

Steel Surface Processing:

Grinding and Brushing Measured with the Rhopoint TAMS

Evaluation of a steel sample set ground with grits K36 to K600, with and without a brushing step

Summary

A set of steel samples ground with grits from K36 (coarsest) to K600 (finest), some of them subsequently brushed (D), was measured with the Rhopoint TAMS. The instrument images each field in 3D and delivers areal height values, a perception-linked Quality score and the height maps.

The measurements show:

- **TAMS separates every grinding stage.** Over the dry ladder K36 to K400, Sa falls from 4.76 to 2.12 μm and Quality rises from 91.7 to 95.8. The readings of neighbouring grits never overlap; the smallest step (K320 to K400) is 0.31 μm .
- **Brushing is clearly visible.** At K240, K320 and K400 it lowers Sa by 54.6 %, 65.9 % and 64.6 % and raises Quality by 2.9, 3.1 and 2.9 points. Brushed K400 (Sa 0.75 μm) equals K600 sanded wet (0.79 μm).
- **Brushing lowers the whole height distribution, not only the peaks.** Sk, Spk and Svk fall by 53 to 71 %; the shape of the material ratio curve stays the same (structures above about 0.8 mm).
- **After brushing the starting grit matters little.** K320 D and K400 D differ by less than 0.1 μm in Sa, within the scatter.
- **The scratch lines run along one direction.** Anisotropy falls with finer finishing: Rz across the lay to Rz along the lay drops from 2.4 (K36) to 1.3 (K600 D).
- **TAMS is well suited to process control of matt and satin steel finishes.** It measures every intermediate stage, shows the cause in the maps and grades on one scale. For acceptance of brushed surfaces, the Quality scale should be confirmed with a visual ranking on your own samples.

Please note

- **Sample names.** K36 is the coarsest, K600 the finest grit. D: ground first, then brushed. "Sanded wet": K600 sanded with wet paper.
- **Direction of the values.** Lower Sa, Sq, Sz and Rz mean a smoother surface, a higher Quality (0 to 100) a better-looking one.
- **Not stylus values.** The TAMS values (0.8) are calculated after a Gaussian low-pass filter with a 0.8 mm cut-off. They describe structures from about 0.8 mm up to the size of the measured area; fine roughness below about 0.4 mm does not contribute. They must not be compared with stylus Ra values or with grit-to-Ra tables.
- **Scatter and sample set.** Each condition was measured twice; differences within the scatter of the two readings are not meaningful. The results apply to this sample set only and are not specification values.

Samples and Method

Item	Value
Instrument	Rhopoint TAMS
Samples	10 conditions, 2 readings each (20 measurements)
Conditions	Dry grinding K36, K180, K240, K320, K400; the grits K240, K320, K400 and K600 additionally brushed after grinding (D); K600 sanded wet
Field	672 x 388 pixels of 0.037 mm = 24.9 x 14.4 mm
Instrument values	Sa, Rax and Ray (0.8 mm), Quality and Waviness; heights in μm , lengths in mm
Further evaluation	ISO 25178 areal, functional, spatial and lay parameters recomputed from the height maps of every reading
Statistics	Mean of the two readings per condition; the scatter of the two readings is used where differences between conditions are small

Verification of the evaluation. Sa, Rax and Ray recomputed from the height maps with the filter of the TAMS software reproduce the instrument values to within 0.1 % for all 20 readings, and the 1 to 5 mm and 1 to 10 mm bands to within 4 %. This confirms that the instrument's calculation is understood; it does not show that the TAMS amplitudes are accurate. The values describe structures from about 0.8 mm up to the size of the measured area (about 25 x 14 mm); fine roughness below about 0.4 mm does not contribute.

Finer structure, such as the individual scratches of the finer grits, is therefore not described by these values.

What the Parameters Mean

Parameter	What it describes	How to read it
Sa (μm)	Average height deviation of the filtered surface (structures above about 0.8 mm) from its mean plane; the main height number	Lower = smoother
Sq (μm)	Root-mean-square height deviation; like Sa, but weights high peaks and deep valleys more strongly	Lower = smoother; always slightly above Sa
Sz (μm)	Height from the highest peak to the deepest valley in the evaluated area	Lower = smoother; single extremes influence it strongly
Rax, Ray (μm)	Average height deviation along a line in the horizontal direction (along the scratch lines) and in the vertical direction (across them)	Ray larger than Rax = rougher across the scratches than along them
Quality (0 to 100)	TAMS grade of how good the surface looks to an observer	Higher = better

