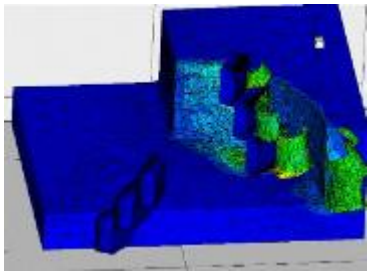
Moderní metody obrábění

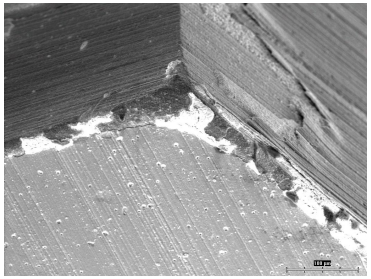
– zvyšování řezivosti nástroje

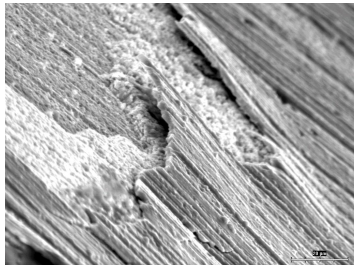
Cíle

- vliv teploty na vlastnosti tenké vrstvy a řezný proces

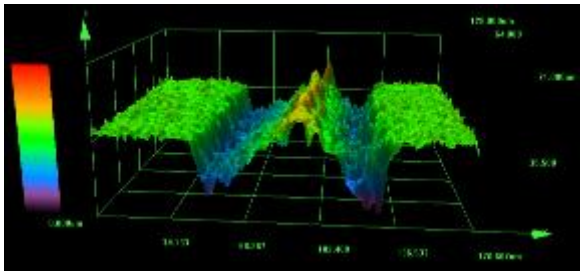


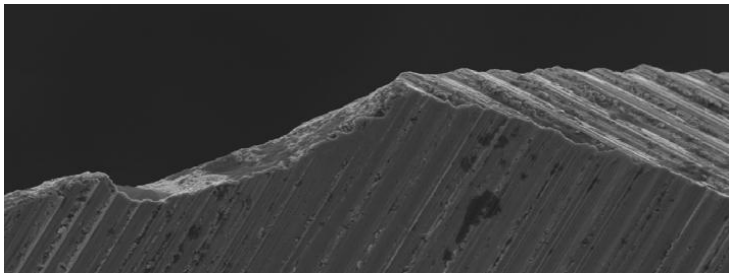
- kvalita břitu nástroje - mikrogeometrie břitu





- možnosti monitoringu mikrogeometrie břitu nástroje

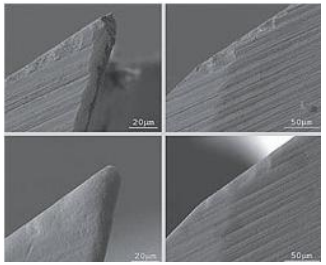




- vliv mikrogeometrie nástroje na řezný proces

Možnosti zvyšování řezivosti

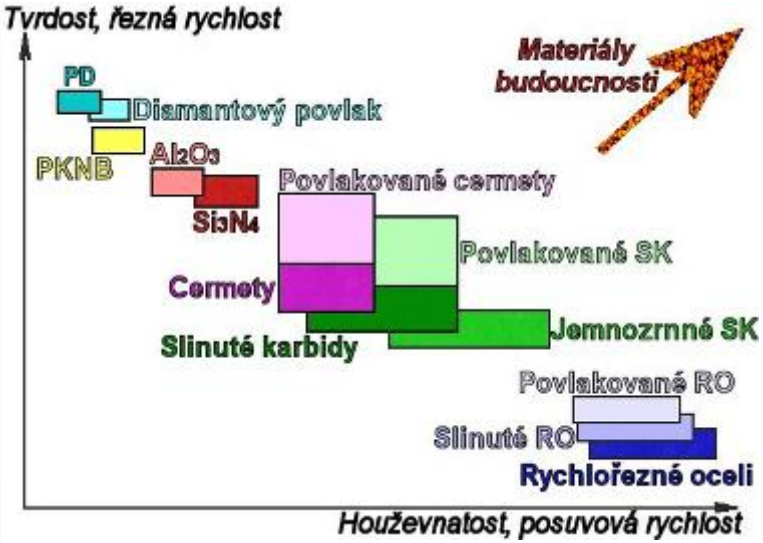
Možnosti zvyšování řezivosti řezných nástrojů



