TAMPEREEN TEKNILLINEN YLIOPISTO

ULTRA BURNISHING

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Abstract

An ultra burnishing equipment developed by Elpro Oy was tested in numerically controlled lathe for different kinds of steel and aluminium. The research was carried out at the Tampere University of Technology, Institute of Production engineering.

The ultra burnishing equipment was found suitable for burnishing used materials. Ra values between 0,5…3,2 µm were measured from turned surfaces and ultra burnished surfaces were between Ra 0,01…0,022 µm. Ultra burnished surfaces of micro-alloy steel, tempering steel, case hardening steel and stainless steel were 2…3 % from turned surfaces evaluated by Ra, Rq and Rp – values and 4…8 % evaluated by Rz, Rt and Rmax – values. Similar surface roughness changes were found with aluminium, but differences of turned and ultra burnished surfaces were smaller in some cases. The profile resolution (0,012 µm) of the stylus type surface roughness gauge were found inadequate for measuring Tp –values from ultra burnished surfaces and remarkable changes compared to turned surfaces were found. Influences to work piece’s geometry were found insignificant.

The best characters of the ultra burnishing equipment are integration of methods and short processing times relative to achieved surface roughness values. Dimensional changes due to storage and re-fixing will be eliminated when the work piece is machined completely in one machine tool. The equipment can be fixed to different kind of machine tools what will give versatile possibilities to its usage. Plain and double-curvature surfaces can be treated with different types of tool tip geometries and it is possible to apply this method in finishing and maintaining moulds, gear wheels and different types of axes. Higher cutting speeds can be used with different types of tool tip geometries.

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Acronyms and denotations

Ø	Diameter
f	Feedrate mm/r
F	Force
ISO	International Organization for Standardization
LSD	Least Significant Deviation
v_c	Cutting speed m/min
P	Output power of a generator
Ra	Arithmetical mean deviation of the assessed profile
Rmax	Local maximum height of profile
Rp	Maximum profile peak height
Rq	Root mean square deviation of the assessed profile
Rt	Total height of profile
Rz	Maximum height of profile
Tp	Relative material (bearing) ratio

2 EXPERIMENTAL ARRANGEMENT

The functionality of the ultra burnishing equipment was tested at the Tampere University of Technology Institute of Production Engineering heavy laboratory with Georg Fischer nc-lathe. Five different materials were used; micro-alloy steel, tempering steel, case hardening steel, stainless steel and aluminium. Materials and used inserts are shown in Table 1.

Table 1. Materials and used inserts.

MATERIAL	INSERT
Micro-alloy steel, IMAMIC (Ovako Steel)	Sandvik DCMT 11T308-UF
Tempering steel, 42 CrMo 4 (Ovako Steel)	Sandvik DCMT 11T304-UF
Case hardening steel, 16 MnCr 5 (Ovako Steel, hardened by Sisu Diesel Oy, Linnavuori)	Kyocera Ceratip DCMW 11T308S2E
Stainless steel, 1,4301	Sandvik DCMT 11T304-UF
Aluminium, AV6262 T6	Arno DCGT 11T304 FN-ALU

300 mm long test pieces were fixed to lathe as shown in Figure 3. Semi-synthetic, water soluble cooling lubricant Hakuform 70/69 was used with 5 % concentration in turning and ultra burnishing. The cooling lubricant was filtered using Finn Filter FC 7005 type filter element with 10 µm filtration ratio and separate magnetic filter.

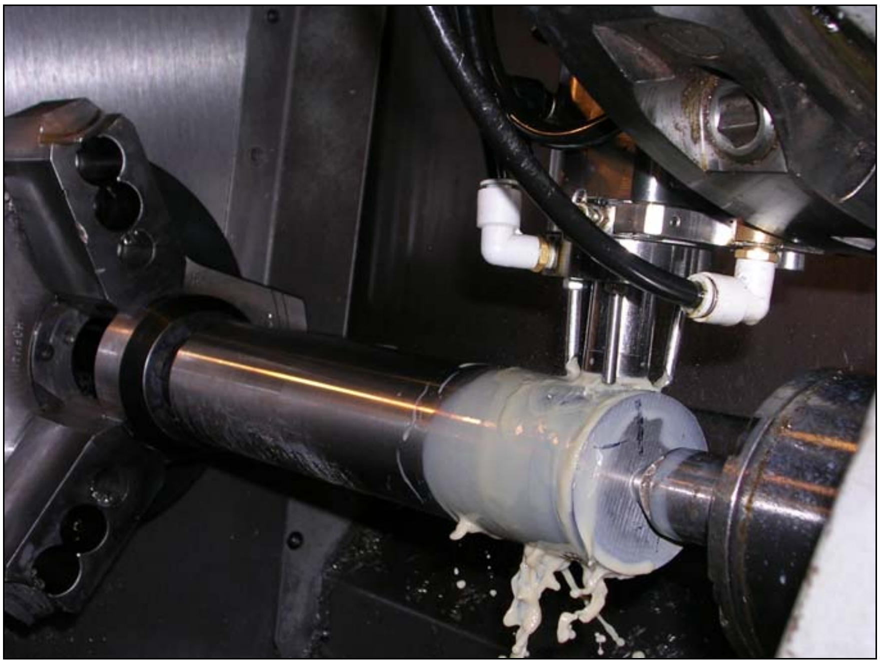

Figure 3. Ultra burnishing in nc-lathe.

Test pieces were straightened and three different 100 mm long surfaces with nominal Ra – values of 0,8 / 1,6 / 3,2 µm were turned. Different combinations of treatment parameters were used in ultra burnishing three different surfaces to turned surfaces. The right frequency for the generator was achieved separately to every material according to the ultrasonic converter's temperature (<50 ºC).

Two different types of forging tool tips were used with the initial inclination of 45º (Figure 4). The tool tip on the right was used for case hardened steel and other materials were treated with the one shown on the left.

Figure 4. The forging tool tips used in ultra burnishing.

Turned and ultra burnished surfaces were measured using Mahr Perthometer M2 surface roughness gauge, which tool tip radius is 2 µm and profile resolution 0,012 µm. The manufacturer hasn't notified the measurement uncertainty, but ± 2 % of reading ± LSD (Least Significant Deviation) is used in common for this kind of gauges. The measurement uncertainty was defined with a surface grinded standard block gauge (Ra 0,025 µm) and LSD value of 0,006 µm was defined at the coverage factory of 95 % while the standard deviation was 0,0022 µm and average 0,024 µm in ten measurements. The bearing ratios (Tp – values) of the ultra burnished surfaces couldn't be measured with the used gauge and it was estimated that the profile resolution was inadequate. The changes of the bearing ratios in ultra burnished surfaces were remarkable.

The surface roughness measurements and calculations are carried out according to ISO 3274 (1996) and ISO 4288 (1996) standards. Measured surface roughness parameters are shown in Table 2. Temperatures of the test pieces were stable (20 ± 2 ºC) during the measurements.

Table 2. Measured surface roughness values.

Parameter	Description
Ra	Arithmetical mean deviation of the assessed profile
Rmax	Local maximum height of profile
Rp	Maximum profile peak height
Rq	Root mean square deviation of the assessed profile
Rt	Total height of profile
Rz	Maximum height of profile

3 RESULTS

3.1 Micro-alloy steel, IMAMIC, axel 300 mm, Ø 100 mm in ultra burnishing

Influences of different treatment parameters to achieved average Ra-values with micro-alloy steel are depicted in Figure 5. The test series was made using three base surfaces Ra, three contact forces F, three cutting speeds v_c, three feed rates f and three generator output powers P.

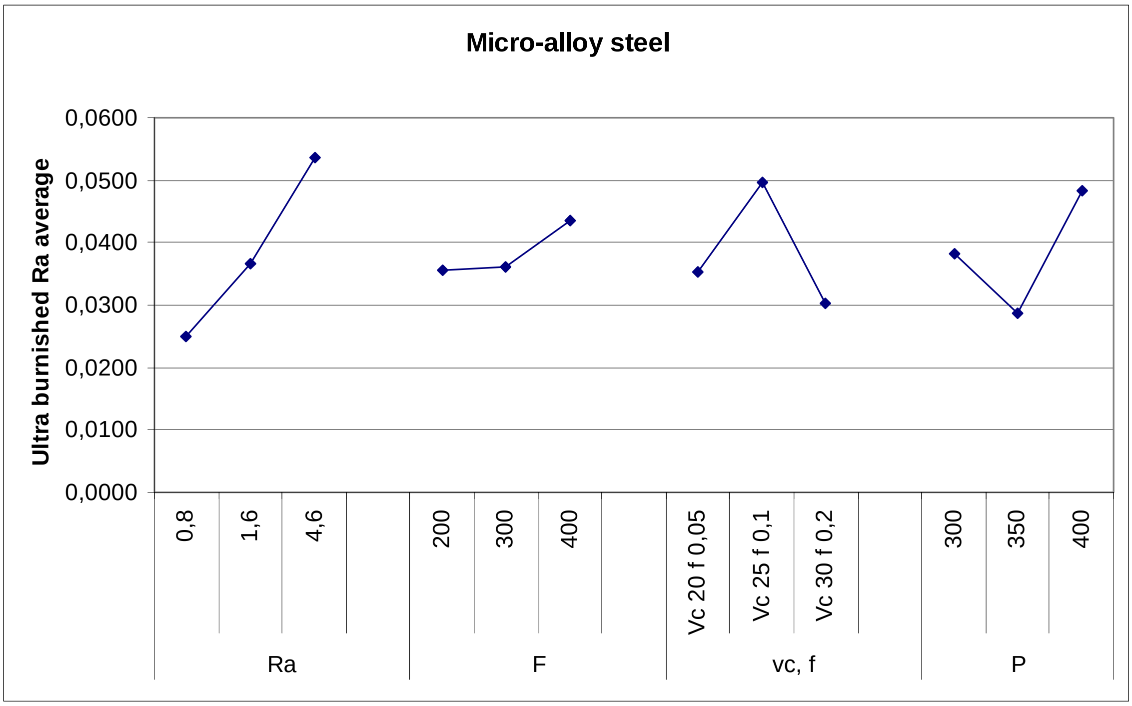

Figure 5. Influences of different parameters to achieved average Ra –values with micro-alloy steel.

