Variation of roughness parameters on some typical manufactured surfaces

T.R. Thomas and G. Charlton*

A number of specimen surfaces, including machined surfaces and calibration standards, are examined by a stylus instrument on-line to a microcomputer. For each measurement on each specimen 14 roughness parameters are computed for each of 10 profiles, and the mean and standard deviation of each parameter is calculated. Variations of up to 15% are found even on calibration standards, and 50% variations or larger are found on many machined surfaces. Increasing the range setting and decreasing the cut-off are both found to increase scatter. Using a skid has little effect. Measuring with the lay increases the scatter. Decreasing the sampling interval has no effect on R_a and R_q roughness but increases R_z and similar roughness and makes texture parameters 'sharper'

Until quite recently, the only parameter available for characterising roughness with commercial stylus instruments was the average roughness, R_a. However, it has long been recognised that this parameter alone is not sufficient to describe the topography of real engineering surfaces for the purposes either of research or of quality control[1]. In recent years the advent of computer techniques has made a wide range of additional parameters available to the research worker, and these have been used with some success in a variety of applications[2]. With the appearance of microprocessor-based instruments these techniques have spread to the shopfloor; compact instruments offering 10, 15 or more roughness parameters are currently available from several different manufacturers.

Before these new parameters can safely and reliably be used, however, it is necessary to have some idea of their natural variation. Everyone who has used the stylus instrument knows that the traditional R_a roughness as displayed on the instrument meter can vary appreciably from place to place on the same surface. It may not be generally known that this can be true even for calibration specimens[3]. For reasons which we will consider later, this variation may be even more pronounced in the case of some of the newer computer-based parameters. In this paper we describe the results of an extensive investigation into the natural variation of a range of roughness parameters on a wide variety of specimens, including calibration standards and surfaces machined by a number of techniques.

Experiment

Equipment

Measurements were carried out with a standard Talysurf 4 stylus instrument (Rank Taylor Hobson, Leicester) fitted with a proprietary interface designed in our laboratories for Advanced Metrology Systems of Leicester and linking it to a 32k CBM PET microcomputer with a printer. The software originally written for this system permitted the computation of 14 roughness parameters on line: average roughness R_a, rms roughness R_q, skewness *Sk*, kurtosis *K*, 10-point height R_z, mean peak-to-valley height R_{tm}, average roughness depth R_{3z}, mean peak height R_{pm}, average wavelength λ_a, high spot count *HSC*, mean slope *MS*, mean high-spot spacing s_m, mean peak radius of curvature *MPRC*, and mean valley radius of curvature *MVRC*. The system design, including both hardware and software, has been described extensively elsewhere[4]

For the purposes of this paper it will serve to emphasise two points. Firstly, each profile measurement consists of a single sample length, ie at 0.8mm cut-off the parameters displayed are computed over a total measured profile length of 0.8mm. The variations described are thus the true variations from place to place on the specimens and they are not confused with or obscured by the effect of averaging over several consecutive sample lengths in the same profile. Secondly, computation is carried out on the raw profile without any distortion due to analogue filtering; trend removal is accomplished by fitting a least-squares straight line to each sample length as laid down in BS1134:1972.

For the present series of experiments the software has been modified to facilitate the sequential measurement of a number of profiles on the same specimen. For a single profile the same 14 roughness parameters are computed and displayed on the screen, and the operator may choose to print them if they present any unusual feature. The 14 values are in any case stored and the operator may proceed to the measurement of another profile. Up to a hundred profiles may be measured in this way. When the operator signifies that he does not want to measure any more profiles on that particular specimen the computer prints out, for each of the 15 parameters, the mean value averaged over all profiles measured, the standard deviation, and the coefficient of variation, that is the ratio of the standard deviation to the mean.

