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APPENDIX

A1. Specifications of equipment

A1.1 Specifications of continuous kneader

Model	S1 Type
Maker	Kurimoto Co., Ltd.
Paddle dimension	25 D x 255 L mm. (L/D = 10.2)
Paddle speed	81 ~ 324 rpm(Variable) at 50 Hz. 96 ~ 384 rpm(Variable) at 60 Hz.
Barrel heating, cooling system Heating system Cooling system	 Band heater (electric cap. 1.5 kW) Water
Drive unit	Variable speed reducer (with motor) Type : AIV SS25D-10R 0.4-4 Motor : 0.4 kW x 4P T.E.F.C. Type
Power source	A.C. 200/220 V. 50/60 Hz. 3ϕ
Power consumption	1.9 kW (Motor 0.4 kW + Heater 1.5 kW)
Capacity	approx. 2 kg/hr
Material of main parts Barrel Screw & paddle Main shaft	 SUS 316 + WC CIX SUS 630
Size	540 mm(W) x 1100 mm(L) x 1260 mm(H)
Weight	Approx. 150 Kg

A.1.2 Specifications of accurate feeder

Model	102 Type
Maker	Kurimoto Co., Ltd.
Electrical requirement	110 Volt., 60 cycle A.C. , single phase
Motor A.C. D.C.	 1/25 HP. 1/20 HP. 24 Volt DC, Gear motor, 45 rpm output
Control A.C. D.C.	 Direct A.C. Control KB Electronics Circuit Board with : 20:1 Speed range Adjustable current limit
Feed rates	Approx. 8.496×10^{-5} to 28.32 liter/hr using stainless steel screws 0.75 inch. Dia. with center core helix.
Contact material Hopper Helix Discharge nozzle	 0.094 inch. thick flexible PVC stainless steel stainless steel
Non-contact material	304 Stainless steel frame and side panels
Dimensions	215 mm(W) x 314 mm(L) x 200 mm(H)
Capacity	Max. 18 liter/hr
Weight	6.5 Kg

A1.3 Specifications of roller temperature controller

Model	MC III -15 H Type
Maker	Kurimoto Co., Ltd.
Power supply	A.C. 3 ϕ 200/220 V 50/60 Hz.
Medium	Clean water (soft water)
Operational temperature range	140 ^{o}F ~ 248 ^{o}F 60 ^{o}C ~ 120 ^{o}C
Pump motor	250 W, 4P
Heater : capacity	3 kW
Heater box Material Capacity	 SUS 304 3.5 liter
Temperature controller Operation Input (Thermocouple) Setting/indication Timer function Alarm	 Heating or cooling PID action K (CA) Digital setting and indication Setting range of 0 to 99.9 hr (0.1 hr - 6 min.). Operation starts when the timer has run out. Drop in medium level, abnormal temperature rise, pump overload, power supply phase reversal, broken wire in the sensor, and upper and lower limit alarm
Water level detection	Float switch
Pressure gauge	ϕ 50 x 6 kg_f/cm^2
External dimensions	232 mm(W) x 506 mm(D) x 538 mm(H)
Unit weight	Approx. 50 Kg.
Power consumption	3.25 kW

A1.4 Specification of press roller

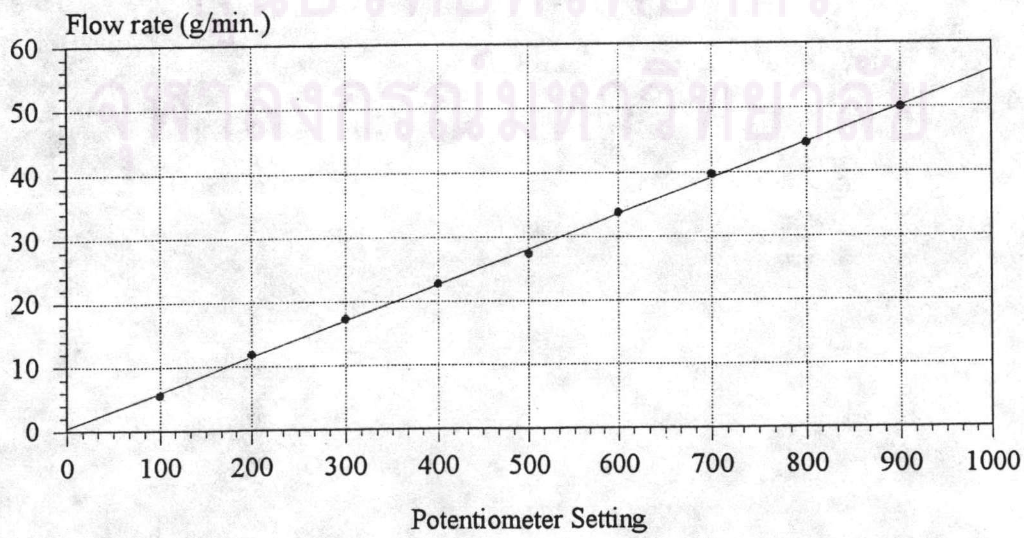
Model	ϕ 90 x 200 L
Maker	Kurimoto Co., Ltd.
Size	600 mm(W) x 920 mm(L) x 894 mm(H)
Roller speed	0 - 10 rpm.
Weight	Approx. 100 Kg
Power consumption	0.2 kW
Voltage and phase	200/220 V, 50/60 Hz., 3 phase
Capacity	Approx. 2 kg/hr.