Combinations of treatment parameters were set up according to Table 3.

Table 3. Combinations of the treatment parameters.

	BASE SURFACE	F	v_c, f	POWER @ 20200 Hz
TEST 1	0,8	200	v_c 20 f 0,05	400 W
TEST 2	0,8	300	v_c 25 f 0,1	350 W
TEST 3	0,8	400	v_c 30 F 0,2	300 W
TEST 4	1,6	200	v_c 25 f 0,1	300 W
TEST 5	1,6	300	v_c 30 F 0,2	400 W
TEST 6	1,6	400	v_c 20 f 0,05	350 W
TEST 7	3,2	200	v_c 30 F 0,2	350 W
TEST 8	3,2	300	v_c 20 f 0,05	300 W
TEST 9	3,2	400	v_c 25 f 0,1	400 W

Average influences of treatment parameters to different surface parameters with micro-alloy steel are depicted in Figure 6.

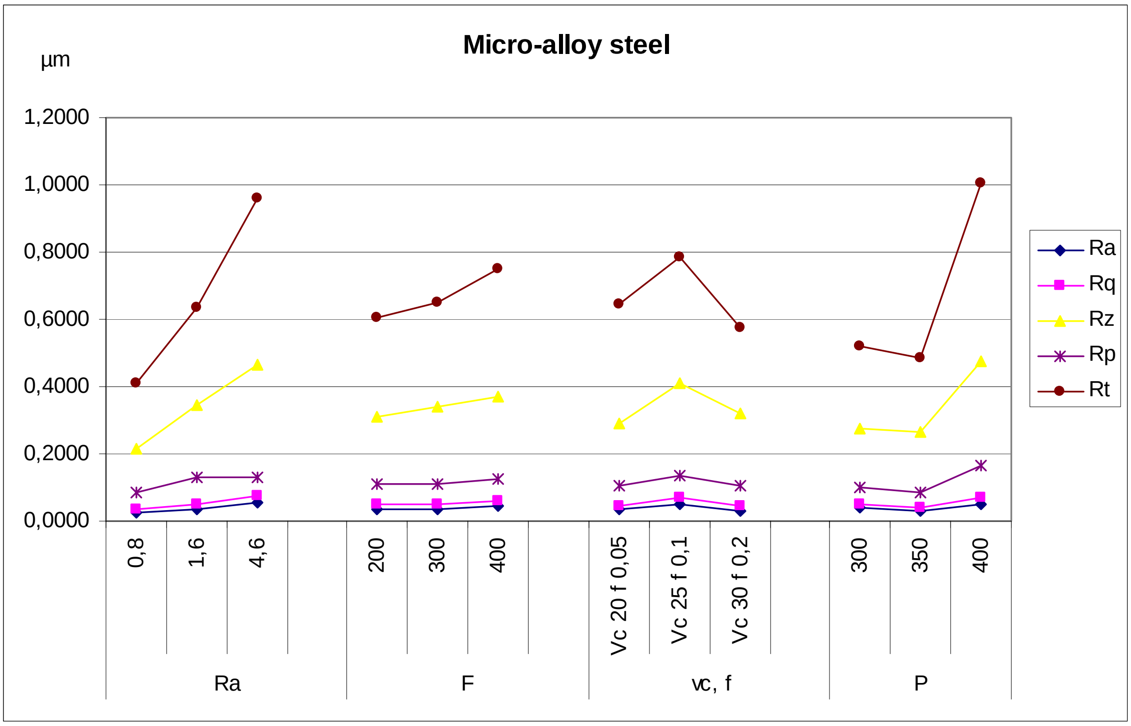

Figure 6. Average influences of treatment parameters to different surface roughness parameters with micro-alloy steel.

Surfaces treated with different parameter combinations were measured and surface parameters were calculated as an average value for every treatment parameter. The smallest Ra – value of the whole test was achieved in test three (Ra 0,022 µm) and the largest in test nine (Ra 0,08 µm). The minimum values of other surface parameters were also found in test three and maximum values in test nine. The best parameter combination for ultra burnishing can be estimated from the picture according to Ra and Rt values (base surface Ra 0,8 µm, F 200 N, v_c 30 m/min, f 0,2 mm/r, P 350 W).

Surface roughness profiles for turned and ultra burnished micro-alloy steel surfaces are shown in Figure 7.

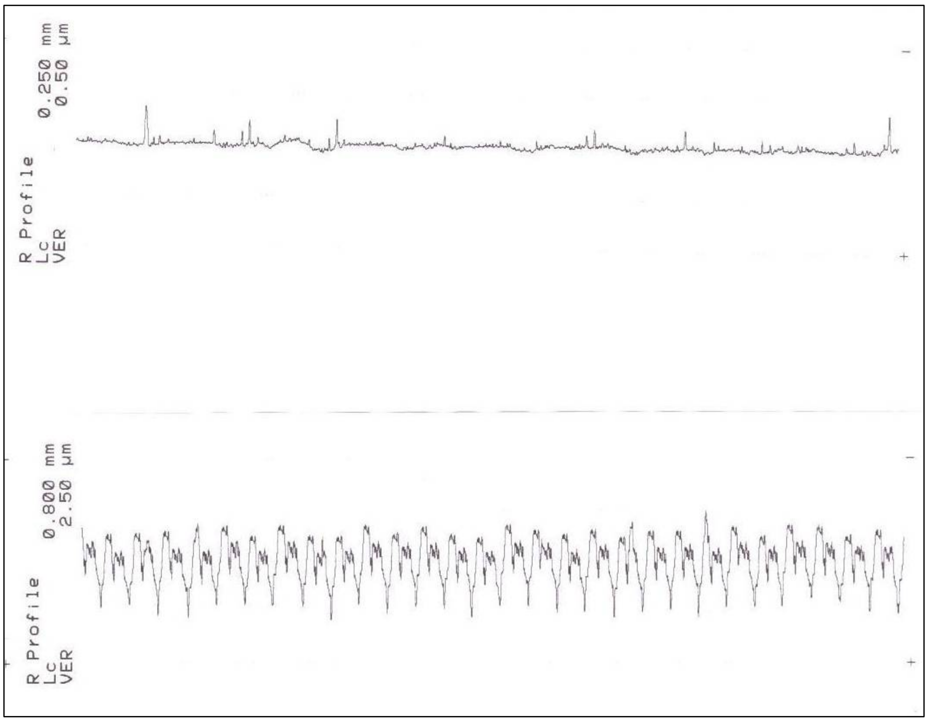

Figure 7. Surface profiles of turned (below) and ultra burnished (above) micro-alloy steel surfaces.

3.2 Tempered steel, 42 CrMo 4, axel 300 mm, Ø 60 mm in ultra burnishing

Influences of different treatment parameters to achieved average Ra-values with tempered steel are depicted in Figure 8. The test series was made using three base surfaces Ra, three contact forces F, three cutting speeds v_c, three feed rates f and three generator output powers P.

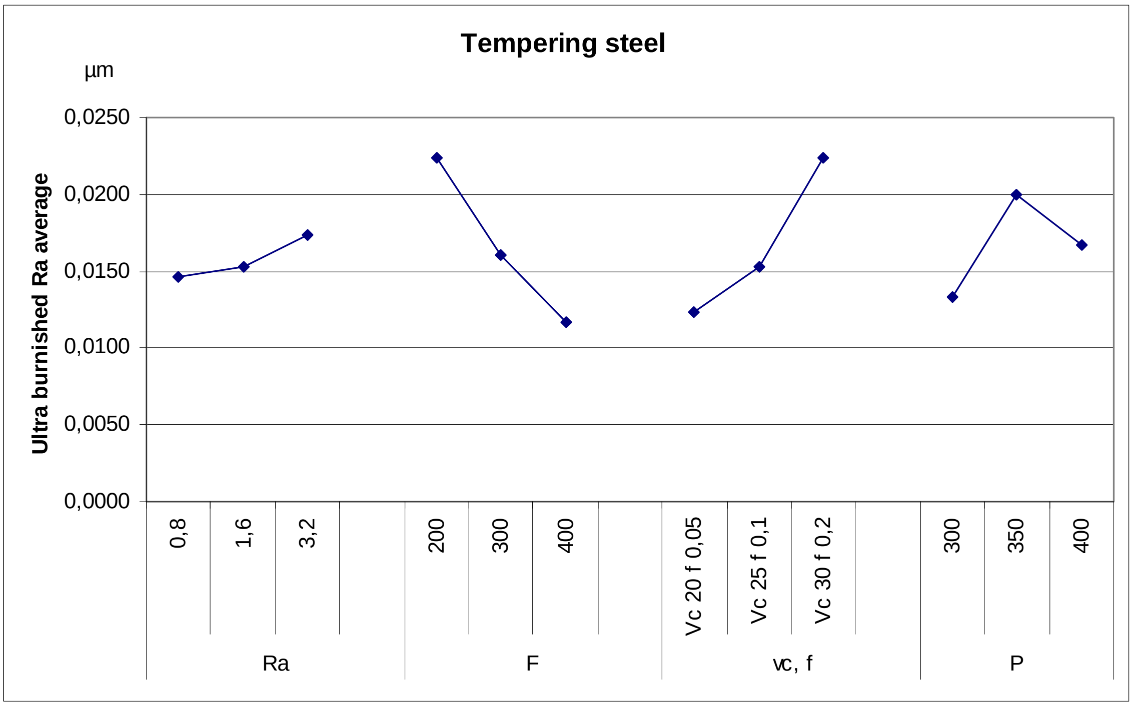

Figure 8. Influences of different parameters to achieved average Ra –values with tempering steel.

