Available online at https://ijmras.com/

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND STUDIES
ISSN: 2640 7272
Volume: 05; Issue: 02 (2022)
Doi:10.33826/ijmras/v05i02.4

POWDER PARTICLE SHAPE AND SIZE DIFFERENTIATION

Wranj Kargu[1], Garren Batceor[2].

[1,2,]*Bioresource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia.*

ARTICLE INFO.

Corresponding Author:
Wranj Kargu[1.]
Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800
Email: ran.kupta@tutanota.com

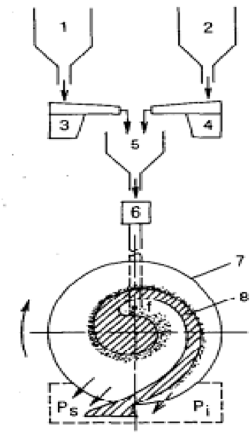
ABSTRACT

The separation of particles in keeping with shape is important for improving the standard of powder products. the form of a particle significantly affects its bulk properties. Various kinds of shape separators reported up to now are reviewed during this paper to supply useful information when choosing the foremost effective one, and also the separation mechanism and features are compared. Problems within the further development of the technique are explained.

KEYWORDS: synthetic polymer; Nano cellulose; packaging industry; laboratory PFI mill; high aspect ratio nano-cellulose fibers

INTRODUCTION

Bulk means properties of particles depend upon the properties of individual particles, like size, density, shape, cohesive force, etc. Hence, the particle quality, based not only on the scale but also on the actual property, should be controlled. so as to regulate the particle size, many separation techniques are developed and extensively used to this point in powder industries [l]. Research into particle separation supported shape, however, is at an early stage, in spite of its significance in improving the standard of powder products PI* In the present article, the form separation techniques reported up to now are reviewed so as to check their separation mechanisms and features. Problems and future subjects in developing the techniques are discussed. Shape separation methods The difference within the dynamic behavior of particles may be utilized within the separation on the idea not only of shape but also of the opposite criteria. Since the dynamic behavior of particles depends on the form, size, density, etc., and a mixture thereof, particle separation supported a specific single property is difficult generally. Hence, within the shape separation of particles, a dynamic characteristic predominantly full of the particle shape is employed while keeping the opposite factors unchanged. the form separation methods proposed thus far are often classified into four groups which make use of the difference in 1) the particle velocity on a tilted solid wall, 2) the time the particles desire labor under a mesh aperture, 3) their cohesive force to a solid wall, and 4) their settling velocity in liquid. within the following, the separation mechanism and features of assorted methods are going to be explained. Shape separation by tilted plate This method is one that the most elementary and straightforward and lots of shape separation methods proposed to date belong to This category. As observed by Yamamoto et al. [3], Nakagawa et al. [4], and Furuuchi et al. [5], in this method particles tend to be separated per the flatness of the scene of the moving particle. The shape separation appears applicable particularly for round particles that roll on the plate but not for flat particles that slide on that [5]. particle velocity because of the particle shape. Hence, the plate is typically tilted by some degrees to forestall particles from sliding or jumping. The tilted rotating disk, the tilted rotating cylinder, and therefore the tilted vibrating trough are devised for utilization. The lower limit to the particle size in these shape separators is also some hundred PM because small particles become vulnerable to agglomerate thanks to the influence of the humidity and also the cohesive force between them. Tilted rotating disk The trajectory of particles fed onto the middle of a tilted or conical disk rotating at an occasional speed (< 10 rpm) changes in keeping with the particle shape. Spherical particles go down faster while non-spherical ones stay longer on the disk [7-211. Figure 1 shows a schematic diagram of the form separator devised by Yamamoto et al. [12], which having of a named glass disk, hoppers, and vibratory feeders. The binary mixture of spherical and non-spherical particles is continuously fed onto the purpose f near the disk center and scraped by a logarithmic spiral curved scraper placed on the disk. Rounded and non-rounded particles are collected sequentially in reservoirs P, and Pi. The disk inclined usually ranges from 3 to 7” and various range of particle scrapers are devised: Viswanathan et al. [17] and Aravamudhan et al. [18] used a plate scraper and Riley [8] and Klar



1 Hopper for spherical particles
2 Hopper for non-spherical particles
3,4 Electric vibratory feeder
5 Collecting vessel
6 Electric vibratory conveyor
7 Inclined rotating disk
8 Stationary spiral scraper
P_s Spherical particle products
P_i Non-spherical particle products

Fig. 1. The tilted rotating disk with a logarithmic-spiral scraper.

