Chapter III
Literature Surveys

In this present study, the effects of the change in particle shape, and flowability of ground powder are investigated. As the specification of the particle shape is based on the concept of fractal dimension. In previous researches related to this work are reported as follows.

K.Ridgway and R.Rupp (1969) reported their study on the effect of particle shape on powder properties. In their work, closely-sized batches of sand in the size ranges 18-20 mesh, 30-36 mesh and 44-60 mesh were separated into fractions of different shape by using a vibratory shape-sorting table which is originally developed for the shape classification of grinding grit in the diamond industry. The surface shape coefficient and volume shape coefficient were determined for the various fractions. The ratio of these two parameters was considered as an accepted criterion for the degree of departure of particle shape from the spherical manner. For each fraction, the following properties were measured: angle of repose , bulk density and rate of flow through an orifice. In all case, with increasing the degree of departure from the sphere, the angle of repose increased, whilst the bulk density and flowability decreased.

G.S.Riley and G.R.Mann (1972) extended the effects of particle shape on angles of repose, together with poured, tap and minimum bulk densities of a granular solid. They used glass particles of four different shapes in two size grades. The glass particles were prepared by sieving with 10/16 and 22/30 mesh. Their shape are spherical, cylinder, irregulars and flakes. Viewed under the microscope, the irregular particles showed a sharply angular outline with a jagged surface, while the flakes were straight edged, angular, with smooth flat faces. Mixtures of spherical and non-spherical particles had also been examined. From their research, it was shown that the differently shaped particles in a mixture exerted a mutual effect on the bulk behavior of the system. Both angle of repose and Hausner Ratio (the ratios of tap to poured bulk density) increased with increasing the degree of departure from the sphere, but the relationship between the two parameters is unpredictable when the particle shape became extremely irregular, as with flakes. This may be due to anomalous packing behavior. These results can offer further confirmation that Hausner Ratio is a useful characteristic of a particulate system.

S.B.Wen , C.K.Chen and H.S.Liu (1988) studied about size reduction of magnetite sand to nanometer powder in a laboratory vibration mill. On the basis of average particle size and duration of comminution , five sequential stages in the progress of size reduction can be divided , namely : (I) fine sand, (II) micrometer powder, (III) sub-micrometer powder, (IV) nanometer (single domain 30-70 nm) powder, and (V) nanometer (sub-domain < 30nm) powder. The operating conditions and powder characteristics were determined for each stage. The results showed that on the basis of the morphology of the particles and change in viscosity of the pulp (distilled water), the mode of comminution for the different stages appeared to be more or less different and possibly related to the microstructure of the test materials.

M.Suzuki , Y.Muguruma , M.Hirota and T.Oshima (1990) studied about the correlation among many kinds of quantities which were used to determine a particle shape. In their study , the profile data of particle-projected figures were fed into a personal computer using a digitizer , and then the fractal dimensions of the 28 different kinds of particles , such as glass beads, crushed glass particles, aluminum powders, calcium carbonate powder, flyash, flour, etc., were calculated using the divider method and were compared with Wadell's working sphericity and the degree of circularity (or the perimeter ratio). The results showed that the fractal dimensions of samples were correlated with circularity rather than Wadell's working sphericity. Because both fractal dimensions and circularity indicate the irregularities of particle surface. Nevertheless, the Wadell's working sphericity shows the whole shape of the particles, i.e. spherical or long and narrow. Therefore, the fractal dimension becomes a useful means for representing a particle shape as well as circularity even if the definition of the fractal dimension is quite different from the other shape indices previously used.

M.Hasegawa, T.Honma and Y.Kanda (1990) investigated the effect of mills with the same internal volume but different diameters and lengths on the rate of initial grinding in vibration ball mills. The variations of specific surface area produced with time were investigated at a constant vibration intensity using feldspar with an initial size range of 74-149 μm. The results showed that the product size distributions as well as specific surface area differed, not only with the vibration condition, but also with the mill type used even though the vibration intensities were identical. They also found that the rate of initial grinding was greatly affected by differences in the diameter of the mill. The dependence of the rate of grinding on mill diameter could be explained by considering an effective area of mill shell capable of colliding with balls and the motion of balls in each mill.