Specimens

A wide variety of specimens were selected for measurement. In view of the work of Young and Scire previously referred to it was thought useful to begin by an examination of the variation on calibration standards, and measurements were made on a Rank Taylor Hobson standard which is a nominally two-dimensional sinusoidal surface, and a Ferranti Tokio Seimitsu standard of nominally triangular wave-form. Two Rubert tactile comparison standards, often used for research work as examples of reproducible surface finishes, were measured, one ground and the other shot-blasted; finally a range of machined specimens were measured which had originally been carefully prepared for some comparative trials with a laser scanning analyser[5]; these comprised surfaces which were milled, spark eroded, shaped and ground. On each specimen, ten parallel profiles were measured separated by equal distances of 1mm.

**Department of Mechanical Engineering, Teesside Polytechnic, Middlesbrough, Cleveland TS1 3BA, UK*

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Measurements

The experimental programme was intended to investigate the effect of a number of variables. Of these, the first was the range setting of the stylus instrument. When a computer system is used it is not necessary to spend time seeking the range setting which will give a meter reading, as the computer will give a more or less sensible answer provided the stylus transducer is within its dynamic range. However, not all these answers may be equally valid. At low magnifications, where the total signal may only be a fraction of full scale deflection, quantisation error can become a problem, as discussed by Whitehouse[6]. At high magnifications, on the other hand, the signal to noise ratio may be poor. Thus it seems likely that there may be some optimum range setting for the use of computer instruments, and it is interesting to determine how serious these fluctuations may be.

The effect of cut-off is also likely to be important. With a computer system working at a fixed sampling interval, the shorter the sampling length the smaller the sample of discrete height readings on which computation is performed (see below), and it has been suggested that this effect can give rise to large variations.

Shopfloor stylus measurements are usually made with a skid fitted to the pick-up, an expedient which often saves a good deal of setting-up time. It has been claimed that the presence of the skid does not seriously affect measurements (see for example Nara[7]), but if comparative facilities are available it seems of some interest to determine how serious this effect really is. Accordingly a number of measurements were made on the same specimen with a skid and then with the manufacturers' optional straight-line datum.

It has been known for many years that surfaces with highly directional properties, for example ground surfaces, give different measurements of average roughness along and across the lay[8]. These differences appear also in other roughness parameters[9]. Are these differences accompanied by corresponding differences of variation?

Finally some measurements were made of the effect of varying the sampling interval. This is the distance between discrete height measurements and is a variable in a digital measuring system. For a given sample length the shorter the sampling interval, the greater the number of discrete height measurements. If the number of measurements is too few, the degree of uncertainty in the result may be unacceptable. If it is too many, much time and computer memory capacity may be wasted unnecessarily. Measurements were therefore made over exactly the same ten profiles across the lay of a ground specimen at a cut-off of 0.25mm at sampling intervals of 10, 2 and 0.4 μm.

Full details of the experimental programme, including specimen particulars, range settings, nominal roughnesses, and cut-offs, are presented in Table 1.

Table 1 Specimens and tests

Test	Specimen	Nominal R_a, μm	Range	Cut-off, mm
1			1	
2			2	
3	RTH reference standard	0.27	3	0.8
4			4	
5			5	
6			1	
7			2	
8	RTH reference standard	0.8	3	0.8
9			4	
10			1	
11			2	
12	Ferranti reference standard	0.5	3	0.8
13			4	
14			5	
15			1	
16	Ferranti reference standard	3.0	2	0.8
17			3	
18			1	
19	Rubert ground tactile comparison standard	1.6	2	0.8
20			3	
21	Rubert shotblasted tactile comparison standard	1.6	1	0.8
22			2	
23				2.5
24	Milled surface with datum		1	0.8
25				0.25
26	Milled surface with skid	3.6	1	2.5
27				0.8
28				2.5
29	Milled surface with datum	4.6	1	0.8
30				0.25
31	Milled surface with datum	15.5	1	2.5
32				0.8
33				2.5
34	Milled surface with datum	1.2	1	0.8
35				0.25
36				2.5
37	Milled surface with skid	1.2	1	0.8
38				0.25
39				2.5
40	Milled surface with datum	1.6	1	0.8
41				0.25