Average influences of treatment parameters to different surface parameters in tempering steel are depicted in Figure 9.

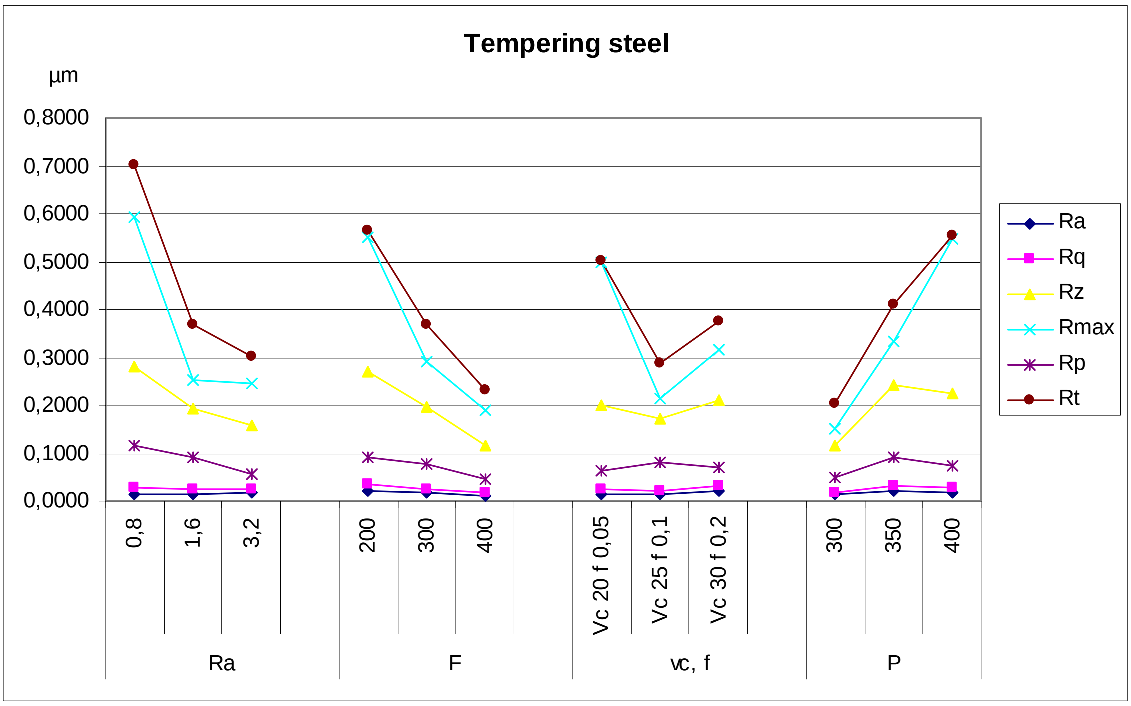

Figure 9. Average influences of treatment parameters to different surface roughness parameters with tempering steel.

Combinations of treatment parameters were set up according to Table 3 and the generator frequency of 20800 Hz was used. The smallest Ra – value of the whole test was achieved in test eight (Ra 0,01 µm) and the largest in test seven (Ra 0,033 µm). Maximum values of Rz, Rmax, Rp and Rt were achieved in test one and Rq in test seven. Minimum values of all surface parameters were found in test eight. The best parameter combination for ultra burnishing can be estimated from the picture according to Ra - values (base surface Ra 0,8 µm, F 400 N, v_c 20 m/min, f 0,05 mm/r, P 300 W) and according to Rt – values (base surface Ra 3,2 µm, F 400 N, v_c 25 m/min, f 0,1 mm/r, P 300 W). Differences between these combinations are explained by narrow area appearance of the average Ra - values (0,0117…0,0223 µm).

Surface roughness profiles for turned and ultra burnished tempering steel surfaces are shown in Figure 10.

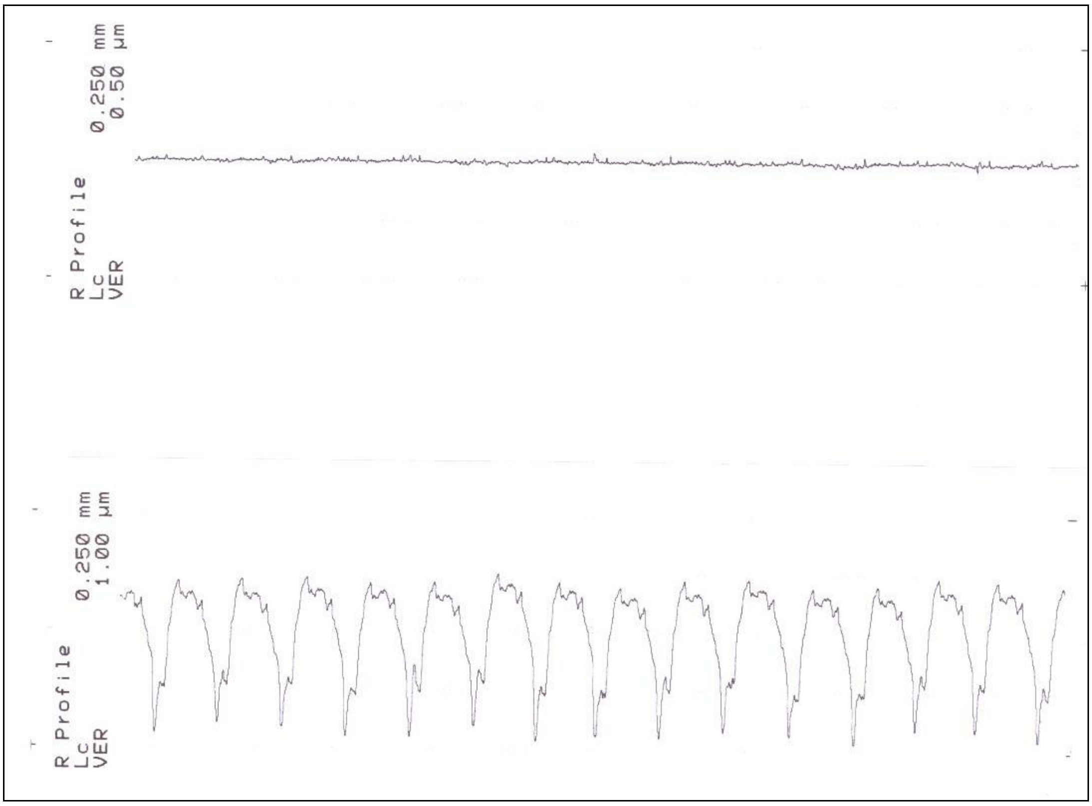

Figure 10. Surface profiles of turned (below) and ultra burnished (above) tempering steel surfaces.

3.3 Aluminium, AV 6262 T6, axel 300 mm, Ø 60 mm in ultra burnishing

Influences of different treatment parameters to achieved average Ra-values with tempered steel are depicted in Figure 11. The test series was made using three base surfaces Ra, three contact forces F, three cutting speeds v_c, three feed rates f and three generator output powers P.

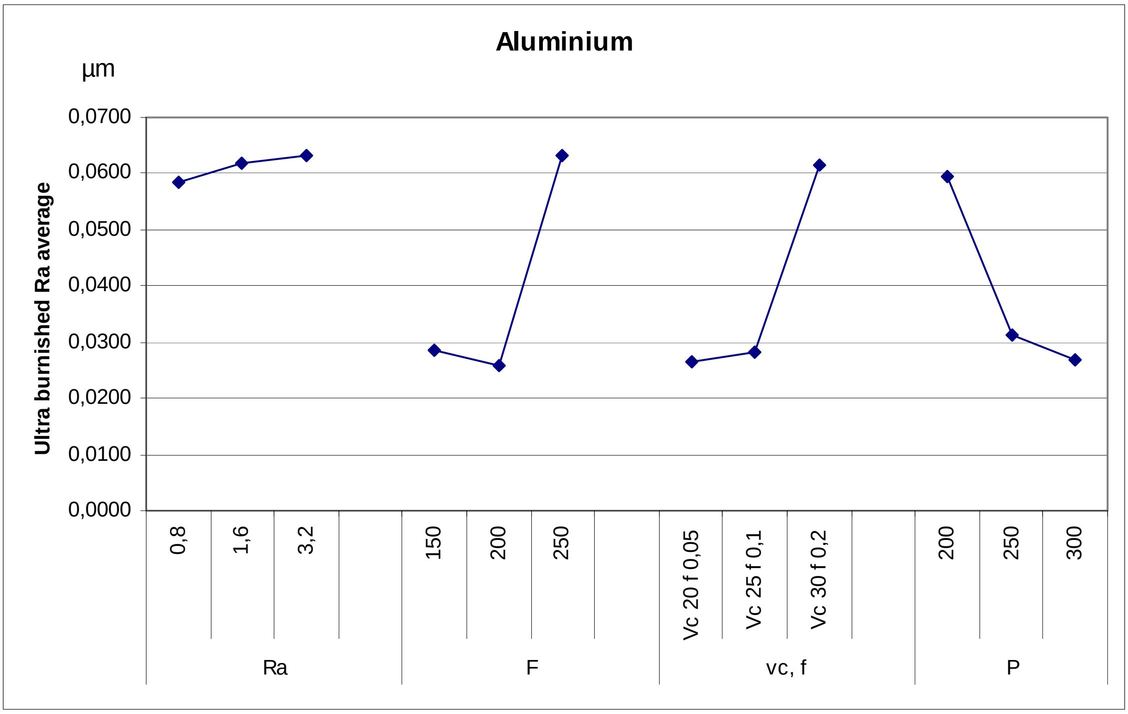

Figure 11. Influences of different parameters to achieved average Ra –values with aluminium.

Average influences of treatment parameters to different surface parameters in aluminium are depicted in Figure 12.