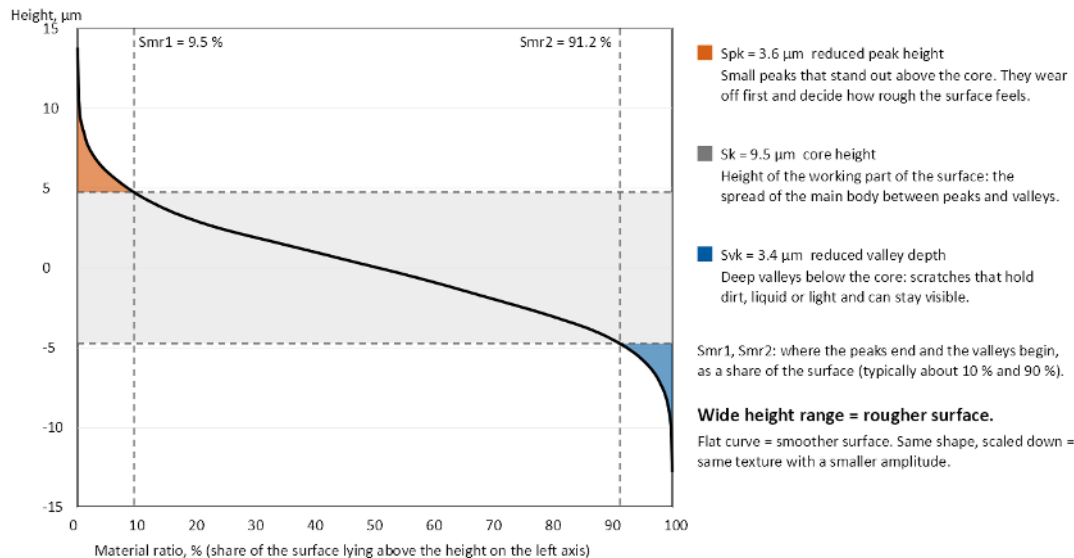
Parameter	What it describes	How to read it
Waviness	TAMS value for the longer-wave structure of the surface	Lower = smoother
Ssk	Symmetry of the height distribution	0 = peaks and valleys balanced; positive = peaks dominate; negative = valleys dominate
Sku	Peakedness of the height distribution	3 = random, Gaussian-type surface; above 3 = a few extreme peaks or valleys; below 3 = evenly spread heights
Sk, Spk, Svk (μm)	Core height, reduced peak height and reduced valley depth from the material ratio curve (explained below)	Lower = smoother
Smr1, Smr2 (%)	Share of the surface where the peaks end (Smr1) and where the valleys begin (Smr2)	Typically about 10 % and 90 %; changes show a change of the curve shape
Sal (mm)	Correlation length: the distance over which the surface still resembles itself	Longer = broader, smoother structures
Str (0 to 1)	Texture aspect ratio	Near 0 = strongly directional lines; near 1 = the same in all directions
Lay angle (degrees)	Direction of the scratch lines against the horizontal axis of the map	0 = horizontal lines
Directional concentration (0 to 1)	How strongly one direction dominates the texture	1 = a single direction; 0 = no preferred direction
Rz along / across lay (μm)	Typical peak-to-valley height of a line profile (mean over 2.5 mm sections), along or across the scratch lines	Lower = smoother
Rz ratio	Rz across the lay divided by Rz along the lay	1 = no difference between the directions; larger = stronger directional character
RSm across lay (mm)	Mean spacing of the structure along a line across the scratch lines	Larger = wider structures

The material ratio (Abbott-Firestone) curve

How it is made. All height values of the evaluated area are sorted from the highest to the lowest. The curve plots every height against the share of the surface that lies above it.

The left end of the curve is the highest points of the surface, the right end the deepest valleys, and the middle is the main body of the surface.

How to read the material ratio (Abbott-Firestone) curve - example: K240 ground, one reading



Material ratio curve of one K240 reading with the parameters read from it.

What it shows

- **Amplitude.** The height range spanned by the curve shows how rough the surface is. A flat curve belongs to a smooth surface, a curve spanning a wide height range to a rough one.
- **Shape.** The ends of the curve show the peaks (Spk, upper left) and the valleys (Svk, lower right), and the middle shows the core (Sk). A surface with few high peaks above a large core has a steep upper end; a surface with deep isolated scratches has a steep lower end.
- **Process effects.** A process that cuts off the peaks and leaves a flat, load-bearing plateau, such as running-in or plateau honing, shows up as a strongly flattened left end: a small Spk compared with Sk and a larger Smr1.
- **Comparison.** Two curves of the same shape but different size show the same texture at different amplitude.

In this report:

The curves of all conditions (figure in the section on functional parameters) are scaled copies of each other.

Brushing makes the curve flatter without changing its shape: core, peaks and valleys all become smaller.

