

Hard machining of agricultural machines parts

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Abstract

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For the renovation and/or improvement of the surface properties of machine elements, hard facing is often used. Hard structures obtained in layers or by heat treatment achieve a hardness of up to 68 hardness (HRC) or even more. The grinding of these surfaces demands the use of processing fluids and causes sometimes changes in the surface layers structure. Hard turning can replace grinding when certain requirements are fulfilled, particularly tough machining system. Hard deposits of two weld-on materials on a sample of steel grade S235JRG1 have been turned using cemented carbide inserts with a TiAlN coating of PVD type. The surface roughness measurements along with the observation of insert wear have been conducted to find proper machining parameters and conditions for this application. Cutting inserts manufacturer guidelines for special application could be insufficient or even not provided. Besides that, it is necessary in the experiments to take into account and examine the cutting ceramics and cubic boron nitride (CBN)/polycrystalline cubic boron nitride (PCBN).

Keywords: hard turning; tool wear; surface quality; roughness; hardness

One of the main advantages of hard turning resides in the effectiveness potential of the machining of the tribological nodes elements.

Hard machining can be applied in many typical machining operations, but extremely demanding tribological conditions causing relatively rapid tool wear, which results in the tool dimension and shape accuracy loss, limit its use to such applications where tools made of a suitable cutting material are available.

Hard turning is generally defined as rotating and taper parts machining with a hardness of more than 45 hardness (HRC) using a lathe or turning centre. Allowing to achieve surface roughness $R_{\max}/R_z = 1.6 \mu\text{m}$, it can replace grinding or can be used as roughing in the case of finishing grinding. Currently, it is most used for the turning of heat-treated parts with a hardness of 45 HRC to 68 HRC and more.

The reduction or removal of the cutting fluids from the process is recommended due to two main reasons. The lifecycle cost of the cutting fluid (filtration, cleaning, residues removal) influences significantly the manufacturing costs level (BARÁNEK, JANÁČ 2006). According to many sources, the cutting fluid costs can achieve in automotive industry 16–20% of the total manufacturing costs. The coming definition of quality emphasises the environmental aspects of the products and processes. The restrictions in the application of dangerous materials by law made the fluids manufacturers improve fluid formulas and evolve new fluid types. The user's reaction is a change in preferences of the fluid type and processes (ŽITŇANSKÝ et al. 2002, 2011).

Three types of cutting tool materials are suitable for the hard turning technology, taking its application and characteristics into account:

Table 1. Basic characteristics of Fluxofilcord 58 and Fluxodur 62

	Chemical composition (%)				Hardness (HRC)
	C	Mn	Cr	other	
Fluxodur 62	4	0.5	30	Si: 1.2	57–62
Fluxofilcord 58	0.5	1.5	5.5	Mo: 0.6	56–58

- cemented carbides,
- cutting ceramics based on Al_2O_3 and Si_3N_4 ,
- hard materials – polycrystalline diamond (PCD), cubic boron nitride (CBN)/polycrystalline cubic boron nitride (PCBN).

Hard turning technology advantages in comparison to finish grinding:

- machining in one fixture/clamping maintaining the highest concentricity and perpendicularity,
- lower initial investment costs related to the turning machining centre purchase,
- use of a lower number of machines to achieve the required surface quality,
- at least one order shorter set up times and production cycles (total time saving in comparison with grinding of more than 60% in some cases),
- less time for the manipulation and cutting tool exchange,
- the possibility to produce the radius and curves using common tools with inserts,
- higher material removal rate,
- easy chip disposal.

Finish grinding also has some advantages when compared to hard turning:

- cheaper abrasive cutting tools,
- high level of shape accuracy (cylindricity, roundness),
- machined surface quality – rare and not regular white layer presence,
- half level of the residual stress in the surface layer (MAJERČÍK 2008).

The hard turning technology applied to hard-to-machine materials leads to many problems in the

surface quality achieved. Surface changes affecting the mechanical, stress-corrosion, and fatigue properties of the finished parts may occur. The highest demands are made on the surface and near-surface layers quality of hard-to-machine material parts along with the economic and environmental requirements (cutting tool life) (CZÁN, NESLUŠAN 2005).

MATERIAL AND METHODS

The aim of this paper is to evaluate the possibilities of hard layers machining, created by welding-on hard facing flux-cored wire of two constitutions, using the TIG (Tungsten Inert Gas) method.