Wranj Kargu[1] *Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800*

it's hard to separate and collect particles at the identical time within the lower a part of the disk. Contrarily, the conical disk can separate particles everywhere on the disk in order that the separation capacity becomes large and separated particles are collected at any position along the disk edge [15, 16, 19, 201. Klar [9] continuously separated atomized copper particles of #140 _ #200 into 95% of spherical particles and therefore the remainder of non-spherical ones with a capacity of 14 kg/day. Since non-spherical particles are apt to maneuver randomly on the tilted disk and hence are trapped within the flow of spherical particles, the separation procedure should be repeated to realize high accuracy [14] an analogous sort of shape separator, a tilted belt conveyor, has recently been devised [22]. Tilted rotating cylinder The duration of particles in a very tilted, rotating cylinder could also be associated with the particle shape [23, 241. Figure 2 depicts the form separator devised by Waldie [25] The cylinder is gradually tilted to position B and spherical particles emanate. Before non-spherical particles reach the lower end, the cylinder is returned to the initial position A. This procedure is repeated employing a cam mechanism. A baffle shown in Fig. 3 is ready within the cylinder to agitate the particle flow and hence eliminate the effect of interaction among particles. Figure 4 shows a shape separator consisting of a tilted cylinder with a bottom cover and a row of tilted blades attached to the within wall [4, 261 Particles having positive net velocity toward the upper end emanate of the cylinder, leaving the others within the bottom. for every particle, there exists a critical rotational frequency of the cylinder above which

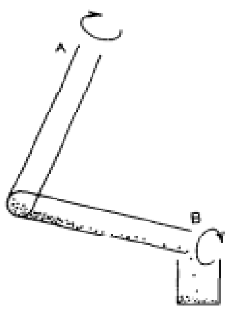


Fig. 2. The tilted rotating cylinder driven by a cam mechanism. (A) Charge and return position. (B) Separating position.

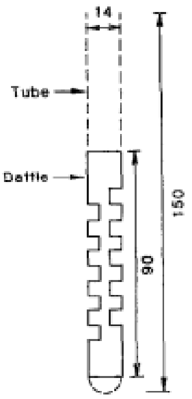


Fig. 3. A baffle inserted in the cylinder shown in Fig. 2.

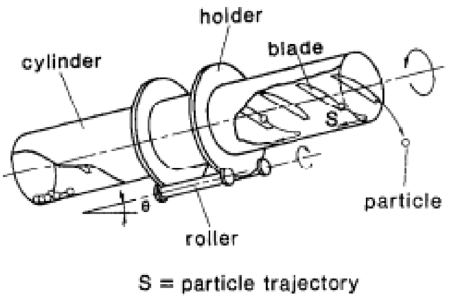


Fig. 4. The tilted rotating cylinder with a raw of blades.

the Tilted vibrating trough Abe et al. [29] devised a shape separator utilizing the difference within the particle motion on a tilted vibrating trough shown in Fig. 5. A brass open channel, 6 cm wide and 23 cm long, is mounted on a vibrator with an inclination angle (Y. The trough is vibrated within the direction of the angle p with a frequency of 60 Hz. The amplitude is regulated at 132 pm to stop particles from jumping. a mix of spherical and non-spherical particles is fed continuously onto the vibrating trough through a slit placed at -5 mm above the underside plate. The particle size is within the range of 210 to 1190 pm. in line with the coefficient of static friction, the particle velocity on the trough becomes positive or negative as shown in Fig. 6. Solid curves in Fig. 6 . Since the coefficient of static friction depends on the particle shape, particles are often separated supported shape by adjusting the operational conditions of the trough. consistent with the numerical analysis by Shinohara et al. [31] for the particle motion on a tilted

Wranj Kargu[1] *Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800*

vibrating plate, the rate and also the moving direction of the particle rely on its size and ratio and

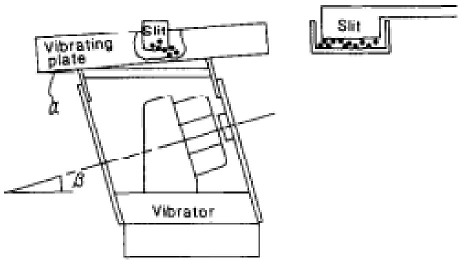


Fig. 5. The tilted vibrating trough.

