Influence of grinding parameters on the surface roughness of steel 1.0562 in the softened state

Wpływ parametrów szlifowania na chropowatość powierzchni stali 1.0562 w stanie zmiękczonym

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Results from testing the grinding process of structural elements made of alloy steel 1.0562 in the softened state are presented. Influence of the grinding depth a_e and the longitudinal feedrate of the workpiece v_{ft} on the surface roughness is analyzed. Roughness values of *Ra*, *Rz* and *Rt* were considered available to obtain under accepted test conditions.
KEYWORDS: surface grinding, feed speed, depth of grinding, surface roughness parameters

The correct course of the grinding process is related to the appropriate selection of technological parameters, which allows to meet certain construction requirements, mainly to obtain high dimensional accuracy and shape of the required surface geometry (WW) and achieve the desired condition of the workpiece (PO) [2, 5]. In addition to the low surface roughness and high grinding efficiency [1], the research also reduces the process energy consumption and carbon dioxide emissions [6]. The grinding wheel and its conditioning parameters also have a significant influence on the process and technological effects [3]. Proper selection of machining parameters with correct delivery of cooling-lubricating fluid (CCS) avoids damage in the form of micro-cracks and cures in WW-PO [4] and prolongs the service life of the workpieces, e.g. railway rails [5].

The results of the study along with the assessment of the effect of grinding depth a_e and the longitudinal feedrate of the object v_{ft} on the values of surface roughness parameters of structural elements made of 1.0562 steel in the softened state, were presented. Obtaining *Ra* roughness value below 0.1 µm was one of the basic design requirements for plates (fig. 1), which is a research hydraulic device.

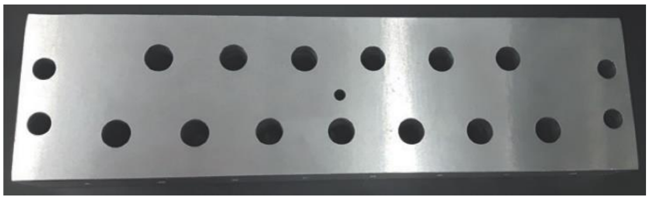

Fig. 1. Plate with holes after grinding

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Test conditions

Grinding tests were performed on a CNC grinding machine for SPG 25X60 planes with horizontal spindle axis. The panels of 256×68×28 mm dimensions (fig. 1) made of 1.0562 steel with hardness of 220 HB, tensile strength *Rm* = 490÷630 MPa and yield strength *Re* = 335 MPa, were machined. By default, the components of this material are heat treated to increase their hardness and wear resistance. In the research carried out for the purpose of the hydraulic equipment, in accordance with the requirements of the constructor, the plates were softened. The treatment was carried out with Norton Grinding Wheels at 38A60LVS and dimensions (*D*×*T*×*H*) 250×25×76.2 mm.

The grinding was performed at constant wheel circumferential speed v_s = 25 m/s, using coolant. The transverse feedrate of the grinding wheel followed the grinding wheel along the grinding surface and was 15 mm (60% of the grinding wheel). Prior to each test, the grinding wheel was conditioned with a diamond dresser with the following parameters set in the control program:

- depth a_e at one passage – 0.01 mm,
- number of crossing passages – 4,
- abrasive wheel circumferential velocity – v_s = 23 m/s,
- transverse feedrate of abrasive wheel – f_a = 0.2 mm/rev.

TABLE I. Grinding parameters

Number of sample	Levels of initial parameters		Values of parameters	
	Feedrate v_{ft}	Grinding depth a_e	v_{ft} m/min	a_e mm
1	1	1	0.3	0.002
2	1	2	0.3	0.004
3	1	3	0.3	0.006
4	2	1	0.9	0.002
5	2	2	0.9	0.004
6	2	3	0.9	0.006
7	3	1	1.8	0.002
8	3	2	1.8	0.004
9	3	3	1.8	0.006

Statistically determined complete 3-value study plan – PS/DK-3^2 was adopted. Each grinding test (Table I) was repeated.

Less velocity of the longitudinal feedrate v_{ft} than the recommended ones [2] was assumed, because at higher velocities, the roughness and the waviness of the surface of the PO increased with visible inequalities in the form of bands. After each grinding and repetition test, 4 surface roughness measurements were taken – a total of 8 measurements. For this purpose, the contact profilometer HOMMEL TESTER T1000 was used. Measurements were made for an elementary section of 0.8 mm.