The objective is to find the possibilities of hard machining application in the function surface obtaining for tribological joints with high demands on the finishing quality. The applicability is reviewed in terms of not only the final surface quality but also the machining process basis.

Two of flux wires different chemical compositions and strength properties were used as the filler material, namely Fluxodur 62 (Oerlikon, Zurich, Switzerland) and Fluxofilcord 58 (Air Liquide Welding, Lužianky, Slovak Republic). Their chemical composition and effective hardness are described in Table 1.

Fluxodur 62 application: worn parts of worm conveyor, mixers blades, pump parts, gravel stirrer, and other parts of mixing devices. The structure of the deposit is overeutectoid with chrome carbides addition.

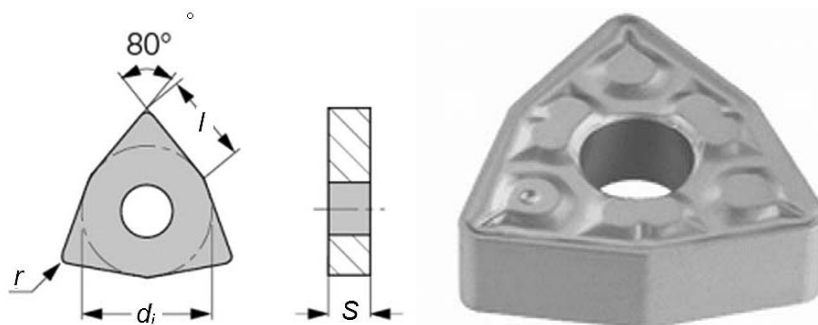


Fig. 1. Cutting insert WNMG 06T308-TF dimensions (mm): $l = 6.52$, $d_i = 9.52$, $S = 3.9$, $r = 0.8$

Table 2. Measured values of the arithmetic average of absolute values (Ra)

Weld-on material	Fluxofilcord 58			Fluxodur 62		
f_n (mm)	0.12	0.23	0.35	0.12	0.23	0.35
Measuring planes	Ra (μm)					
1	0.34	0.9	1.08	0.28	0.52	0.36
2	0.37	0.97	1.01	0.49	0.66	0.47
3	0.28	0.73	1.14	0.17	0.65	0.52
4	0.30	0.78	1.08	0.41	0.46	0.49
Mean value	0.32	0.85	1.08	0.34	0.57	0.46
σ_{Ra}	0.04	0.11	0.05	0.14	0.10	0.07

f_n – feed per revolution; σ_{Ra} – standard deviation of Ra

Table 3. Comprehensive roughness measurement in one of the measuring planes

Weld-on material	Fluxofilcord 58			Fluxodur 62		
f_n (mm)	0.12	0.23	0.35	0.12	0.23	0.35
No.	4	5	6	1	2	3
Rq (μm)	0.31	0.90	1.27	0.14	1.22	0.84
σ_{Rq} (μm)	0.08	0.09	0.11	0.03	0.10	0.12
Rt (μm)	1.3	3.6	5.2	0.9	4.1	3.3
σ_{Rt} (μm)	0.10	0.25	0.42	0.07	0.31	0.35
Rz (μm)	0.8	1.6	3.2	0.6	3.6	0.8
σ_{Rz} (μm)	0.06	0.17	0.21	0.06	0.37	0.11
Rp (μm)	0.6	1.6	2.5	0.4	2.4	2.2
σ_{Rp} (μm)	0.04	0.17	0.13	0.02	0.14	0.23

f_n – feed per revolution; No. – sample number; Rq – root mean squared; Rt – max. height of the profile; Rz – average distance between the highest peak and lowest valley in each sampling length; Rp – max. peak height; σ_{Rq} , σ_{Rt} , σ_{Rz} , σ_{Rp} – standard deviations of Rq , Rt , Rz , Rp , respectively

Fluxofilcord 58 application: parts exposed to strong abrasion: excavator, digger, dredger, conveyor, hammer, shatter parts. The deposit has no cracks, pores, and it is resistant to impact load.

The testing sample was a cylindrical shaft of diameter 45 mm and length 200 mm, steel grade S235JRG1. Welding was realised using the machine Cemont Smarty TX 160alu (Air Liquide Welding, Lužianky, Slovak Republic). Pure argon was used as the shielding gas in both cases with a flow of 7.5–8.0 l/min. Based on the flux-cored wire diameter and material, the welding current was set to 140 A.

