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APPENDIX

A1. Specification of equipment

A1.1 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 Accurate feeder

Model	102 Type
Maker	Kurimoto Co., Ltd.
Electrical requirement	110 Volt., 60 cycle A.C. , single phase
Motor	
A.C.	1/25 HP.
D.C.	1/20 HP. 24 Volt DC, Gear motor, 45 rpm output
Control	
A.C.	Direct A.C. Control
D.C.	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	0.094 inch. thick flexible PVC
Helix	stainless steel
Discharge nozzle	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 Mold 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 Press roller

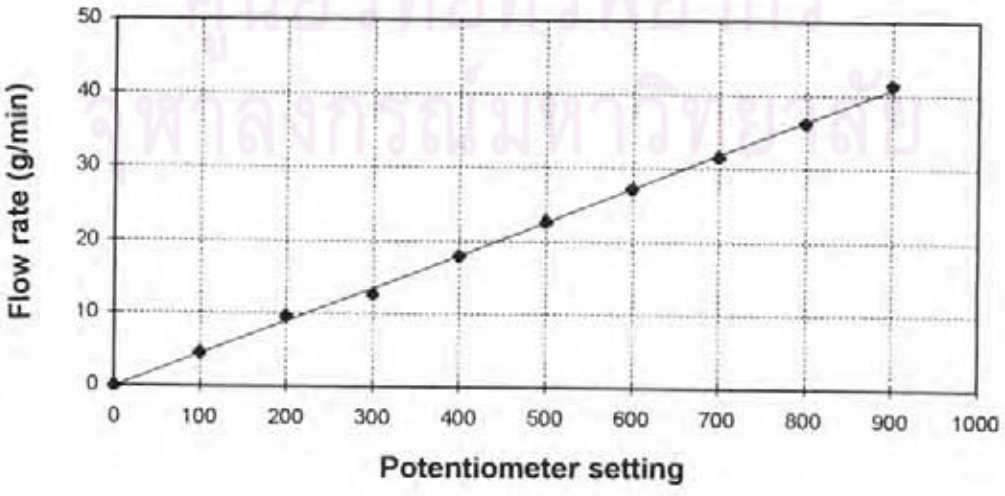
Model	ϕ 90 x 200 L
Maker	Kurimoto Co., Ltd.
Size	600 mm(W) x 920 mm(L) x 894 mm(H)
Roller speed	0 - 10 rpm.
Weight	Approx. 100 kg
Power consumption	0.2 kW
Voltage and phase	200/220 V, 50/60 Hz., 3 phase
Capacity	Approx. 2 kg/hr.

A2. Experimental data

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

Potentiometer Setting.	Flow rate (g/min.)
100	4.54
200	9.63
300	12.82
400	18.09
500	22.76
600	27.21
700	31.51
800	36.15
900	41.37

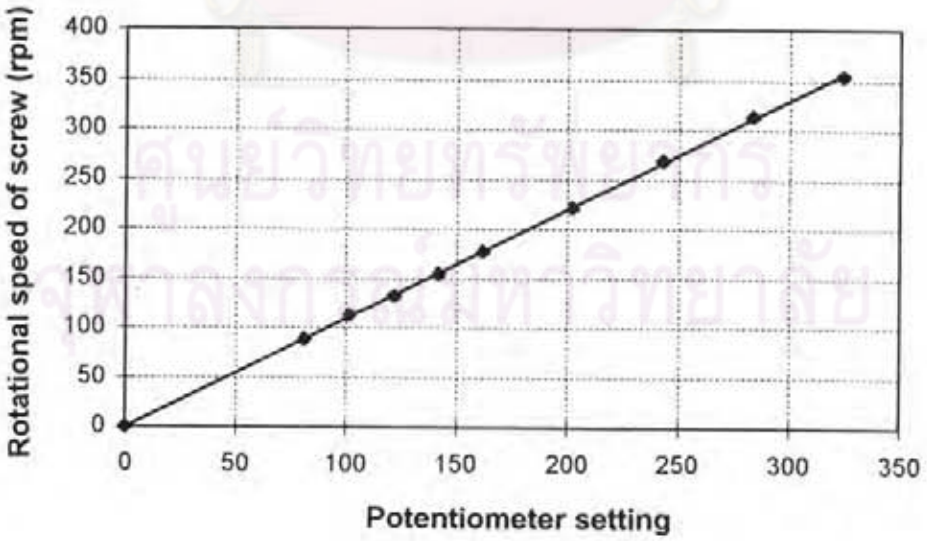
A2.2 Calibration curve of accurate feeder (PS powder)



A2.3 Calibration data of rotational speed of paddle

Potentiometer setting.	Rotational speed (rpm)
81	89
101.5	112.8
122	132.5
142	155.5
162	177.6
202.5	221.7
243	268.7
283.5	313.4
324	353.8

A2.4 Calibration curve of rotational speed of paddle



A2.5 The actual experimental data

A2.5.1 Iron Oxide

1) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	24	22
8	47	53	45	42
10	60	63	60	49
16	101	87	105	75
20	104	111	109	89
40	195	177	193	144
80	407	326	386	257
Sample size	98	90	92	58

2) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	23	23	22
8	53	50	52	38
10	71	62	68	53
16	100	94	99	74
20	117	97	122	90
40	198	202	193	146
80	397	356	330	290
Sample size	97	105	92	74

3) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	15	15	15	16
5	25	23	23	24
8	46	39	37	52
10	61	48	50	64
16	79	64	71	87
20	97	86	84	100
40	192	139	146	166
80	380	246	263	279
sample size	112	65	74	73

4) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	24	24	23	24
8	49	47	48	53
10	67	57	59	64
16	118	72	83	90
20	138	84	99	111
40	305	143	170	178
80	671	256	307	359
sample size	137	70	107	106

5) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	14	16	16
5	25	20	22	23
8	60	35	41	48
10	81	44	48	55
16	137	66	71	86
20	166	69	80	87
40	326	121	135	144
80	746	249	277	282
sample size	130	116	84	130

6) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	14
5	23	22	24	19
8	44	39	50	38
10	58	49	67	50
16	81	73	98	79
20	99	90	126	96
40	175	195	155	148
80	346	344	335	297
sample size	143	67	73	84

7) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	15
5	24	25	25	25
8	51	61	60	48
10	70	82	79	59
16	124	127	124	93
20	145	145	63	106
40	279	249	276	212
80	589	472	504	427
sample size	109	98	98	73

8) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	15	16	16	16
5	24	25	24	25
8	45	49	44	54
10	58	66	59	71
16	86	103	94	117
20	97	109	118	145
40	170	186	200	264
80	309	377	372	497
sample size	133	129	129	121

9) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	14	15	16
5	25	23	24	24
8	59	41	47	51
10	78	51	61	58
16	121	79	85	78
20	148	86	107	99
40	267	159	178	177
80	503	294	341	323
sample size	83	101	103	119

10) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	15	16	16
5	24	23	25	25
8	46	44	62	63
10	58	57	90	90
16	76	80	165	186
20	90	86	228	217
40	165	151	419	432
80	342	309	852	877
sample size	127	89	116	101

11) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	23	23	24	25
8	39	35	52	53
10	52	53	65	65
16	77	71	100	104
20	93	94	15	122
40	162	157	216	207
80	317	280	405	411
sample size	109	72	184	190

12) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	14	15
5	23	24	20	28
8	42	44	33	43
10	52	49	40	45
16	83	79	63	77
20	94	91	64	90
40	189	176	122	152
80	392	361	240	285
sample size	76	82	112	118

13) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	15	16	16	15
5	25	25	24	24
8	46	52	47	41
10	67	79	68	56
16	101	124	115	89
20	118	153	143	105
40	221	270	268	195
80	423	507	577	387
sample size	79	87	54	59

14) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	15
5	24	24	25	24
8	52	52	53	39
10	66	67	72	48
16	98	108	115	72
20	113	131	140	96
40	189	229	246	148
80	345	404	493	297
sample size	100	125	147	111

15) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	24	24	24	25
8	46	59	48	56
10	59	74	66	69
16	88	115	86	94
20	114	136	118	121
40	210	225	175	214
80	415	442	336	425
Sample size	93	117	123	61

16) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	5
8	51	60	62	61
10	65	84	91	94
16	102	145	187	174
20	116	190	247	251
40	214	314	468	493
80	430	476	909	1023
Sample size	111	117	90	122

17) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 324 rpm

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	15	16	16
5	23	24	25	24
8	51	52	52	47
10	65	68	68	65
16	99	107	104	93
20	121	125	123	102
40	213	239	222	192
80	416	467	484	365
Sample size	86	154	213	144

18) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	23	25	24
8	46	49	47	41
10	74	60	62	56
16	107	96	85	88
20	134	107	103	103
40	212	218	183	199
80	465	471	382	434
Sample size	97	115	120	103

19) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	23	25	25	25
8	39	57	56	51
10	55	81	85	68
16	75	159	140	107
20	80	189	170	120
40	129	398	311	229
80	264	827	575	445
Sample size	115	118	104	69

20) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	24	24	25	25
8	54	48	59	6
10	65	59	77	92
16	100	106	116	162
20	132	114	136	194
40	230	182	238	370
80	473	388	430	699
Sample size	77	182	137	97

21) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	15	15	16	16
5	18	24	20	21
8	29	42	41	40
10	36	54	44	43
16	41	80	67	73
20	61	94	77	78
40	85	184	141	149
80	165	414	284	303
Sample size	113	83	121	182

22) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	22	25	25	25
8	49	64	64	58
10	63	89	88	83
16	98	158	181	123
20	116	210	197	164
40	213	381	391	266
80	424	763	780	534
Sample size	41	121	57	64

23) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	15	16	16	16
5	21	25	25	25
8	34	61	59	56
10	39	90	81	71
16	64	149	129	102
20	83	161	165	128
40	153	329	280	232
80	326	607	508	497
Sample size	115	160	163	127

24) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	24	24	24
8	59	51	44	54
10	80	69	56	71
16	141	125	84	113
20	170	144	90	143
40	332	275	153	226
80	675	581	310	466
Sample size				

25)Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	63	63	63	63
10	95	95	96	96
16	185	190	182	180
20	252	242	248	233
40	435	516	437	464
80	965	1156	1031	982
sample size	229	229	231	234

26) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	51	63	63	57
10	76	87	94	81
16	106	158	174	142
20	141	219	230	191
40	243	450	441	358
80	485	966	955	730
Sample size	133	220	186	154

27) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	15	16	16
5	25	21	24	25
8	52	41	47	46
10	75	59	54	58
16	120	95	87	78
20	141	120	95	106
40	258	204	168	191
80	471	409	329	384
Sample size	141	164	94	105

A2.5.1 Carbon Black

1) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	24	25
8	57	61	55	59
10	84	85	82	85
16	153	167	147	161
20	206	177	185	210
40	403	346	381	409
80	790	716	826	803
Sample size	217	228	134	240

2) Condition : Kneading temperature = 170 °C

Speed of screw = 81 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	59	60	57	55
10	85	87	82	80
16	150	154	133	145
20	203	218	168	176
40	364	394	321	339
80	785	795	638	640
Sample size	164	173	135	157

3) Condition : Kneading temperature = 170 °C

Speed of screw = 81 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	15	16	16
5	25	25	25	24
8	56	60	60	60
10	87	86	83	85
16	167	170	172	159
20	231	254	227	216
40	531	480	486	438
80	1139	1086	1080	953
Sample size	214	198	206	178

4) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	15	16	16
5	25	25	25	24
8	61	55	62	58
10	91	88	86	82
16	182	170	163	165
20	223	224	209	208
40	429	434	460	436
80	947	968	913	876
Sample size	156	146	149	149

5) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	63	59	60	60
10	96	83	89	87
16	185	159	168	153
20	252	222	233	188
40	560	452	476	425
80	1134	973	1039	902
Sample size	195	164	162	137

6) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	24	24
8	57	59	52	50
10	77	82	71	64
16	140	154	123	108
20	173	194	153	141
40	424	399	341	275
80	746	856	758	603
Sample size	148	132	144	111

7) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	60	57	58	63
10	85	86	84	96
16	158	166	167	204
20	198	213	217	275
40	418	450	520	673
80	913	1005	1154	1247
Sample size	165	176	189	209

8) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	58	57	59	61
10	86	82	88	93
16	157	154	185	197
20	200	214	257	262
40	398	396	576	581
80	890	837	1285	1280
Sample size	143	176	244	226

9) Condition : Kneading temperature = 170 ^{o}C

Speed of screw = 324 rpm

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	61	62	59	56
10	92	87	89	76
16	165	158	183	138
20	221	206	230	173
40	446	421	539	377
80	928	884	1122	818
Sample size	197	173	202	149

10) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	63	58	63	60
10	99	84	96	84
16	212	155	200	158
20	285	210	264	190
40	631	447	589	397
80	1345	971	1255	876
Sample size	236	199	147	125

11) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	24	25	25
8	59	60	62	60
10	84	82	87	86
16	151	153	164	158
20	169	198	227	194
40	364	374	451	435
80	755	715	991	947
Sample size	116	118	166	159

12) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	51	55	52	54
10	73	87	74	77
16	116	140	118	132
20	153	204	171	174
40	294	394	306	310
80	626	833	593	580
Sample size	113	152	119	117

13) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	63	64	63	64
10	98	96	97	98
16	193	202	200	199
20	265	272	264	283
40	559	611	569	601
80	1204	1301	1215	1274
Sample size	226	231	217	226

14) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	61	60	62	63
10	86	87	96	94
16	182	168	211	192
20	231	206	286	269
40	588	483	675	616
80	1146	1037	1427	1210
Sample size	177	187	180	259

15) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	59	63	64	64
10	87	88	93	96
16	175	181	185	208
20	221	240	242	282
40	475	483	485	619
80	1030	1033	973	1305
Sample size	186	162	158	154

16) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	62	64	64	64
10	94	96	95	98
16	180	215	192	207
20	250	269	256	279
40	518	591	533	670
80	1010	1211	1165	1547
Sample size	207	244	215	296

17) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 324 rpm

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	59	63	64	64
10	87	88	93	96
16	175	181	185	208
20	221	240	242	282
40	475	483	485	619
80	1030	1033	973	1305
Sample size	194	193	221	220

18) Condition : Kneading temperature = 190 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	59	59	62	62
10	93	92	89	94
16	159	186	169	183
20	220	254	220	255
40	435	508	438	577
80	876	1111	937	1157
Sample size	141	182	155	190

19) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	63	63	62	62
10	92	91	85	90
16	193	190	183	192
20	249	253	227	246
40	563	551	523	594
80	1398	1314	1053	1318
Sample size	216	184	166	204

20) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	24	25
8	60	64	58	62
10	83	93	84	94
16	184	198	152	187
20	222	260	197	259
40	486	591	411	569
80	1064	1276	796	1211
Sample size	138	198	156	197

21) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 81 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	63	61	61	63
10	94	90	90	93
16	176	179	174	166
20	228	229	206	237
40	496	496	454	511
80	1100	1143	994	1073
Sample size	189	207	219	211

22) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	64	63	64	63
10	98	100	98	93
16	209	207	218	201
20	292	279	300	256
40	673	638	657	604
80	1521	1476	1417	1276
Sample size	275	272	268	252

23) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	62	60	62	61
10	92	85	86	87
16	180	165	194	188
20	240	233	259	255
40	553	507	585	564
80	1160	1086	1243	1214
Sample size	203	182	214	197

24) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 162 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	61	58	61	63
10	88	96	86	84
16	198	193	165	168
20	272	268	220	218
40	636	602	481	465
80	1481	1329	1049	106
Sample size	242	217	175	159

25) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 100

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	64	64	61	64
10	93	97	94	98
16	195	207	202	226
20	264	293	296	304
40	576	643	664	737
80	1268	1350	1493	1765
Sample size	194	224	236	276

26) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 500

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	62	62	62	63
10	81	94	94	95
16	194	210	197	205
20	248	282	274	278
40	535	651	639	650
80	1225	1468	1358	1415
Sample size	191	224	208	207

27) Condition : Kneading temperature = 210 ^{o}C

Speed of screw = 324 rpm.

Feed rate = 900

n	N(r)			
	1	2	3	4
2	4	4	4	4
4	16	16	16	16
5	25	25	25	25
8	62	64	63	64
10	94	94	98	97
16	224	186	204	207
20	269	264	276	277
40	615	543	604	663
80	1413	1222	1331	1537
Sample size	275	247	241	275

A2.6 The fractal dimension and the normalized values of the fractal dimension in the case of the carbon black pigment at various co

Kneading temp., T_k, (°C)	Speed of screw, R, (rpm)	Feed rate, F, (g/min)	Number of particle	Fractal dimension			Normalized fractal dimension	
				experiment	$D_{uniform}$	D_{normal}	D_1^*	D_2^*
170	81	4.5	160	1.697	1.76	1.55	0.964	1.095
		22.7	157	1.676	1.75	1.55	0.958	1.081
		41.4	250	1.760	1.86	1.65	0.946	1.066
	162	4.5	179	1.746	1.78	1.57	0.981	1.112
		22.7	203	1.750	1.81	1.59	0.967	1.101
		41.4	134	1.607	1.71	1.52	0.940	1.057
	324	4.5	177	1.760	1.78	1.57	0.989	1.121
		22.7	197	1.767	1.81	1.59	0.976	1.111
		41.4	118	1.721	1.70	1.50	1.012	1.147
190	81	4.5	220	1.785	1.82	1.61	0.981	1.109
		22.7	140	1.702	1.75	1.55	0.972	1.098
		41.4	125	1.617	1.70	1.50	0.951	1.078
	162	4.5	250	1.845	1.84	1.64	1.003	1.125
		22.7	201	1.800	1.81	1.59	0.994	1.132
		41.4	165	1.734	1.77	1.56	0.979	1.111
	324	4.5	241	1.836	1.85	1.64	0.992	1.120
		22.7	243	1.804	1.83	1.63	0.986	1.107
		41.4	239	1.778	1.83	1.61	0.971	1.104
210	81	4.5	193	1.803	1.81	1.59	0.996	1.134
		22.7	195	1.780	1.80	1.60	0.989	1.112
		41.4	207	1.764	1.81	1.59	0.974	1.109
	162	4.5	267	1.865	1.85	1.64	1.008	1.137
		22.7	199	1.793	1.81	1.59	0.990	1.127
		41.4	198	1.790	1.81	1.59	0.989	1.126
	324	4.5	233	1.869	1.82	1.61	1.027	1.161
		22.7	208	1.841	1.81	1.59	1.017	1.158
		41.4	260	1.851	1.85	1.64	1.000	1.128

A2.7 The fractal dimension and the normalized values of the fractal dimension in the case of the iron oxide pigment at various conditions

Kneading temp., T_k, (°C)	Speed of screw, R, (rpm)	Feed rate, F, (g/min)	Number of particle	Fractal dimension			Normalized fractal dimension	
				experiment	$D_{uniform}$	D_{normal}	D_1^*	D_2^*
170	81	4.5	88	1.508	1.65	1.47	0.914	1.026
		22.7	102	1.528	1.68	1.48	0.910	1.033
		41.4	105	1.429	1.68	1.49	0.851	0.959
	162	4.5	91	1.520	1.65	1.47	0.921	1.034
		22.7	141	1.631	1.75	1.55	0.932	1.052
		41.4	90	1.504	1.65	1.47	0.912	1.023
	324	4.5	95	1.465	1.66	1.48	0.883	0.993
		22.7	128	1.650	1.72	1.52	0.959	1.086
		41.4	102	1.557	1.68	1.48	0.927	1.052
190	81	4.5	109	1.528	1.68	1.49	0.909	1.025
		22.7	79	1.519	1.60	1.45	0.949	1.048
		41.4	71	1.396	1.55	1.39	0.900	1.004
	162	4.5	81	1.390	1.60	1.45	0.869	0.959
		22.7	121	1.592	1.71	1.51	0.931	1.055
		41.4	99	1.553	1.66	1.48	0.935	1.049
	324	4.5	110	1.558	1.69	1.50	0.922	1.039
		22.7	180	1.772	1.79	1.48	0.990	1.197
		41.4	109	1.575	1.68	1.49	0.937	1.057
210	81	4.5	113	1.527	1.69	1.50	0.904	1.018
		22.7	123	1.650	1.71	1.51	0.965	1.092
		41.4	175	1.664	1.78	1.57	0.935	1.060
	162	4.5	70	1.330	1.50	1.38	0.887	0.964
		22.7	220	1.795	1.82	1.61	0.986	1.115
		41.4	138	1.623	1.73	1.53	0.941	1.064
	324	4.5	155	1.873	1.78	1.57	1.052	1.193
		22.7	173	1.758	1.78	1.57	0.987	1.119
		41.4	80	1.532	1.60	1.45	0.957	1.056

A2.8 Estimated number of pigment particles in a SEM microphotograph sample

1) For iron oxide

Accroding to the experimental procedure, polystyrene and iron oxide are premixed at the ratio 25:1 by weight.

