INFLUENCE OF THE HIGH SPEED PART POLISHING COATING TOOLS ON THE CHANGES SURFACE TEXTURE

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Abstract

Coating of the thin layers is a direct way to increase productivity and tool life. To enhance these benefits, there are a number of finishing operations. The paper focuses on changes surface texture of the coated tools after surface finishing of the functional surfaces by the polishing. Changes selected parameters of the surface texture influence the behaviour of the tool and change its functional characteristic. This experiment was carried out on three types of the tools (two profiling tools and forming tool) with different coatings (TiN, TiAlN, nACo®). The coatings were deposited on tools by PVD method. Tools with coatings were subsequently polished. The qualitative assessment of the changes surface texture was carried out by the 3D topography measurement of the surface by using Talysurf CCI Lite on the coated and polished surfaces. TalyMap software was used for evaluation of the changes surface texture 2D profiles and 3D areas. The results in this paper are showing positive influence of the polishing on the surface texture of the coating tools. Parameters of the surface roughness Ra and Sa were reduced in case of polished coatings.

Keywords: Coating layers, polishing, surface texture, parameters of the surface roughness.

1. INTRODUCTION

Surface texture significantly affects the functional properties of the component. It is estimated that surface conditions cause of the functional failure about 10 % of the products, which of course affects efficiency of the overall production of the engineering. The aim of the evaluation of the surface texture is to ensure objective evaluation of the surface profile in relation to its function. Nevertheless it is not just about finding out quality of the prepared surface but also predict the performance of the additional functional changes. Properties will improve due to polishing of applied coating in particular cases of coating tools. Surface texture together with properties of the surface layers are decisive factors for their lifetime and durability of the cutting tools. The 3D measurements was used for qualitative assessment of changes in surface texture which provides a more objective presentation condition of the surface with much greater statistical significance assessed characteristics. In addition to the basic parameters of the surface texture such as Sa, Ra and St, Rt were subsequently evaluated parameters Sdq and Rdq. These parameters belong to group of the hybrid parameters; higher slopes indicate more likelihood deformation under load, increase friction and wear of the tool. Using only one parameter for the evaluation offers mostly limited partial view of the behaviour of the surface and could lead to misleading and unreliable conclusions and for this reason parameters Spk and Rpk were subsequently evaluated. These parameters belong to a group of the functional parameters and the parameters of the material ratio. Spk, Rpk determine the properties of the running-in tool.

2. EXPERIMENT

Deposition of the coating and their additional finishing - experiments were performed on three tools from high speed tool steel HS6-5-2-5 (CSN 41 9852). Coatings which were deposited on tools are shown in **Table 1.**

Table 1 Coatings on tools

Order number	Tool	Coating	Coating thickness [µm]
1.	Profiling tool	TiN	2.93
2.	Profiling tool	TiAlN	2.73
3.	Forming tool	nACo®	3.64

Coatings were deposited by PVD (Physical Vapour Deposition) in devices Platit Pi80, PI1000 using cathodic arc evaporation. Conditions of the deposition coatings are shown in **Table 2.**

Table 2 Conditions of deposition coatings

Coating	Temperature [°C]	Bias [V]	Arc [A]	Targets	Pressure N_2 [mbar]
TiN	450	100	160	Ti	0.01
TiAlN	450	40	200 + 180	Ti + (Ti/Al 50/50)	0.02
nACo®	480	60	80 + 100	Ti + (AlSi 12% Si)	0.018

nACo® is nanocomposite coating AlTiN matrix of Si_3N_4. The coating has high hardness and extremely high thermal resistance. Using the coating is widespread in milling high strength steel, cast iron milling and machining of the quenching steel or cutting high strength steels.

Polishing - one part of the coated tool was left without adjustments after coating and the second part of the coated tool was subsequently polished by special medium Multi-Cone. Medium consist of an elastic abrasive particles, which upon impact on the surface deform and glide over the surface. The method ranks among finishing operation, which are carrying out in necessary cases after coatings for less surface roughness and thereby improves properties of the PVD layers (especially creation of cold joints during cutting).

The measurements of the surface roughness [1] - measurements were performed on polished and unpolished coating of the tools. For qualitative evaluation of the surface were measured three selected place. The measurement was carried out by the 3D profilometer Talysurf CCI Lite with magnification of the lens 20x [1]. Subsequently, surfaces were evaluated by software TalyMap Platinum. The basic conditions for measuring surface are shown in **Table 3.**

Table 3 Conditions of the measuring surface texture

Lens	Measuring area	Measuring profile	Step	Cut off
20 x	0.83 mm x 0,83 mm	0.83 mm	0.5 µm	0.25 mm

The evaluation of the surface texture was carried out by methodic with following steps [2]:

- 3D area - Leveling surface => Form removing => Filtering primary surface to waviness and roughness => Display roughness and waviness surface => Calculation 3D parameters
- 2D profile - Selection of the profile from measurement area => Leveling profile=> Form removing => Filtering primary profile to waviness and roughness => Display roughness and waviness profiles => Calculation 2D parameters

Changes of the surface texture were evaluated by selected parameters. For 3D assessment were used parameters [4]:

- Sa - arithmetic mean deviation of the surface [µm];
- St - area peak to valley height [µm];
- Sdq - root mean square surface slope [-];
- Spk - reduced peak height [µm].