Volba řezného materiálu

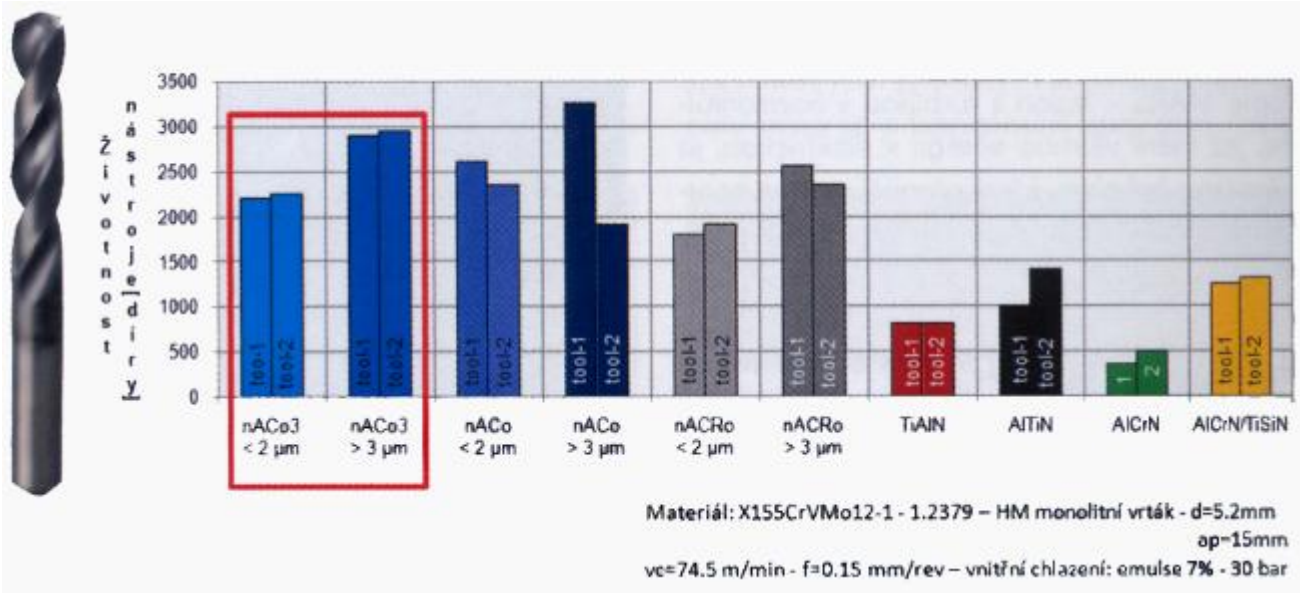
Úprava mikrogeometrie

Volba tenké vrstvy

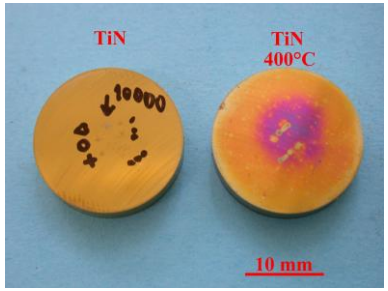


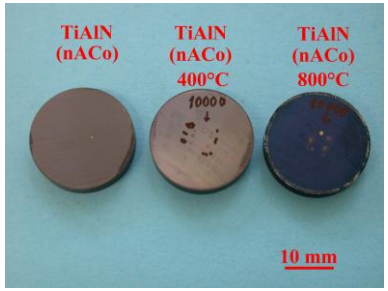
Vrstva	+ prvek	Jemnost zrna	snížení vnitřního pnutí	Tvrdost	Odolnost proti abrazi	Odolnost proti oxidaci	Tvrdost za tepla	Teplotní vodivost	Max. tepelné zatížení	Možnost zvýšení tloušťky	Snížení koeficientu tření	Možnost nanokompozitních struktur
Ti+N: základní vrstva TiN	+N	0	-	+	+	+	0	0	0	-	0	N
TiCN	+C	0	- -	+ +	++	-	-	- -	-	- -	+ +	N
typická TiAlCN Al (20 25)%	+Al	(+)	+	-	-	+	+	+	+	+	-	N
typická TiAlN	+Al (-C)	+	-	+ jestliže Al < 65% - jestliže Al > 65%	+	+	+	+ +	+	-	-	N
typická AlTiCrN	+Cr	-	+	+	+	+	+	+	(+)	+	-	N
typická AlCrN Cr cca 30%	+Cr (-Ti)	- -	+	(+)	+ +	(+)	+	+	(+)	+	(-)	N
typická TiAlN/SiN CrAlN/SiN nebo AlCrTiN/SiN	+Si	+ +	(+)	++	+	++	++	++	++	0	0	A

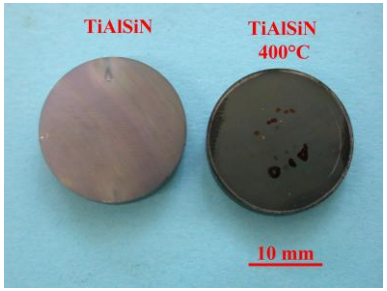
Volba tenké vrstvy



Vliv teploty na vlastnosti tenké vrstvy



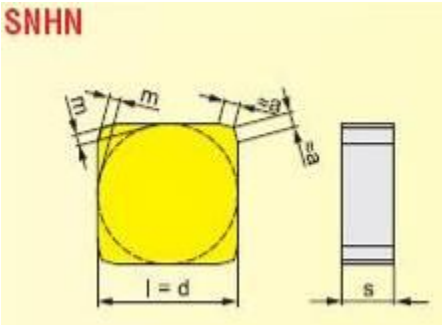




VRSTVA	Tloušťka [µm]
TiAlN (nACo)	1,8
TiAlSiN	3,2
TiN	0,9

Volba řezných podmínek

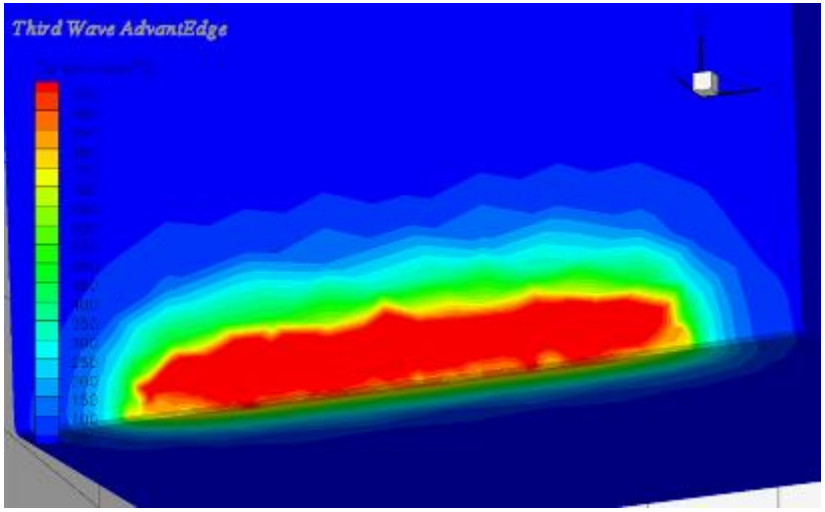
Řezný materiál	SK H10
Obráběný materiál	ocel 19452.4 – 55HRC
Řezná rychlost (konst.)	v_c = 89 m/min
Posuv na otáčku	f_{ot} = 0,10 mm
Hloubka řezu	a_p = 0,5 mm
Řezné prostředí	ZA SUCHA
Tenké vrstvy	bez vrstvy, TiN, TiAlN, TiAlSiN