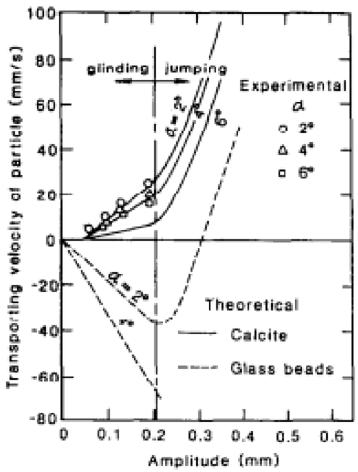


Fig. 6. The relation between the transporting velocity of particles and the amplitude of the vibration. Solid curves denote the theoretical results by Taniguchi *et al.* [30].

The wall friction similarly because the vibratory condition. Particles having a side ratio but about 0.7 will be separated, which can't be done by the separation methods mentioned previously. Figure 7 depicts the tilted vibrating trough employed by Ridgway et al. [32, 331 and Lenn et al. [34], which was originally designed for sorting industrial diamond crystalline (Jeffrey-Galion Ltd., Johannesburg). It consists of a triangular matt surfaced deck with a little slope to the horizontal and a bigger slope to the vertical. Particles are fed by a vibratory feeder into one corner of the deck and move across it by gravity and therefore the deck vibration, following different trajectories consistent with shape. Spherical particles leave the deck at the lower point of the correct edge, while irregular ones leave at the upper point. The particles are collected in 13 pots placed next to the deck so as to classify them into various shapes. Iwata et al. [35] made use of the form difference within the particle trajectory on a horizontal circularly vibrating disk with a peripheral wall (Fig. 8). Non-spherical particles, fed between the wall and also the circular sink at the middle, move toward the wall then along the wall to the direction inverse to the vibration, while spherical ones with higher outward velocity rebound from the wall to the sink, where they're captured. The circular vibration could also be a good way of dispersing the particles.

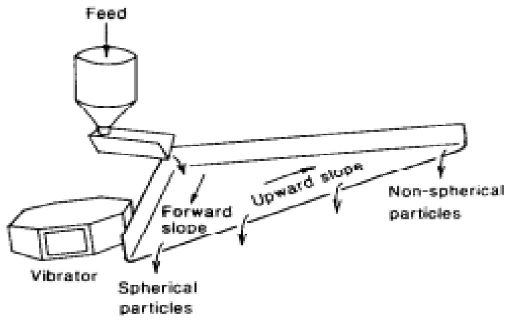


Fig. 7. The Jeffrey–Galion shape-sorting table.

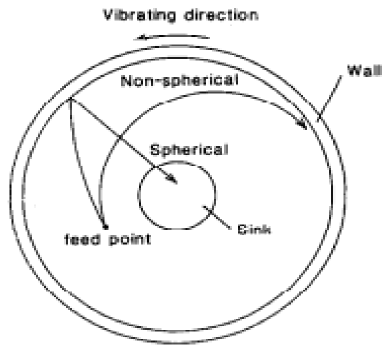


Fig. 8. The horizontal circularly vibrating disk.

Tilted chute In the shape separators mentioned above, the solid the wall is tilted only by some degrees so on prevent particles from sliding or jumping. In contrast, Glezen et al. [36] utilized the jumping motion positively. As shown in Fig. 9, the form separator consists of a feed hopper, chute A with gate, deflector, one collector vial, chute B with gate, deflector, and two collector vials. Each chute is created of six long narrow passages shown in Fig. 10. the fabric of the chute floor and walls is aluminum sand-blasted to the feel of 600-grit abrasive material. The slopes of chutes A and B are respectively 26.0 and 18.5”, which are much larger than those of other shape separators. Particles fed from the hopper through the gate bounces up and down and collides with the wall repeatedly while flowing downwards due to

Wranj Kargu[1] Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800

gravity. Flatter particles are unlikely to bounce and skill higher friction on the wall that the descending velocity becomes lower. Particles that traverse chute A in additional than 10.3 s are classified as tabular; particles that traverse chute A in but 10.3 s and traverse chute B in but 12.5 s are classified as spherical, and therefore the others as intermediate. it's said that the device is applicable to any particle larger than 0.35 mm.