For 2D assessment were used parameters [2, 3]:

- Ra - arithmetical average deviation of the assessed profile [µm];
- Rt - maximum peak to valley height of the assessed profile in the assessment length [µm];
- Rdq - root mean square slope of the assessed profile [°];
- Rpk - reduced peak height of the assessed profile [µm].

3. RESULTS AND DISCUSSION

The results of the measurement polished and unpolished coating surfaces are shown in **Table 4.**

Table 4 Surface roughness of the polished and unpolished coatings

Parameters of the surface roughness	Tool face		Circumference of the tool	
	Unpolished	**Polished**	**Unpolished**	**Polished**
Profiling tool - coating TiN				
Ra [µm]	0.182 ± 0.007	0.116 ± 0.015	0.122 ± 0.007	0.110 ± 0.003
Rt [µm]	1.440 ± 0.191	0.861 ± 0.205	0.723 ± 0.027	0.638 ± 0.022
Profiling tool - coating TiAlN				
Ra [µm]	0.237 ± 0.015	0.146 ± 0.020	0.057 ± 0.005	0.028 ± 0.007
Rt [µm]	1.440 ± 0.191	0.844 ± 0.135	0.435 ± 0.033	0.235 ± 0.059
Forming tool - coating nACo®				
Ra [µm]	-	-	0.358 ± 0.033	0.198 ± 0.014
Rt [µm]	-	-	1.996 ± 0.097	1.259 ± 0.066

Profiles of the surface roughness Ra polished and unpolished coatings are shown in **Fig. 1** and **Fig. 2.**

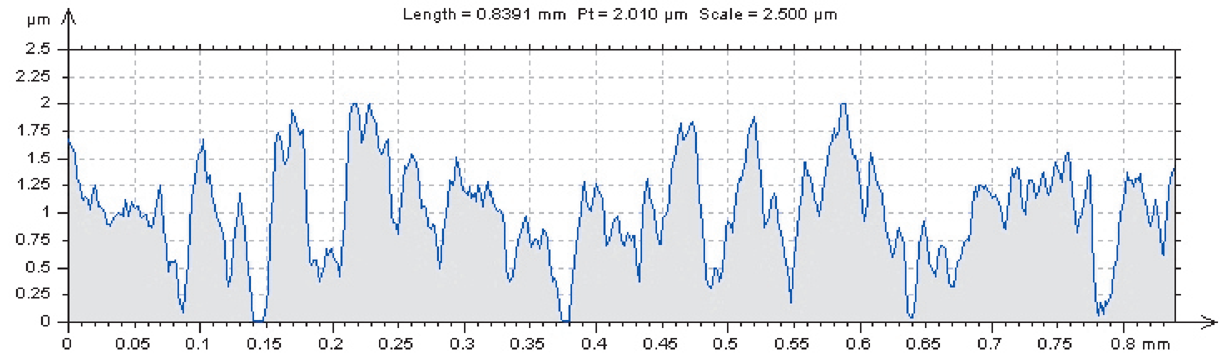


Fig. 1 The 2D profile of the unpolished forming tool with coating nACo® - circumference of the tool

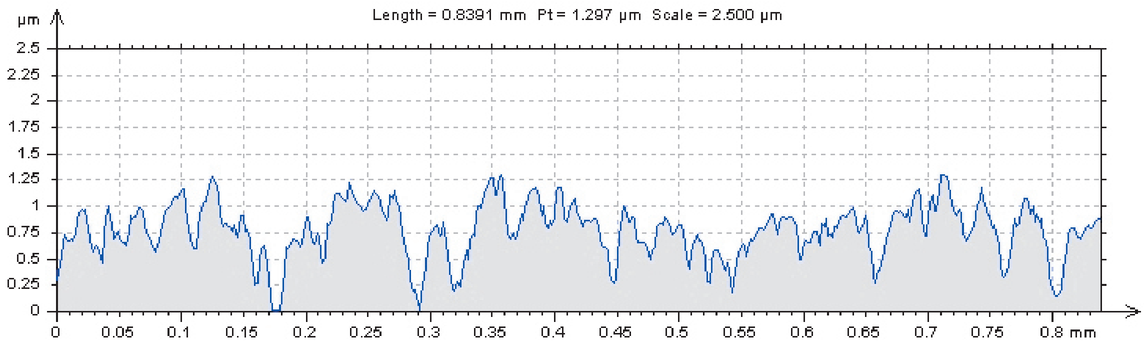


Fig. 2 The 2D profile of the polished forming tool with coating nACo® - circumference of the tool