Results and discussion

Most of the results are set out in Table 2. As the main point of this experiment was to investigate the range of variation, mean values have been suppressed as irrelevant, and the only figures presented are those for the percentage coefficient of variation. The sole exception to this is the skewness; as its nominal mean value for a symmetrical distribution is zero, the concept of coefficient of variation is a meaningless one, and the absolute (ie normalised) values of the standard deviation are therefore presented for this parameter. It is appreciated that even in this abbreviated form Table 2 is somewhat lengthy, but it is felt that these results are of such importance that it is worthwhile quoting them in full for the benefit of research workers and of the many quality control engineers who are currently seeking to evaluate computerized roughness measuring systems. To give a visual impression of the results some of them are summarized in Figs 1–3.

Parameters

In the case of the calibration specimens, where it is reasonable to regard differences between individual profiles as small random perturbations, one would expect the conditions of the Central Limit Theorem to apply and hence that differences between parameters would be explained by the

Test	Specimen	Nominal R_a, µm	Range	Cut off, mm
42 43 44	Milled surface GP6 with datum	2.9	1	2.5 0.8 0.25
45 46 47	Spark-eroded surface GP7 with datum	11	1	2.5 0.8 0.25
48 49 50	Spark-eroded surface GP7 with skid	11	1	2.5 0.8 0.25
51 52 53	Spark-eroded surface GP8 with datum	3.1	1	2.5 0.8 0.25
54 55 56	Shaped surface GP9 with datum	1.6	1	2.5 0.8 0.25
57 58 59	Shaped surface GP9 with skid	1.6	1	2.5 0.5 0.25
60 61 62	Shaped surface GP10 with datum	1.4	1	2.5 0.8 0.25
63 64 65	Ground surface 46 wheel with lay with datum	–	4	2.5 0.8 0.25
66 67 68	Ground surface 46 wheel across lay with datum	–	4	2.5 0.8 0.25
69 70	Ground surface 60 wheel with lay with datum	0.15	4	2.5 0.8
71 72 73	Ground surface 60 wheel across lay with datum	0.40	4	2.5 0.8 0.25
74 75 76	Ground surface 80 wheel with lay with datum	0.50	4	2.5 0.8 0.25
77 78 79	Ground surface 80 wheel across lay with datum	0.54	4	2.5 0.8 0.25
80 81 82	Ground surface 80 wheel across lay with skid	0.54	4	2.5 0.8 0.25

Superposition of Errors Theorem (eg Leaver and Thomas[10]). On this basis one would expect percentage variations in R_a and R_q to be much the same as each other and as the variation in mean slope, because these all sum essentially the same heights, and the results of Fig 1 agree very roughly with this.

Computations of peak and valley radii of curvature are based on a central difference formula for the curvature C at ordinate y_0 [11]

$$C \simeq 2y_0 - y_{-1} - y_1$$

Application of the Superposition of Errors Theorem is not strictly justified here, as it requires the variables to be independent whereas they are actually correlated. However, it may be used to predict a worst case, which would be an error in radii of curvature of $\sqrt{6} \simeq 2.5$ times the error in R_a or R_q, and Fig 1 would seem to bear this out for the RTH standard. By the same token, as kurtosis involves height raised to the fourth power, one would

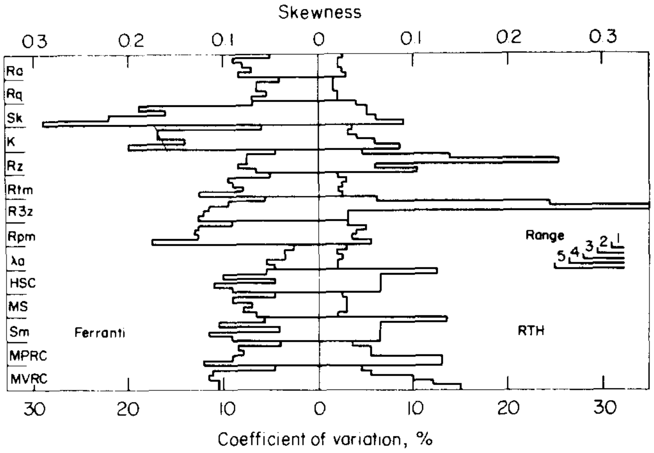

Fig 1 Coefficients of variation of 14 roughness parameters measured on two calibration standards, Ferranti (left) and RTH (right), showing also the effect of instrument range setting