Basis of Calculation :

weight of polystyrene = 25 g.

weight of iron oxide = 1 g.

true density of polystyrene = 1.04 g/cm^3

true density of iron oxide = 5.24 g/cm^3

particle size of iron oxide = 0.2 μm

volume of polystyrene = 25 / 1.04 = 24.04 cm^3

volume of iron oxide = 1 / 5.24 = 0.19 cm^3

$\therefore$ Total volume = 24.04 + 0.19 = 24.23 cm^3

volume of each pigment particle $= \frac{4}{3}\pi\left(\frac{0.20}{2}\mu m\right)^3 = 4.19 \times 10^{-3}$ μm^3

Total particles of pigment = $0.19 \times 10^{12} / 4.19 \times 10^{-3}$

= 4.53×10^{13} particles

$\therefore$ Number of pigment particles per unit volume = $4.53 \times 10^{13} / (24.23)$

= 1.87×10^{12} particles/cm^3

= 1.87 particles/μm^3

Total area of one SEM = 250.0 μm^2

Assume 1 μm depth of field depth

$\therefore$ number of particles in one SEM micorphotograph

= 1.87 x 250.0 x 1.0 particles

= 467.5 $\approx$ 470 particles

2) For Carbon black

Polystyrene and carbon black are premixed at the ratio 25:1 by weight.

Basis of calculations :

weight of polystyrene = 25 g.

weight of carbon black = 1 g.

true density of polystyrene = 1.04 g/cm^3

true density of carbon black = 2.25 g/cm^3

particle size of carbon black = 0.095 μm

volume of polystyrene = 25 / 1.04 = 24.04 cm^3

volume of corbon black = 1 / 2.25 = 0.44 cm^3

$\therefore$ Total volume = 24.04 + 0.44 = 24.48 cm^3

volume of each pigment particle $= \frac{4}{3}\pi\left(\frac{0.095}{2}\mu m\right)^3 = 4.49 \times 10^{-4}$ μm^3

Total particles of pigment = $0.44 \times 10^{12} / 4.49 \times 10^{-4}$

= 9.80×10^{14} particles

$\therefore$ Number of particles per unit volume = $9.80 \times 10^{14} / (24.48)$

= 4.00×10^{13} $particles/cm^3$

= 40.0 $particles/\mu m^3$

Total area of one SEM = 25.60 μm^2

Assume 1 μm depth of field depth

$\therefore$ amount of particles in sampling area

= 40.0 x 25.06 x 1.0 particles

= 1002.4 particles

$\approx$ 1000 particles

A3. Simulation program

A3.1 Listing of simulation program (Qbasic language)

```
'  ********************************************************************
'  *** 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                                ***
'  ********************************************************************
DECLARE SUB SUBUNIFORM ( )
DECLARE SUB SUB2 ( )
DECLARE SUB SUB1 ( )
COMMON SHARED IY, IA, IT, IT AS LONG
COMMON SHARED PAI, RANR, TI, TR, XO, XT, YY AS DOUBLE
COMMON SHARED Q, MS, N, S, Z( ), ST, P( ), Sf, MSF, SUM, SSUM, STD, Ds, A,
              B, TB, A  AS DOUBLE
DIM Z( 100, 100 ), P( 100, 100), Sf(100, 100)
CLS
INPUT "TI = ", TI
PRINT "TI = "; TI
IT = TI * 101#
100   IF (IT - 24350542) < 0 THEN GOTO 200 ELSE 150
```

```
150     IT = IT/10
        GOTO 100
200     IY = 42758321 + IT
        IA = INT(IY/2)
        IY = IA * 2 + 1
        INPUT "Sample population size = ", Q
        INPUT "Mean particle size (micron) = ", MP
        PAI = 4# * ATN(1#)
        AP = PAI *(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
        CALL SUBUNIFORM
        X = INT ( RANR * MS + 1 )
        CALL SUBUNIFORM
        Y = INT ( RANR * MS + 1 )
        Z ( X, Y ) = Z ( X, Y ) + 1
    NEXT I
END SUB
SUB SUB2
    FOR I = 1 TO Q
        CALL SUBUNIFORM
        XO = SQR ( -2# * LOG ( RANR ) )
        CALL SUBUNIFORM
        XR = 6.2831853072# * RANR
        XT = XO * SIN ( XR )
        X = INT ( XT / 3 * MS /2 + MS / 2 + 1 )
        IF X > 80 THEN X = 80
        IF X < 1 THEN X = 1
        CALL SUBUNIFORM
        YO = SQR ( -2# * LOG ( RANR ) )
        CALL SUBUNIFORM
        YR = 6.2831853072# * RANR
        YT = YO * SIN ( 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
SUB SUBUNIFORM
    YY = 3125# * IY
    IY = INT(YY/67108864# + 1# * 10 ^ (-8))
    IY = INT(YY - IY * 67108864# + 0.05)
    RANR = IY / 67108864#
END SUB
```