Results

Ground samples

Grit	Sa (µm)	Rax (µm)	Ray (µm)	Quality	Waviness
K36	4.76	4.55	4.74	91.7	2.49
K180	3.88	3.56	3.85	92.7	2.18
K240	2.90	2.56	2.88	94.7	1.58
K320	2.43	2.28	2.39	95.4	1.38
K400	2.12	2.03	2.09	95.8	1.25
K600 sanded wet	0.79	0.72	0.67	98.8	0.37

Ground and brushed (D)

Grit	Sa (µm)	Rax (µm)	Ray (µm)	Quality	Waviness
K240 D	1.31	1.14	1.28	97.6	0.71
K320 D	0.83	0.69	0.76	98.5	0.44
K400 D	0.75	0.65	0.69	98.7	0.39
K600 D	0.54	0.51	0.42	99.1	0.28

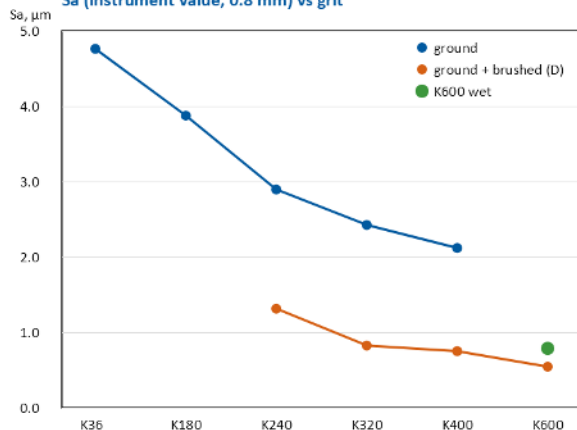
Effect of brushing

Grit	Sa ground to D (µm)	Sa change	Quality ground to D	Waviness change
K240	2.90 to 1.31	-54.6 %	94.7 to 97.6	-54.8 %
K320	2.43 to 0.83	-65.9 %	95.4 to 98.5	-68.2 %
K400	2.12 to 0.75	-64.6 %	95.8 to 98.7	-69.1 %

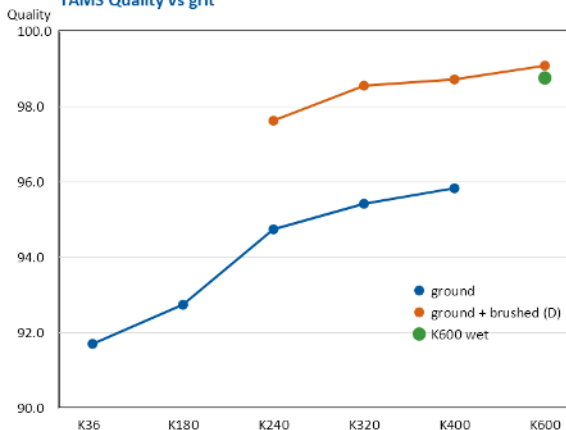
K600 D against K600 sanded wet (a different process):

Sa 0.54 µm against 0.79 µm, 30.8 % lower.