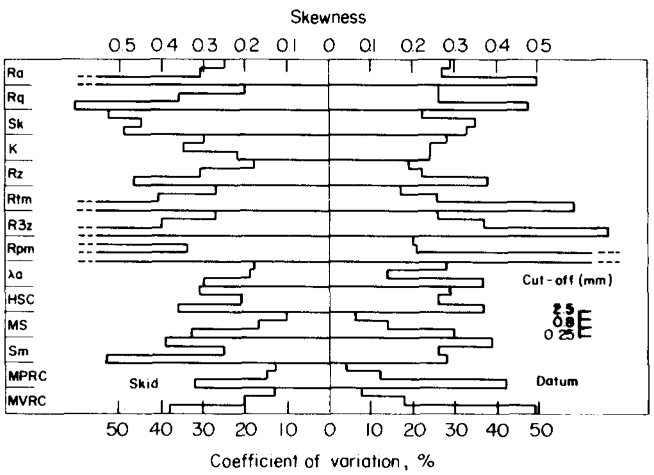

Fig 2 Coefficients of variation measured on a shaped surface with (left) and without (right) a skid, showing also the effect of cut-off

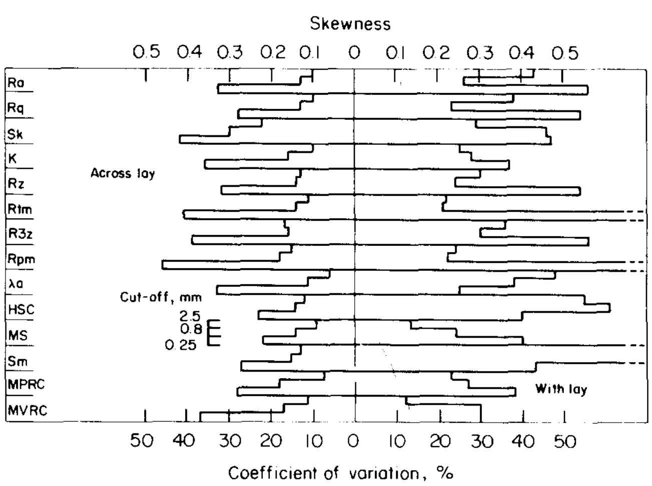

Fig 3 Coefficients of variation measured on a ground surface across (left) and along (right) the lay, showing also the effect of cut-off

Table 2 Percentage coefficients of variation (except* which is absolute value)