A3.2 Simulation data

A3.2.1 The simulation data calculated by Equation (3.4)

(Present work)

1) Sample population size = 10

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

2) Sample population size = 64

n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	4	4	4	4	4	4	4	4
4	16	16	16	16	12	12	12	11
5	25	22	24	23	14	14	16	16
8	43	38	38	35	29	26	27	30
10	52	46	47	43	36	33	35	38
16	58	55	54	51	52	48	49	47
20	62	58	60	56	52	53	51	52
40	64	63	63	60	62	63	61	60
80	64	63	64	62	64	63	63	63

3) Sample population size = 256

n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	4	4	4	4	4	4	4	4
4	16	16	16	16	16	14	16	14
5	25	5	5	25	20	21	21	18
8	64	62	64	64	42	40	42	37
10	94	89	95	90	57	56	61	51
16	152	155	165	161	105	97	103	95
20	183	181	191	191	132	128	133	129
40	236	230	242	242	207	202	208	204
80	252	250	251	253	243	242	244	239

4) Sample population size = 640

n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	4	4	4	4	4	4	4	4
4	16	16	16	16	15	15	16	16
5	25	25	25	25	23	23	25	22
8	64	64	64	64	53	50	53	49
10	100	100	100	100	73	75	76	73
16	236	236	234	237	143	143	155	139
20	320	319	319	325	198	197	203	197
40	527	530	540	541	383	398	412	399
80	618	608	617	618	545	565	547	556

5) Sample population size = 1280

n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	4	4	4	4	4	4	4	4
4	16	16	16	16	16	16	16	16
5	25	25	25	25	24	24	24	24
8	64	64	64	64	54	60	55	53
10	100	100	100	100	83	86	82	77
16	255	254	254	254	174	180	171	166
20	384	386	377	386	239	249	248	236
40	883	878	878	886	571	584	576	595
80	1154	1153	1172	1169	995	981	980	982

6) Sample population size = 3200

n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	4	4	4	4	4	4	4	4
4	16	15	16	16	16	16	16	16
5	25	25	25	25	25	25	25	25
8	64	64	64	64	61	60	61	61
10	100	100	100	100	93	92	92	92
16	256	256	256	256	210	210	213	209
20	400	399	400	400	307	305	307	306
40	1381	1390	1402	1402	847	835	833	856
80	2536	2534	2616	2524	1841	1795	1854	1852

7) Sample population size = 6400

n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	4	4	4	4	4	4	4	4
4	16	16	16	16	16	16	16	16
5	25	25	25	25	25	25	25	25
8	64	64	64	64	62	36	61	62
10	100	100	100	100	96	96	97	95
16	256	256	256	256	229	228	230	226
20	400	400	400	400	335	339	345	338
40	1567	1574	1576	1575	1042	1018	1012	1036
80	4041	4019	4271	4089	2614	2586	2557	2609

8) Sample population size = 12800

n	Number of counted segments in each sample ; N(r)							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	4	4	4	4	4	4	4	4
4	16	16	16	16	16	16	16	16
5	25	25	25	25	25	25	25	25
8	64	64	64	64	64	64	64	63
10	100	100	100	100	97	96	99	98
16	256	256	256	256	234	239	238	235
20	400	400	400	400	360	361	362	366
40	1599	1599	1600	1599	1212	1218	1186	1201
80	5553	5570	5899	5581	3361	3372	3367	3357

A3.2.2 The simulation data calculated by the coefficient of variance (Terashita' s fractal dimension)

1) Sample population size = 10

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00024	0.00024	0.00028	0.00019	0.00011	0.00006	0.00041	0.00002
4	0.00095	0.00054	0.00067	0.00054	0.00123	0.00054	0.00123	0.00109
5	0.00127	0.00084	0.00105	0.00127	0.00169	0.00105	0.00127	0.00105
8	0.00380	0.00275	0.00222	0.00275	0.00380	0.00328	0.00380	0.00328
10	0.00614	0.00450	0.00368	0.00450	0.00450	0.00532	0.00532	0.00450
16	0.01209	0.01000	0.01000	0.01209	0.01625	0.01000	0.01000	0.01000
20	0.02233	0.01584	0.01584	0.01584	0.01908	0.01584	0.01584	0.01584
40	0.06444	0.06444	0.06444	0.06444	0.06444	0.06444	0.06444	0.06444
80	0.25888	0.25888	0.25888	0.25888	0.25888	0.25887	0.25882	0.25888

2) Sample population size = 64

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00014	0.00045	0.00028	0.00019	0.00010	0.00015	0.00033	0.00006
4	0.00037	0.00067	0.00067	0.00054	0.00346	0.00408	0.00428	0.00387
5	0.00046	0.00158	0.00105	0.00127	0.00531	0.00594	0.00534	0.00389
8	0.00189	0.00346	0.00222	0.00275	0.00494	0.00658	0.00667	0.00518
10	0.00314	0.00467	0.00368	0.00450	0.00774	0.00953	0.00838	0.00595
16	0.00976	0.01106	0.01000	0.01209	0.01204	0.01431	0.01496	0.01464
20	0.01466	0.01669	0.01584	0.01584	0.02075	0.01923	0.02278	0.02075
40	0.06225	0.06428	0.06444	0.06444	0.06631	0.06428	0.06833	0.07036
80	0.25666	0.26476	0.25888	0.25884	0.25666	0.26477	0.26465	0.26477