Sa (instrument value, 0.8 mm) vs grit

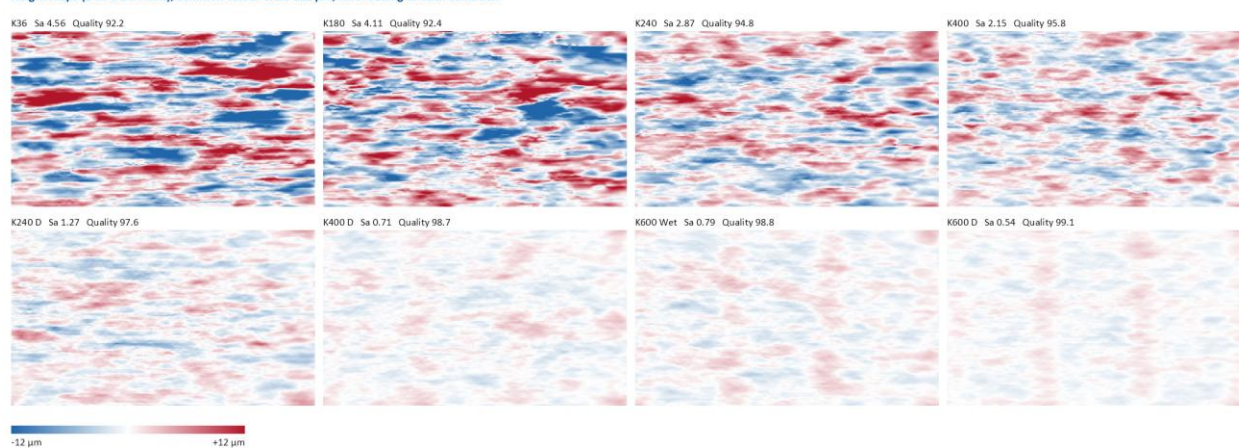


TAMS Quality vs grit



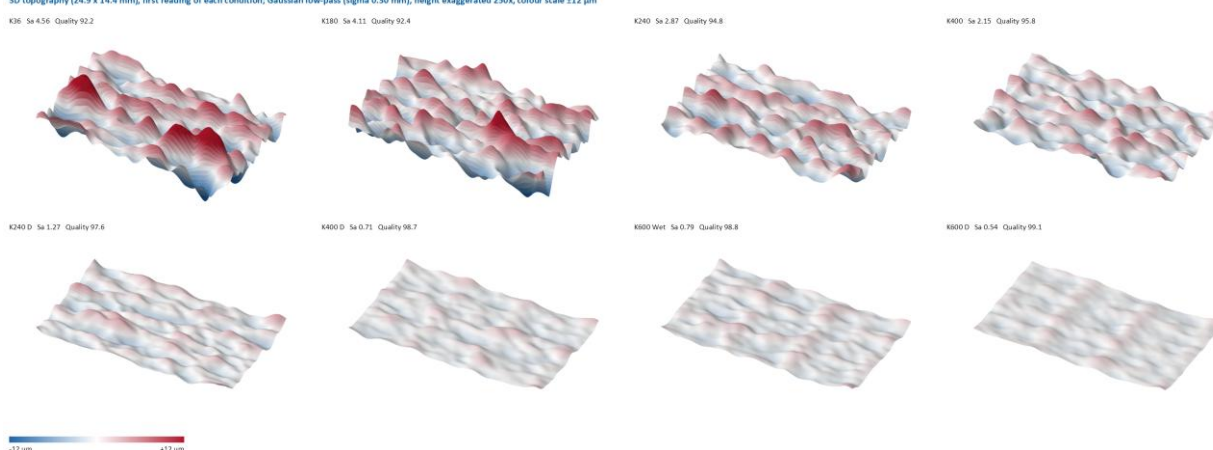
Sa and TAMS Quality against grit; mean of two readings per condition.

Height maps (24.9 x 14.4 mm), common colour scale $\pm 12 \mu\text{m}$, first reading of each condition



Height maps, first reading of each condition, common colour scale $\pm 12 \mu\text{m}$. Ground samples show elongated horizontal scratch structures; brushed samples are nearly flat on the same scale.

3D topography (24.9 x 14.4 mm), first reading of each condition; Gaussian low-pass (sigma 0.30 mm), height exaggerated 250x, colour scale $\pm 12 \mu\text{m}$



3D topography of the same eight readings, from one common viewpoint with a common colour scale ($\pm 12 \mu\text{m}$) and 250 times vertical exaggeration. For display only, the height data are averaged over 4 x 4 pixels (0.148 mm) and smoothed with a Gaussian filter (sigma 0.30 mm) to suppress fine line structure. The smoothing keeps 72 to 80 % of the mean absolute height, so the amplitudes shown are lower than the measured ones; all values in this report come from the unsmoothed data. Ground samples (top row) show ridges and valleys along the scratch direction whose depth shrinks from K36 to K400. Brushed samples (bottom row) are low and smooth.

Areal and Grinding Parameters from the Height Maps

The parameters below are computed from the instrument's height maps for every reading; the tables show the mean of the two readings. The Sa values equal the instrument values above.

Method

- **Surface:** as in the TAMS software: Gaussian low-pass filter with 0.8 mm cut-off (ISO 16610-21) applied to the whole map in one step, mean removed, no plane fit and no edge cropping.
- **Areal parameters** follow ISO 25178-2: Sa, Sq, Ssk, Sku, Sz, and the material ratio parameters Sk, Spk, Svk, Smr1 and Smr2 (40 % window).
- **Spatial and lay parameters:** Sal and Str from the autocorrelation function (decay threshold 0.2); lay angle and directional concentration from the directional power spectrum. The lay angle is the direction of the scratch lines against the horizontal axis of the map. The directional concentration runs from 0 (no preferred direction) to 1 (a single direction).
- **Profile parameters:** Rz (2.5 mm sampling length) along the lay and across the lay, and RSm across the lay.