A2. Experimental data

A2.1 Calibration data of accurate feeder flow (for HDPE powder used)

Potentiometer No.	Flow rate (g/min.)
100	5.6
200	11.82
300	17.32
400	22.72
500	27.43
600	33.83
700	39.70
800	44.57
900	50.05

A2.2 Calibration curve of accurate feeder (HDPE powder)



A2.3 The obtained experimental data

Run No. 1

Condition :

Kneading temperature = 160 °C Speed of screw = 81 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.11 μm.

Sample n	N (r)			
	1	2	3	4
2	4	4	4	4
4	14	14	13	15
5	21	20	19	22
8	37	41	31	33
10	48	65	50	53
20	78	87	66	76
40	129	135	114	135
80	215	231	209	228

Run No. 2

Condition :

Kneading temperature = 180 °C Speed of screw = 81 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.11 μm.

Sample n	N (r)			
	1	2	3	4
2	4	4	4	4
4	14	14	13	14
5	18	21	17	19
8	33	32	31	26
10	40	36	38	34
20	62	60	62	54
40	117	110	98	103
80	230	238	238	239

Run No. 3

Condition :

Kneading temperature = 200 °C Speed of screw = 81 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.11 μm.

Sample	N (r)			
n	1	2	3	4
2	4	4	4	4
4	12	16	15	13
5	19	23	17	18
8	23	32	24	30
10	33	44	23	36
20	58	80	47	55
40	106	140	77	105
80	177	281	159	222

Run No. 4

Condition :

Kneading temperature = 220 °C Speed of screw = 81 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.11 μm.

Sample	N (r)			
n	1	2	3	4
2	4	4	4	4
4	11	16	15	8
5	15	21	18	11
8	20	31	32	17
10	25	37	38	16
20	42	58	55	28
40	87	119	98	57
80	178	236	179	115

Run No. 5

Condition :

Kneading temperature = 140 ^oC Speed of screw = 81 rpm.

Roller temperature = 77 ^oC Particle size of pigment = 0.11 μm.

Sample / n	N (r)			
	1	2	3	4
2	4	4	4	4
4	15	14	9	14
5	21	16	11	19
8	41	34	16	27
10	45	32	15	36
20	83	58	20	52
40	215	98	41	87
80	518	184	65	156

Run No. 6

Condition :

Kneading temperature = 140 ^oC Speed of screw = 122 rpm.

Roller temperature = 77 ^oC Particle size of pigment = 0.11 μm.

Sample / n	N (r)			
	1	2	3	4
2	4	4	4	4
4	11	15	12	11
5	13	17	17	19
8	20	31	23	18
10	25	33	31	23
20	41	53	50	36
40	75	97	95	59
80	166	220	230	122

Run No. 7

Condition :

Kneading temperature = 140 °C Speed of screw = 162 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.11 μm.

Sample n	N (r)			
	1	2	3	4
2	4	4	4	4
4	12	14	12	12
5	15	20	13	19
8	23	29	25	21
10	23	32	26	27
20	43	55	39	44
40	76	116	88	73
80	175	268	233	175

Run No. 8

Condition :

Kneading temperature = 140 °C Speed of screw = 243 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.11 μm.

Sample n	N (r)			
	1	2	3	4
2	4	4	4	4
4	13	11	12	12
5	19	15	13	15
8	23	21	21	22
10	29	21	21	27
20	45	37	27	45
40	63	68	58	77
80	147	158	141	186

<u>Run No. 9</u>

Condition :

Kneading temperature = 140 °C Speed of screw = 324 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.11 μm.

Sample / n	N (r)			
	1	2	3	4
2	4	4	4	4
4	13	15	11	13
5	18	19	14	19
8	35	29	20	21
10	33	34	26	30
20	61	58	41	46
40	132	112	78	84
80	349	275	195	188

<u>Run No. 10</u>

Condition :

Kneading temperature = 180 °C Speed of screw = 81 rpm.

Roller temperature = 57 °C Particle size of pigment = 0.11 μm.