Parameters Ra and Rt are reduced in case of the polished against unpolished coatings. The most significant decrease surface roughness of the tools was achieved in case of the coating TiAlN and nACo® on the circumference of the tools. Values in this case were reduced about from 45 % to 51 %. Surface roughness was reduced about 10 % in case of TiN coating. Parameters of the surface roughness were also reduced about 37 % on tool face. Significant reduction of the surface roughness on the circumference of the tools relate to preferable position circumference area of the tool considering to polishing tool. Values of the parameters Sdq, Rdq are very important because the parameters determine functional properties and reduce friction and wearing. Results of the measured slopes of the assessed profile are shown in **Table 5.**

Table 5 Root mean square slope of the profile polished and unpolished coatings

Profiling tools - coating TiN				
Parameters of the surface roughness	Tool face		Circumference of the tool	
	Unpolished	Polished	Unpolished	Polished
Rdq [°]	3.589 ± 0.055	2.552 ± 0.432	2.170 ± 0.230	1.976 ± 0.180
Profiling tool - coating TiAlN				
Rdq [°]	4.745 ± 0.652	2.336 ± 0.279	1.784 ± 0.134	0.758 ± 0.402
Forming tool - coating nACo®				
Rdq [°]	-	-	5.142 ± 0.094	3.031 ± 0.369

Values of the Rdq parameter (root mean square slope of the assessed profile) were reduced in case of the polished against unpolished coatings. The decrease slope of the profile is different. Rdq parameters were reduced about 29 % on tool face and 9 % on the circumference of the tool with coating TiN. Tools with TiAlN and nACo® coating exhibit significant slope of the profile and values of the parameters Rdq are about from 40 % to 60 %. Slope of the profile is very significant parameter, because lower slope causes less friction on surface of the tool, less wear of the functional areas, higher resistance of the surface during load and less adhesion. Simultaneously smaller slopes of the profile result in reduced vibration during operation. The other parameters are parameters material ratio, which influence on the functional properties of the surface. One of them is parameter Rpk. Rpk is reduced peak height of the assessed profile and influence running-in properties [3]. Results of the Rpk parameters are shown in **Table 6.**

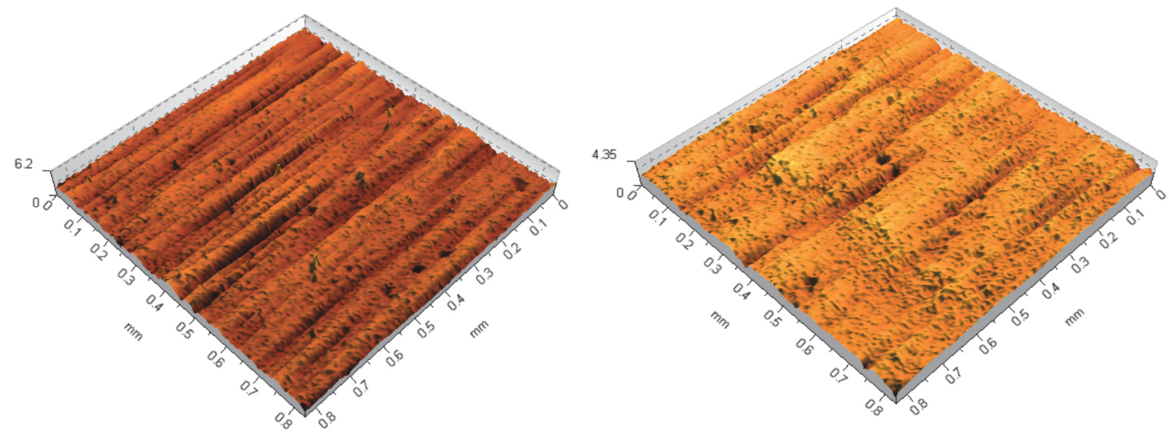
Table 6 Reduced peak height of the profile polished and unpolished coatings

Profiling tool - coating TiN				
Parameters of the surface roughness	Tool face		Circumference of the tool	
	Unpolished	Polished	Unpolished	Polished
Rpk [μm]	0.178 ± 0.050	0.116 ± 0.040	0.118 ± 0.016	0.089 ± 0.021
Profiling tool - coating TiAlN				
Rpk [μm]	0.126 ± 0.049	0.098 ± 0.023	0.124 ± 0.063	0.030 ± 0.021
Forming tool - coating nACo®				
Rpk [μm]	-	-	0.199 ± 0.188	0.132 ± 0.076

Values of the parameters Rpk are reduced in case of the polished against unpolished coatings. The decrease of the peaks heights were about from 22 % to 75 %. Reducing the reduced heights of the profile after polishing will help to reduce time to obtain a uniform load of the tool, i.e., that shortening the time of the surface load only on tops of the surface causes that pressure of the surface reduce faster between the tool and the part in the process.