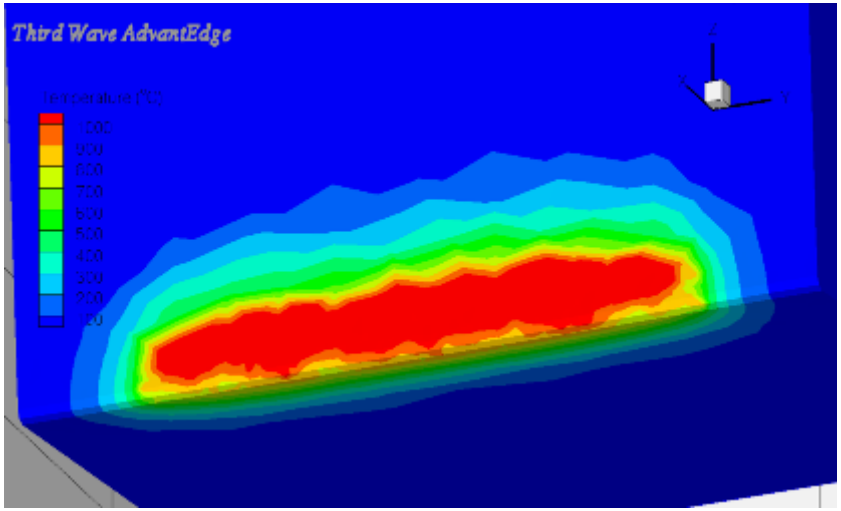
Velikost	l [mm]	d [mm]	s [mm]	m [mm]	a [mm]
1204	12,700	12,700	4,76	0,95	1,40