Sample / n	N (r)			
	1	2	3	4
2	4	4	4	4
4	14	14	12	14
5	19	16	15	16
8	29	26	25	20
10	32	28	22	27
20	56	50	33	45
40	107	103	69	73
80	232	230	159	162

Run No. 11

Condition :

Kneading temperature = 180 °C Speed of screw = 81 rpm.

Roller temperature = 67 °C Particle size of pigment = 0.11 μm.

Sample n	N (r) 1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	23	22	20	24
8	40	41	37	46
10	46	41	39	60
20	74	78	69	98
40	120	126	104	168
80	273	282	226	352

Run No. 12

Condition :

Kneading temperature = 180 °C Speed of screw = 81 rpm.

Roller temperature = 87 °C Particle size of pigment = 0.11 μm.

Sample n	N (r) 1	2	3	4
2	4	4	4	4
4	16	16	15	14
5	21	23	19	21
8	32	41	27	35
10	40	49	34	47
20	69	63	54	83
40	128	162	105	134
80	277	298	203	243

Run No. 13

Condition :

Kneading temperature = 180 ^oC Speed of screw = 81 rpm.

Roller temperature = 97 ^oC Particle size of pigment = 0.11 μm.

Sample n	N (r)			
	1	2	3	4
2	4	4	4	4
4	14	15	13	13
5	17	21	15	17
8	28	31	20	24
10	24	34	25	27
20	36	50	40	45
40	77	100	68	86
80	178	223	154	190

Run No. 14

Condition :

Kneading temperature = 140 ^oC Speed of screw = 81 rpm.

Roller temperature = 77 ^oC Particle size of pigment = 0.17 μm.

Sample n	N (r)			
	1	2	3	4
2	4	4	4	4
4	11	10	13	12
5	14	15	14	13
8	19	17	25	22
10	25	17	28	30
20	47	34	54	43
40	107	64	95	86
80	260	151	188	189

Run No. 15

Condition :

Kneading temperature = 140 °C Speed of screw = 81 rpm.

Roller temperature = 77 °C Particle size of pigment = 0.20 µm.

Sample n	N (r)			
	1	2	3	4
2	3	4	4	4
4	7	7	10	10
5	7	8	7	9
8	11	11	12	13
10	13	12	11	16
20	20	18	19	26
40	37	41	37	53
80	101	100	135	116

A2.4 Theoretical number of particles in a sample

From experimental procedure, polyethylene and pigment are premixed in ratio 25:1 by weight.

weight of polyethylene = 25 g.

weight of pigment = 1 g.

density of polyethylene = 0.968 g/cm^3

density of pigment = 5 g/cm^3

volume of polyethylene = 25 / 0.968 = 25.83 cm^3

volume of pigment = 1 / 5 = 0.20 cm^3

$\therefore$ Total volume = 25.83 + 0.20 = 26.03 cm^3

volume of pigment per particle = $\frac{4}{3}\pi(0.11\,\mu m)^3$ = 0.0056 μm^3

Total particles of pigment = 0.2 x 10^{12} / 0.0056

= 3.57 x 10^{13} particles

$\therefore$ Amount of particles per unit volume = 3.57 x 10^{13} / (26.03)

= 1.37 x 10^{12} particles/cm^3

Analytical area of sample = 174.24 μm^2

For 1 μm depth of sample

Amount of particles = 1.37 x 10^{12} / (1 x 10^{12})

= 1.37 particles/μm^2

$\therefore$ amount of particles in sampling area

= 1.37 x 174.24 particles

= 239 particles

For 0.17 μm particle size of pigment

amount of particles in sampling area = 65 particles

For 0.20 μm particle size of pigment

amount of particles in sampling area = 40 particles

In Terashita's work (1988), polystyrene and pigment are premixed in ratio 10:1 by weight.

weight of polystyrene = 10 g.

weight of pigment = 1 g.

density of polystyrene = 0.901 g/cm^3

density of pigment = 0.260 g/cm^3

volume of polystyrene = 10 / 0.901 = 11.10 cm^3

volume of pigment = 1 / 0.260 = 3.85 cm^3

$\therefore$ Total volume = 11.10 + 3.85 = 14.95 cm^3

volume of pigment per particle = $\frac{4}{3}\pi(0.05\ \mu m)^3$ = 5.24×10^{-4} μm^3

Total particles of pigment = $3.85 \times 10^{12} / 5.24\times10^{-4}$

= 7.35×10^{15} particles

$\therefore$ Amount of particles per unit volume = 7.35×10^{15} / (14.95)

= 4.91×10^{14} particles/cm^3

Analytical area of sample (200 μm x 156 μm)