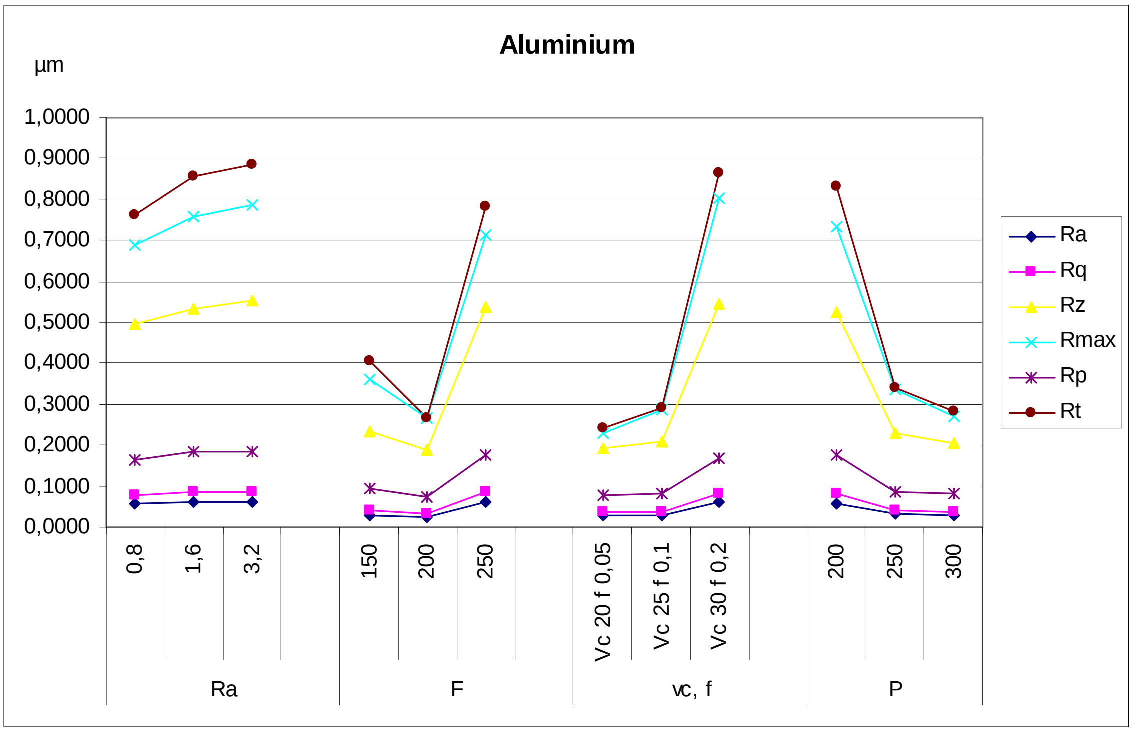

Figure 12. Average influences of treatment parameters to different surface roughness parameters with aluminium.

Combinations of treatment parameters were set up as shown in Table 4 and the generator frequency of 20400 Hz was used. The smallest Ra – value of the whole test was achieved in test eight (Ra 0,019 µm) and the biggest Ra –value in test three (Ra 0,125 µm). Minimum values of all surface parameters were found in test eight and maximum values in test three. The best combination of parameters for ultra burnishing can be estimated from the picture according to Ra and Rt - values (base surface Ra 0,8 µm, F 200 N, v_c 20 m/min, f 0,05 mm/r, P 300 W).

Table 4. Combinations of treatment parameters

	BASE SURFACE	F	v_c, f	POWER @ 20400 Hz
TEST 1	0,8	150	v_c 20 f 0,05	300 W
TEST 2	0,8	200	v_c 25 f 0,1	250 W
TEST 3	0,8	250	v_c 30 F 0,2	200 W
TEST 4	1,6	150	v_c 25 f 0,1	200 W
TEST 5	1,6	200	v_c 30 F 0,2	300 W
TEST 6	1,6	250	v_c 20 f 0,05	250 W
TEST 7	3,2	150	v_c 30 F 0,2	250 W
TEST 8	3,2	200	v_c 20 f 0,05	200 W
TEST 9	3,2	250	v_c 25 f 0,1	300 W

Surface roughness profiles for turned and ultra burnished aluminium surfaces are shown in Figure 13.

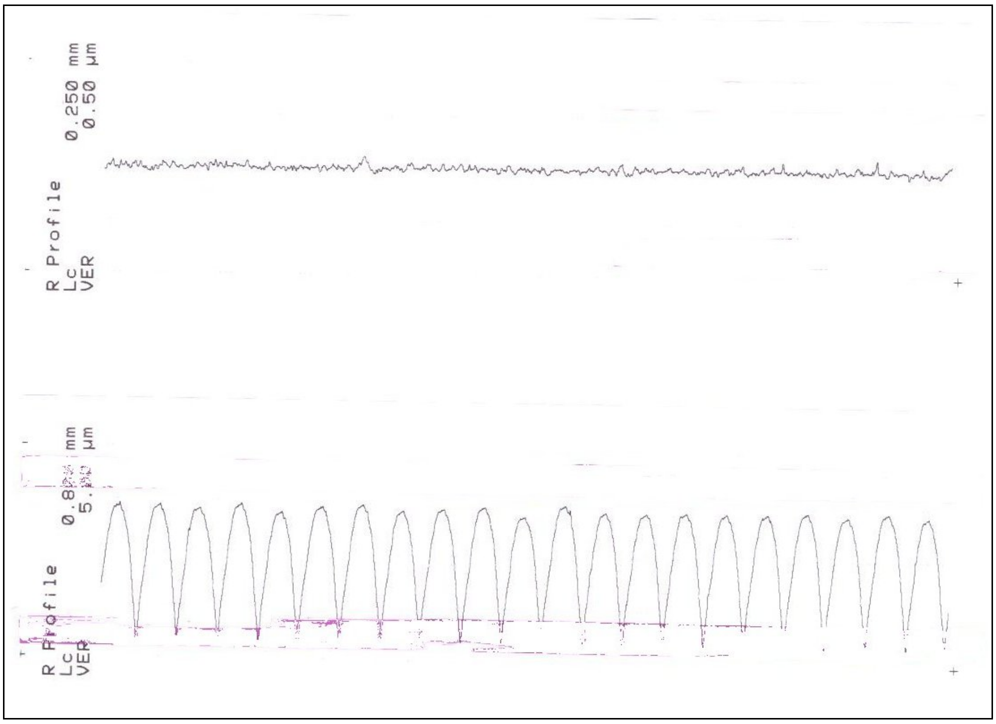

Figure 13. Surface profiles of turned (below) and ultra burnished (above) aluminium surfaces.

3.4 Case hardening steel, 16 MrCr 5, hardness 58…63 HRC, axel 300 mm, Ø 60,4 mm in ultra burnishing

Influences of different treatment parameters to achieved average Ra-values with case hardening steel are depicted in Figure 14. The test series was made using two base surfaces Ra, three contact forces F, three cutting speeds v_c, three feed rates f and three generator output powers P.

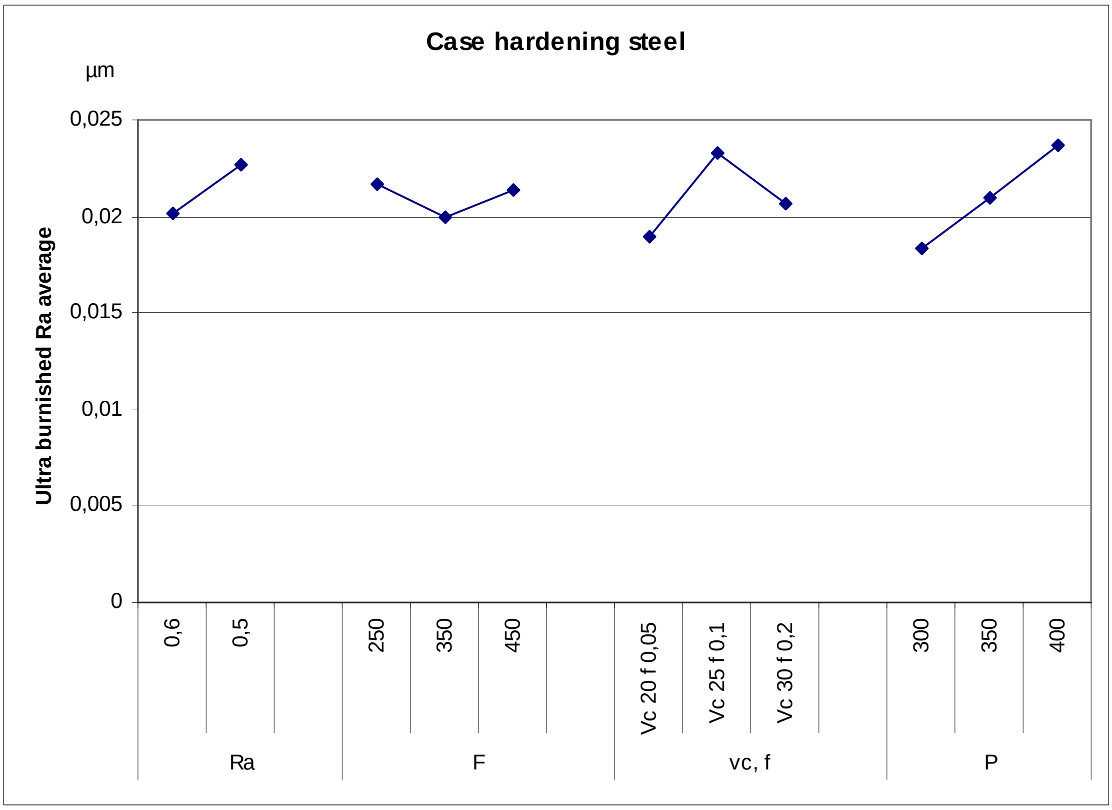

Figure 14. Influences of different parameters to achieved average Ra –values with case hardening steel.

Average influences of treatment parameters to different surface parameters with case hardening steel are depicted in Figure 15.