3) Sample population size = 256

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00016	0.00006	0.00032	0.00043	0.00033	0.00007	0.00011	0.00004
4	0.00077	0.00072	0.00082	0.00108	0.01574	0.01734	0.01614	0.01740
5	0.00062	0.00077	0.00088	0.00119	0.01770	0.01898	0.01685	0.02095
8	0.00231	0.00281	0.00198	0.00337	0.02265	0.02267	0.01938	0.02391
10	0.00355	0.00389	0.00321	0.00461	0.02315	0.02405	0.02005	0.02593
16	0.00982	0.00973	0.00960	0.01041	0.03237	0.03342	0.02911	0.03172
20	0.01502	0.01604	0.01676	0.01536	0.04062	0.03808	0.03376	0.03389
40	0.06343	0.06282	0.06156	0.06156	0.08436	0.08791	0.08234	0.08538
80	0.25196	0.26007	0.25903	0.25497	0.27209	0.27723	0.27723	0.28533

4) Sample population size = 640

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00016	0.00006	0.00004	0.00004	0.00015	0.00016	0.00004	0.00022
4	0.00000	0.00072	0.00067	0.00070	0.03792	0.04109	0.03598	0.03706
5	0.00062	0.00077	0.00067	0.00164	0.04788	0.04404	0.03755	0.04132
8	0.00231	0.00281	0.00307	0.00215	0.05573	0.05101	0.04339	0.04720
10	0.00355	0.00389	0.00263	0.00499	0.05678	0.05126	0.04493	0.05161
16	0.00982	0.00973	0.00947	0.00917	0.06532	0.05924	0.05364	0.05924
20	0.01502	0.01604	0.01452	0.01574	0.06878	0.06888	0.06020	0.06466
40	0.06343	0.06282	0.06140	0.06181	0.12179	0.11916	0.10659	0.11429
80	0.25196	0.26007	0.25196	0.25280	0.32002	0.30220	0.31581	0.30787

5) Sample population size = 1280

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00005	0.00040	0.00013	0.00019	0.00012	0.00020	0.00006	0.00002
4	0.00061	0.00112	0.00042	0.00086	0.07784	0.07697	0.07972	0.07592
5	0.00102	0.00134	0.00097	0.00123	0.08081	0.08895	0.09562	0.09016
8	0.00279	0.00290	0.00252	0.00233	0.09595	0.09703	0.10250	0.10033
10	0.00354	0.00407	0.00384	0.00385	0.09329	0.10032	0.10651	0.10107
16	0.01018	0.00976	0.01041	0.01041	0.10686	0.10781	0.11312	0.11381
20	0.01670	0.01388	0.01645	0.01518	0.11009	0.11380	0.12298	0.11941
40	0.06404	0.06627	0.06424	0.06150	0.16009	0.16424	0.16526	0.16759
80	0.26250	0.26230	0.25197	0.25580	0.35161	0.35709	0.35470	0.35838

6) Sample population size = 3200

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00007	0.00001	0.00005	0.00016	0.00007	0.00002	0.00006	0.00042
4	0.00027	0.00031	0.00053	0.00084	0.18606	0.18739	0.18548	0.18290
5	0.00045	0.00059	0.00085	0.00113	0.20705	0.20736	0.21324	0.20285
8	0.00200	0.00237	0.00244	0.00232	0.22962	0.22887	0.23298	0.21947
10	0.00273	0.00366	0.00296	0.00391	0.23804	0.23768	0.23704	0.22305
16	0.00871	0.00931	0.00954	0.01045	0.24826	0.25042	0.24971	0.23498
20	0.00146	0.01558	0.01383	0.01616	0.25249	0.25609	0.23622	0.24115
40	0.06335	0.06420	0.06100	0.06388	0.29952	0.30393	0.29495	0.29118
80	0.25250	0.25399	0.23610	0.25697	0.44569	0.45652	0.43520	0.43913

7) Sample population size = 6400

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00001	0.00001	0.00019	0.00002	0.00002	0.00007	0.00003	0.00001
4	0.00035	0.00073	0.00044	0.00058	0.38077	0.38147	0.39342	0.36585
5	0.00081	0.00161	0.00054	0.00072	0.35024	0.34846	0.35782	0.34177
8	0.00284	0.00320	0.00224	0.00218	0.38486	0.37969	0.39262	0.37048
10	0.00350	0.00552	0.00313	0.00443	0.39490	0.39964	0.41197	0.38315
16	0.01095	0.01199	0.00823	0.01031	0.40395	0.40246	0.40827	0.39282
20	0.01605	0.01703	0.01375	0.01663	0.39944	0.39985	0.41648	0.39247
40	0.06746	0.06560	0.05709	0.06361	0.41958	0.41928	0.42992	0.40868
80	0.24830	0.25256	0.25197	0.23795	0.48855	0.48967	0.49597	0.48509