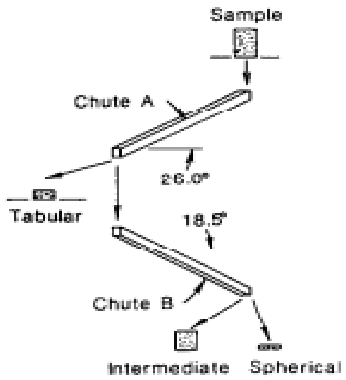


Fig. 9. Shape separation by tilted chutes.

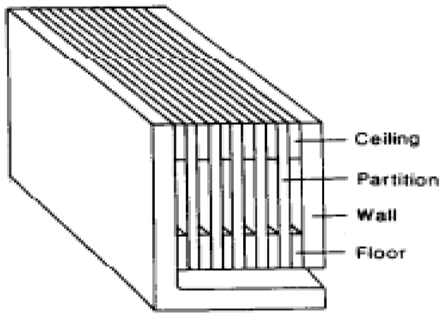


Fig. 10. Chute battery.

S Shape separation by sieves Shape dependency on the time required for a particle to have a mesh aperture has been reported [37-43]. Because the particle elongation increases, for example, the passage time increases because the elongated particle takes a protracted time to vary its orientation and tolerate the mesh aperture. The relation between the particle shape and therefore the passage time has been investigated by Ludwick et al. [38], Roberts et al. [39], Endoh et al. [41, 42, and Nakayama et al. [43]. Endoh et al. [41, 42 concluded that the speed for a cylindrical particle to suffer the oblong mesh screen is inversely proportional to the cubic power of the particle elongation (length) /(diameter). The passage rate, however, is additionally suffering from the operational conditions of sieves like the vibratory waveform and also the shape of the sieve opening. Hence, the relation between the particle shape and therefore the passage rate is set experimentally. Although this separation method is often applied to a good range of particle sizes, very cheap limit may exist due to the choking of the particles on the screen. The particle size should be made more uniform than that within the shape separators of the tilted plate type. a combination of spheres and elongated or flat particles, also as a mix of elongated particles, is also easily separated by this method.

TILTED VIBRATING SCREEN

Figure 11 depicts the form separator reported by Hsyung et al. [44] and Monts et al. 1451 which consists of an inclined screen, particle collectors aligned under the screen, an oscillator, an amplifier, and a vibrator. Particles fed onto the upper end of the screen flow down by gravity and vibration. Spherical particles prone to withstand the screen are collected upstream while elongated ones flow toward the lower end and are collected. The relation between the gap from the feed point and also the average shape of particles collected at the corresponding distance is shown in Fig. 12, where VAR denotes the moment of the radius of the particle profile about its centroid [46]

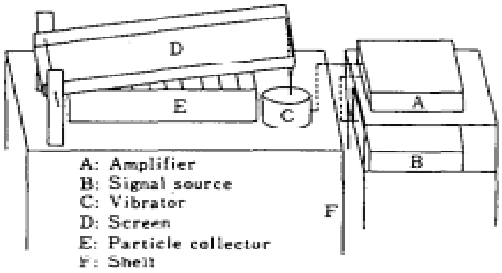


Fig. 11. The tilted vibrating screen.

vibrating stacked screens Meloy et al. [47, 481 and Clark et al. [49] proposed a brand new device to live the form distribution of particles. The device, called a sieve-cascado graph, consists of a stack of identical screens placed in an

