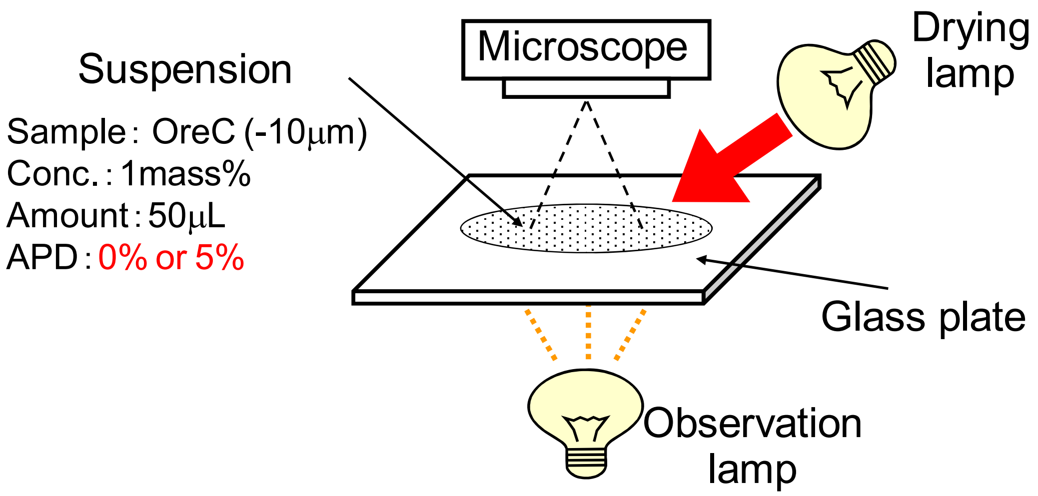

Figure1. Schematic of observation method for migration phenomena of micro-particle in drying process.

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3 RESULTS

3.1 Influence of Micro-particles in the Growth of Granules

The relationship between micro-particles and granulation moisture is shown in Fig. 2. In Fig.2, "□" represents the condition where the yield of +5 mm was less than 10 mass %, "●" represents the condition where the yield of + 5 mm was more than 10 mass % and normal pellets could be recovered, and "△" represents the condition where the specimen became slurry due to excessive moisture. It shows that the range in which pellets form is a negative correlation between the correct moisture and the amount of micro-particles is observed.

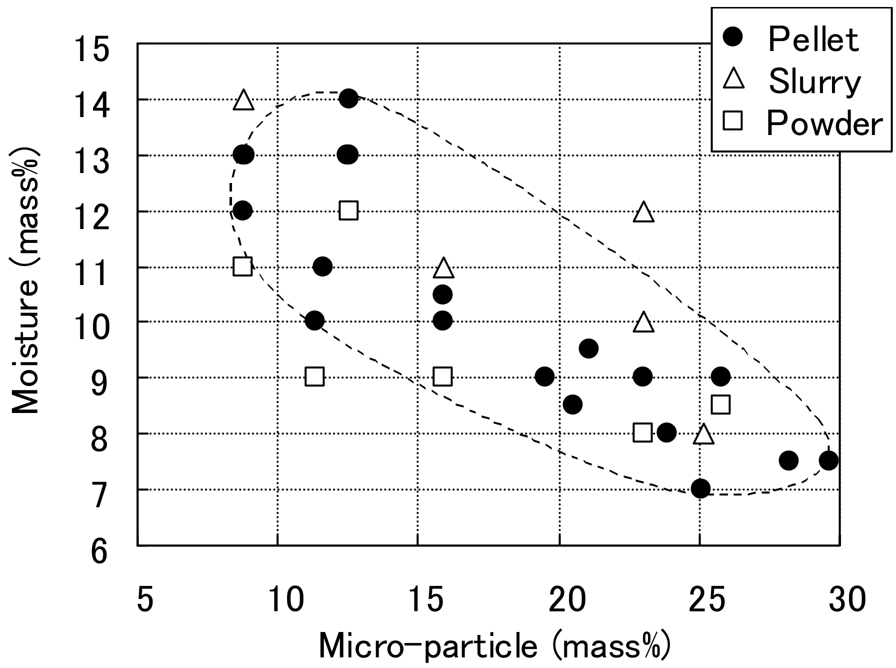

Figure 2. Relation between moisture and micro-particle.