Teplo na čele nástroje

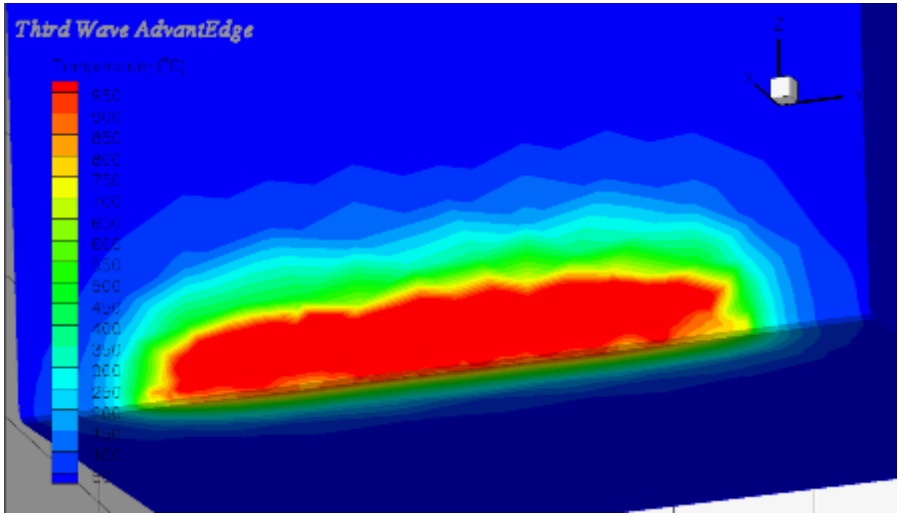
systém SK - bez vrstvy



systém SK – TiN

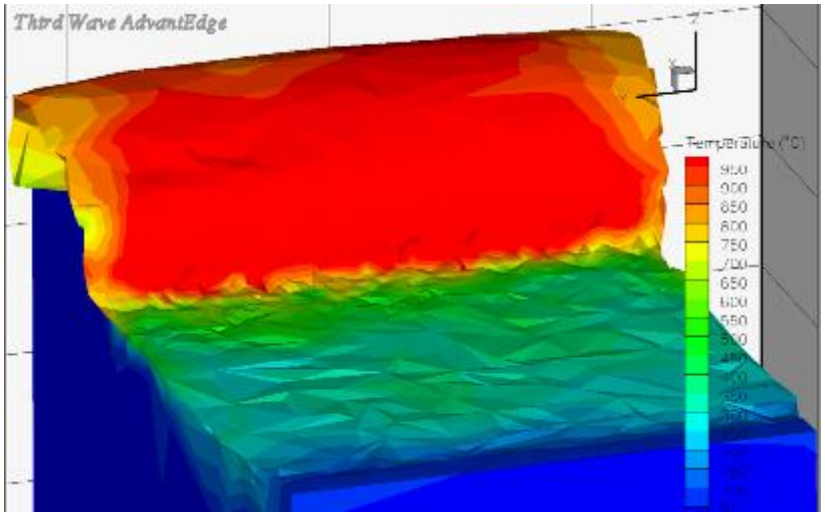


systém SK - TiAlN

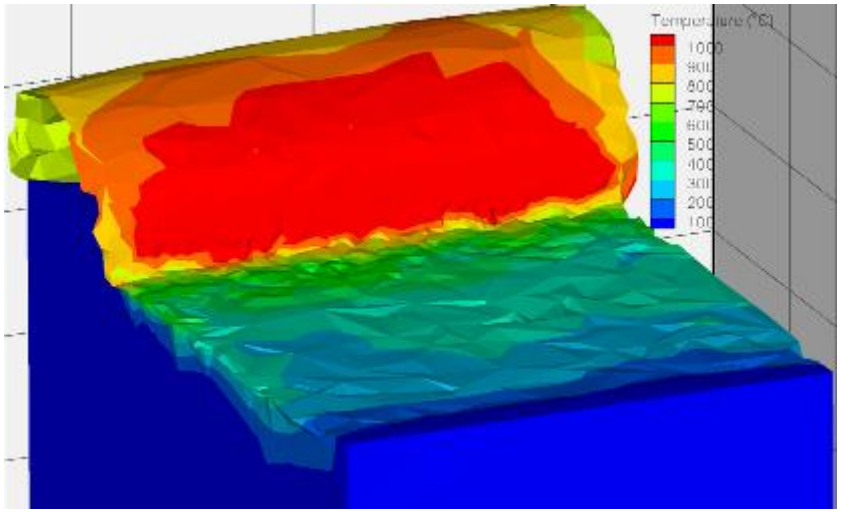


Teplo na povrchu třísky

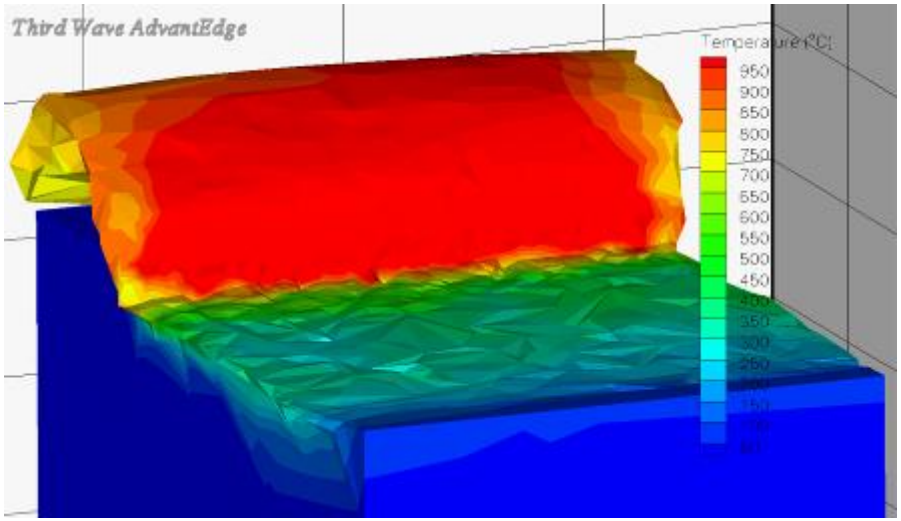