8) Sample population size = 12800

n	Coefficient of variation ; Ds							
	Uniform distribution				Normal distribution			
	1	2	3	4	1	2	3	4
2	0.00015	0.00021	0.00018	0.00006	0.00011	0.00006	0.00003	0.00014
4	0.00080	0.00088	0.00043	0.00062	0.38178	0.37882	0.38252	0.38326
5	0.00116	0.00125	0.00068	0.00074	0.38625	0.38767	0.39301	0.38560
8	0.00229	0.00197	0.00199	0.00255	0.37953	0.38167	0.38771	0.38189
10	0.00416	0.00376	0.00246	0.00395	0.39458	0.38921	0.39770	0.38750
16	0.01096	0.01011	0.00692	0.01243	0.39350	0.39239	0.40019	0.39436
20	0.01565	0.01530	0.01009	0.01595	0.39545	0.39764	0.39981	0.39703
40	0.06356	0.05902	0.04568	0.06070	0.41311	0.40782	0.41363	0.41067
80	0.19656	0.19689	0.14732	0.19370	0.46596	0.46475	0.46701	0.46757

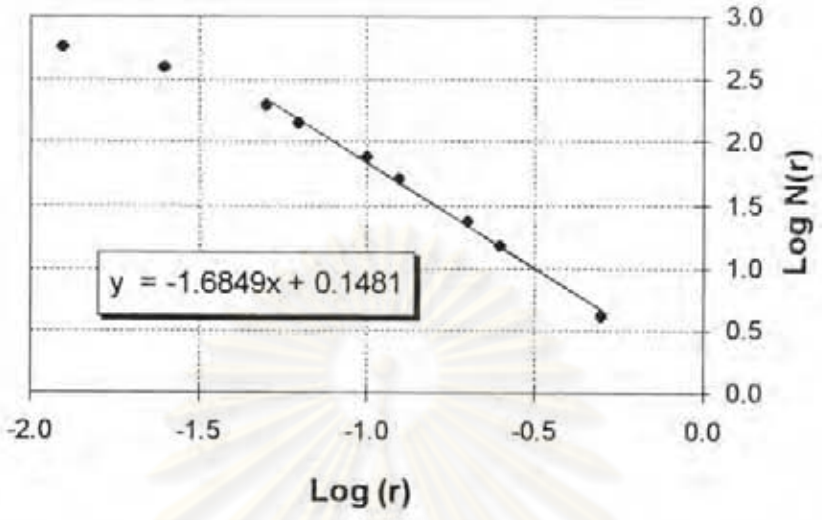
A4. Example of calculation of fractal dimension

1) Fractal dimension based on the counting method

Here is an example of the calculation of fractal dimension for the ideal case of normal random dispersion. The table and plot below shows the relationsip between N(r) and r obtained from the simulation result for a sample population size of 640 particles.

n	r	N(r)
2	0.5	4
4	0.25	15
5	0.2	23
8	0.125	50
10	0.1	75
16	0.0625	143
20	0.05	197
40	0.025	398
80	0.0125	565

Plotting the relationship between log (N(r)) and log r



From $$D = \frac{-\log N(r)}{\log (r)}$$

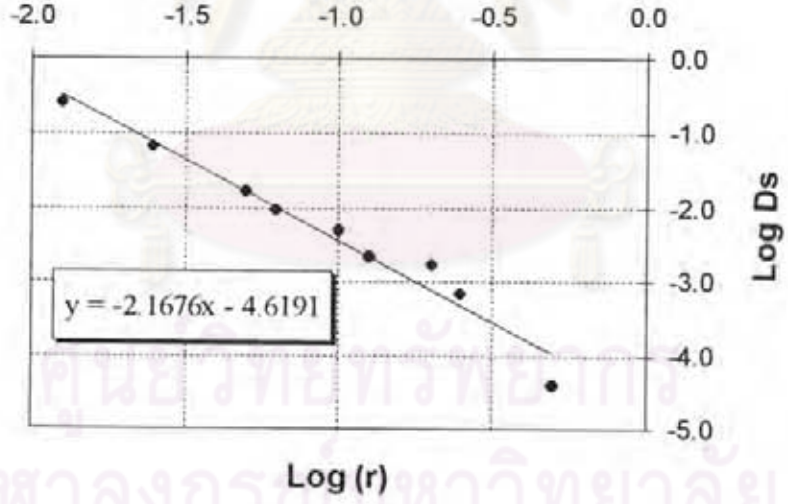
The fractal dimension was obtained by linear regression from the portion of the most numerous observed data lying on the same straight line.

Thus D = 1.6849

2) Fractal dimension based on Terashita's approach

In case of Terashita's fractal dimension for ideal case of the uniform random dispersion, plotting the relationship between coefficient of variation (D_s) and the similarity ratio (a sample population size of 640 particles) gives the following table and figure.

n	r	Ds
2	0.5	0.00004
4	0.25	0.00070
5	0.2	0.00164
8	0.125	0.00215
10	0.1	0.00499
16	0.0625	0.00917
20	0.05	0.01574
40	0.025	0.06181
80	0.0125	0.25280



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

In the same way, the fractal dimension can be obtained by linear regression to be

$$D = 2.1676$$

VITA

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