Wranj Kargu[1] Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800

exceedingly sieve shaker (see Fig. 13 [49]). The stack of 20 sieves is employed [47-49]. Previously sieved sample particles are poured into the highest sieve and also the shape distribution is decided by measuring the rate of flow of the particles at the underside sieve. As shown in Fig. 14 [49], the continuance of spherical particles within the stack is way but that of elongated ones, in order that the mixture of those particles will be separated. Whether or not the form difference is little, increasing the amount of sieves gives rise to a rise within the separation efficiency. As will be seen from its separation mechanism,

Only the batch operation is applicable. Orr [50] investigated the particle flow through a vibrating vertical column loosely filled with glass beads to work out the influence of the particle size and shape on the speed of passage. The continuance of particles is also associated with the space traveled by the particles through the column also because the particle size and shape and also the void size. the tactic might also be used for the form separation of particles. Rotating cylindrical sieve A rotating cylindrical sieve is employed for separating elongated zinc particles on the premise of the ratio [51, 521. The particles fed into the horizontal drum are separated per duration. Longer particles are collected at a later period of your time. it should be a merit of the sieve drum that in the operation, lodged particles can easily be removed. Continuous separation may be conducted by tilting the sieve, where the particles continuously fed from the upper end of the drum are separated consistent with the ratio [511. Particle holding or adhesion methods Sano et al. [53, 541 recently developed a replacement shape separator. As shown in Fig. 15, the separator consists of a drum with circular holes of 0.3 mm in diameter, whose inside is split into the inhaling section A and therefore the exhaling section D. Particles fed from the hopper are spread on the drum and survived the holes by the air suction as shown within the magnified figure. Spherical particles are held more tightly than non-spherical ones due to the narrower gap between the particle and therefore the hole. Making use of the difference within the particle holding force, particles may be separated in step with shape. The non-spherical particles are dismissed by brush B and picked up into reservoir C while the spherical ones are carried to section D, blown off, and picked up into reservoir E. The separation accuracy is decided by the suction pressure in section A. By keeping the pressure above 20 mmH, O, the mixture of spherical glass beads and non-spherical crushed ones of #40 _ #45 in size was efficiently separated. The surface roughness of particles similarly as their elongation or flatness may affect the performance of the form separator. The adhesion force of particles to a solid wall increases with increasing particle sphericity at a relentless humidity, as reported by Sano et al. [55] (see Fig. 16), in keeping with whom the adhesion force of irregular particles onto the solid wall is unstable as a result of the little effective contact area. Sano et al. [56] devised a shape separator shown in Fig. 17 which utilizes the form dependency of the particle adhesion force. A glass cylinder of 0150~ 120 mm is rotated at 4 rpm and vibrated by an electrical magnet with an amplitude of 0.35 mm and a frequency of fifty Hz. The mixture of spherical and non-spherical glass beads fed from a hopper is spread on the cylinder. The non-spherical particles crumple into reservoir ages the spherical ones carried on the cylinder are brushed aside and picked up into reservoir B. Since the humidity and also the temperature affect the adhesion force, they need to be adjusted so on make it large It should be noted that the form separator can efficiently separate particles smaller than 100 pm in diameter. The separation performance is sensitive to the humidity and temperature of the atmosphere and therefore the contamination of the cylinder wall therefore the operation is incredibly hard in practice, though this is often a general problem encountered in any process managing fine particles. Settling velocity methods Particles settling in an exceedingly fluid experience the drag force. The coefficient of drag C depends on the particle shape likewise because the particle Reynolds number Re as shown in Fig. 19 [57]. For a spherical particle settling under Stokes’ condition (Re -=z l), Davies [58] theoretically obtained the relation between the ratio of the spheroid and

Wranj Kargu[1]. *Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800*

therefore the dynamic shape factor K as depicted in Fig. 20 where K = VJV, R = (major axis)/(minor axis), V is that the velocity of a sphere of the identical volume because the spheroid and V is that the velocity of the spheroid. As may be seen in Fig. 19, the speed becomes smaller for the flatter or elongated particle with the identical volume. Hence, the particles is separated consistent with the difference within the settling velocity. It should be noted that a spherical particle doesn't always settle faster than a non-spherical one whether or not it's the identical size because the settling velocity of the particle depends not only on the coefficient of drag but also on the mass and projected area within the settling direction. within the Stokes region, the settling velocity becomes smaller for particles with irregular surfaces [58]. The effect of the particle orientation caused by the speed gradient can't be ignored within the flowing fluid. the tiniest size separable is proscribed by the formation of colloids or agglomerates. in essence, particles of some PMs in size will be separated. Figure 21 shows the form separator developed by Murali et al. [59]. It consists of an oblong channel B, a pump J, a sump H, and a fine wire mesh D to rectify the flow direction.