3.2 Influence of Micro-particles on the Strength of Pellets

As an example that shows the difference in pellet strength depending on the pulverization strength, the relationship between the blending amount of iron ore C and pellet compressive strength is shown in Fig. 3, which shows that there is a trend where the higher the blend amount of iron ore C, the stronger the pellet. When comparing the difference in the method of pulverization, it was confirmed that even if the blend amount of iron ore C is more or less the same, the higher the pulverization rate, the higher the compressive strength.

The data in Fig. 3 are rearranged regarding the relationship between the amount of micro-particles and the compressive strength. The result is shown in Fig. 4, which shows that irrespective of the blend amount of iron ore C and the pulverization method, the compressive strength of pellets is primarily in the order of the amount of

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micro-particles and there is a positive correlation between the amount of micro-particles and the compressive strength. In other words, for strength in iron ore granules, the micro-particles in raw materials can be considered to be the governing factor.

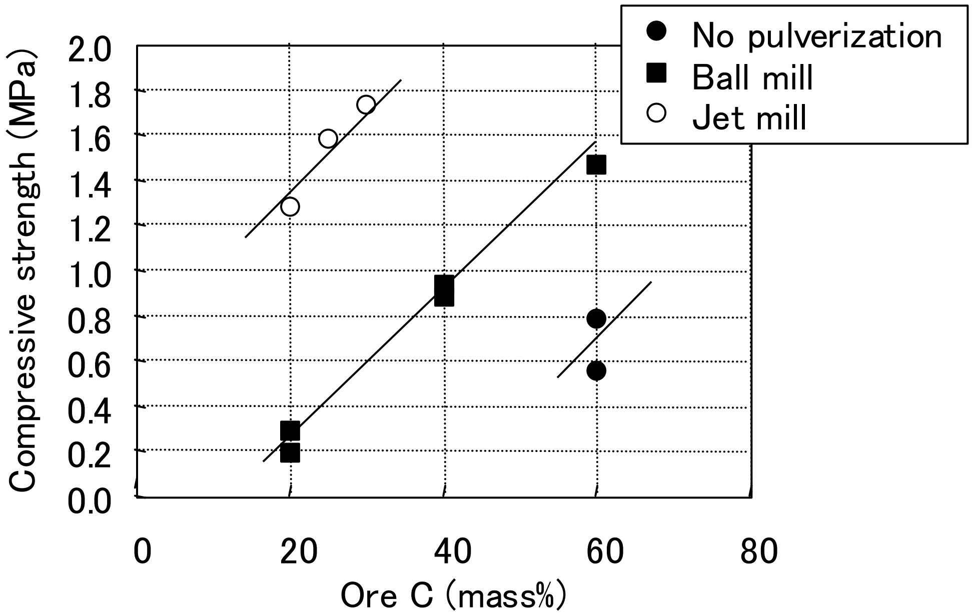

Figure 3. Relation between compressive strength and ore C in the case of ore C and Ore D granulation.