Test results

Fig. 2 and fig. 3 show mean values of roughness parameters from individual grinding tests (Table I), and as a measure of spread, the standard deviation was assumed. The highest values of roughness parameters, irrespective of the grinding depth, were obtained after samples 7–9 with the highest feedrate of v_{ft} = 1.8 m/min. The lowest – values of roughness parameters such as *Ra*, *Rz* and *Rt* were obtained after grinding with v_{ft} = 0.9 m/min and a_e = 0.004 mm.

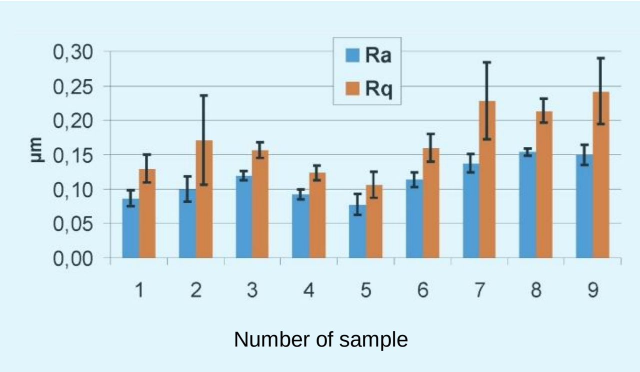

Fig. 2. Average values of surface roughness parameters *Ra* and *Rq* obtained after subsequent grinding tests

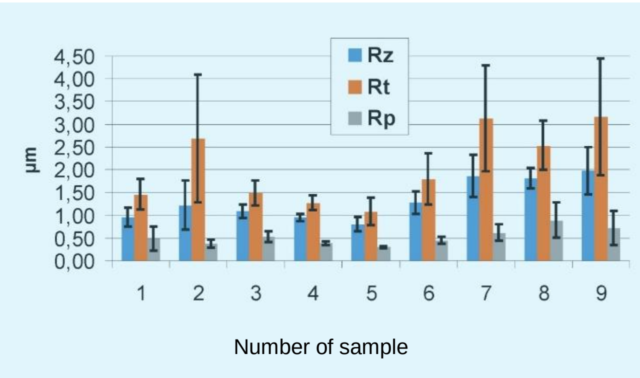

Fig. 3. Average values of surface roughness parameters *Rz*, *Rt* and *Rp* obtained after subsequent grinding tests

TABLE II. ANOVA analysis for parameter *Ra*

Variance source	*SS*	*df*	*MS*	*F*	*p*	*F* test
v_{ft}	0.038	2	0.019	129.805	0.000	3.143
a_e	0.007	2	0.003	23.804	0.000	3.143
$v_{ft} \cdot a_e$	0.005	4	0.001	8.297	0.000	2.518
Error	0.009	63	0.000			
Total	0.05875	71				

Legend: *SS* – sum of squares of deviations; *df* – number of degrees of freedom; *MS* – average square of deviations; *F* – calculated value of *F* statistics; *p* – probability; *F* test – critical value read at significance level *α* = 0.05.

TABLE III. ANOVA analysis for parameter *Rt*

Variance source	*SS*	*df*	*MS*	*F*	*p*	*F* test
v_{ft}	33.952	2	16.976	19.754	0.000	3.143
a_e	0.623	2	0.311	0.362	0.697	3.143
$v_{ft} \cdot a_e$	15.352	4	3.838	4.466	0.003	2.518
Error	54.140	63	0.859			
Total	104.066	71				

TABLE IV. ANOVA analysis for parameter *Rz*

Variance source	*SS*	*df*	*MS*	*F*	*p*	*F* test
v_{ft}	12.871	2	6.435	58.958	0.000	3.143
a_e	0.543	2	0.272	2.489	0.091	3.143
$v_{ft} \cdot a_e$	1.147	4	0.287	2.628	0.043	2.518
Error	6.877	63	0.109			
Total	21.438	71				

Tables II–IV present results of the study upon significance of the influence of grinding parameters on surface roughness parameters. The analysis was performed for assumed significance level *α* = 0.05.

In the case of the roughness parameter *Ra*, the v_{ft} and a_e parameters as well as interaction between them were significantly affected. The parameter *Rt* was most influenced by velocity of the longitudinal feedrate of the object v_{ft} and interaction of this parameter with the grinding depth a_e. Similar results were obtained for *Rz* parameter.