Test	R_a	R_q	S_k*	K	R_z	R_{tm}	R_{3z}	R_{pm}	λ_a	*HSC*	*MS*	S_m	*MP RC*	*MV RC*
1	2.3	1.4	0.04	3.8	4.7	1.8	5.9	2.9	2.8	12.6	2.6	13.6	3.4	4.3
2	1.8	1.3	0.05	3.1	13.9	3.0	24.3	5.0	2.2	6.5	2.8	6.3	5.3	5.3
3	1.8	1.4	0.05	4.0	25.7	2.5	42.0	4.0	2.5	6.7	2.8	6.7	5.6	9.9
4	2.4	1.8	0.06	6.2	6.0	1.9	3.0	3.7	2.1	6.7	2.8	6.7	13.1	12.1
5	3.0	2.0	0.09	8.5	10.5	2.3	3.0	5.5	1.9	6.6	1.8	6.5	12.9	15.0
6	1.9	1.3	0.05	3.8	11.7	3.8	28.8	3.4	2.8	5.6	2.2	5.1	6.1	6.9
7	2.2	1.7	0.07	6.5	15.3	2.2	43.4	5.3	2.0	6.7	2.8	6.7	11.7	7.8
8	1.9	1.4	0.05	3.3	12.4	3.0	3.5	5.1	2.0	6.6	1.1	6.5	7.0	5.4
9	1.9	1.4	0.05	5.0	13.0	2.3	2.3	5.4	1.2	6.5	2.2	6.6	14.3	7.0
10	5.1	4.0	0.07	6.0	4.3	5.2	5.3	8.8	2.4	5.3	4.7	5.3	4.1	4.4
11	9.1	6.4	0.19	16.9	7.6	9.4	9.7	12.7	3.7	10.2	11.5	10.3	8.7	11.1
12	7.8	6.4	0.16	16.8	7.3	9.1	11.6	12.8	3.7	4.3	9.3	4.2	8.1	11.7
13	7.2	5.7	0.22	13.8	8.3	8.2	12.1	12.5	5.5	10.9	10.4	11.3	9.1	10.7
14	8.6	6.9	0.28	20.2	6.7	12.7	12.5	17.4	4.7	9.1	9.2	8.9	11.9	10.7
15	1.3	1.6	0.04	2.9	2.5	5.0	3.9	9.6	1.9	7.3	2.3	6.8	18.9	8.4
16	1.6	1.8	0.08	2.3	9.3	5.4	3.3	9.8	1.7	6.7	2.2	6.1	12.5	5.8
17	2.1	1.8	0.09	4.3	6.7	6.3	3.6	11.3	3.6	7.7	2.5	7.4	17.6	6.9
18	24	23	0.17	13	25	23	29	28	18	36	20	51	18	25
19	24	22	0.18	16	25	25	30	23	17	22	16	22	18	18
20	26	24	0.14	12	23	21	31	20	18	33	13	34	11	12
21	14	9	0.63	45	23	30	59	34	12	38	7	38	16	10
22	21	18	0.53	37	26	38	53	47	19	34	8	37	18	6
23	19	16	0.46	29	17	15	25	20	18	42	10	49	11	22
24	22	20	0.62	27	24	22	46	34	22	45	14	52	15	16
25	53	52	0.35	27	25	71	45	76	30	54	35	35	88	42
26	31	30	0.39	18	27	21	37	19	30	45	9	41	22	17
27	32	28	0.75	29	29	35	57	55	33	72	8	51	23	26
28	19	17	0.39	17	18	17	18	14	23	41	8	40	15	17
29	26	26	0.35	12	23	27	45	25	22	32	17	44	28	16
30	52	49	0.78	52	28	58	27	81	29	35	27	27	33	38
31	17	15	0.42	31	11	18	16	19	12	23	11	30	12	14
32	47	44	0.42	37	35	33	37	52	39	37	15	47	22	18
33	29	26	0.22	28	19	17	26	20	28	29	6	39	4	8
34	27	26	0.35	24	22	26	37	21	14	26	14	26	12	18
35	50	48	0.33	24	38	59	67	110	37	37	30	28	42	49
36	25	20	0.53	30	18	27	27	62	18	31	10	39	13	13
37	31	36	0.45	35	31	41	40	34	19	21	17	25	15	20
38	65	61	0.49	22	47	81	68	94	30	36	33	53	32	38
39	30	34	0.67	45	33	34	51	40	21	16	13	15	11	18
40	37	37	0,38	24	26	37	39	36	19	39	21	40	22	20

expect its variation to be about twice that of R_a or R_q, and Fig 1 confirms this also for the RTH standard. For the machined surfaces the variations are so large that they can no longer be treated as small perturbations, and the distinctions between parameters diminish.

Specimens

The present results confirm the findings of Young and Scire that R_a roughness can vary from place to place on a calibration standard by several percent (Fig 1). Other parameters vary by a good deal more than this, and variations of 15% or more are not uncommon. Fig 1 also shows a clear and systematic difference between the triangular Ferranti standard and the sinusoidal RTH standard, with the Ferranti standard consistently more variable, no doubt a reflection of the different methods of manufacture. On the machined surfaces variations are very much larger, and the differences in variation between parameters are diminished (eg Figs 2 and 3). Variations of 50% or more are quite common.