= 3.12×10^{4} μm^2

Amount of particles = $4.91 \times 10^{14} / (1 \times 10^{12})$

= 492 particles/μm^2

$\therefore$ amount of particles in sampling area

= $492 \times 3.12\times10^{4}$ particles

= 1.53×10^{7} particles

If the analytical area = 174.24 μm^2

$\therefore$ amount of particles in sampling area

= 492 x 174.24 particles

= 8.57×10^{4} particles

A3. Listing of simulation program

A3.1 Listing of simulation program (QBASIC language)

```
DECLARE SUB SUB2 ( )
DECLARE SUB SUB1 ( )
'   **************************************************
'   ***  Q       =  Amount of particle                          ***
'   ***  MS      = Maximum of division                          ***
'   ***  S       = No. of division                              ***
'   ***  Z(X,Y)  = particle                                     ***
'   ***  ST      = Counting  step                               ***
'   ***  P( )    = Amount of particle in a segment              ***
'   ***  SF ( )  = Area ratio of particle                       ***
'   ***  MSF     = Mean ratio of patrcle area                   ***
'   ***  SUM     = Summation of SF                              ***
'   ***  SSUM    = Summation of ( MSF - SF )^2                  ***
'   ***  STD     = Standard deviation of  SF                    ***
'   ***  DS      = Coefficient of variance = STD / MSF          ***
'   ***  TP      = Total of particle                            ***
'   ***  B       = Total of empty segments  ( No  particle )    ***
'   ***  TB      = Amount of segments that have particle        ***
'   ***  A       = Total of segments                            ***
'   **************************************************
COMMON SHARE Q, MS, N, S, Z ( ), ST, P ( ), TP, B, TB, A AS INTEGER
CLS
RANDOMIZE
DIM Z ( 100, 100 ), P ( 100, 100), SF (100, 100)
INPUT "SAMPLE POPOULATION SIZE = ", Q
INPUT "MEAN PARTICLE SIZE (MICRON) = ", MP
AP = 22 / 7 * ( MP / 2 ) ^ 2
INPUT "THE OBSERVED AREA = "; OA
INPUT "MAXIMUM OF DIVISION = ", MS
PRINT
```

```
PRINT "-----------------------------------------------------------------------"
PRINT "TYPE OF RANDOM"
PRINT " 1. UNIFORM RANDOM NUMBER GENERATOR "
PRINT " 2. NORMAL RANDOM NUMBER GENERATOR "
PRINT "-----------------------------------------------------------------------"
PRINT
Z ( X, Y ) = 0
INPUT "TYPE OF RANDOM ( 1, 2 ) = "; N
PRINT
PRINT "--- If you want to stop, input number of division = 0 ---"
SELECT CASE N
      CASE IS = 1
            CALL SUB1
      CASE IS = 2
            CALL SUB2
END SELECT
PRINT
DO
   A = 0: B = 0: TB = 0: TP = 0: SUM = 0: SSUM = 0: SF ( I , J ) = 0
   INPUT "NUMBER OF DIVISION ( S x S ) = " ; S
   IF S = 0 THEN END
   ST = MS / S
   FOR I = 1 TO S
       FOR J = 1 TO S
          P(I, J) = 0
          FOR I2 = 1 TO ST: I3 = ( I - 1 ) * ST + I2
              FOR J2 = 1 TO ST: J3 = ( J - 1 ) * ST + J2
                 P( I , J ) = P( I , J ) + Z ( I3, J3 )
              NEXT J2
          NEXT I2
          A = A + 1
          IF P( I , J ) = 0 THEN B = B + 1 ELSE TP = TP + P
           SF ( I , J ) = P( I , J ) * AP / ( OA / S ^ 2 )
          IF SF ( I , J ) > 1 THEN SF ( I , J ) = 1
          SUM = SUM + SF ( I , J )
       NEXT J
   NEXT I
```

```
  MSF = SUM / A
  FOR I = 1 TO S
    FOR J = 1 TO S
      SSUM = SSUM + ( MSF - SF ( I , J ) ) ^ 2
    NEXT J
  NEXT I
  STD = SSUM / ( S ^ 2 - 1 )
  DS = STD / MSF
  TB = S ^ 2 - B
  PRINT "-----------------------------------------------------------------------------------------"
  PRINT TAB (1) ; "Empty segments = "; B; TAB (25); "Total of segments = "; A; TAB(53);
          "Total of particles = "; TP
  PRINT
  PRINT "Total of segments that have particle = ["; TB; "]"
  PRINT "-----------------------------------------------------------------------------------------"
  PRINT "EVALUATION OF TERASHITA et.al. (1993)
  PRINT
  PRINT TAB (1) "MEAN SF = "; MSF; TAB (27); " STANDARD DEVE. = "; STD ;
          TAB (57); "DS = ["; DS; "]"
  PRINT "-----------------------------------------------------------------------------------------"
  PRINT
LOOP
END


SUB SUB1
  FOR I = 1 TO Q
      X = INT ( RND * MS + 1 )
      Y = INT ( RND * MS + 1 )
      Z ( X, Y ) = Z ( X, Y ) + 1
  NEXT I
END SUB
```

```
SUB SUB2
   FOR I = 1 TO Q
        XO = SQR ( -2! * LOG ( RND ) )
        XR = 6.2831853072# * RND
        XT = XO * SIN ( XR )
        XO = XO * COS ( XR )
        X = INT ( XT / 3 * MS /2 + MS / 2 + 1 )
        IF X > 80 THEN X = 80
        IF X < 1 THEN X = 1
        YO = SQR ( -2! * LOG ( RND ) )
        YR = 6.2831853072# * RND
        YT = XO * SIN ( YR )
        YO = XO * COS ( YR )
        Y = INT ( YT / 3 * MS /2 + MS / 2 + 1 )
        IF Y > 80 THEN Y = 80
        IF Y < 1 THEN Y = 1
        Z ( X, Y ) = Z ( X, Y ) + 1
   NEXT I
END SUB
```