Height parameters

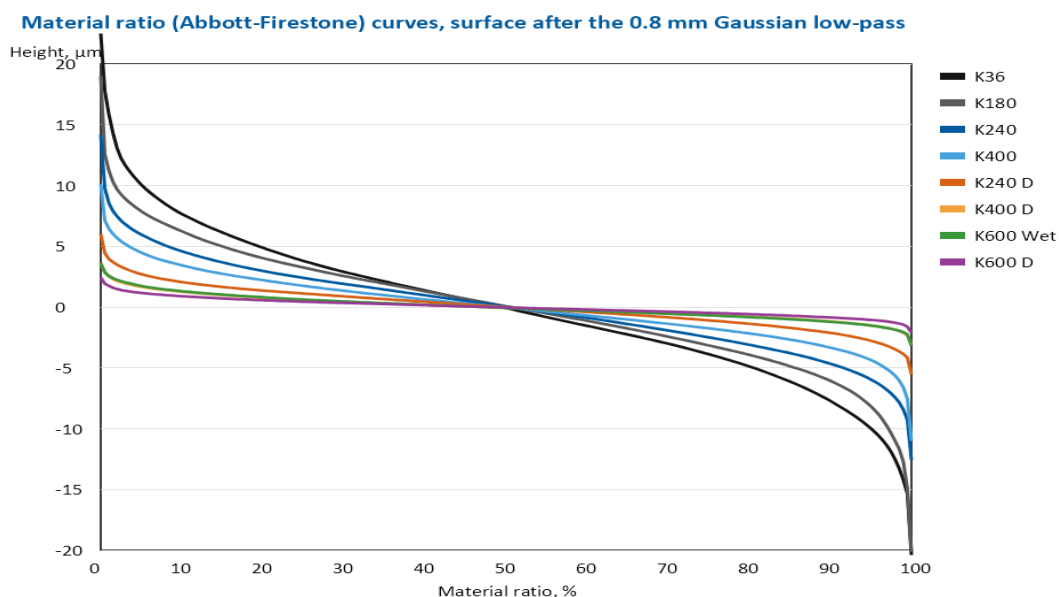
Condition	Sa (μm)	Sq (μm)	Ssk	Sku	Sz (μm)
K36	4.76	6.08	0.13	3.34	42.9
K180	3.88	4.95	-0.17	3.55	39.1
K240	2.89	3.63	0.03	3.06	26.7
K240 D	1.31	1.65	0.02	3.06	11.5
K320	2.42	3.08	0.11	3.37	23.5
K320 D	0.83	1.05	0.17	3.12	7.4
K400	2.12	2.70	-0.01	3.40	21.1
K400 D	0.75	0.96	0.29	3.32	6.7
K600 sanded wet	0.79	0.99	0.34	3.15	6.8
K600 D	0.54	0.68	0.24	3.02	4.5

Sku stays between 3.0 and 3.6 for every condition, the value of a random, Gaussian-type surface: no isolated deep scratches stand out. Ssk is close to zero on the ground samples (-0.17 to 0.13) and positive on the brushed and wet-sanded samples from K320 D on (0.17 to 0.34); with two readings per condition this is an indication only.

Functional parameters (material ratio curve)

Condition	Sk (μm)	Spk (μm)	Svk (μm)	Smr1 %	Smr2 %	Spk/Sk	Svk/Sk
K36	14.64	6.86	6.08	11.4	89.4	0.47	0.42
K180	12.33	4.60	6.14	10.0	90.2	0.37	0.50
K240	9.46	3.66	3.46	9.3	90.3	0.39	0.37
K240 D	4.31	1.72	1.64	8.9	90.2	0.40	0.38
K320	7.76	3.48	3.08	10.3	90.5	0.45	0.40
K320 D	2.62	1.22	0.96	11.3	90.5	0.46	0.37
K400	6.76	2.82	2.94	10.6	90.6	0.42	0.43
K400 D	2.31	1.17	0.86	12.6	90.5	0.50	0.37
K600 sanded wet	2.51	1.17	0.78	11.7	91.9	0.47	0.31
K600 D	1.79	0.74	0.52	10.5	91.7	0.42	0.29

Grit	Sk ground to D (μm)	Spk ground to D (μm)	Svk ground to D (μm)
K240	9.46 to 4.31 (-54 %)	3.66 to 1.72 (-53 %)	3.46 to 1.64 (-53 %)
K320	7.76 to 2.62 (-66 %)	3.48 to 1.22 (-65 %)	3.08 to 0.96 (-69 %)
K400	6.76 to 2.31 (-66 %)	2.82 to 1.17 (-59 %)	2.94 to 0.86 (-71 %)



Material ratio (Abbott-Firestone) curves of the evaluated surface, mean of two readings per condition.

Brushing lowers Sk, Spk and Svk by about the same fraction (53 to 71 %). Spk/Sk (0.37 to 0.50), Smr1 and Smr2 do not move systematically, and the curves in the figure are scaled copies of each other. For structures above about 0.8 mm, brushing therefore reduces the amplitude of the whole texture; it does

not truncate the peaks to form a load-bearing plateau. Whether it does so on finer scales cannot be seen in these values.

Lay and spatial parameters

Condition	Lay angle (deg)	Directional concentration	Str	Sal (mm)	Rz along lay (μm)	Rz across lay (μm)	Rz ratio	RSm across lay (mm)
K36	1.2	0.80	0.19	0.69	6.9	16.8	2.4	3.0
K180	-2.6	0.74	0.27	0.68	6.6	13.7	2.1	2.7
K240	3.3	0.73	0.22	0.68	5.0	9.8	2.0	2.9
K240 D	-0.9	0.78	0.18	0.68	2.2	4.4	2.0	2.7
K320	-1.5	0.64	0.37	0.74	4.5	8.1	1.8	3.0
K320 D	-2.4	0.56	0.29	0.95	1.5	2.5	1.6	2.9
K400	0.6	0.73	0.29	0.66	4.1	7.5	1.8	2.6
K400 D	-1.8	0.58	0.35	1.01	1.4	2.4	1.7	3.1
K600 sanded wet	7.0	0.49	0.58	1.05	1.6	2.2	1.4	3.0
K600 D	-7.2	0.34	0.22	1.22	1.1	1.4	1.3	2.7