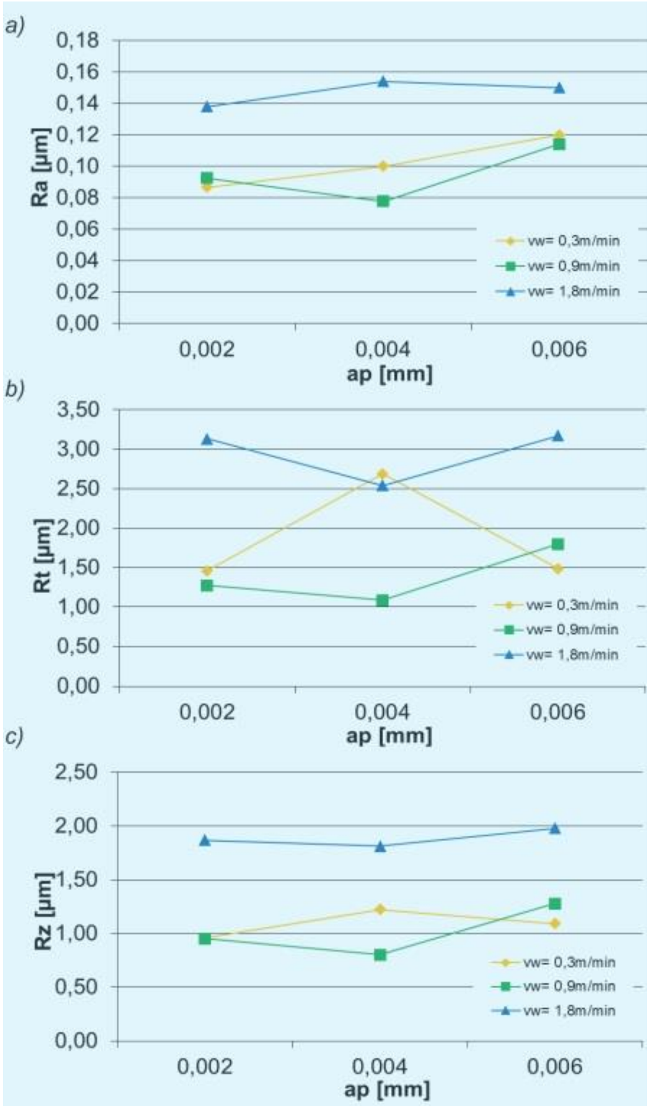

Fig. 4. Dependence of roughness parameters: a) *Ra*, b) *Rt*, c) *Rz* for ground surface on the longitudinal feedrate v_{ft} and grinding depth a_e

Fig. 4 shows the values of roughness parameters *Ra*, *Rt* and *Rz* obtained depending on the feedrate of the object and the depth of grinding. It can be seen that within the range of assumed values of v_{ft} = 0.3 and 0.9 m/min, the *Ra* and *Rz* values were similarly independent of the grinding depth. Only for *Rt*, significant values were recorded for the smallest longitudinal feedrate of the object v_{ft} and grinding depth a_e = 0.004 mm.

Exemplary roughness profiles with material contribution curves and ordinate distributions are illustrated in figs. 5–7.

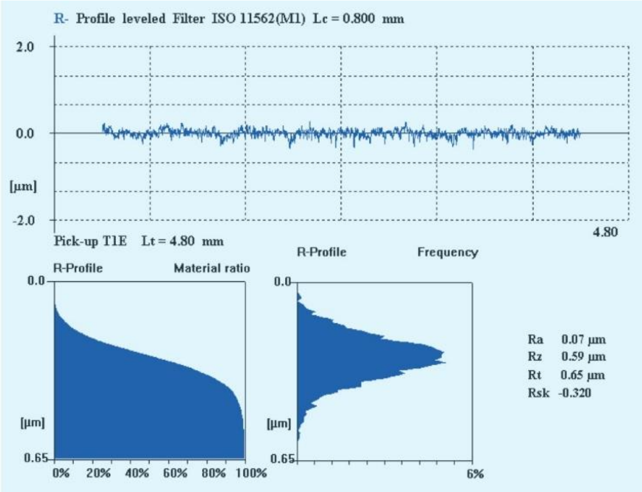

Fig. 5. Exemplary surface roughness profile obtained after grinding with parameters v_{ft} = 0.9 m/min and a_e = 0.004 mm