A3.2 Simulation data

A3.2.1 The present study

A3.2.1.1 Sample population size = 10

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	10	10	10	10	10	10	10	10
40	10	10	10	10	10	10	9	10
20	10	10	10	10	9	10	9	9
16	10	10	10	10	8	9	9	10
10	10	10	9	10	8	8	8	9
8	10	10	8	8	6	9	9	8
5	8	8	8	8	5	7	6	7
4	5	8	8	7	5	7	5	6
2	3	4	4	3	4	4	4	4

A3.2.1.2 Sample population size = 64

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	64	63	64	63	63	62	64	64
40	63	61	64	62	62	57	63	63
20	59	59	58	58	55	50	60	54
16	54	56	56	53	51	47	52	47
10	43	55	47	45	38	32	39	37
8	40	42	41	41	32	24	30	27
5	21	23	24	24	19	15	17	14
4	15	16	16	15	14	13	14	13
2	4	4	4	4	4	4	4	4

A3.2.1.3 Sample population size = 256

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	254	253	248	250	242	246	247	243
40	238	240	235	234	209	211	210	212
20	182	191	183	186	132	135	135	127
16	157	162	164	161	102	107	107	97
10	92	90	89	91	55	59	57	54
8	63	64	62	64	41	43	41	40
5	25	25	25	25	21	21	21	20
4	16	16	16	16	15	16	13	15
2	4	4	4	4	4	4	4	4

A3.2.1.4 Sample population size = 640

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	604	605	617	617	569	563	563	549
40	525	519	542	532	413	396	408	390
20	321	321	331	324	201	183	201	189
16	237	231	241	236	147	135	152	140
10	100	100	100	100	74	68	74	72
8	64	64	64	64	51	47	54	52
5	25	25	25	25	23	22	23	23
4	16	16	16	16	16	16	16	16
2	4	4	4	4	4	4	4	4

A3.2.1.5 Sample population size = 1280

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	1175	1152	1152	1167	995	987	991	997
40	882	884	874	899	592	583	588	581
20	383	384	379	389	242	243	241	240
16	254	255	255	256	173	180	169	170
10	100	100	100	100	84	85	84	82
8	64	64	64	64	58	59	56	55
5	25	25	25	25	25	25	24	25
4	16	16	16	16	16	16	16	16
2	4	4	4	4	4	4	4	4

A3.2.1.6 Sample population size = 3200

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	2528	2511	2535	2526	1848	1866	1829	1826
40	1382	1400	1391	1377	855	843	856	844
20	400	400	400	400	299	307	311	309
16	256	256	256	256	211	208	219	214
10	100	100	100	100	92	90	95	91
8	64	64	64	64	61	59	61	61
5	25	25	25	25	25	25	25	25
4	16	16	16	16	16	16	16	16
2	4	4	4	4	4	4	4	4

A3.2.1.7 Sample population size = 6400

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	4022	4034	4078	4079	2569	2553	2578	2575
40	1569	1565	1573	1566	1019	1017	1024	1008
20	400	400	400	400	333	339	339	340
16	256	256	256	256	225	227	225	230
10	100	100	100	100	91	94	96	97
8	64	64	64	64	60	64	63	64
5	25	25	25	25	25	25	25	25
4	16	16	16	16	16	16	16	16
2	4	4	4	4	4	4	4	4

A3.2.1.8 Sample population size = 12800

Sample / n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	5570	5520	5580	5539	3352	3360	3299	3332
40	1598	1600	1600	1600	1201	1191	1197	1198
20	400	400	400	400	363	364	364	358
16	256	256	256	256	241	238	238	240
10	100	100	100	100	98	99	97	98
8	64	64	64	64	64	64	63	64
5	25	25	25	25	25	25	25	25
4	16	16	16	16	16	16	16	16
2	4	4	4	4	4	4	4	4