Range

The effect of the range setting is more serious for some parameters than for others (eg Fig 1). The R_a and R_q roughness are quite insensitive to range, while the extreme-value parameters are highly sensitive and their variation increases by factors of three or more as the signal-to-noise ratio decreases. The texture parameters are relatively insensitive and in some cases become less variable at the higher ranges. Overall the safest practice would seem to be the easiest one for the operator, namely to stay with the lowest practicable range of the instrument.

Cut-off

The effect of decreasing cut-off or sample length is generally to increase the extent of variation (Figs 2 and 3). However, the increase in variation is by no means proportional to the change in cut-off, and is generally larger as the cut-off falls from 0.8mm to 0.25mm than from 2.5mm to 0.8mm. BS1134:1972 recommends 0.8mm

Test	R_a	R_q	S_k*	K	R_z	R_{tm}	R_{3z}	R_{pm}	λ_a	*HSC*	*MS*	S_m	*MP RC*	*MV RC*
41	35	33	0.40	26	31	73	30	88	31	57	21	57	24	35
42	33	33	0.44	21	31	33	36	40	28	29	9	31	12	9
43	18	17	0.51	24	28	26	46	25	14	29	17	28	21	16
44	35	33	0.61	35	28	58	55	62	19	41	24	53	28	29
45	15	15	0.60	26	18	17	18	18	11	39	8	46	14	28
46	25	23	0.38	22	24	35	45	46	22	32	15	36	27	33
47	36	33	0.20	17	21	67	21	102	29	50	34	44	84	102
48	15	14	0.29	16	18	16	22	20	15	18	14	17	21	14
49	23	20	0.43	28	24	21	39	32	32	28	19	49	27	22
50	39	38	0.46	31	23	31	33	45	25	45	29	47	46	40
51	10	11	0.46	13	13	16	12	26	8	17	9	17	9	16
52	24	25	0.67	30	24	36	35	45	14	22	18	27	22	26
53	29	29	0.38	28	22	43	24	72	27	41	25	43	29	33
54	40	40	0.97	45	38	43	50	52	28	47	25	37	23	28
55	46	45	0.63	43	42	55	54	68	40	43	31	41	24	23
56	52	48	0.92	58	47	72	54	77	30	30	31	30	32	36
57	39	34	0.90	54	30	34	35	48	29	45	15	86	19	12
58	30	32	1.01	72	25	16	44	27	23	25	18	29	21	24
59	43	45	0.23	13	41	35	52	36	25	51	35	70	24	36
60	38	32	0.62	25	26	29	28	33	40	58	17	61	34	18
61	57	61	0.87	33	55	64	49	78	39	71	29	84	34	30
62	80	84	0.68	50	70	101	87	125	27	57	61	50	65	48
63	43	38	0.29	25	30	22	36	24	48	55	13	151	23	12
64	26	23	0.46	28	24	21	30	22	38	61	24	91	27	30
65	56	54	0.47	37	54	80	61	104	25	40	40	43	38	30
66	10	10	0.22	10	13	11	17	15	6	12	9	13	7	11
67	13	13	0.30	16	14	14	16	18	11	14	14	15	18	17
68	33	28	0.42	36	32	41	39	46	33	23	22	27	28	37
69	28	30	0.39	17	28	23	23	22	27	39	21	42	22	31
70	46	43	0.43	24	36	43	40	60	32	54	23	106	25	25
71	17	15	0.35	20	14	15	16	26	11	15	8	17	10	11
72	25	22	0.40	22	22	22	31	27	21	24	13	24	19	21
73	21	17	0.38	27	13	42	38	50	21	25	11	19	17	23
74	21	23	0.51	28	27	25	34	18	19	34	16	46	18	21
75	37	33	0.72	32	36	25	41	31	22	24	25	25	30	29
76	56	56	0.73	32	49	73	59	85	30	47	32	90	43	36
77	9	9	0.21	20	9	13	9	17	6	7	9	7	10	8
78	14	11	0.32	25	10	11	17	18	14	18	11	17	15	14
79	25	21	0.40	25	24	39	49	52	24	28	20	28	26	21
80	8	9	0.24	20	12	18	12	23	7	13	6	14	7	9
81	7	9	0.40	15	10	17	24	17	11	21	11	22	8	22
82	20	20	0.57	30	21	36	37	38	19	30	24	34	29	31