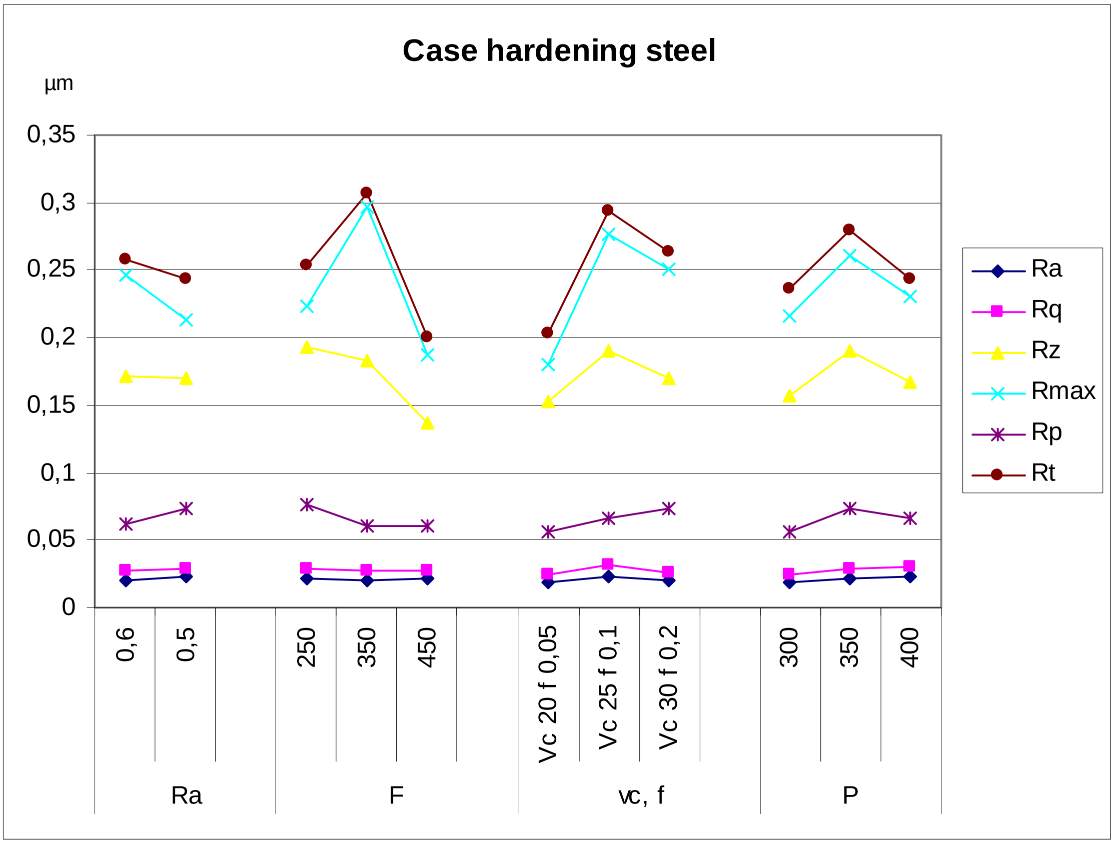

Figure 15. Average influences of treatment parameters to different surface roughness parameters with case hardening steel.

Combinations of treatment parameters were set up as shown in Figure 15 and the generator frequency of 20600 Hz was used. The smallest Ra – value of the whole test was achieved in test eight (Ra 0,015 µm) and the biggest Ra –value in test three (Ra 0,028 µm). The minimum of Rp and Rq values were found in test eight and Rmax, Rz and Rt minimums in test six. The maximum Rz, Rmax and Rt values were achieved in test two, Rq maximum in test nine and Rp maximum in test seven.

The best combination of parameters for ultra burnishing can be estimated from the picture according to Ra - values (base surface Ra 0,5 µm, F 350 N, v_c 20 m/min, f 0,05 mm/r, P 300 W) and according to Rt –values (base surface Ra 0,6 µm, , F 450 N, v_c 20 m/min, f 0,05 mm/r, P 300 W). Differences in achieved Ra – values between these combinations are negligible; according to Ra – values 0,002 µm, according to contact force F 0,001 µm and according to cutting speed v_c 0,003 µm.

Table 5. Combinations of the treatment parameters.

	BASE SURFACE	F	v_c, f	POWER @ 20600 Hz
TEST 1	0,6	250	v_c 20 f 0,05	400 W
TEST 2	0,6	350	v_c 25 f 0,1	350 W
TEST 3	0,6	450	v_c 30 F 0,2	300 W
TEST 4	0,6	250	v_c 25 f 0,1	300 W
TEST 5	0,6	350	v_c 30 F 0,2	400 W
TEST 6	0,6	450	v_c 20 f 0,05	350 W
TEST 7	0,5	250	v_c 30 F 0,2	350 W
TEST 8	0,5	350	v_c 20 f 0,05	300 W
TEST 9	0,5	450	v_c 25 f 0,1	400 W

Surface roughness profiles for turned and ultra burnished case hardening steel surfaces are shown in Figure 16.

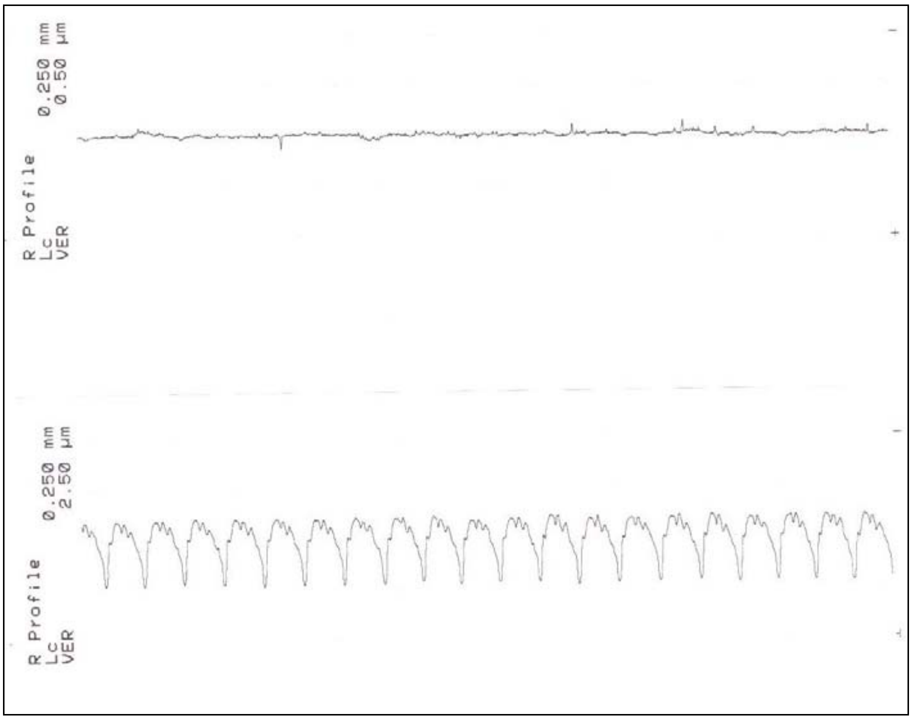

Figure 16. Surface profiles of turned (below) and ultra burnished (above) case hardening steel surfaces.

3.5 Stainless steel, 1,4301, axel 300 mm, Ø 60 mm in ultra burnishing

Influences of different treatment parameters to achieved average Ra-values with stainless steel are depicted in Figure 17. The test series was made using two base surfaces Ra, three contact forces F, three cutting speeds v_c, three feed rates f and three generator output powers P.

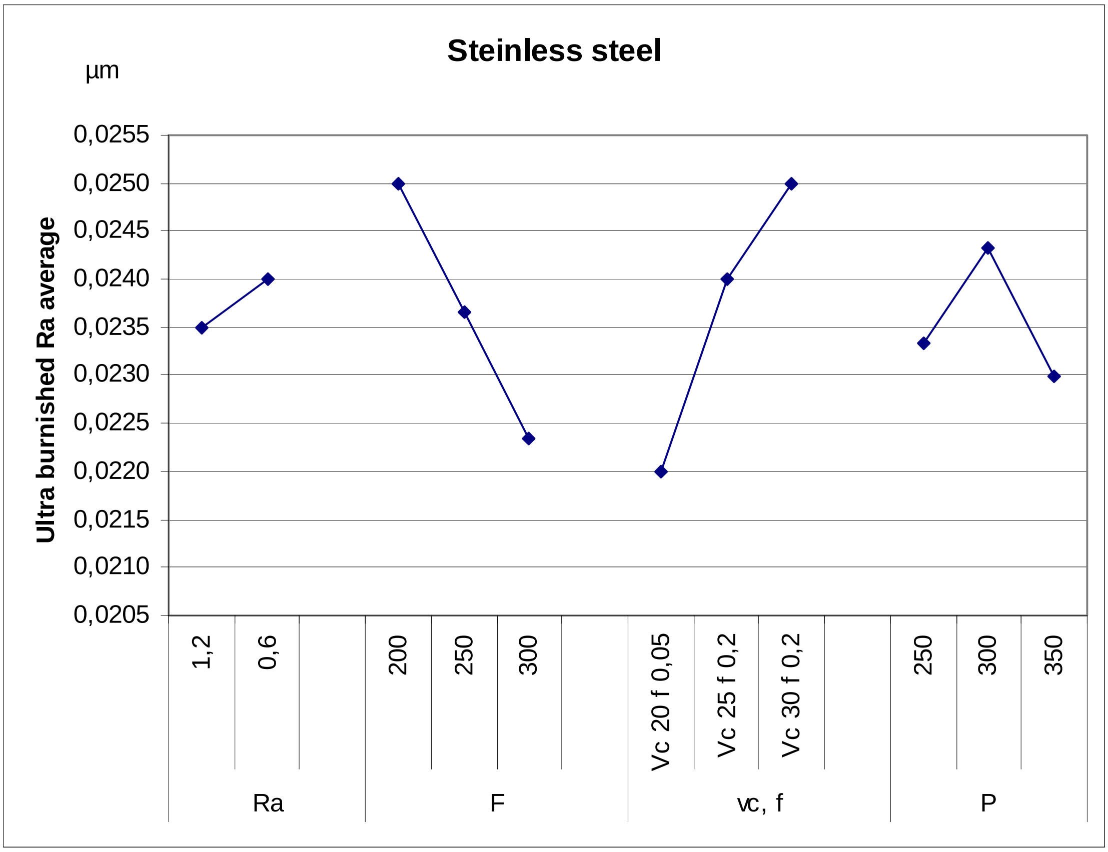

Figure 17. Influences of different parameters to achieved average Ra –values with stainless steel.