- **Lay direction.** The scratch lines run along the horizontal axis of the map (lay angle -2.6 to +3.3 degrees) on all ground samples and on K240 D to K400 D. The wet-sanded K600 (7.0 degrees) and K600 D (-7.2 degrees) deviate slightly, and K600 D has hardly any preferred direction left (directional concentration 0.34).
- **Anisotropy.** The directional concentration falls from 0.80 (K36) to 0.34 (K600 D), and the ratio of across-lay to along-lay Rz from 2.4 to 1.3. Finer finishing and brushing make the surface more isotropic at this scale. Both quantities are more stable than Str, whose two readings scatter considerably (for example K320 D 0.38 and 0.20), so Str alone should not be used to rank these samples.
- **Correlation length Sal.** 0.66 to 0.74 mm on all ground samples and on K240 D, 0.95 to 1.22 mm on K320 D and finer: the finer brushed surfaces are smoother over longer distances.
- **Groove spacing.** RSm across the lay is 2.6 to 3.1 mm for every condition, independent of grit and brushing. This spacing does not follow the abrasive grain: the maps describe the larger-scale texture of the surface, not the individual abrasive scratches.

What can and cannot be derived about the grinding process

- **Can:** lay direction, degree of anisotropy, amplitude of the texture (S_a , S_q , S_z), shape of the height distribution (S_{sk} , S_{ku} , S_k family) and correlation length, per sample and per process stage.
- **Cannot:** process settings such as wheel or belt speed, feed, contact pressure or depth of cut, and the grain-scale scratch geometry. The first group is not contained in a surface measurement; the second lies below the scale these values describe (structures finer than about 0.4 mm). The parameters above are indicators for comparing process stages, not process settings.

What the Results Show

1. **The grit ladder is resolved.** S_a and Waviness fall and Quality rises with every finer dry grit. The mean S_a steps are 0.88 μm (K36 to K180), 0.98 μm (K180 to K240), 0.47 μm (K240 to K320) and 0.31 μm (K320 to K400), and the two readings of neighbouring grits never overlap.
With two readings per grit this is an indication, not a statistical proof.
2. **Two process regimes.** K36 to K400 lowers S_a by 55.5 %. K400 to K600 sanded wet lowers it by a further 62.9 %. The wet-sanded K600 sample belongs to a different process, not to the dry ladder.
3. **Brushing is worth about two grit steps.** It lowers S_a and Waviness and lifts Quality above 97.5 at every grit. The material ratio parameters show that it scales down peaks and valleys alike.
4. **The starting grit is erased from K320 on.** After brushing, the S_a differences between K240 D, K320 D, K400 D and K600 D are 0.49 μm (K240 D to K320 D), 0.07 μm (K320 D to K400 D) and 0.21 μm (K400 D to K600 D), calculated from the unrounded values. Only the K240 to K320 step and the K400 to K600 step are clearly resolved.
5. **The lay and its loss are measurable.** The scratch direction is visible in the maps and quantified by the directional concentration and the R_z ratio. The ratio of R_{Sm} across and along the lay, which Str is meant to describe, tends to rise from 0.37 (K36) to 0.42 to 0.51 for the brushed and wet-sanded samples, in line with the other anisotropy measures.

Published Work for Context

Published work on ground and brushed steel mostly relies on stylus Ra values and on tables relating grit to Ra. We found no areal (ISO 25178) data for brushed stainless steel by grit, so a direct comparison with published values is not possible. There are three points of contact:

- **Height distribution.** Abrasive-ground surfaces are reported in the literature to have a near-normal height distribution [1]. The ground samples agree (S_{ku} about 3, S_{sk} about 0).
- **Anisotropy.** Str is described as the ratio of the spacing across the machining traces to the spacing along them [2]. The ratio of the profile spacings computed here (0.37 to 0.51) and the other anisotropy measures show the same trend towards more isotropy with finer finishing.
- **Comparability with stylus values.** TAMS values and stylus Ra differ in measuring principle, filtering and measured area and must not be compared with each other or with tables relating grit to Ra. A comparison requires measurements with both methods on the same samples.

Sources:

[1] Bulaha et al., study of flat-ground surfaces, 2015:

https://www.iitf.lbtu.lv/conference/proceedings2015/Papers/131_Bulaha.pdf.

[2] Bulaha et al., Research of Surface Roughness Anisotropy, 2017: <https://ortus.rtu.lv/science/en/publications/25401>.

Suitability of TAMS for Judging Steel Surface Processing

Well suited to process control of matt and satin steel finishes. For acceptance of a finished brushed surface, confirm the Quality scale on your own samples.