cut-off for general use, and Figs 2 and 3 suggest that one descends below this at one's peril.

Skid

The difference between measurements taken with and without skid is not large, but seems to be systematic (Fig 2). Most of the height-dependent parameters vary a little more with the skid, while most of the texture-dependent parameters are relatively insensitive to the skid's presence. As the function of the skid is to remove long wavelengths, to which all height parameters are sensitive, the former result seems rather odd. The results do suggest, however, that if consistency is important it may be worth taking the extra trouble to use the datum accessories.

Lay

Measurements made with the lay of a ground surface are clearly subject to larger variation than those made across the lay (Fig 3). This is in line with the prediction of Whitehouse[12] that the variation is inversely proportional to the square root of the signal bandwidth; because of the relative absence of short wavelengths parellel to the lay the bandwidth is narrower. It is also in line with the earlier findings of Thomas[13] that the correlation length varies very markedly in directions close to the lay.

Sampling interval

In Table 3 the three sets of means and standard deviations of the 14 parameters are set out. Varying the sampling interval from 10μm to 0.4μm increases the number of height readings from 25 to no less than 625 for 0.25mm length of profile. The effect on mean and scatter of R_a and R_q roughness, skewness and kurtosis is negligible. For the extreme value parameters R_z and so on their mean value tends to increase as the sampling interval decreases; this is because smaller peaks and valleys are being counted, thus a large peak counted once at 10μm sampling interval may resolve itself into two or more peaks of the same or slightly greater height at 0.4μm interval.

Table 3 Effect of sampling interval

Sampling interval, μm	10	2	0.4
No. of ordinates	25	125	625
R_a, μm	0.26±0.08	0.26±0.04	0.25±0.07
R_q, μm	0.32±0.09	0.34±0.05	0.32±0.08
Sk	-0.12±0.50	-0.32±0.52	-0.32±0.38
K	3.0 ±1.0	3.18±0.89	3.10±0.63
R_z, μm	0.65±0.18	1.02±0.05	1.27±0.28
R_{tm}, μm	0.94±0.39	1.51±0.25	1.59±0.33
R_{3z}, μm	0.80±0.35	0.95±0.22	1.22±0.25
R_{pm}, μm	0.35±0.23	0.67±0.17	0.68±0.19
λ_a, μm	65± 14	28.2±5.2	18.6±4.9
HSC, mm^{-1}	15.5±5.2	37.3±8.3	64± 34
MS, degrees	1.45±0.35	3.45±0.02	5.25±0.00
S_m, μm	72± 25	28.4±7.4	20.0±9.2
MPRC, μm	258±111	26.7±3.9	2.45±0.30
MVRC, μm	-172 ± 52	-15.3±3.1	-2.70±0.52

For the texture parameters the changes are much more dramatic. The average wavelength decreases because shortening the sampling interval has the effect of broadening the spectrum of wavelengths by extending the spectrum at the short-wavelength end. High spot count increases because more mean-line crossings can be resolved by the smaller sampling interval. Mean slope increases, and peak and valley radii of curvature decrease, for the same reason that smaller features are now being resolved. The effect is greater for curvatures than for slopes because the former depend on the square of the sampling interval.