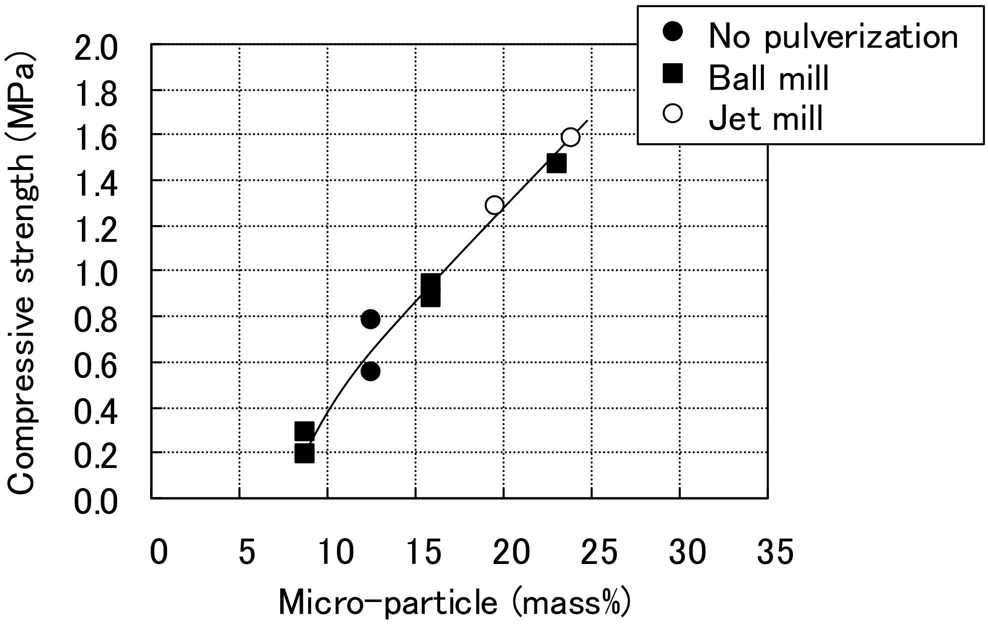

Figure 4. Relation between compressive strength and micro-particle in the case of ore C and Ore D granulation

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The relationship between the amount of micro-particles and the compressive strength as a result of all granulation tests is shown in Fig. 5. Irrespective of the blending of micro-particles of whichever iron ore, the relationship between the micro-particle amount and the compressive strength showed a positive correlation. However, the degree of influence is different depending on the iron ore blended, and when compared based on the same amount of micro-particles, the strength was in descending order of iron ore A that is pisolite iron ore, iron ore C that is Marramamba iron ore, and iron ore D that is hematite iron ore. This order corresponds with amount of gangue or ore density. The effect of gangue and density is subject of further investigations.

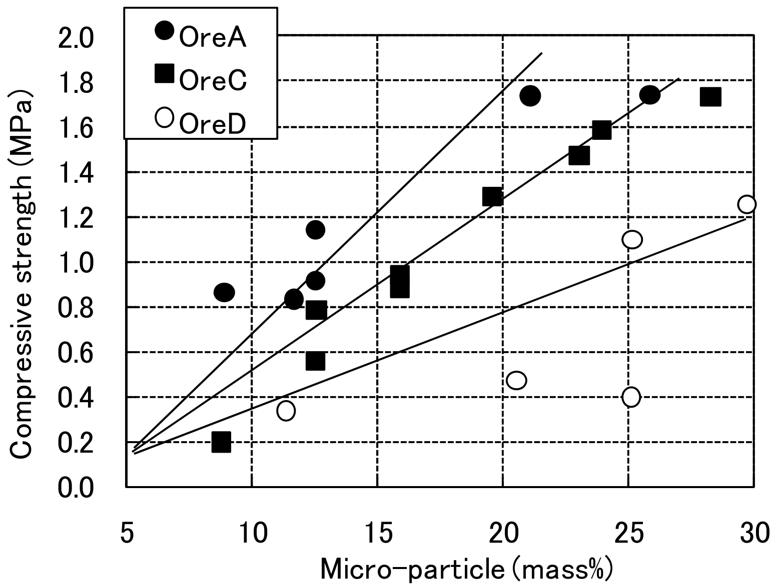

Figure 5. Relation between compressive strength and micro-particle.

3.3 Result of the Observation with SEM of the Fracture Faces of Pellets

As a representative example, SEM observations were made of pellet fracture faces for three conditions: No. 16, 60 mass % blend of Marramamba iron ore C without pulverization, No. 5, 25 mass % blend of jet-milled pulverized ore, and No. 9, 25 mass % blend of jet-milled pulverized ore of hematite iron ore D. The results are shown in Fig. 6. The fracture faces of No. 16 that had medium strength showed a stonewall-looking structure of aggregated iron ore particles comparatively large in size, and there were large voids between particles. On the other hand, as for the fracture faces of No. 5 pellets that were the strongest, the voids between iron ore particles were thickly filled in as if plastered with the mortar of micro-particles. The fracture faces of No. 9 pellets that were low in strength had the same structure as No. 5 filled in by micro-particles, but compared with the fracture faces of pellets blended with iron ore C, the fracture faces of pellets with iron ore D blend were coarse and the voids were filled in by comparatively large micro-particles. The above results indicate that

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to raise the compressive strength, it is effective to fill in the voids between particles with micro-particles.