What supports this

- It separates all dry grinding stages; after brushing only K320 D and K400 D cannot be clearly separated.
- The two readings of a condition agree closely: the K36 pair spreads 8.4 % of the mean in S_a , the K240 to K400 pairs far less.
- It measures matt and sanded stages directly, where gloss meters reach their limit.
- It delivers areal height maps that show the scratch pattern and its direction, not a single line profile.

What to keep in mind

- The Quality score was developed for painted surfaces; its relevance to brushed steel should be confirmed on your own samples.
- At K320 to K600 the S_a differences are only 0.1 to 0.2 μm , close to the scatter.
- The TAMS amplitudes are not verified against a reference instrument and may deviate depending on wavelength; the ranking of the samples is what the data show.
- A brushed finish is judged by line direction and uniformity; no tolerance values exist for these yet.

Annex A: Surface Topography Overview

This annex shows the measured height maps of all ten conditions as isometric 3D views. It illustrates what the parameters in this report describe: the height, direction and size of the structures on the surface.

How to read the figures

- **One row per condition, two versions.** Each row shows the first reading of a condition in the same isometric view in two versions: a) the raw height map as delivered by the instrument (only the mean height removed, no filtering) and b) the filtered height map. Both versions use the same viewpoint, colour scale and vertical exaggeration, so the difference between a) and b) is the filtering only. The scratch lines of the grinding run along the long side of the 24.9 x 14.4 mm field.
- **Colour is height.** The rainbow scale at the right of each figure gives the height above or below the mean plane in μm : blue is a valley, green is close to the mean plane, red is a peak. Values beyond the ends of the scale are shown in the end colours.
- **The two figures use different scales.** So that the finer surfaces remain readable, Figure A1 uses a colour scale of -15 to +15 μm and a vertical exaggeration of 250 times, and Figure A2 uses -6 to +6 μm and 600 times. Heights must be compared between the figures through the scale bars and not by the look of the surfaces. The comparison on one common scale is the height map figure in the section Results.
- **The filtered version (b).** The height data are averaged over 4 x 4 pixels (0.148 mm) and smoothed with a Gaussian filter (sigma 0.30 mm) to suppress fine line structure. The filter keeps 72 to 80 % of the mean absolute height, so the amplitudes shown in b) are lower than the measured ones. The raw version (a) shows the full detail of the map, sampled at 0.037 mm. Structures down to roughly 0.2 mm period may be visible there; their amplitude is strongly attenuated and not quantitative.
- **Relation to the parameters.** Neither version is identical to the surface used for the parameter calculation in this report (0.8 mm Gaussian low-pass over the whole map, see Method). The raw version contains finer structure than that surface and the filtered version less. All values in this report come from the unfiltered height data, evaluated as described in Method.
- **Sa and Quality in the row titles** are the instrument values of the displayed reading and can differ slightly from the means in the tables.

The results refer to the sample set measured and are not specification values.

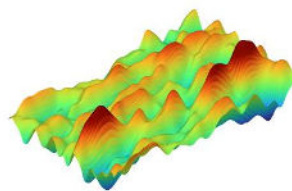
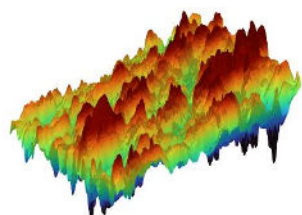
Figure A1: Ground samples (dry)

Isometric view of the 24.9 x 14.4 mm field, raw and filtered, height exaggerated 250x, colour scale -15 to +15 μm (values outside are shown in the end colours)

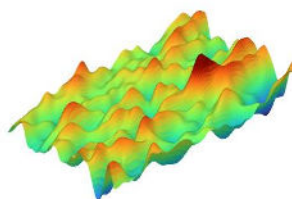
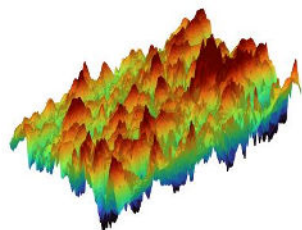
K36 Sa 4.56 μm Quality 92.2

a) Raw (unfiltered)

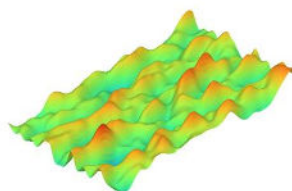
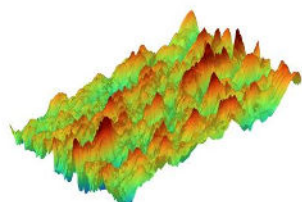
b) Filtered