J.C.Graf (1991) applied the fractal dimension to characterize the structure of 224 lunar soil grains. The result showed that the fractal dimension could be used to successfully quantify the ruggedness of a particle, but was highly sensitive to the resolution limits. Therefore fractal interpretations without consideration of the prevailing resolution could be misleading. To obtain the fractal dimension, a particle perimeter was measured many times with many different scales of measurement. The scale of the measurement was called the stride length. With a contain stride lengths, the particle was modelled as a polygon with several hundred sides of equal length. Decreasing in the stride length resulted in an increase in the estimated perimeter.

The log-log plot of the stride length versus the perimeter estimate is called Richardson plot. The fractal dimension is $1.0+\beta$, where β is the value of the slope of the best-fit line of the plot. Sometimes one line can be drawn through all data point; It means that degree of ruggedness is the same for all the scales measured. Sometimes, particles have two fractal components with linear segments and two different slope. The linear segment corresponding to large stride lengths is called the structure while the linear segment corresponding to small stride lengths is called the texture. The interpretation of fractal structures can be linked to physical processes. A particle with different structural and textural fractal elements may have two different physical mechanisms forming two distinct values for ruggedness at different scales of observation.

Three Richardson diagrams have been made from the same perimeter measurements of the same particle profile. The diagrams appear to be very different and the interpretations seem to be contradictory. These apparent contradictions are potentially misleading, but investigators can do things to minimize the confusion. They proposed four recommendations to remedy the problem of scale sensitivity : (I) Always scale all Richardson diagrams using both absolute and Feret-normalized measures. (II) Select a consistent upper bound as the maximum stride length. (III) Use the highest possible resolution. (IV) Make interpretations with the help of physical models and physical processes

M.Otani, H.Minoshima, T.Uchiyama, K.Shichara, K. Takayashiki, and T. Ura, (1995). In their research, The effect of particle shape on the mechanical properties of powder bed, the angular stainless steel powder was processed in several steps toward sphericity by a hybridizer. Various tests were carried out with the prepared powder. It was found that the coefficients of internal friction and cohesive shear strength decreased as the particle increased in sphericity because of a decrease in the interlocking effect. It was also found that the flowability was increased with increasing the sphericity by measuring compressibility under tapping and a poured angle of repose.

T.Oshima, Y.L.Zhang, M.Hirota, M.Suzuki and T.Nakagawa (1995) have studied about the effects of the types of mill on the flowability of ground powders. In their study, five kinds of test powders of the same size made from the same raw material (limestone) were prepared by five different type of mills and classifiers. The relationship between flowability of the powder and particle shape was investigated. The circularity, Wadell's working sphericity, the fractal dimension of particle perimeters and the specific surface area ratio of the test powders were measured, and the effect of the particle shape on the flowability index was studied. The result showed that the flowability index could be correlated with the circularity, the fractal dimension and the specific surface area ratio rather than the working sphericity. This result means that the surface roughness is more effective in determining the flowability of a powder whether the macroscopic shape of a particle's perimeter is closer to a circle or not.

It is clear that the surface roughness of a particle and the macroscopic particle shape vary with the milling mechanism, which depends on the types of mill. They are effective in determining the flowability of a powder.

M. Otani, T.Uchiyama, K. Arahori and K. Shinahara (1997) investigated the preparation of differently shaped particles by grinding. Substance and a mill used in this study are Oribin sand and a disk mill, respectively. A mass of the sample was charged into the mill, and the grinding time was adjusted to prepare particles with a variety of shapes. Then, the particles obtained from grinding were separated into each size by sieving. In this study, particle shape was expressed by expanding particle outline coordinate into Fourier series. The shape index was defined as the ratio of short to long axis of the approximated ellipse. It was found that the shape index strongly depended on the charged mass and grinding time.

C.Y. Leonard and W.Page Neil (1997). studied particle shape and load effects on internal friction in powders. In their work, fractal measures of particle shape have been applied to powder with a range of commercially similar size ranges. The flow and packing properties of powders under gravity loading conditions were examined using flow time tests for known mass, apparent density and tap density. In addition to these tests, a ring shear cell provided the internal friction of approximately 0.35 MPa. Fractal measures have been found to be better discriminators of shape than conventional two-dimensional shape factors. There was good correlation between fractal measurements of particle shape complexity and the Hausner ratio as well as flow time and coefficient of internal friction.