Sample particles funneled into the liquid at a brief distance from the mesh rectifier settle along some trajectory to the underside of the channel, where they're collected in funnels E and removed in an exceedingly batch or continuous mode. A binary mixture of round (mustard seeds) and non-spherical (silica gel) particles, both of which are sieved to the typical size of 1.5 mm, is separated.

Typical results are listed in Table 1. Most non-spherical particles are collected within the first funnel, and spherical ones within the downstream funnels, mainly within the second. The recovery efficiency of every particle and therefore the overall separation efficiency are addicted to the flow of water and also the height of the feed funnel. the efficiency is comparable that of the tilted rotating disk separator devised by Aravamudhan et al. [18] who used the identical particles. The apparatus might be improved to realize more accurate separation of the particle shape by setting variety of narrower funnels on the channel floor. The hydroclone was recently used for the form separation of fine particles with a diameter lo- 100 pm. Conclusions Fig. 21. Basic construction of the continual settler: A=feed funnel; B=channel; C=inlet for liquid; D =rectifier mesh; E= collection funnels; F = V-notch weir; G = liquid outlets; H = sump; J = circulation pump. TABLE 1. Results of shape separation of binary mixtures of spherical and non-spherical particles using the continual settler flow Collection (g) (cm' s-l) First funnel Second funnel Spherical Non-spherical Spherical Non-spherical 285.2 5 17 12 8 281.5 3.5 20.5 9.5 2.5 277.7 6 21 14 8 253.6 4 17 11 5 240.4 11 23.5 8 3 223.2 5.5 21 7 4 216.6 8 30 6.5 2 203.9 8 22 6.5 1.5 185.2 8 24 6.5 1.5 138.8 10 23 4 0.3 127.8 7 23 2.5 0.6 106.4 7 19 4 0 Feed rate =2.0 gs -'; feed amount=50 g; feed ratio 1:l; feed at the water surface. in funnels E and removed in a very batch or continuous mode. A binary mixture of round (mustard seeds) and non-spherical (silica gel) particles, both of which are sieved to the common size of 1.5 mm, is separated. Typical results are listed in Table 1. Most non-spherical particles are collected within the first funnel, and spherical ones within the downstream funnels, mainly within the second. The recovery efficiency of every particle and also the overall separation efficiency are addicted to the rate of flow of water and also the height of the feed funnel. the general efficiency is comparable that of the tilted rotatingdisk separator devised by Aravamudhan et al. [18] who used the identical particles. The apparatus may be improved to realize a more accurate separation of the particle shape by setting variety of narrower funnels on the channel floor. The hydroclone was recently used for the form separation of fine particles with a diameter lo- 100 pm and blocky mica particles were separated from flaky ones [60]. Various shape separators proposed to date are summarized and compared. The separation performance of the form separators has been explained by employing a single shape descriptor measured from one direction despite the actual fact that the particles are separated on the premise of the three-dimensional form and various physical properties. Hence, the difference within the performance

Wranj Kargu[1] *Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800*

between shape separators remains unknown so it's impossible to decide on the simplest method whether or not the form characteristics of particles are given. Although the authors tried to elucidate the features of every shape separator, most descriptions maybe just a presumption. For practical applications, the features and merits of every separation method should be specified more clearly. Using the form separators proposed to date, a large range of particles is separated. However, new separation techniques supported a unique principle should be developed so as to unravel extensive problems within the shape separation of particles. The high-speed shape separation of particles with sizes but 100 pm is also important for practical applications.