systém SK - bez vrstvy



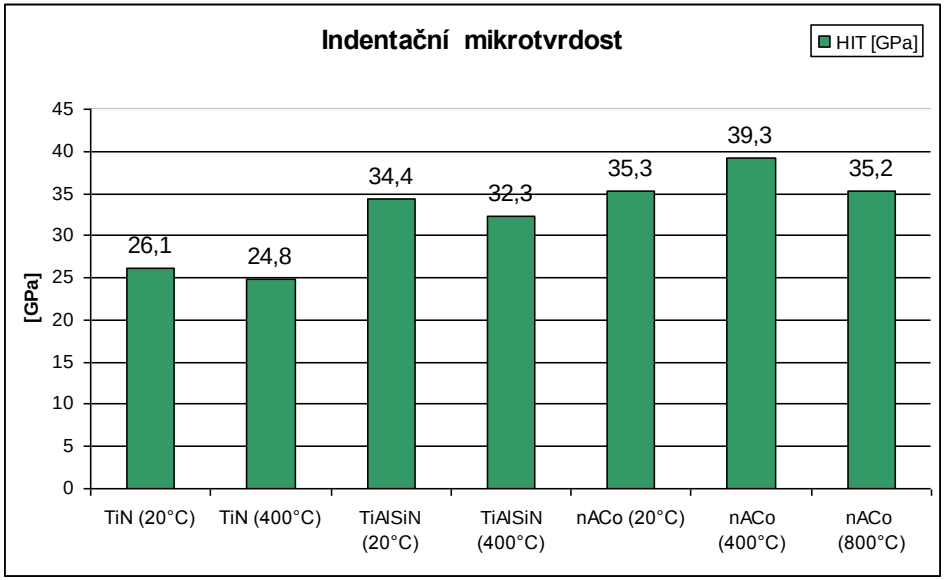
systém SK – TiN

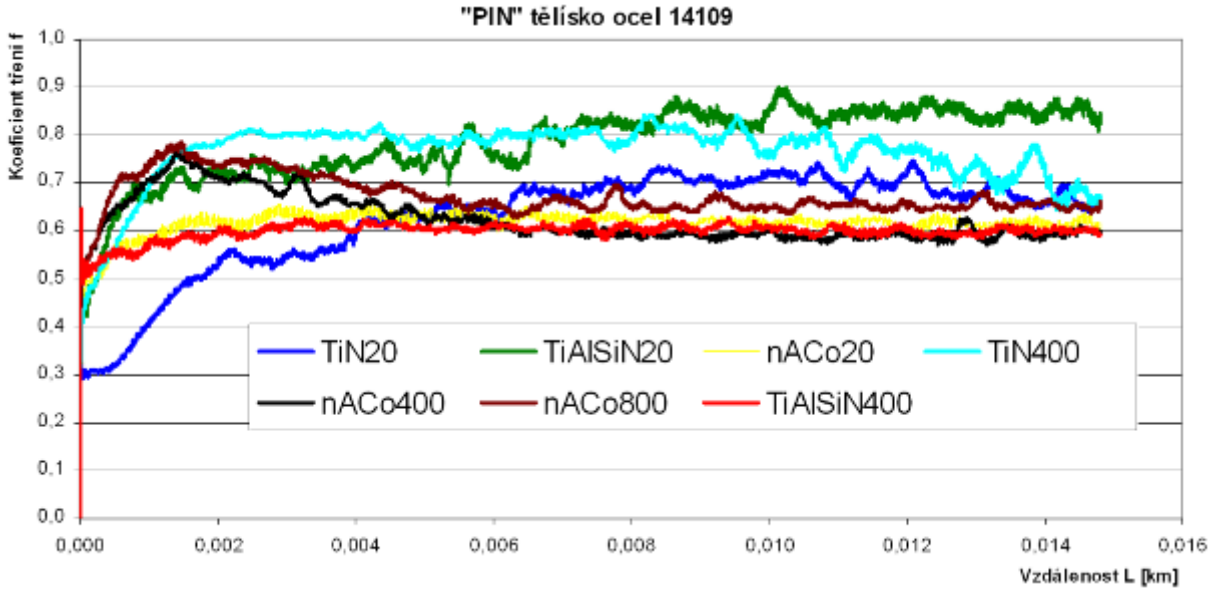


systém SK - TiAlN



Vliv teploty na vlastnosti tenké vrstvy

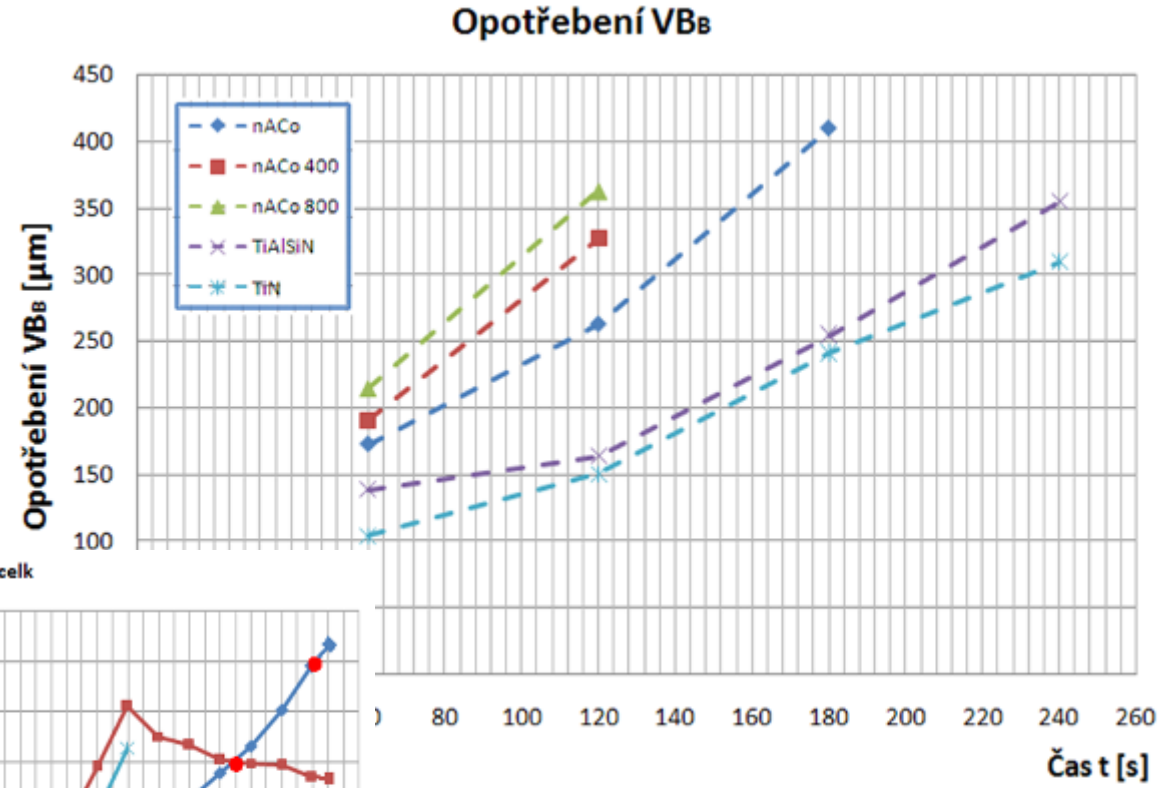


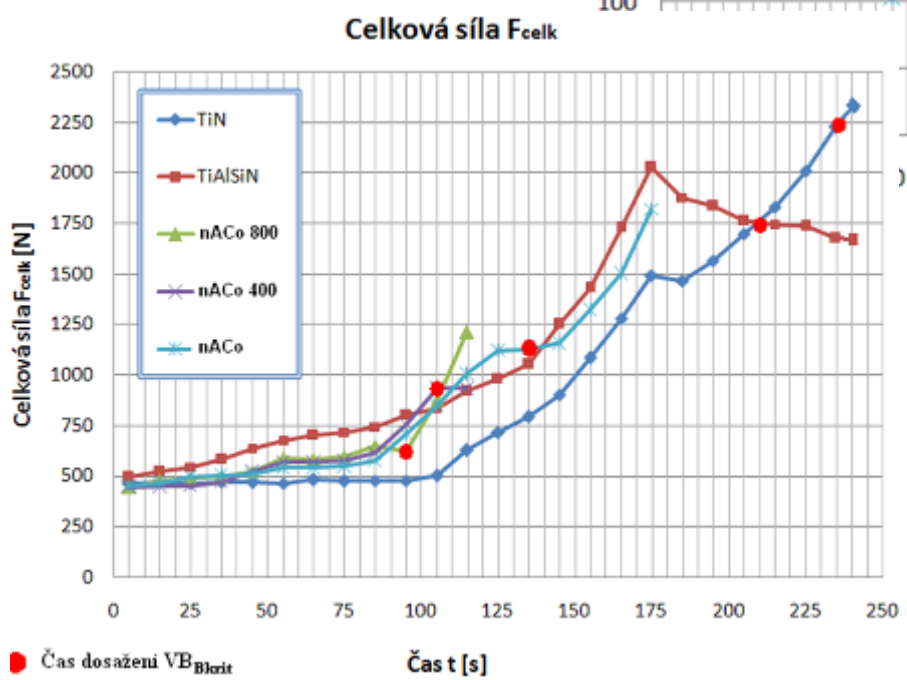