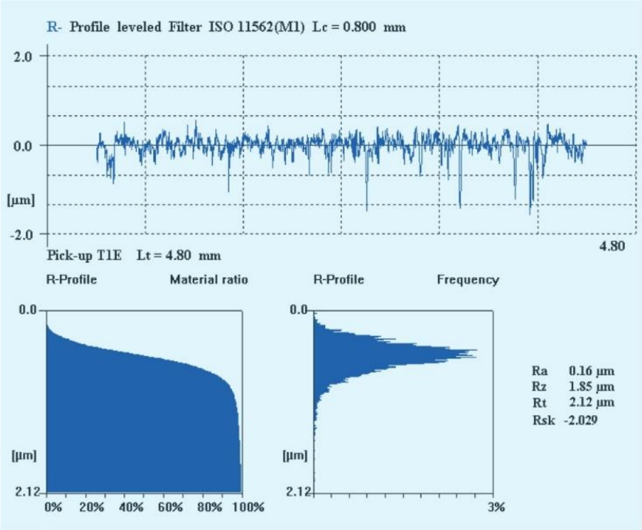

Fig. 6. Exemplary surface roughness profile obtained after grinding with parameters v_{ft} = 1.8 m/min and a_e = 0.006 mm

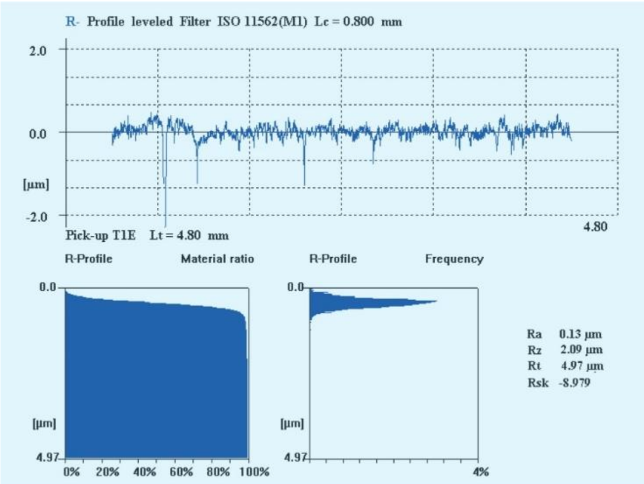

Fig. 7. Exemplary surface roughness profile obtained after grinding with parameters v_{ft} = 0.3 m/min and a_e = 0.004 mm

The most favorable surfaces were obtained after grinding the sample No. 5. An example of such surface area is shown in fig. 5. The surface profile after grinding with the highest values of parameters (sample No. 9) is shown in fig. 6. When comparing the profiles of fig. 5 and fig. 6, the differences can be seen due to the occurrence of scratches on the surface, which can be contributed to the small hardness of the workpiece. The scratches are also visible on the roughness profile of fig. 7 obtained after the grinding the sample No. 2. Their formation influenced on the value of *Rt* parameter.

Fig. 8 shows values of the asymmetry coefficient of the roughness profile *Rsk* obtained after individual grinding tests. Negative values of this parameter indicate that the ground surfaces have a high bearing load.

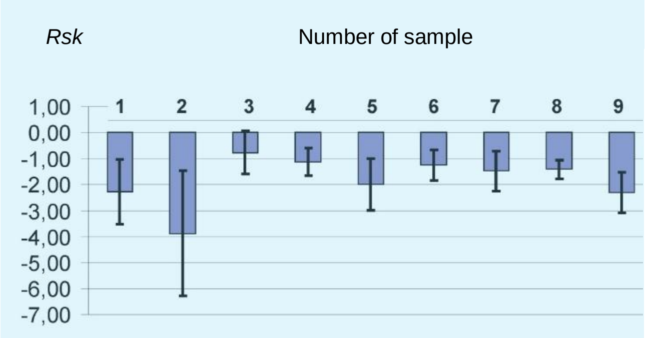

Fig. 8. Average values of the asymmetry coefficient for the roughness profile *Rsk* after subsequent grinding tests

Conclusions

Based on the grinding of 1.0562 steel in the softened state, it has been determined that the longitudinal feedrate v_{ft} has a greater effect on the surface roughness than the grinding depth a_e. The lowest surface roughness was reported for the grinding parameters No. 5. The smallest values of the *Ra* roughness parameter – in the range of 0.06÷0.08 µm – appear to be the limiting values that can be achieved under the accepted conditions of grinding of low hardness objects. Increasing the v_{ft} speed over 1.8 m/min resulted in an increased surface roughness. At the lowest accepted feedrate, the best results were also not obtained.

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