3.4 Change in Pellet Strength Due to Drying

The relationship between the residual moisture and the compressive strength from pellet drying tests is shown in Fig. 7. Irrespective of the blending condition, the compressive strength and the residual moisture showed a certain constant relationship. All pellets were confirmed whereby the strength increased as the residual moisture decreased. There are no effects of micro-particle in this moisture range. The compressive strength showed a rather slow rising curve during the drying process of 11 mass % to 2 mass %. However, it showed a sudden steep rise during the drying process nearing complete dryness of 2 mass % to 0 mass % and the plots are separated by effect of micro-particle. As such, the rising curve of strength associated with the drying process is characterized by a slow rise at the early stage of drying, changing suddenly to a steep rise at the end of the drying process, indicating that there are different strength-generating mechanisms at work. The former mechanism is due to moisture and the latter is due to micro-particle.

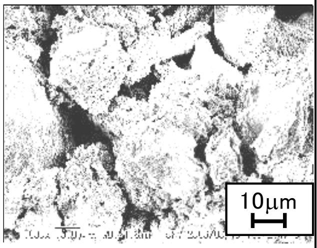
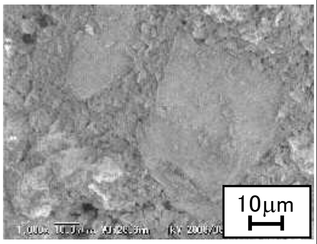
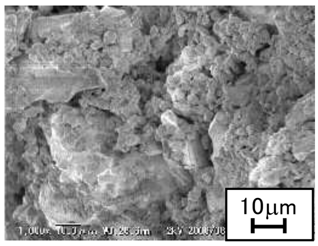
No.	16	5	9
Micro-Particle	OreC : 12.5%	OreC : 23.9%	OreD : 25.1%
Strength	0.55MPa	1.58MPa	0.39MPa
SEM image of fracture face			

Figure 6. SEM image of fracture face of iron ore pellet.

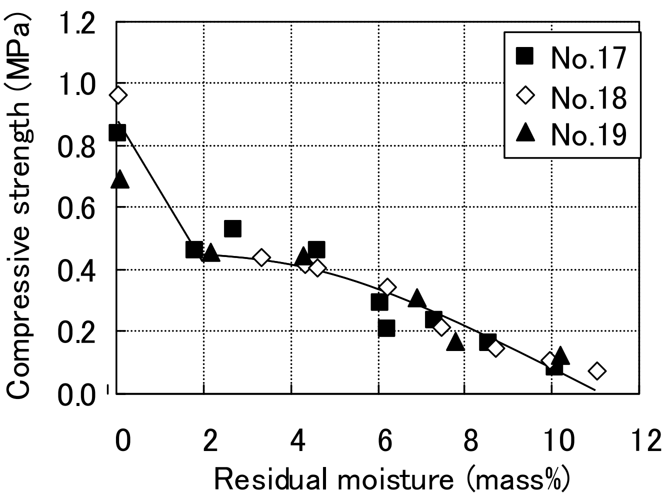


Figure 7. Relation between compressive strength and residual moisture.

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3.5 Behavior of Micro-particles in Suspension During the Drying Process

The result of the transmission microscopic observation of the behavior of micro-particles in suspension during the drying process is shown in Fig. 8. Under the condition where 5 mass % APD was added, it was observed that particles of hematite were in a long, thin cluster form of 50 to 100 μm, and that between the clusters, goethite particles exist independently. Also observed was the drifting in Brownian motion in the water of submicron particles inferred to be clay or goethite particles. At the early stage of drying, only the submicron particles were convected by liquid, and in time, the goethite particles also started moving. At the stage immediately prior to complete dryness, the hematite particles also moved, finally forming several large aggregates by their rearrangement. On the other hand, under the condition where APD is not added, hematite particles formed aggregates that took in goethite particles, and almost no floating of submicron particles in the water was observed. Even after the start of drying, no large movement of particles was observed, and at the time of complete dryness, they solidified where they were.