Technologická zkouška řezivosti TON soustružením

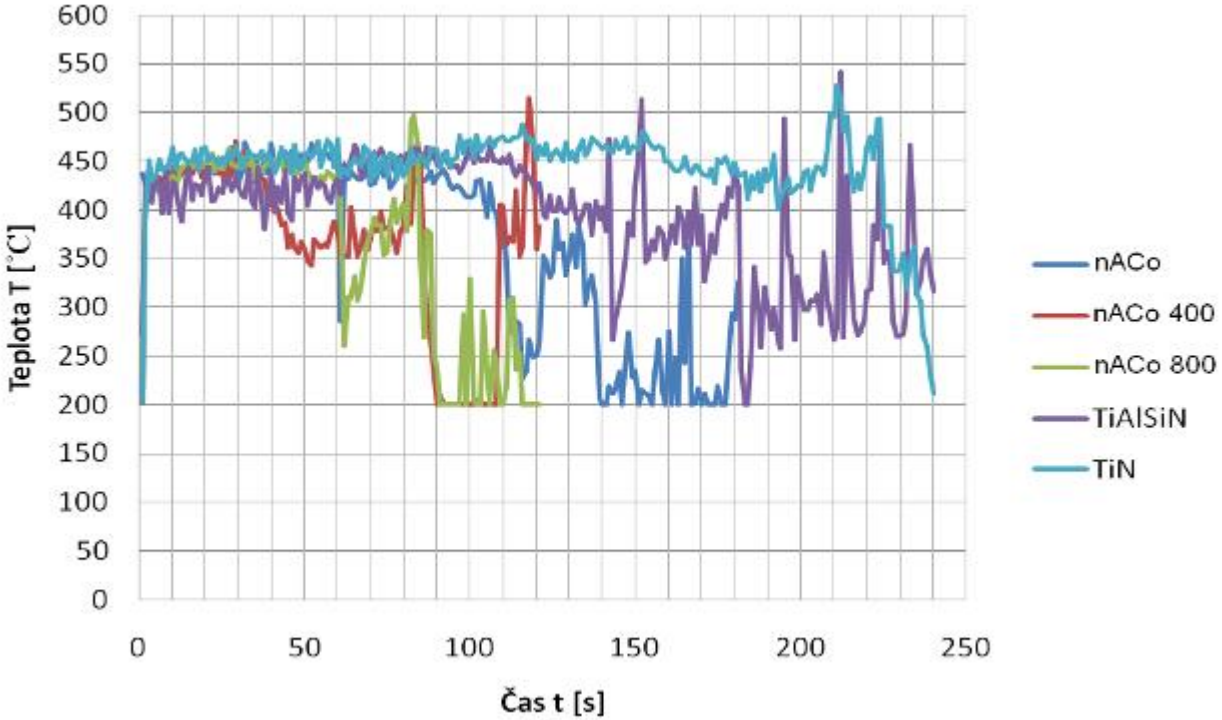
Řezná rychlost (konst.)	$v_c = 89$ m/min
Posuv na otáčku:	$f_{ot.} = 0{,}10$ mm/ot.
Hloubka řezu:	$a_p = 0{,}5$ mm
Průměr obrobku:	d = 78 mm
Řezné prostředí:	ZA SUCHA