Average influences of treatment parameters to different surface parameters in stainless steel are depicted in Figure 18.

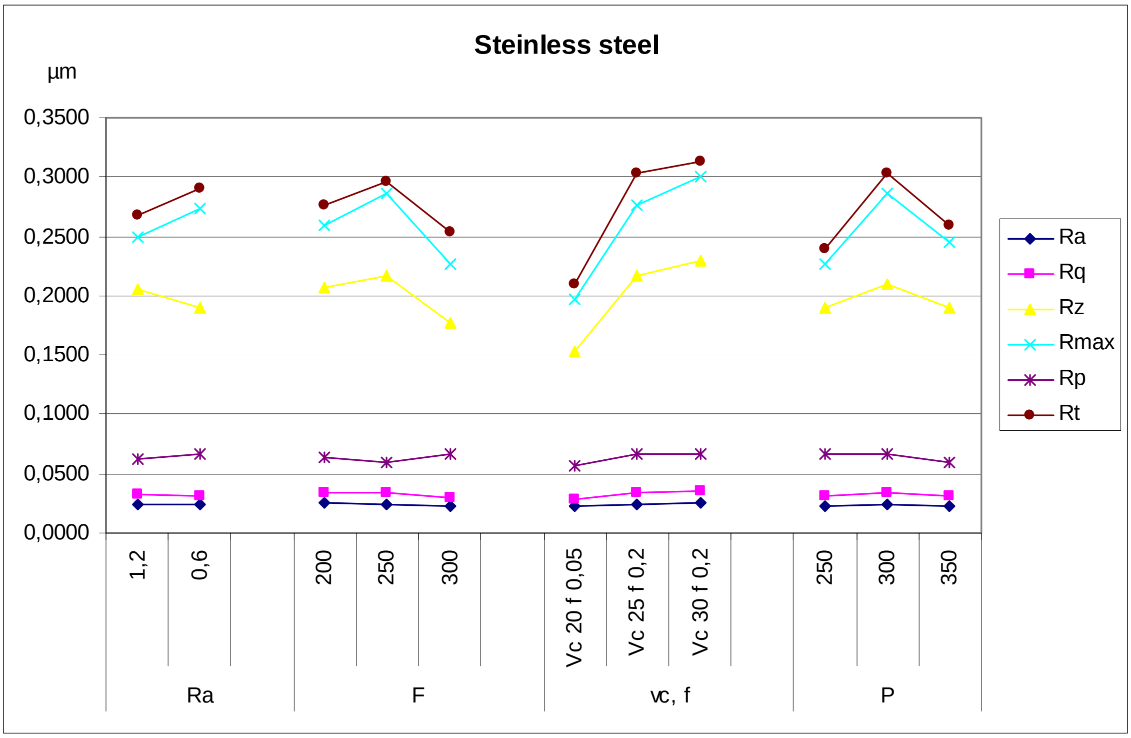

Figure 18. Average influences of treatment parameters to different surface roughness parameters with stainless steel.

Combinations of treatment parameters were set up as shown in Table 6 and the generator frequency of 20600 Hz was used. The smallest Ra – value of the whole test was achieved in test six (Ra 0,021 µm) and the biggest Ra –value in test seven (Ra 0,027 µm). The best combination of parameters for ultra burnishing according to Ra – values for base surface Ra 1,2 µm, F 300 N, v_c 20 m/min, f 0,05 mm/r, P 350 W and according to Rt – values for base surface Ra 1,2 µm, F 300 N, v_c 20 m/min, f 0,05 mm/r and P 250 W. Differences in Ra – values according to generator output power P are negligible (Ra –values are between 0,023…0,0243 µm).

Table 6. Combinations of treatment parameters.

	BASE SURFACE	F	v_c, f	POWER @ 20600 Hz
TEST 1	1,2	200	v_c 20 f 0,05	350 W
TEST 2	1,2	250	v_c 25 f 0,1	300 W
TEST 3	1,2	300	v_c 30 F 0,2	250 W
TEST 4	1,2	200	v_c 25 f 0,1	250 W
TEST 5	1,2	250	v_c 30 F 0,2	350 W
TEST 6	1,2	300	v_c 20 f 0,05	300 W
TEST 7	0,6	200	v_c 30 F 0,2	300 W
TEST 8	0,6	250	v_c 20 f 0,05	250 W
TEST 9	0,6	300	v_c 25 f 0,1	350 W

Surface roughness profiles for turned and ultra burnished stainless steel surfaces are shown in Figure 19.

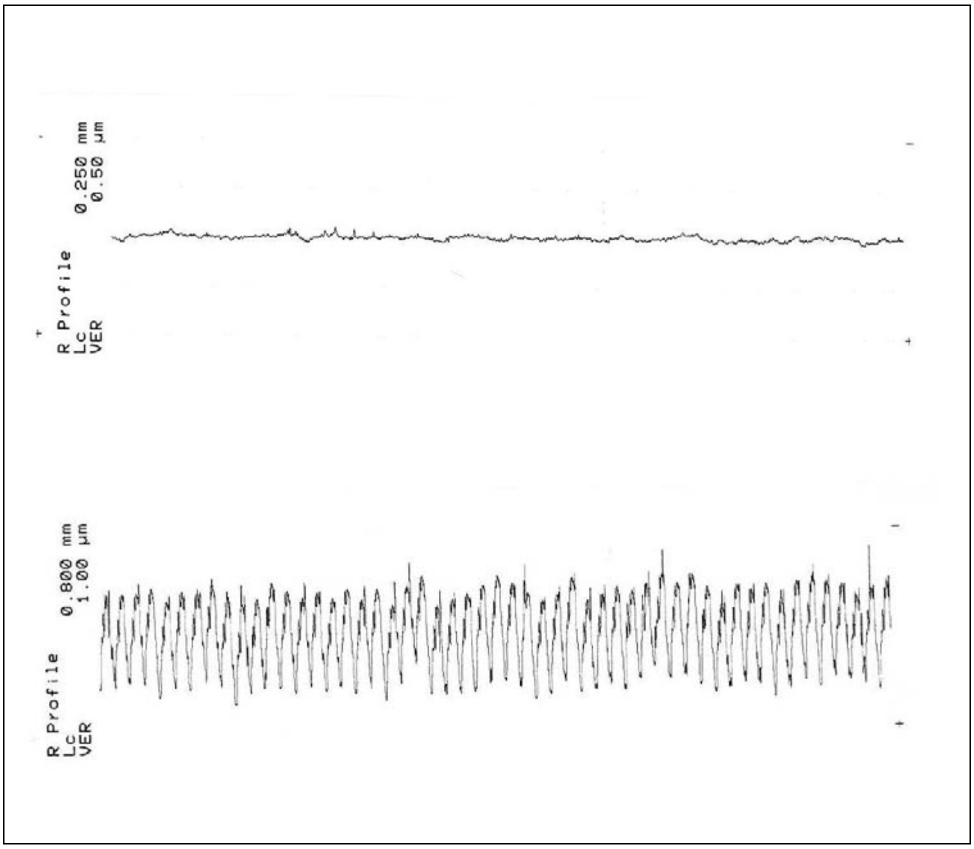

Figure 19. Surface profiles of turned (below) and ultra burnished (above) stainless steel surface.

3.6 INFLUENCE OF THE CUTTING SPEED IN ULTRA BURNISHING

The influence of different cutting speeds to achieved Ra – value was tested with micro-alloy steel by three cutting speeds (20, 50 and 90 m/min) and constant feed rate 0,1 mm/r. Differences in ultra burnished surface's Ra – values are very small with different cutting speeds when the measurement uncertainty and resolution are taken into consideration with measured values. The influence of the cutting speed to achieved Ra – value is shown in Figure 20.

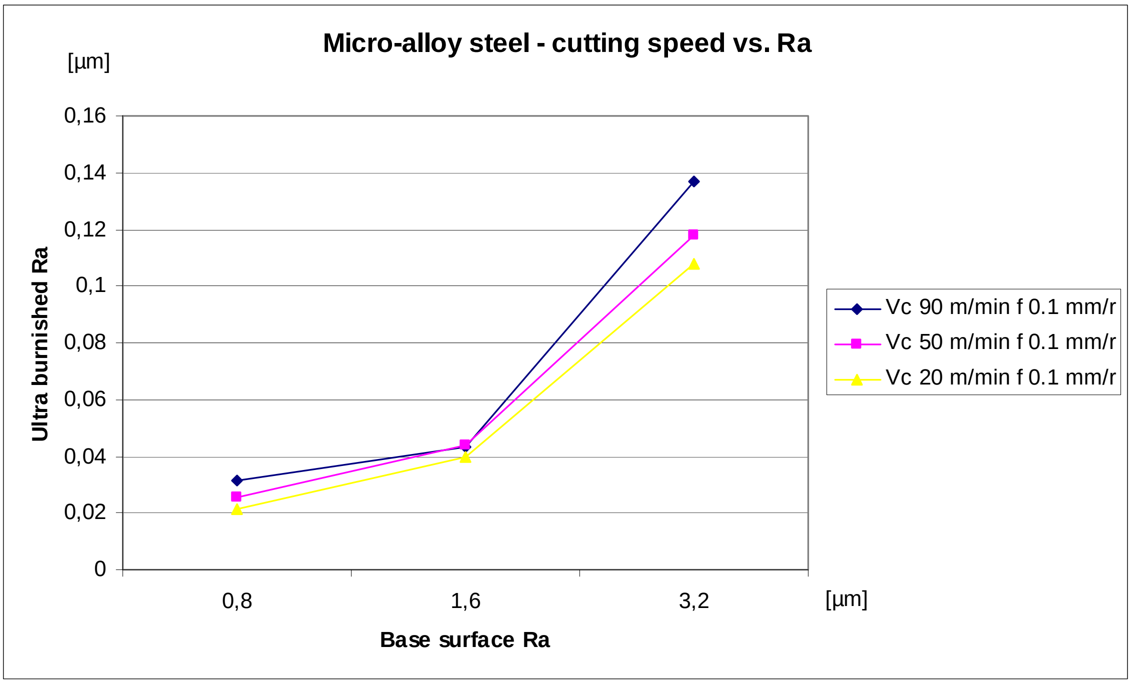

Figure 20. Influence of the cutting speed to achieved Ra – value with micro-alloy steel.