The deposits were turned on the CNC lathe Doosan LYNX 220 A (Doosan Infracore Co., Seoul, South Korea). The tool holder MWLNR

2525M-06W (ISCAR Ltd., Tefen, Israel) with $\kappa_r = 95^\circ$ was used. The cutting insert WNMG 06T308-TF (Fig. 1) (ISCAR Ltd.) was used with a negative cutting part geometry and nose angle 80° with respect to the not evenly deposited weld-on. It has a submicron substrate with the TiAlN coating of Physical Vapor Deposition (PVD) type, designed for machining heat resistant alloys, austenitic stainless steels, carbide steels at medium to high cutting speeds, interrupted cut and severe cutting conditions. It is resistant to notch creation on the main edge and build-up.

Machining conditions. The sample was prepared for hard turning using the lathe to make the surface smoother after manual welding on. It is very important to set the depth of the cut to prevent the in-

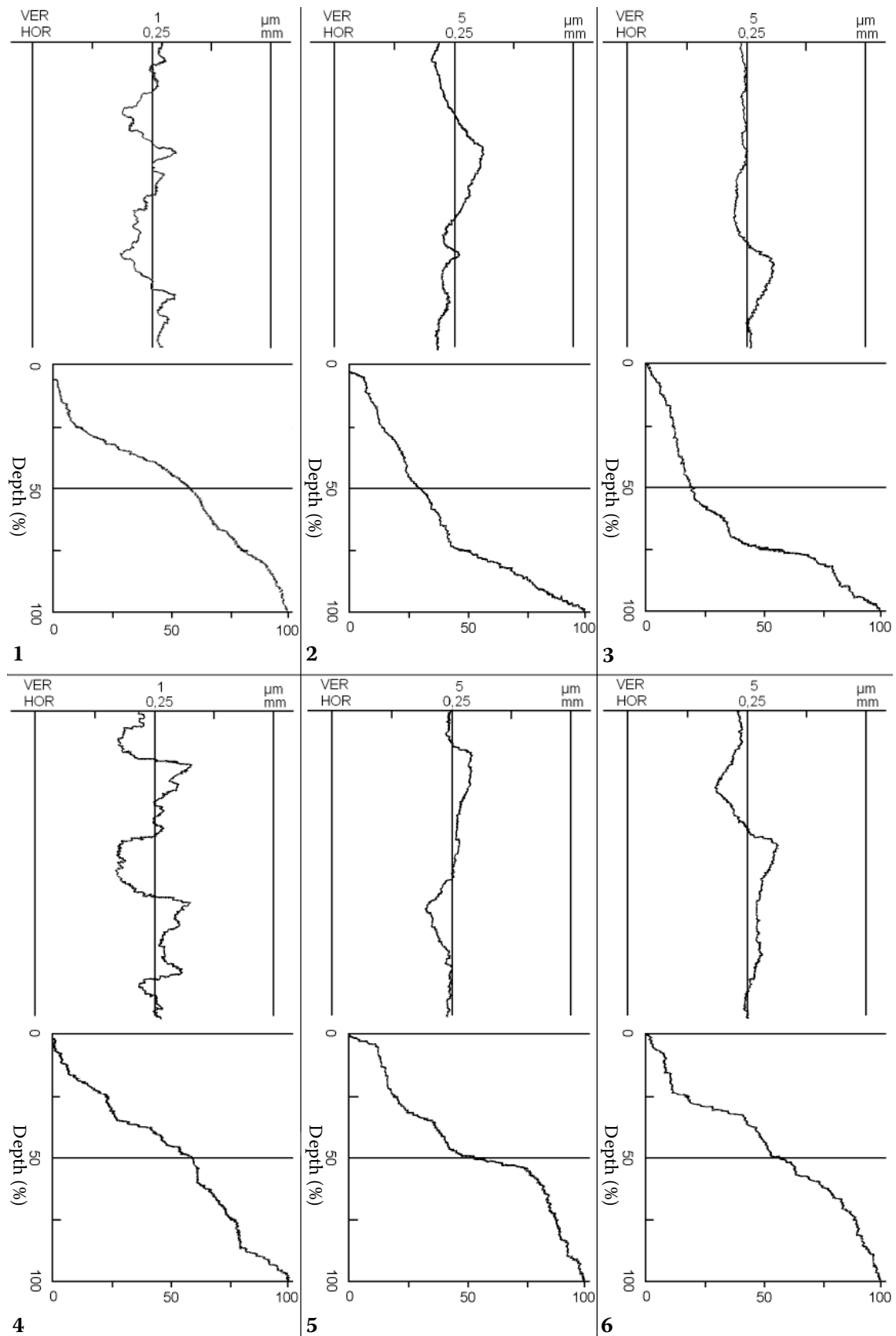


Fig. 2. R_a (average of absolute values) measurement record (first and third row graphs: VER (vertical), HOR (horizontal) – axes units) and carrier surface on section level graphs (second and fourth row)