A3.2.2 Terashita's work

A3.2.2.1 Sample population size = 10

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.3487	0.3487	0.3487	0.3487	0.3487	0.3487	0.3487	0.3487
40	0.0868	0.0868	0.0868	0.0868	0.0868	0.0868	0.1043	0.0868
20	0.0213	0.0213	0.0213	0.0213	0.0257	0.0213	0.0257	0.0257
16	0.0135	0.0135	0.0135	0.0135	0.0191	0.0163	0.0163	0.0135
10	0.0050	0.0050	0.0061	0.0050	0.0072	0.0072	0.0072	0.0061
8	0.0030	0.0030	0.0044	0.0044	0.0065	0.0037	0.0037	0.0044
5	0.0014	0.0014	0.0017	0.0014	0.0051	0.0017	0.0020	0.0017
4	0.0007	0.0009	0.0007	0.0009	0.0017	0.0009	0.0018	0.0015
2	0.0003	0.0001	0.0003	0.0006	0.0001	0.0000	0.0001	0.0001

A3.2.2.2 Sample population size = 64

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.3458	0.3567	0.3458	0.3567	0.3567	0.3676	0.3458	0.3458
40	0.0866	0.0921	0.0839	0.0893	0.0893	0.1030	0.0866	0.0866
20	0.0218	0.0218	0.0232	0.0225	0.0252	0.0307	0.0211	0.0252
16	0.0153	0.0140	0.0145	0.0153	0.0180	0.0202	0.0162	0.0193
10	0.0072	0.0037	0.0059	0.0061	0.0084	0.0127	0.0092	0.0085
8	0.0037	0.0039	0.0030	0.0040	0.0070	0.0103	0.0078	0.0084
5	0.0020	0.0008	0.0011	0.0015	0.0054	0.0087	0.0054	0.0063
4	0.0010	0.0008	0.0001	0.0011	0.0036	0.0070	0.0044	0.0051
2	0.0005	0.0002	0.0003	0.0004	0.0002	0.0002	0.0001	0.0001

A3.2.2.3 Sample population size = 256

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.3407	0.3435	0.3571	0.3516	0.3735	0.3626	0.3617	0.3726
40	0.0857	0.0850	0.0877	0.0884	0.1171	0.1123	0.1095	0.1123
20	0.0227	0.0212	0.0229	0.0216	0.0494	0.0438	0.0451	0.0520
16	0.0149	0.0149	0.0135	0.0137	0.0402	0.0370	0.0372	0.0466
10	0.0052	0.0061	0.0058	0.0055	0.0284	0.0298	0.0276	0.0330
8	0.0038	0.0047	0.0026	0.0029	0.0276	0.0285	0.0262	0.0297
5	0.0014	0.0021	0.0013	0.0006	0.0224	0.0239	0.0229	0.0288
4	0.0010	0.0015	0.0010	0.0007	0.0216	0.0205	0.0216	0.0210
2	0.0001	0.0002	0.0003	0.0001	0.0004	0.0002	0.0001	0.0000

A3.2.2.4 Sample population size = 640

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.3458	0.3567	0.3458	0.3567	0.3971	0.4044	0.4029	0.4219
40	0.0866	0.0921	0.0839	0.0893	0.1428	0.1583	0.1417	0.1581
20	0.0218	0.0218	0.0232	0.0225	0.0843	0.0894	0.0817	0.0849
16	0.0153	0.0140	0.0145	0.0153	0.0732	0.0814	0.0773	0.0762
10	0.0072	0.0037	0.0059	0.0061	0.0645	0.0722	0.0652	0.0632
8	0.0037	0.0039	0.0030	0.0040	0.0626	0.0690	0.0624	0.0606
5	0.0020	0.0008	0.0011	0.0015	0.0525	0.0643	0.0544	0.0561
4	0.0010	0.0008	0.0001	0.0011	0.0511	0.0552	0.0535	0.0461
2	0.0005	0.0002	0.0003	0.0004	0.0002	0.0002	0.0001	0.0001

A3.2.2.5 Sample population size = 1280

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.3382	0.3504	0.3522	0.3422	0.4219	0.4502	0.4584	0.4501
40	0.0857	0.0854	0.0906	0.0834	0.1581	0.2173	0.2157	0.2193
20	0.0230	0.0215	0.0235	0.0192	0.0849	0.1545	0.1521	0.1546
16	0.0133	0.0125	0.0151	0.0127	0.0762	0.1439	0.1245	0.1449
10	0.0060	0.0053	0.0057	0.0052	0.0632	0.1336	0.1312	0.1318
8	0.0027	0.0036	0.0033	0.0026	0.0606	0.1281	0.1246	0.1277
5	0.0010	0.0011	0.0019	0.0010	0.0561	0.1112	0.1138	0.1136
4	0.0001	0.0006	0.0010	0.0004	0.0461	0.1050	0.0980	0.1047
2	0.0001	0.0000	0.0006	0.0000	0.0001	0.0002	0.0000	0.0000