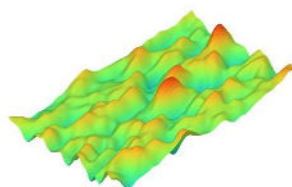
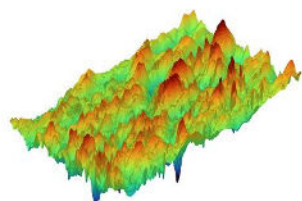
K180 Sa 4.11 μm Quality 92.4



K240 Sa 2.87 μm Quality 94.8



K320 Sa 2.38 μm Quality 95.2



K400 Sa 2.15 μm Quality 95.8

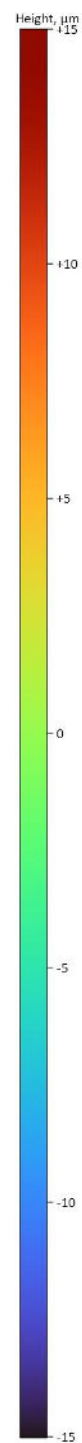
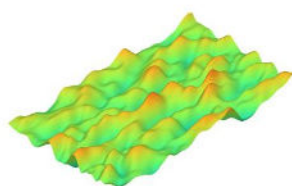
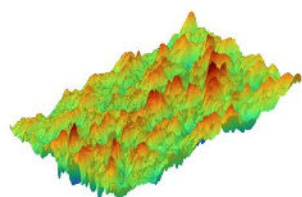


Figure A1: Isometric view of the dry ground samples K36 to K400, a) raw and b) filtered, colour scale -15 to +15 μm , vertical exaggeration 250 times. Ridges and valleys along the scratch direction become lower from K36 to K400; the raw maps show many more fine peaks than the filtered maps.

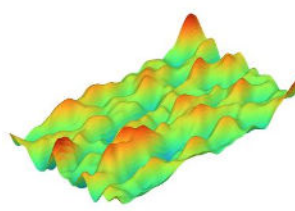
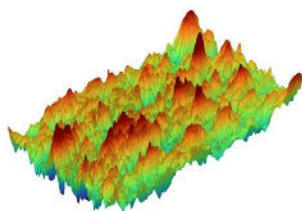
Figure A2: Brushed (D) and wet-sanded samples

Isometric view of the 24.9 x 14.4 mm field, raw and filtered, height exaggerated 600x, colour scale -6 to +6 μm (values outside are shown in the end colours)

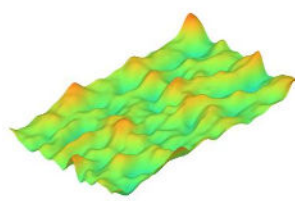
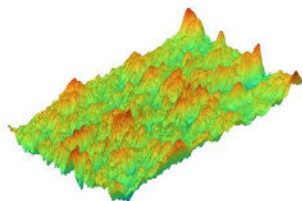
K240 D Sa 1.27 μm Quality 97.6

a) Raw (unfiltered)

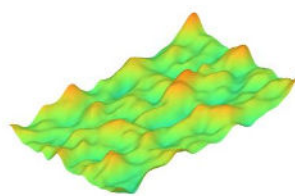
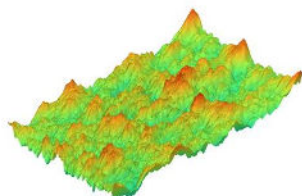
b) Filtered



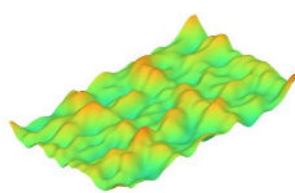
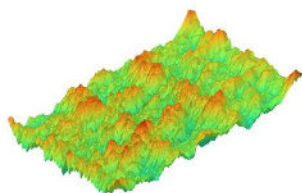
K320 D Sa 0.79 μm Quality 98.5



K400 D Sa 0.71 μm Quality 98.7



K600 sanded wet Sa 0.79 μm Quality 98.8



K600 D Sa 0.54 μm Quality 99.1

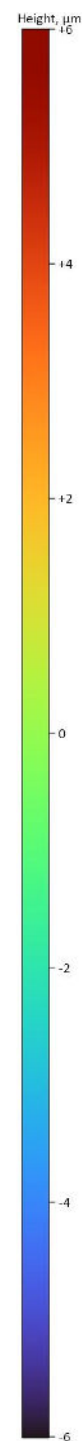
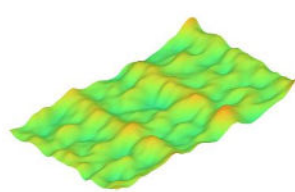
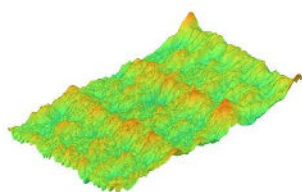


Figure A2: Isometric view of the brushed samples (D) and the K600 sample sanded wet, a) raw and b) filtered, colour scale -6 to +6 μm , vertical exaggeration 600 times, a different scale from Figure A1. The surfaces are smoother and more uniform than the ground samples; K600 D is the most uniform.

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