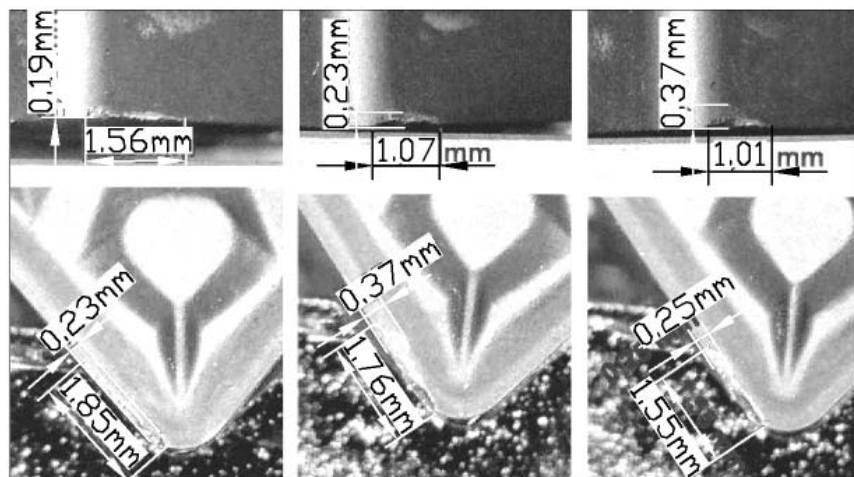


Fig. 3. Tool inserts wear in turning Fluxofilcord 58

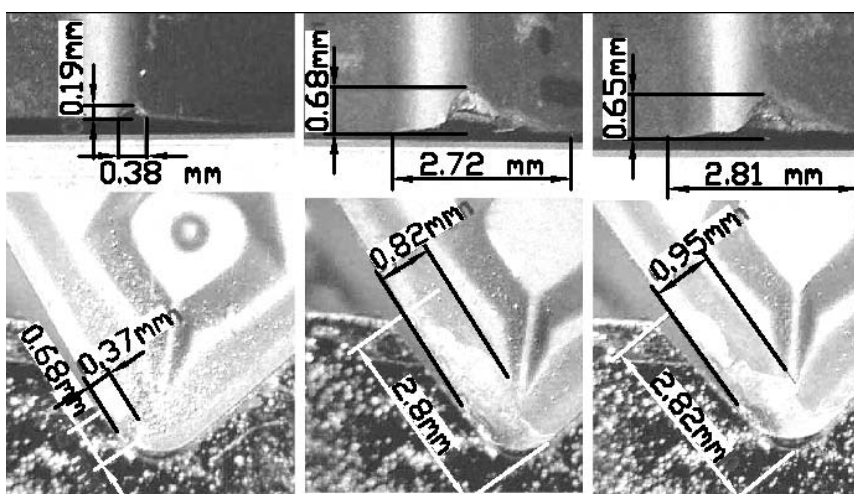


Fig. 4. Tool inserts wear in turning Fluxodur 62

errupted cutting as a main reason of rapid wear of the cutting insert. It is not possible to achieve non-interrupted cutting in the first pass due to craters and small pits on the surface as a result of welding and roughing.

The parameter allowing changes in some range was fed. It was chosen from the low, middle, and high limits of the manufacturer's recommended range. The cutting speed selected was in the middle of the manufacturer's recommended range, while the depth of the cut considering the weld properties was set lower:

- spindle rotation: $n = 1.537/\text{min}$,
- cutting speed: $v_c = 200 \text{ m/min}$,
- feed per revolution: $f_n = 0.12\text{--}0.35 \text{ mm}$,
- depth of cut: $a_p = 0.2 \text{ mm}$.

Measurement of cutting insert wear. The digital microscope BBCGROUP DA-70350 (BBC Tools, Nitra, Slovak Republic) was used to measure the cutting insert wear. It was connected to the PC via USB and allowed a real-time screen display, 10–200× magnification, LED assistant light, VGA resolution,

video capture at 30 fps, a holder with easy positioning and capturing, user-friendly environment.