A3.2.2.6 Sample population size = 3200

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.3342	0.3372	0.3343	0.3346	0.5114	0.5075	0.5204	0.5185
40	0.0860	0.0862	0.0904	0.0921	0.3751	0.3702	0.3709	0.3806
20	0.0223	0.0216	0.0232	0.0223	0.3328	0.3239	0.3333	0.3323
16	0.0143	0.0140	0.0149	0.0126	0.3329	0.3202	0.3283	0.3348
10	0.0046	0.0057	0.0067	0.0052	0.3189	0.3038	0.3132	0.3126
8	0.0039	0.0039	0.0044	0.0036	0.3161	0.2982	0.3083	0.3102
5	0.0007	0.0010	0.0022	0.0013	0.2848	0.2671	0.2721	0.2783
4	0.0007	0.0008	0.0015	0.0005	0.2487	0.2499	0.2594	0.2581
2	0.0002	0.0001	0.0004	0.0001	0.0003	0.0003	0.0005	0.0001

A3.2.2.7 Sample population size = 6400

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.3023	0.3006	0.2967	0.2593	0.5209	0.5245	0.5220	0.5213
40	0.0889	0.0866	0.0841	0.0875	0.4370	0.4439	0.4388	0.4429
20	0.0240	0.0209	0.0200	0.0247	0.4170	0.4228	0.4115	0.4222
16	0.0139	0.0132	0.0120	0.0165	0.4112	0.4172	0.4084	0.4192
10	0.0049	0.0057	0.0043	0.0056	0.4036	0.4089	0.4013	0.4140
8	0.0028	0.0040	0.0029	0.0037	0.4160	0.4243	0.4190	0.4223
5	0.0016	0.0019	0.0009	0.0008	0.4037	0.4147	0.4010	0.4167
4	0.0014	0.0007	0.0004	0.0011	0.4744	0.4811	0.4760	0.4770
2	0.0005	0.0000	0.0001	0.0003	0.0001	0.0002	0.0000	0.0004

A3.2.2.8 Sample population size = 12800

Sample / n	Coefficient of variance ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
80	0.1953	0.1992	0.1937	0.1999	0.4662	0.4651	0.4735	0.4674
40	0.0646	0.0681	0.0682	0.0678	0.3965	0.3925	0.4052	0.3977
20	0.0198	0.0220	0.0205	0.0197	0.3755	0.3738	0.3862	0.3802
16	0.0138	0.0151	0.0135	0.0130	0.3741	0.3722	0.3837	0.3768
10	0.0045	0.0067	0.0061	0.0058	0.3665	0.3674	0.3800	0.3796
8	0.0026	0.0039	0.0035	0.0026	0.3576	0.3544	0.3638	0.3599
5	0.0011	0.0014	0.0013	0.0013	0.3812	0.3807	0.3977	0.3956
4	0.0009	0.0009	0.0008	0.0008	0.3079	0.3066	0.3180	0.3153
2	0.0001	0.0003	0.0003	0.0003	0.0003	0.0003	0.0001	0.0004

A4. Example of calculation of fractal dimension

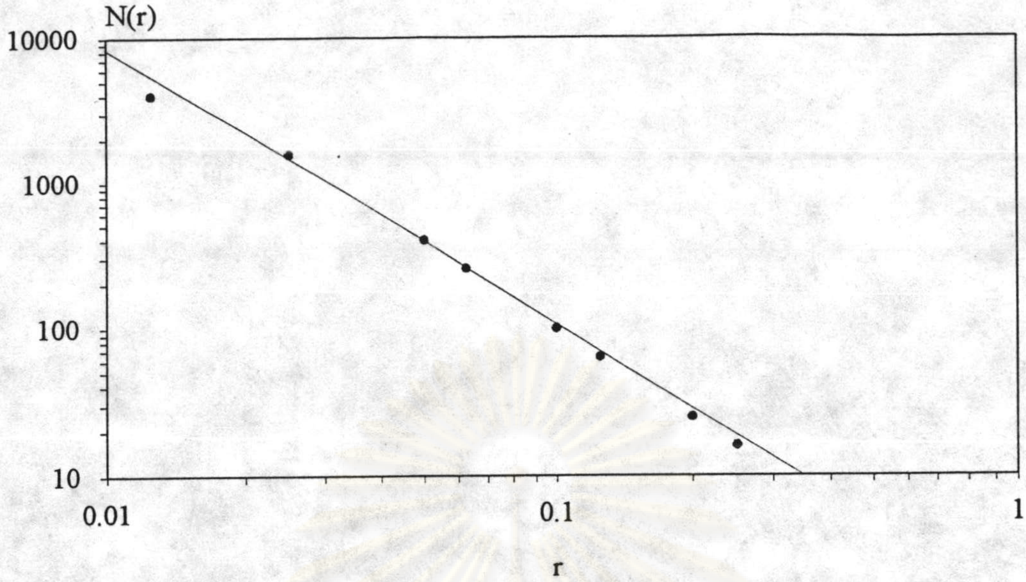
A example of calculation of fractal dimension from the uniform random dispersion data of case A3.2.1.7 (sample population size = 6400 ; 1st analysis)