REFERENCES

1. J. K. Beddow, Chem. Eng., 10 (1981) 7.
2. J. K. Beddow, Particle characterization in Technology, vol. 2, CRC Press, Boca Raton, FL, 1984.
3. K. Yamamoto and M. Sugimoto, .I. Sot. Powder Technol. Jpn., 22 (1985) 3.
4. M. Nakagawa, M. Furuuchi, M. Yamahata, K. Gotoh and J. K. Beddow, Powder Technol., 44 (1985) 195.
5. M. Furuuchi, E. Ohno and K. Gotoh, A&. Powder TechnoZ., I (1990) 89.
6. K. Shinohara, Powder Technol., 48 (1986) 15.
7. F. G. Carpenter and V. R. Deitz, J. Res. Nat. Eur. Stand., 47 (1951) 139.
8. G. S. Riley, Powder Technol., 2 (1968/69) 315.
9. E. Klar, Powder Technol., 3 (1969/70) 313.
10. M. Sugimoto and K. Yamamoto, .I. Res. Ass. Powder Technol. Jon., 8 (1971) 35.
11. M. Sugimoto; K. Yamamoto and J. C. Williams, J. Chem. Eng. Jpn., 10 (1977) 137. K. Yamamoto and M. Sugimoto, .I. Sot. Powder Technol. Jpn.,
12. K. Yamamoto and M. Sugimoto, .I. Sot. Powder Technol. Jpn., 16 (1979) 521. S. Endoh, Y. Kuga,
13. J. Koga and K. Yamaguchi, Kagaku Kogaku Ronbunshu, 8 (1982) 476. S. Endoh and K. Yamaguchi, J. Chem. Eng. Jpn., I7 (1984) 21. K.
14. Yamamoto and M. Sugimoto, J. Sot. Powder Technol. Jpn., 22 (1985) 626.
15. (1979) 521. S. Endoh, Y. Kuga, J. Koga and K. Yamaguchi, Kagaku Kogaku Ronbunshu, 8 (1982) 476. S. Endoh and K. Yamaguchi, J. Chem. Eng. Jpn.,
16. (1984) 21. K. Yamamoto and M. Sugimoto, J. Sot. Powder Technol. Jpn., 22 (1985) 626.
17. K. Yamamoto and M. Sugimoto, .I. Sot. Powder Technol. Jpn., 22 (1985) 813.
18. K. Viswanathan, S. Aravamudhan and B. P. Mani, Powder Technol., 39 (1984) 83. S. Aravamudhan, N. Premkumar, S. S. Yerrapragada, B. P. Mani and K. Viswanathan, Powder Technot., 39 (1984) 93.
19. M. Sugimoto, Funsai, 31 (1987) 40.
20. K. Yamamoto, T. Tsukada and M. Sugimoto, J. Sot. Powder Technol. Jpn., 26 (1989) 12.
21. K. Yamamoto and M. Sugimoto, Proc. Spring Meet. Sot. Powder Technol. Jpn., Kyoto, May 30-31, 1989, pp. 18.
22. H. Ohya, S. Endoh, M. Yamamoto, H. Iwata and H. Nakamura, Proc. Spring. Meet. Sot. Powder Technol. Jpn., Kyoto, 1991, pp. 183.
23. M. Furuuchi and K. Gotoh, Proc. 15th Fine Particle Sot. Meet., Orlando, FL, July 28-31, 1984, pp. 74.
24. M. Furuuchi, E. Ohno and K. Gotoh, Adv. Powder Technol., 1 (1990) 101.
25. B. Waldie, Powder Technol., 7 (1973) 244.
26. M. Furuuchi, M. Nakagawa, M. Suzuki, M. Tsuyumine and K. Gotoh, Powder Technol., 50 (1987) 137.
27. M. Furuuchi and IL Gotoh, Powder Technol., 54 (1988) 31.
28. Ph. H. Kuenen, Developments in Sedimentology, vol. 1, Elsevier, Amsterdam, 1964, pp. 207.