On the base surface with Ra 0,8 µm ultra burnished surface's Ra – values increased 18 % while the cutting speed increased 150 % (20…50 m/min) and 47 % while the cutting speed increased 350 % (20…90 m/min). On the base surface with Ra 1,6 µm ultra burnished surface's Ra - values increased 11 % while the cutting speed increased 150…350 % (measured Ra – value was only 0,0004 µm smaller with the cutting speed of 50 m/min than 90 m/min). Changes of the Ra – values produced with different cutting speeds could not be shown on the base surfaces with Ra 0,8 and Ra 1,6. On the base surface with Ra 3,2 µm ultra burnished surface's Ra – values increased 10 % while the cutting speed increased 150 % and 27 % while the cutting speed increased 350 %.

The influence of different cutting speeds to achieved Ra – value was tested with tempering steel too. A 300 mm long axis with diameter of 60 mm and Ra 0,8 µm was used and three different surfaces were ultra burnished with cutting speeds of 30, 60 and 80 m/min and feed rate of 0,2 mm/r. Measured Ra – values are shown in Figure 21.

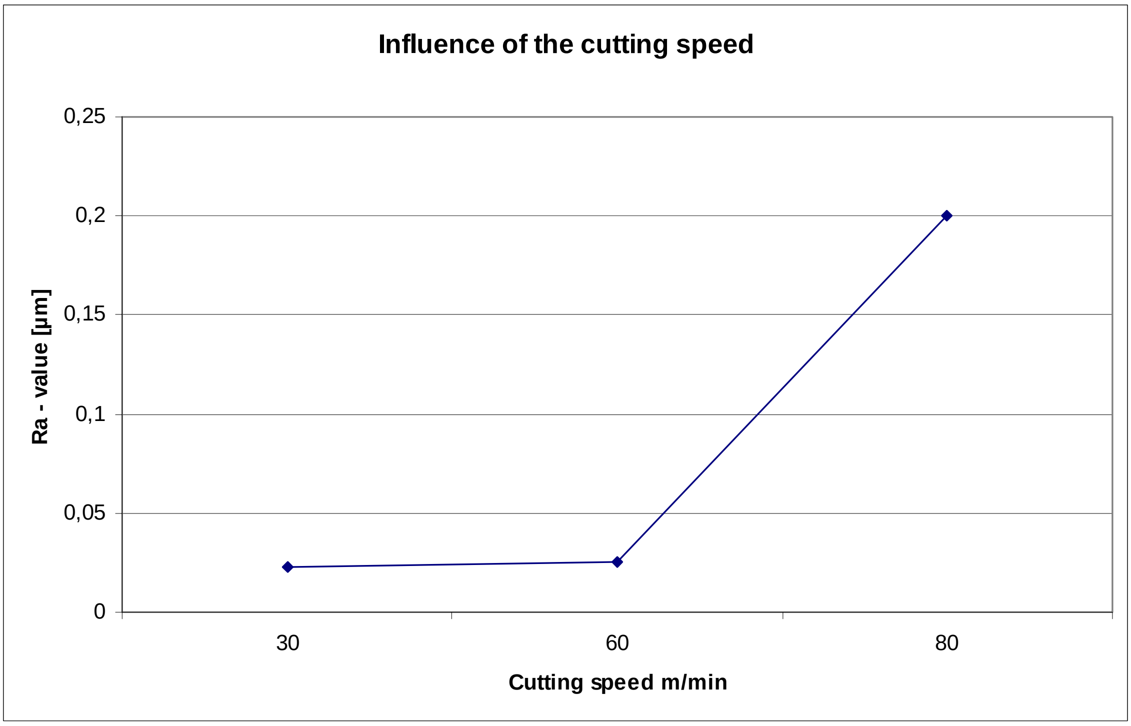

Figure 21. Influence of the cutting speed to achieved Ra – value with tempering steel.

The cutting speed of ultra burnishing can be increased without remarkable changes in achieved Ra – values. With too high cutting speeds the work piece starts to vibrate which will affect to ultra burnished surface. The ratio of the circumferential speed to diameter of the work piece was shown to be more important factory than the circumferential speed itself. The difference in rotational frequencies with the same cutting speeds in two cases shown above was 66,7 % and lower cutting speeds had to be used with the smaller work piece.

3.7 INFLUENCE OF THE ULTRA BURNISHING TO WORK PIECE'S GEOMETRY

The best ultra burnishing parameters were selected for micro-alloy steel, tempering steel and case hardening steel as descried earlier. The influence of ultra burnishing to work piece's geometry was tested with 300 mm long test pieces which were turned and ultra burnished for 150 mm. Surface roughness values shown in Table 7 were measured after turning and ultra burnishing.

Table 7. Surface roughness values after turning and ultra burnishing.

		Ra	Rq	Rz	Rmax	Rp	Rt
Micro-alloy steel	Turned	0,825	0,998	4,72	5,23	2,81	5,32
	Ultra burnished	0,023	0,037	0,31	0,41	0,06	0,44
Tempering steel	Turned	0,623	0,729	2,77	2,80	1,84	2,87
	Ultra burnished	0,012	0,016	0,10	0,12	0,04	0,15
Case hardening steel	Turned	0,732	0,916	3,41	3,47	2,36	3,49
	Ultra burnished	0,015	0,021	0,14	0,18	0,06	0,27

Test pieces were measured with co-ordinate measuring machine SIP CMM 5 n:o 401 -93 (measuring uncertainty will be found from http://www.finas.fi/Scopes/K003_A09_2005.htm.) Measured form fault of test pieces are shown in Table 8.

Table 8- Measured form faults of test pieces.

Cylindricity [mm]	Turned	Ultra burnished	Deviation
Micro-alloy steel	0,0494	0,01841	-0,03099
Tempered steel	0,01491	0,01899	0,00408
Case hardening steel	0,01928	0,0203	0,00102
Conicity [mm]	Turned	Ultra burnished	Deviation
Micro-alloy steel	0,04952	0,0174	-0,03212
Tempered steel	0,0149	0,0177	0,0028
Case hardening steel	0,0193	0,0205	0,0012
Circularity [mm]	Turned	Ultra burnished	Deviation
Micro-alloy steel	0,0146	0,0098	-0,0048
Tempered steel	0,0105	0,0092	-0,0013
Case hardening steel	0,0124	0,01	-0,0024

4 COMPARISON TO OTHER METHODS

Machining times of ultra burnishing, roller finishing, burnishing and cylindrical grinding are compared in Figure 22 and achieved Ra – values in Figure 23. These cases were found from literature and machining times and achieved Ra - values for ultra burnishing are estimates based on earlier research.

Roller finished work piece was Ø 55 * 890 mm piston rod. The material was C45, Ra – value of the base surface was 0,7 µm and after roller finishing Ra 0,04 µm. The machining time was 360 s. The base surface for ultra burnishing could be Ra 1,6 µm and after ultra burnishing Ra 0,025 µm and machining time 923 s.

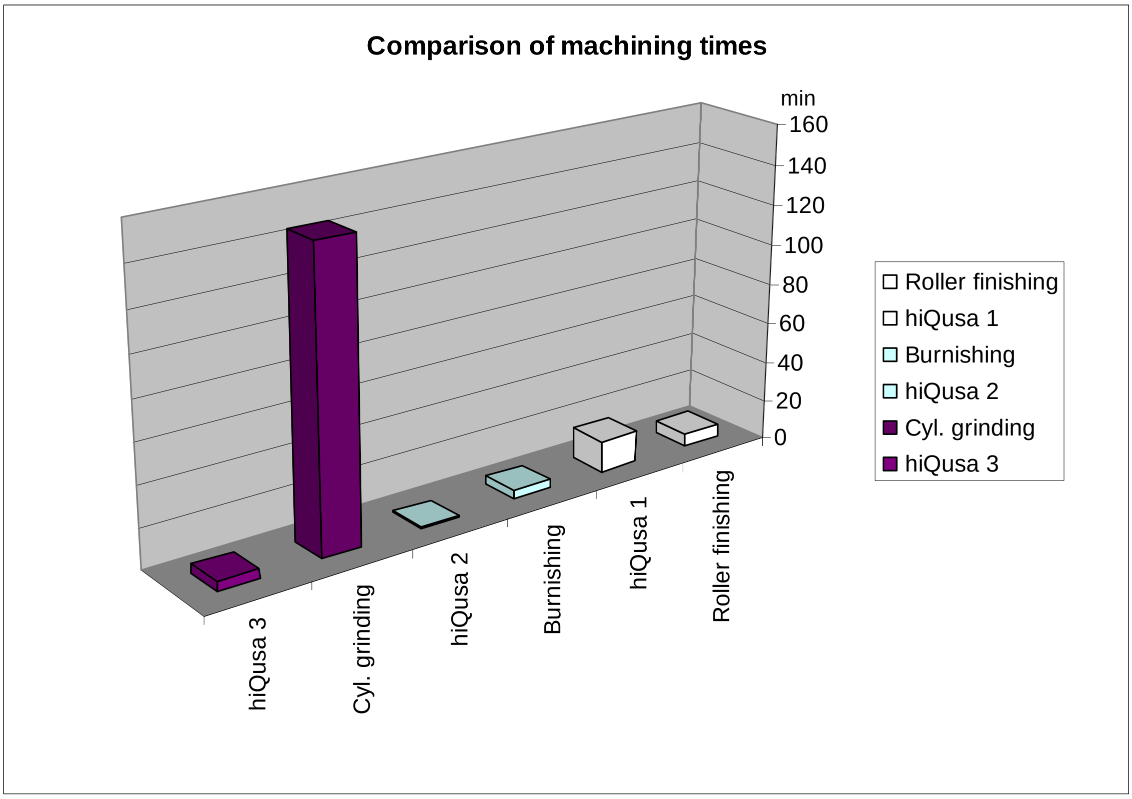

Figure 22. Machining times of different methods compared to ultra burnishing.