The Carl-Zeiss application AxioVision LE (Carl Zeiss AG, Oberkochen, Germany) was used to measure the common reference and obtain the real-scale factor. The dimensioned lengths in pixels were then converted to millimetres automatically. The maximal error occurring due to operator's error in the reference setting was 0.01 mm.

RESULTS AND DISCUSSION

The measured results of roughness show a relation to machining parameters in the case of Fluxofilcord 58 weld-on, less trends in the case of Fluxodur 62 weld-on.

Besides the R_a value in Table 2, Table 3 shows the values of parameters R_z , R_t , R_y , and others. In the case of R_z , the relation is similar to R_a . More than the numerical values, the graphical record of the measurement expresses the surface character.

Table 4. Dimensions of tool wear in turning Fluxofilcord 58

Fluxofilcord 58	f_n (mm)		
	0.12	0.23	0.35
VB_{\max}	0.19	0.23	0.37
KB	0.23	0.37	0.25
Rake face wear length	1.85	1.76	1.55

VB_{\max} – maximal width of flank wear land; KB – crater centre distance; f_n – feed per revolution

Steadily growing carrier profile, appears in measurement 1 Fluxodur 62 (feed per revolution 0.12 mm) and in measurements 4 and 6 Fluxofilcord (feed per revolution 0.12 and 0.35 mm) (Fig. 2).

Cutting insert wear evaluation

The images of cutting inserts wear were processed in the graphical application mentioned above and dimensioned. The wear snapshots are placed in Figs 3 and 4 from the left to the right according to the increasing feed values. The tables with the wear values at the rake face and flank face are provided to make the comparison easier (Tables 4 and 5). The width of the wear on the flank face VB_{\max} had the main influence on the tool life. The width increased with the feed in both cases, with a small exception in the case of Fluxodur 62 feed change from 0.23 to 0.35 mm.

As for the rake face, the tool wear measured according to standard STN ISO 3685 (1999) as the KB parameter showed an increasing trend in the case of Fluxodur 62, but not in the case of Fluxofilcord 58. The rake face wear area length decreased slightly when turning the first weld-on material, but increased in the case of Fluxodur 62. These ma-

terials differ in hardness (57–60 HRC for Fluxofilcord 58 when compared to 61–64 HRC for Fluxodur 62) due to the nature of the material structure.

Based on the previous, it can be stated generally that the wear grows with the feed in the inspected range of the cutting parameters. Despite the manufacturer's guidelines, the wear values did not respond to the machined area and reduced the tool life significantly.

CONCLUSION

The application of innovation in machining technologies, that is the improvement of advanced technologies, is a desirable trend in industry today. The economic, environmental, and legislative reasons may accelerate this effort, resulting in the cost and production time reduction and environment protection.

This research needs to be coupled with wear resistance tests simulating real operation conditions as well as the structures after the machining study in terms of residual stress and microhardness distribution.

To prove proper friction properties of the surface created in machining, quantitative evaluation of the surface roughness proceeds in tribological tests. The tool wear exceeds the prior expectations. The TiAlN coated cemented carbide showed quite a poor wear resistance although it should withstand the interrupted cut of hard materials. Besides the weld structure character, the removal of the coating layers, leaving the substrate unprotected, as observed e.g. by NABHANI (2001), should be considered in the cutting edge wear mechanism evaluation. Based on the results of other authors (DAWSON et al. 2001; BROOKES et al. 2002), in the following research the CBN tool insert needs to be examined as well as cemented carbide with different types of coating.

The manual type of welding-on technology has been chosen in relation to the testing purposes. In some cases, the mechanised welding-on can be used instead of the former, resulting likely in a smoother deposit surface. Keeping the process type, the TOPTIG (Air Liquide Welding patented) technology could be adopted to examine this.

Regardless of the problems mentioned above, it can be concluded that the hard turning with a properly selected parameter and suitable machining system has a great potential as concerns the time reduction and productivity increase.

Table 5. Dimensions of tool wear in turning Fluxodur 62

Fluxodur 62	f_n (mm)		
	0.12	0.23	0.35
VB_{\max}	0.19	0.68	0.65
KB	0.37	0.82	0.95
Rake face wear length	0.68	2.80	2.82

VB_{\max} – maximal width of flank wear land; KB – crater centre distance; f_n – feed per revolution

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