This may cause the new user of computerized roughness measuring systems some bewilderment. What, he asks, is the real slope of the profile, and which is the correct sampling interval? The answer, as first pointed out by Whitehouse and Archard[11], is that slopes, curvatures and so on are not intrinsic properties of a profile and do not have unique values. To specify a slope or whatever one must also specify a sampling interval. At the moment no national roughness standards specify this parameter. Until standards are brought up to date one sensible way to proceed is to base the sampling interval on the relevant physical property of the measured surface[14]. To do this successfully, however, it is necessary to have a second-generation measuring system where the sampling interval can be varied by the user; in earlier systems the sampling interval is preset by the manufacturer regardless of the user's particular needs.

Conclusions

The extent of variation is different for different roughness parameters. On calibration standards these variations are smallest for R_a, R_q and mean slope and greatest for extreme-value parameters, as error theory predicts. On machined surfaces the differences are less. Variations of 15% or more in particular roughness parameters are found even on calibration standards. On machined surfaces variations of 50% are not uncommon. This implies firstly that multi-parameter roughness measuring systems will be difficult to calibrate, and secondly that some caution will be needed in specifying tolerances for quality control applications.

It is safest to make measurements at the lowest practicable range of the instrument. Reducing the sampling length increases the scatter of the results. A cut-off below 0.8mm should not be used if possible. Using a skid does not make much difference, but there is a slight increase in consistency with a datum. Measurements with the lay on a directional surface should be avoided if possible, as the narrower bandwidth of surface wavelengths gives greater scatter.

For a given length of profile, decreasing the sampling interval, that is increasing the number of discrete height measurements used for computation, has no appreciable effect on average-height parameters; it increases extreme-height parameters; and it makes texture parameters 'sharper', an effect already well known. It is essential that the sampling interval be quoted when texture measurements from a computerized system are presented.

References

1. **Thomas T.R.** Recent Advances in the Measurement and Analysis of Surface Microgeometry. *Wear, 1975,* **33,** *205–233*
2. **Thomas T.R.** The Characterisation of Changes in Surface Topography in Running-in. *Proc. 4th Leeds-Lyon Symp., pp. 99–103 MEP, London, 1978*
3. **Young R.D. and Scire F.E.** Precision Reference Specimens of Surface Roughness: Some Characteristics of the Cali-Block. *J. Res. Nat. Bur. Stand., 1972* **C76C,** *21–23*
4. **Thomas T.R. and Walker M.** Roughness Measurement with a Microcomputer. *Measurement and Inspection Technology, Nov. 1979, 34–35*
5. **Clarke G.M. and Thomas T.R.** Roughness Measurement with a Laser Scanning Analyser. *Wear, 1979,* **57,** *107–116*
6. **Whitehouse D.J.** The Digital Measurement of Peak Parameters on Surface Profiles. *J. Mech. Eng. Sci., 1978,* **20,** *221–227*
7. **Nara J.** On CLA Value Obtained with Direct Reading Surface Roughness Testers – Effects of Skid and High Pass Filter. *Bull. Japan Soc. Prec. Engg., 1966,* **1,** *263–273*
8. **Schlesinger G.** Surface Finish. *Instn. of Production Engineers, London, 1942*
9. **Thomas T.R. and Probert S.D.** Establishment of Contact Parameters from Surface Profiles. *J. Phys. D:Appl. Phys., 1970,* **3,** *277–289*
10. **Leaver R.H. and Thomas T.R.** Analysis and Presentation of Experimental Results. *Macmillan, London, 1974*
11. **Whitehouse D.J. and Archard J.F.** The Properties of Random Surfaces of Significance in their Contact. *Proc. Roy. Soc. Lond, 1970,* **A.316,** *97–121*
12. **Whitehouse D.J.** Digital Techniques, *in T.R. Thomas ed., Rough Surfaces, Longmans, London (in press)*
13. **Thomas T.R.** Correlation Analysis of the Structure of a Ground Surface. *Proc. 13th Int. Machine Tool Design and Research Conf., 303–306, Macmillan, London, 1973*
14. **Thomas T.R. and Sayles R.S.** Some Problems in the Tribology of Rough Surfaces. *Tribology Int., 1978,* **11,** *8–9*