Wranj Kargu[1] *Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800*

29. E. Abe and H. Hirosue, J. Chem. Eng. Jpn., 15 (1982) 323.
30. Taniguchi, M. Sakata, Y. Suzuki and Y. Osanai, Trans. Sot. Mech. Eng. Jpn., 28 (1962) 485.
31. K. Shinohara, T. Maenami and T. Tanaka, Part. Sci. Technol., 4 (1986) 161.
32. K. Ridgway and R. Rupp, J. Pharm. Pharmac., 21, suppl. (1969)30.
33. K. Ridgway and J. B. Scotton, Sedimentology 20 (1973) 263.
34. C. P. Lenn and C. B. Halt, in N. G. Stanley-Wood and T. Allen (eds.), Particle Size Analysti 1981, Wiley Heydon, 1982, pp. 233.
35. H. Iwata, H. Ohya, K. Masuda, M. Yamamoto and S. Endoh, Proc. Spring Meet. Sot. Powder Technol. Jpn., Kyoto, May 28-29, 1991, pp. 178.
36. W. H. Glezen and J. C. Ludwick, J. Sediment. Petrol., 33 (1963) 23.
37. G. Rittenhouse, Znd. Eng. Chem., 15 (1943) 153.
38. J. C. Ludwick and P. Henderson, Sedimentology, I1 (1968) 197.
39. T. A. Roberts and J. K. Beddow, Powder Technol., 2 (19681 69) 121.
40. Y. Nakajima, W. J. Whiten and M. E. White, Trans. Inst. Min. MetalL Sect. C, 87 (1978) 194.
41. S. Endoh, J. Koga and K. Yamaguchi, .I. Sot. Powder Technol. Jpn., 20 (1983) 8.
42. S. Endoh, J. Koga and K. Yamaguchi, Kona, 2 (1984) 7.
43. S. Nakayama, T. Shibata and K. Yamaguchi, Proc. 25th Forum on Powder, Sapporo, 24-26 Sept., 1987, pp. 188.
44. N. B. Hsyung, J. K. Beddow and A. F. Vetter, Proc. 8th Powder and Bulk Solids Con$, Rosemont, IL, 1983. 45 K. W. Monts, J. K. Beddow and A. F. Vetter, Proc. 9th Powder and Bulk Soli& Con$, Rosemont, IL, 1984. 46
45. A. F. Vetter and P. A. Swanson, Part. Sci. Technol., 1 (1983) 127.
46. T. P. Meloy, N. N. Clark, T. E. Dumey and B. Pitchmani, Part. Sci. Technol., 2 (1984) 259.
47. T. P. Meloy, N. N. Clark, T. E. Dumey and B. Pitchmani, Chem. Eng. Sci., 40 (1985) 1077.
48. N. N. Clark and T. P. Meloy, Powder Technol., 54 (1988) 271. 50 C. Orr, Powder Technol.,(1987) 217.
49. M. Furuuchi, C. Yamada and K. Gotoh, Proc. 2nd World Cong. Part. Technol., Kyoto, Sept. 19-22, 1990, p. 151.
50. M. Furuuchi, C. Yamada and K. Gotoh, submitted to Powder Technol.
51. S. Sano and S. Yashima, Proc. Spring Meet. Sot. Powder Technol. Jpn., Osaka, May 26-27, 1987, p. 1.
52. S. Sano and M. Nikaidoh, Proc. 2nd World Cong. Part, Technol., Kyoto, Sept. 19-22, 1990, p. 214.
53. S. Sano, F. Saito and S. Yashima, Kagaku Kogaku Ronbunshu, 10 (1984) 17.
54. S. Sano and S. Yashima, Proc. Spring Meet. Sot. Powder Technol. Jpn., Osaka, May 26-27, 1987, p. 5.
55. H. W. King, C. 0. Wisler and J. G. Woodburn, Hydraulics, 5th edn., Krieger, Malabar, FL, 1980, p. 306.
56. C. N. Davies, J. Aerosol Sci., 10 (1979) 477.
57. C. Murali, B. Pitchmani and N. N. Clark, Znt. J. Min. Process., 18 (1986) 237.
58. S. Endoh and H. Iwata, Proc. 24th Autumn Meet. Sot. Chem. Eng. Jpn., Nagoya, Oct. 16-18, 1991, p. 404.
59. . MASAMI FURUUCHI,
KANAZAWA UNIVERSITY | KINDAI · GRADUATE SCHOOL OF NATURAL SCIENCE AND TECHNOLOGY
60. III . PROFESSOR

Wranj Kargu[1] *Bio resource Processing Research Institute of Australia, Chemical Engineering Department, Monash University, Clayton, Australia, 3800*