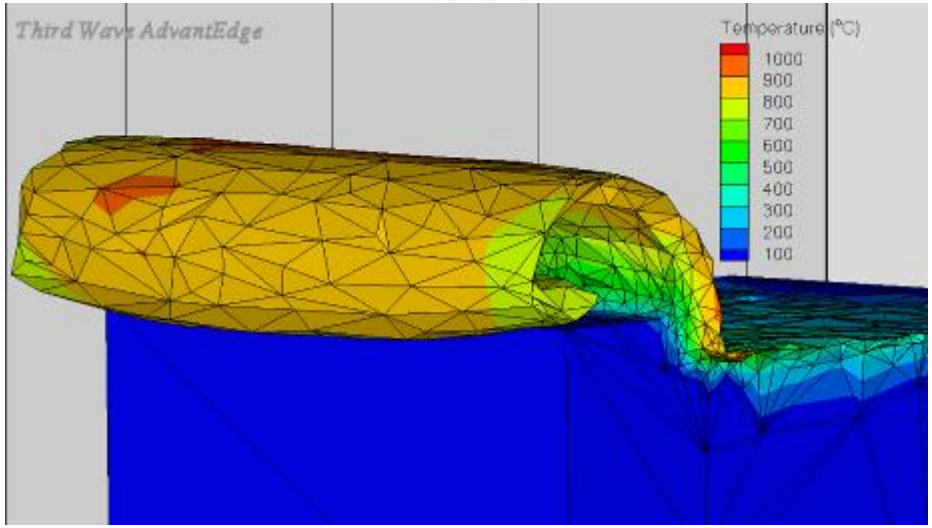
Vliv teploty na vlastnosti tenké vrstvy





Vliv teploty na vlastnosti tenké vrstvy



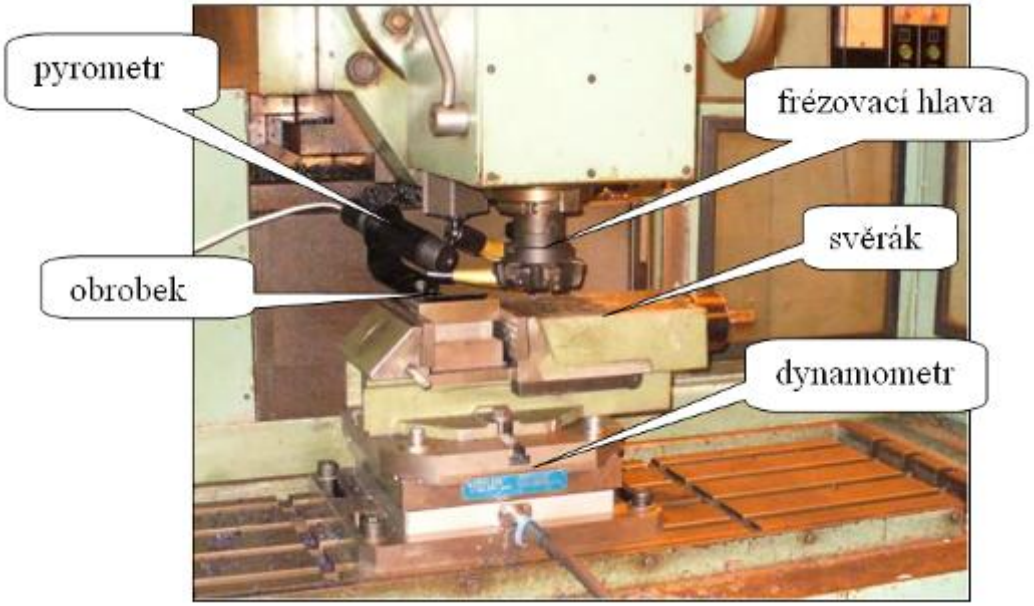


Závěr z technologických zkoušek řezivosti TON soustružením

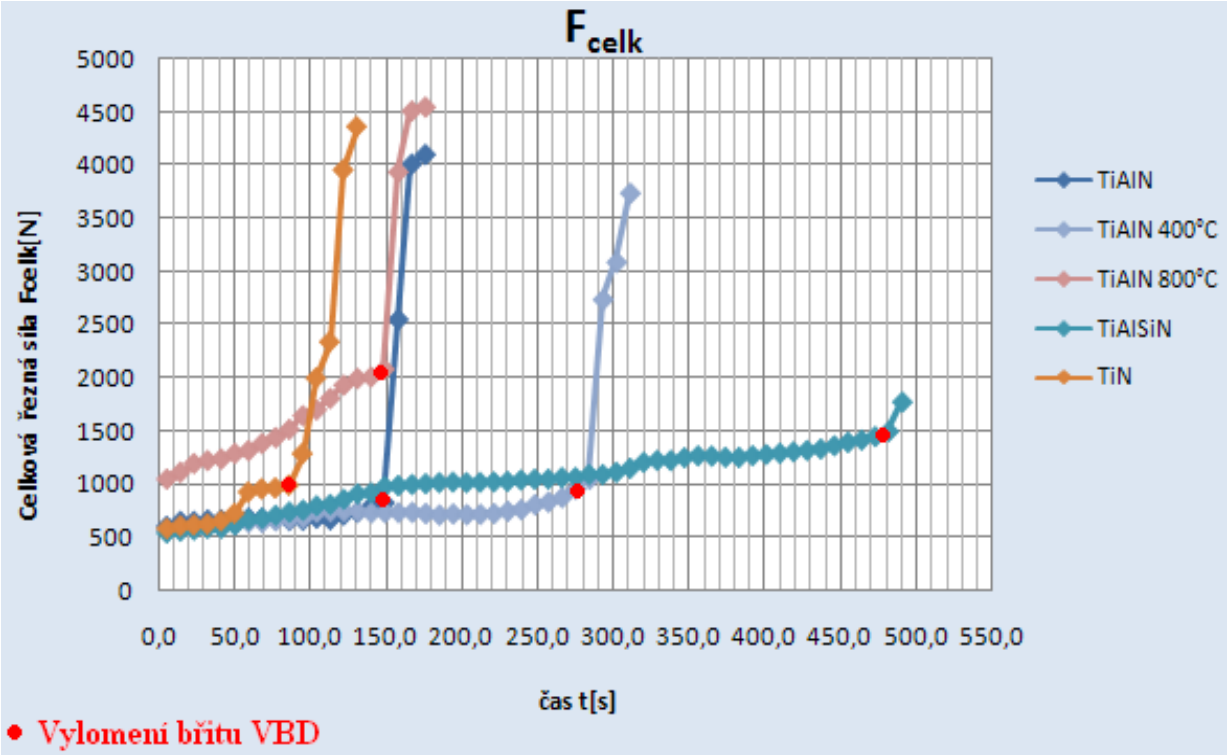
	TiN	TiAlSiN	nACo	nACo400°C	nACo800°C
Mikrotvrdost HIT [GPa]	25,1	34,4	35,3	39,3	35,2
Koeficient tření f	0,69	0,81	0,62	0,58	0,65
Velikost výsledné řezné síly F(75s) [N]	480	740	600	615	630
Trvanlivost T [s]	230	210	140	110	95
Teplota T(25s) [°C]	450	430	420	440	450
	Nejlepší systém ze všech sledovaných				
	Nejlepší systém z TON				

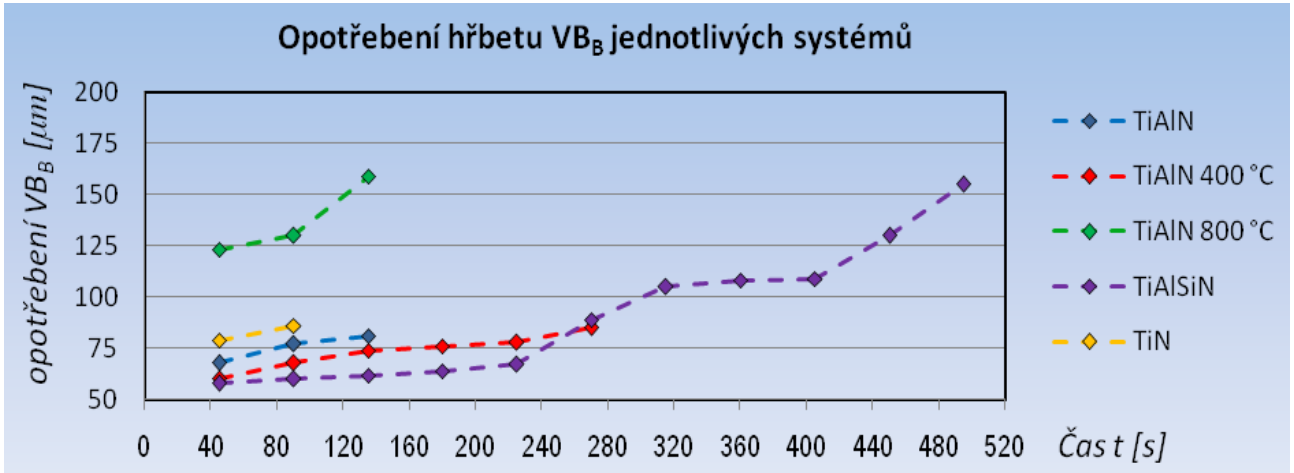
Technologická zkouška řezivosti TON frézováním