3.1 Texture of the surface

Parameters Sa, St achieve reduced values in case of polished coatings against unpolished coatings. The decrease surface texture is lower than for 2D parameters. The tool with TiN coating shows reduction of the parameters Sa only about from 4 % to 17 %. More reduction was detected after polishing TiAlN and nACo®



unpolished surface polished surface

Fig. 3 3D surface topography - forming tool with nACo® coating **-** circumference of the tool

The results of the measurements surface texture unpolished and polished coating are shown in **Table 7.**

Table 7 3D parameters of the surface textures polished and unpolished coating

Parameters of the surface roughness	Tool face		Circumference of the tool	
	Unpolished	Polished	Unpolished	Polished
Profiling tool - coating TiN				
Sa [µm]	0.192	0.160	0.176	0.170
St [µm]	1.625	1.623	6.859	4.165
Profiling tool - coating TiAlN				
Sa [µm]	0.314	0.192	0.080	0.035
St [µm]	3.996	2.271	5.428	2.118
Forming tool - coating nACo®				
Sa [µm]	-	-	0.356	0.281
St [µm]	-	-	6.279	4.373

Differences between decrease of the surface textures on the circumference and face of the tools are not significant. This condition is caused by evaluation considerably larger set of data in case of the 3D measuring surface textures. 3D topography of the coating polished and unpolished surface is shown in **Fig. 3.**

The same effect of the 2D parameter Rdq **-** root mean square slope of the assessed profile show 3D parameters Sdq - root mean square surface slope. The results of parameters root mean square surface slope after polishing and unpolished are shown in **Table. 8**.

The values of the parameters Sdq are reduced in case of polished coatings against unpolished. Decrease surface slope is different in case of TiN. Surface slope was reduced about 1, 5 % on the tool face. Tools with TiAlN and nACo® reduced surface slope about from 20 % to 51 %.

Decrease values surface slopes have the same effect as 2D parameters Rdq on functional areas of the tools. Lower values of the surface slopes on tools after polishing have positive effect on friction, wear, adhesion and reduce vibration

Table 8 Surface slope unpolished and polished coatings

Profiling tool - coating TiN				
Parameters of the surface roughness	Tool face		Circumference of the tool	
	Unpolished	Polished	Unpolished	Polished
Sdq [-]	-	-	0.071	0.070
Profiling tool - coating TiAlN				
Sdq [-]	0.135	0.077	0.067	0.033
Forming tool - coating nACo®				
Sdq [-]	-	-	0.108	0.087

The other parameter from 3D measurement surface texture which influences functional properties is reduced peak height Spk. The values Spk parameters of the polished and unpolished coatings are shown in **Table 9.**

Table 9 Reduced peak height unpolished and polished coating

Profiling tool - coating TiN				
Parameters of the surface roughness	Tool face		Circumference of the tool	
	Unpolished	Polished	Unpolished	Polished
Spk [μm]	0.163	0.122	0.188	0.163
Profiling tool - coating TiAlN				
Spk [μm]	0.136	0.097	0.126	0.037
Forming tool - coating nACo®				
Spk [μm]	-	-	0.348	0.234

The values of the parameters Spk are reduced in case of the polished coatings against unpolished. Reduced peak height was decreased about from 13% to 70%. Reduced peak height has the same effect like in case of Rpk.

CONCLUSION

The results in the paper demonstrate positive effect of the polishing on texture coating layers on the tools. It has been achieved reduce of the surface roughness assessed with parameters Ra, Sa in all cases polished coatings. Reduce of the surface roughness was from 45% to 51% on the tool with TiAlN coatings and nACo® was significant changes on the circumference areas of the tools. Surface roughness was reduced only about 10 % in case of the tool with TiN coating. Less reduction values of the surface texture were in case of the 3D parameters Sa and it can be attributed greater number of measured data on the surface. It indicates that there are also other inequalities which 2D measurements cannot determine. Reduce slopes of the profile and surface slopes measured area in range from 5% to 60% has significant affect on functional properties coatings of the tools. Reduced values of the slopes exhibit less friction and thereby with less wear functional areas of the tools. Reduced values of the parameters Rdq, Sdq has influence on greater surface resistance during its load and less adhesion. Evaluation of methods of polishing of coated tools showed a reduction in the basic parameters of surface texture and simultaneously was confirmed a significant reduction of surface texture parameters that affect the functional properties of surfaces.

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