As a result of the above observation, APD plays the role of not only prompting the dispersing movement of submicron micro-particles as its proper function of dispersant, but also enabling the rearrangement of comparatively large particles during the final drying process.

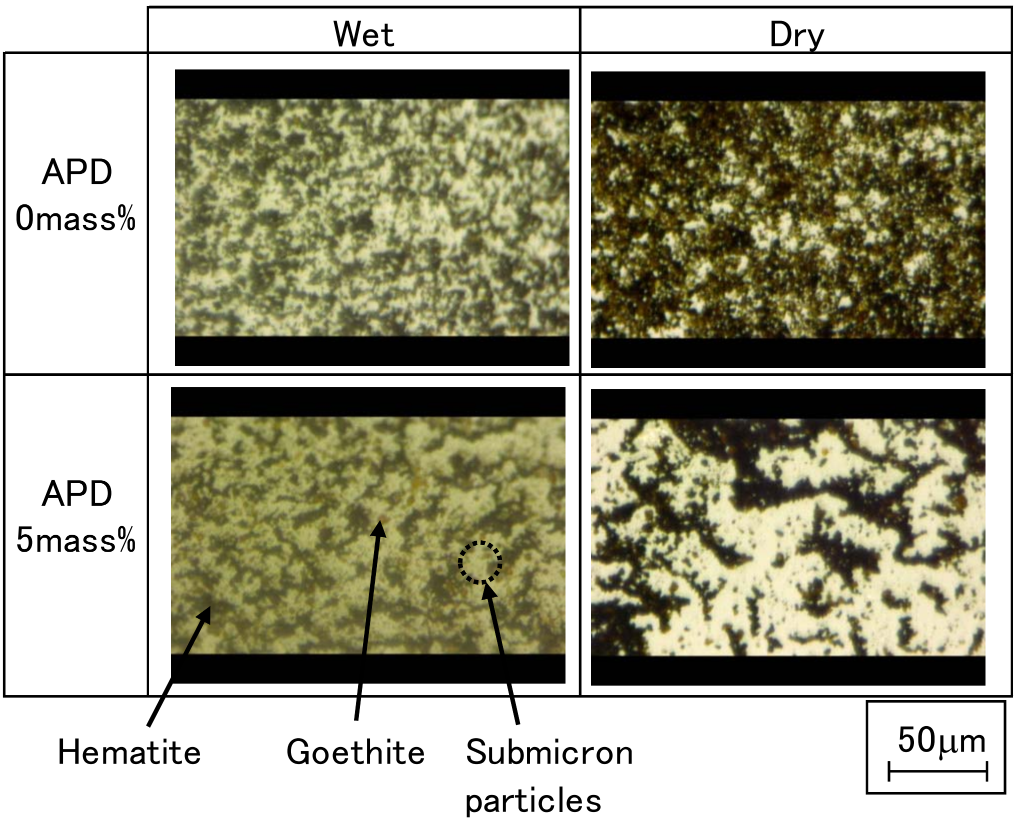

Figure 8. Observation result of suspension by transmission microscope.

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4 DISCUSSION

4.1 Mechanism of Promoting Growth of Granules by Micro-particles

The relationship between the ratio of granulation moisture volume and the ratio of micro-particle volume within the pellet formation range is shown in Fig. 9. For this purpose, the true density of water was presumed to be 1,000 kg/m^3, the same as micro-particles of 4,000 kg/m^3, and the ratio of amount was calculated for each. Between the ratio of the volume of micro-particles and the optimal granulation moisture, a negative correlation was observed and its gradient was about 1. Under the condition where APD is added, micro-particles are considered to behave as not solid which ingenerates voids but as part of effective liquid which fills in voids,[(4)], and it is presumed that the moisture needed for pelletization can be reduced.