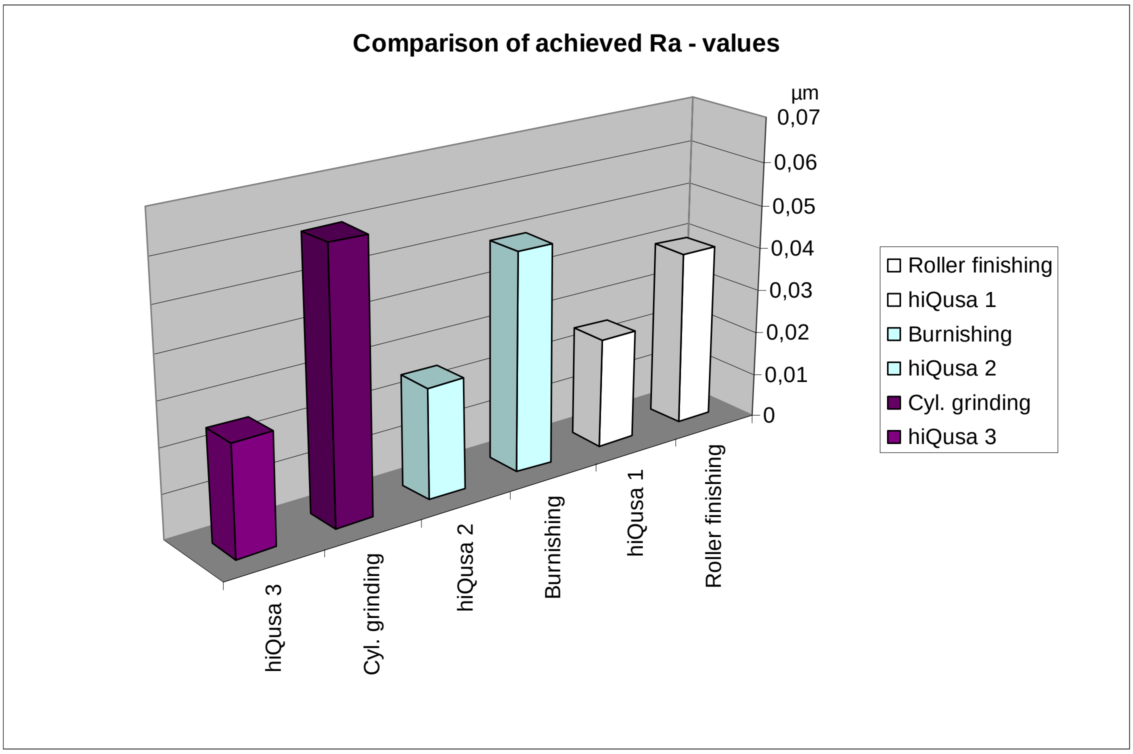

Figure 23. Comparison between Ra – values achieved by different methods.

Burnished work piece was Ø 51 * 38 mm steel piston with the base surface of Ra 0,3 µm and Ra 1,14 µm and after burnishing Ra 0,05 µm and Ra 0,13 µm. Machining time for burnishing was 261 s. Compared ultra burnished piston could have base surface with Ra 1,6 µm and after ultra burnishing Ra 0,025 and machining time 37 s.

Cylindrical grinded work piece was Ø 50,25 * 300 mm 34 CrNiMo 6 axel. A diameter of an abrasive disc was 290 mm, width 22 mm, speed of rotation 1640 r/min and cutting speed 1490 m/min. Cylindrical grinded surface was Ra 0,061 µm and machining time 8760 s. Compared ultra burnished axel could be base surface Ra 1,6 µm and after ultra burnishing Ra 0,025 µm and machining time 284 s.

5 CONCLUSIONS

Ranges of variations of average surface roughness parameters calculated separately for every treatment parameter was material dependent. These ranges of variations are shown in Table 9…Table 12.

Table 9. Range of variation of average surface roughness values according to base surface Ra –value.

[Ra]	Ra	Rq	Rz	Rmax	Rp	Rt
Micro-alloy steel	0,0287	0,0413	0,2500	*********	0,0433	0,5500
Tempering steel	0,0027	0,0060	0,1233	0,3467	0,0600	0,4000
Aluminium	0,0050	0,0073	0,0567	0,0967	0,0200	0,1233
Case hardening stee	0,0025	0,0018	0,0017	0,0333	0,0117	0,0150
Steinless steel	0,0005	0,0005	0,0150	0,0233	0,0050	0,0217

Table 10. Range of variation of average surface roughness values according to contact force F.

[F]	Ra	Rq	Rz	Rmax	Rp	Rt
Micro-alloy steel	0,0080	0,0110	0,0600	*********	0,0167	0,1433
Tempering steel	0,0107	0,0200	0,1533	0,3600	0,0433	0,3333
Aluminium	0,0377	0,0503	0,3467	0,4467	0,1033	0,5167
Case hardening stee	0,0017	0,0023	0,0567	0,1100	0,0167	0,1067
Steinless steel	0,0027	0,0040	0,0400	0,0600	0,0067	0,0433

Table 11. Range of variation of average surface roughness values according to cutting speed v_c.

[V]	Ra	Rq	Rz	Rmax	Rp	Rt
Micro-alloy steel	0,0193	0,0243	0,1200	*********	0,0333	0,2067
Tempering steel	0,0100	0,0103	0,0367	0,2867	0,0167	0,2167
Aluminium	0,0350	0,0473	0,3500	0,5733	0,0900	0,6233
Case hardening stee	0,0043	0,0060	0,0367	0,0967	0,0167	0,0900
Steinless steel	0,0030	0,0073	0,0767	0,1033	0,0100	0,1033

Table 12. Range of variation of average surface roughness values according to generator power P.

[P]	Ra	Rq	Rz	Rmax	Rp	Rt
Micro-alloy steel	0,0197	0,0317	0,2100	*********	0,0800	0,5200
Tempering steel	0,0067	0,0137	0,1267	0,3967	0,0400	0,3500
Aluminium	0,0323	0,0453	0,3167	0,4633	0,0967	0,5500
Case hardening stee	0,0053	0,0060	0,0333	0,0433	0,0167	0,0433
Steinless steel	0,0013	0,0023	0,0200	0,0600	0,0067	0,0633

Some requirements for range of variations can be set when the measurement uncertainty and resolution of the used measuring equipment are taken into account. Rt, Rz and Rmax values should vary more than 0,01 µm and Ra – values more than 0,006 µm when different treatment parameters are used. Other wise changed treatment parameter can be seen unimportant for achieved surface roughness values.

The base surface’s Ra – value has influence to ultra burnished Ra – value only with micro-alloy steel. These test pieces were turned to Ra 0,8…4,6 µm and larger range of variation compared to other material explain this result. The contact force of the tool tip F, cutting speed v_c, feed rate f and generator power P are effective ultra burnishing parameters with micro-alloy steel, tempering steel and aluminium. Measured values are close to each other with other materials.

Although the Ra – value of the base surface can not be assumed as an effective treatment parameter it does not mean that any Ra – values could be used.

All parameters have effect to Rmax, Rt and Rz – values with every material (Rmax –value was not measured from micro-alloy steel surfaces).

When the influence of ultra burnishing to work piece's geometry is evaluated, the measuring method of the geometry should be taken into consideration. Circularity values of ultra burnished test pieces show slightly better values than turned test pieces, but this change can be explained with much better Ra –values of the ultra burnished test pieces. Remarkable changes in cylindricity and conicity could not be shown with ultra burnished test pieces because values measured from different surfaces are not comparable

Pre-filtering of cooling lubricant was difficult with used type of filter element because of a short change interval. The filter element with high filtration rate cause remarkable flow resistance and cooling lubrication pump should be revised. Decreased flow rate of cooling lubricant cause heating of the ultrasonic converter especially when generator power over 350 W is used and contact force of the tool tip is over 350 N. This can be solved by using other type of filter element or independent cooling lubricant circulation. Different types of automated filters could also be used.

Production times play important role in evaluating ultra burnishing equipment usage in industrial environment. Starting up and achieving set power and frequency rates are part of total production time. This delay can be adjusted by generator settings.

The best characters of the ultra burnishing equipment are integration of methods and short processing times compared to achieved surface roughness values. Dimensional changes due to storage and re-fixing will be eliminated when the work piece is machined completely in one machine tool. The equipment can be fixed to different kind of machine tools what will give versatile possibilities to its usage.

The material removal rate of ultra burnishing process is low and pre-machined work piece should meet the geometrical demands as closely as possible.

Plain and double-curvature surfaces can be treated with different types of tool tip geometries and it is possible to apply this method in finishing and maintaining moulds, gear wheels and different types of axes. Higher cutting speeds can be used with different types of tool tip geometries.