n	2	4	5	8	10	16	20	40	80
N (r)	4	16	25	64	100	256	400	1569	4022

From chapter III define r = 1/n

n	r	N (r)
2	0.5000	4
4	0.2500	16
5	0.2000	25
8	0.1250	64
10	0.1000	100
16	0.0625	256
20	0.0500	400
40	0.0250	1569
80	0.0125	4022

Plotting the relationship between N(r) and *r* on log-log scales.



From chapter 3, $$D = \frac{-\log N(r)}{\log(r)} \qquad (3.3.4)$$

Next, calculate the fractal dimension from the slope of the convergent straight line.

at r = 0.35 N(r) = 10

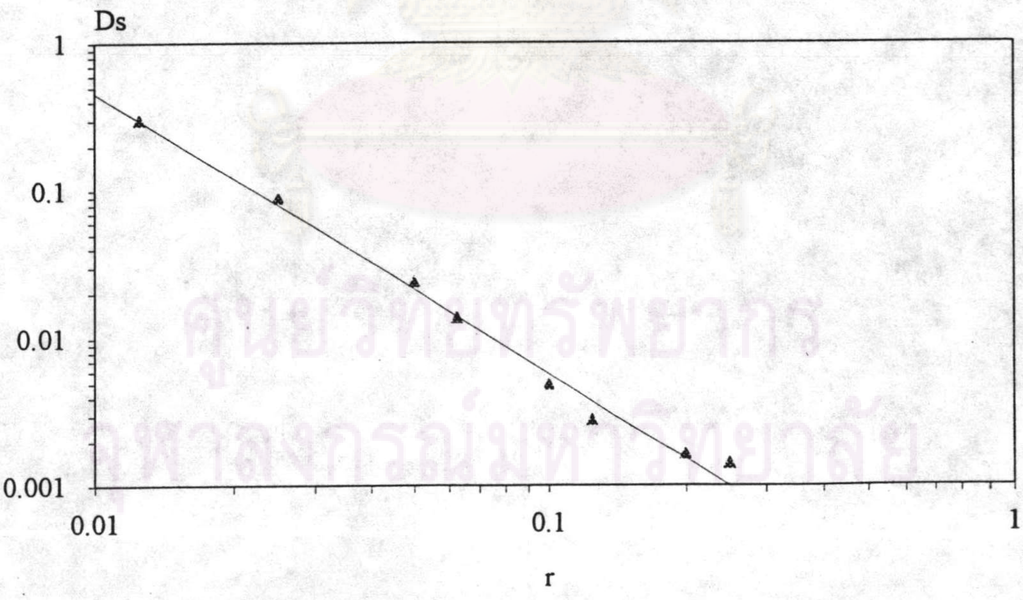
at r = 0.01 N(r) = 8200

$$D = \frac{-[\log(8200) - \log(10)]}{\log(0.01) - \log(0.35)}$$

$$= 1.8871$$

In case of Terashita's fractal dimension, plotting the relationship between coefficient of variance (Ds) and the similarity ratio (*r*) on the log-log scales.

n	r	Ds
2	0.5000	5.184x10-4
4	0.2500	1.420x10-3
5	0.2000	1.639x10-3
8	0.1250	2.813x10-3
10	0.1000	4.878x10-3
16	0.0625	1.387x10-2
20	0.0500	2.404x10-2
40	0.0250	8.894x10-2
80	0.0125	0.3023



From chapter 3, $$D = \frac{-\log(Ds)}{\log(r)}$$

Next, calculate the fractal dimension from the slope of the convergent straight line.

at r = 0.255 Ds = 0.001

at r = 0.01 Ds = 0.45

$$D = \frac{-[\log(0.45) - \log(0.001)]}{\log(0.01) - \log(0.255)} = 1.8863$$

BIOGRAPHY

Mr.Pijarn In-eure was born on June 10 , 1970, in Bangkok , Thailand. Mr.In-eure graduated from Chulalongkorn University with a Bachelor Degree of Science in Chemical Technology in 1992.