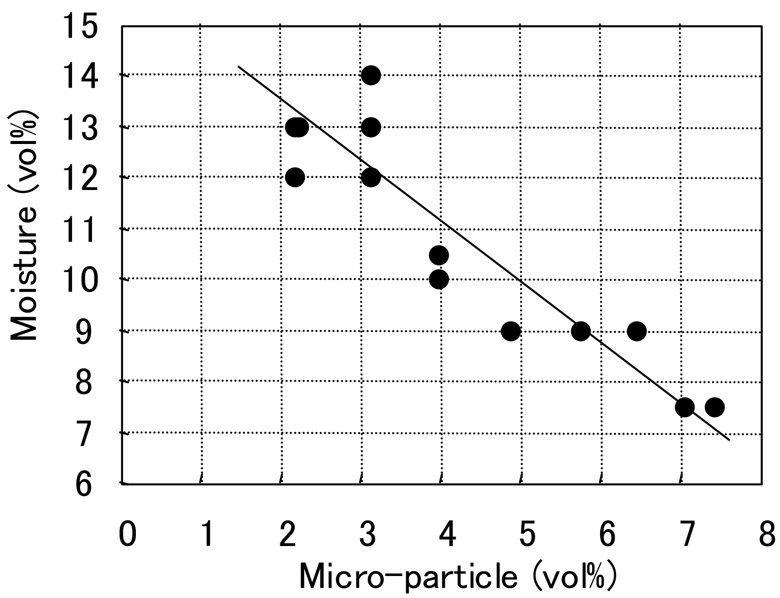

Figure 9. Relation between volumes of moisture and volumes of micro-particle.

4.2 Mechanism of Generating Strength During the Drying Process

The behavior image of micro-particles in granules during the drying process prepared based on the above result is shown in Fig. 10. Micro-particles have much to do with the strength of granules in both moist and dry conditions, and the increase in micro-particles is considered to increase the strength not only in a moist condition but also in a dry condition. In other words, by using the dispersant binder, it is possible to improve granule yield and to increase strength when dried.

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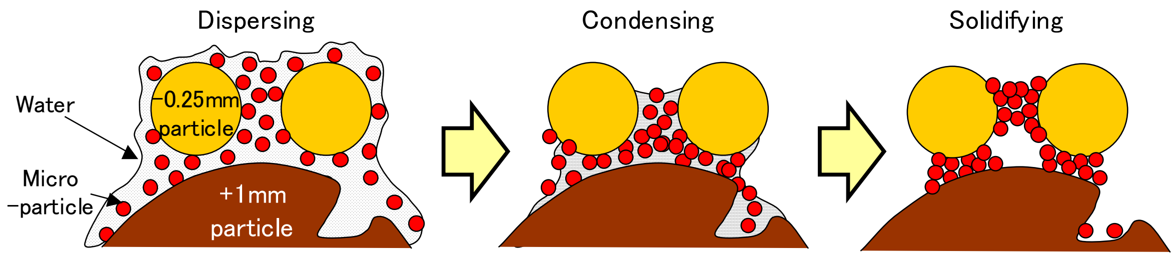

Figure 10. Migration phenomena of micro-particles in granulation.

5 CONCLUSION

We studied the iron ore granulation mechanism under the existence of a micro-particle dispersant and obtained the following knowledge:

1） The strength of pellets when completely dried can be explained by the amount of micro-particles in ore, and the greater the amount of micro-particles, the higher the strength of pellets.

2） The rate of increase in pellet strength by micro-particles when completely dried varies depending on the ore type of micro-particles and the strength increases in the order of pisolite, Marramamba, and hematite.

3） In the moist condition, since the suspension where micro-particles in dispersion behaves as the liquid, the greater the amount of micro-particles, the less the moisture needed for granulation.

4） Regarding the generation of pellet strength during the moisture drying process, there are two different mechanisms at work at the early stage and the last stage before complete dryness. The rise in strength at the early stage of drying is considered attributable to the increase in liquid viscosity due to the condensation of micro-particles and APD in the liquid, and the increase in strength just before complete dryness is considered attributable to the formation of solid bridges caused by the movement and rearrangement of micro-particles.

5） By using a dispersant binder in the granulation of iron ore, it is possible to improve the yield and strength of granules when dried.

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