Řezná rychlost (konst.)	$v_c = 89$ m/min
Posuv na otáčku:	$f_{ot} = 0{,}10$ mm/ot.
Hloubka řezu:	$a_p = 0{,}5$ mm
Šířka řezu:	$a_e = 30$ mm
Velikost obrobku:	60x30x40 mm (dxšxv)
Řezné prostředí:	ZASUCHA

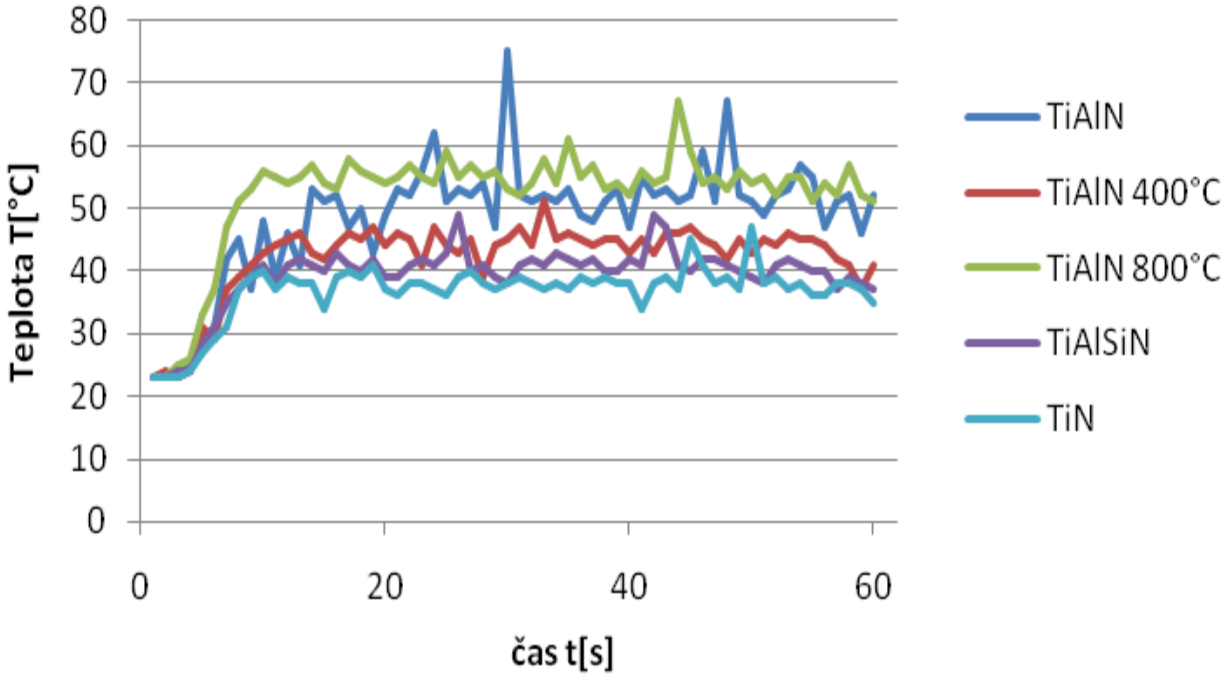


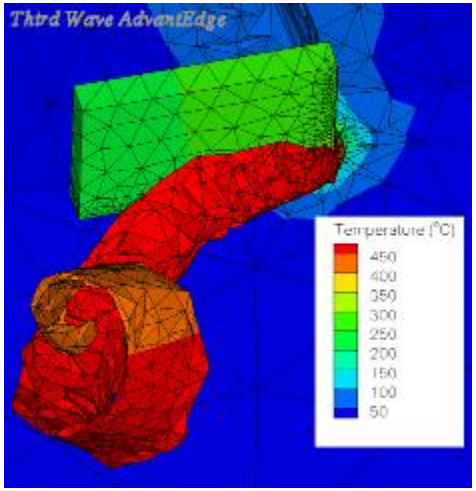
Vliv teploty na vlastnosti tenké vrstvy

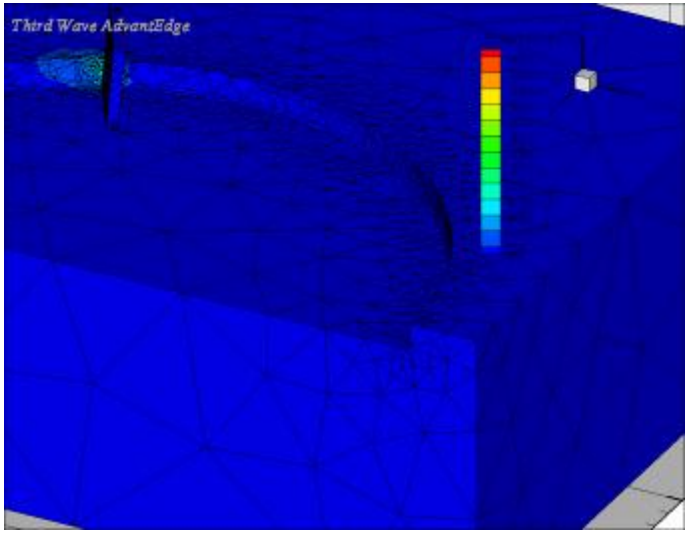




Vliv teploty na vlastnosti tenké vrstvy



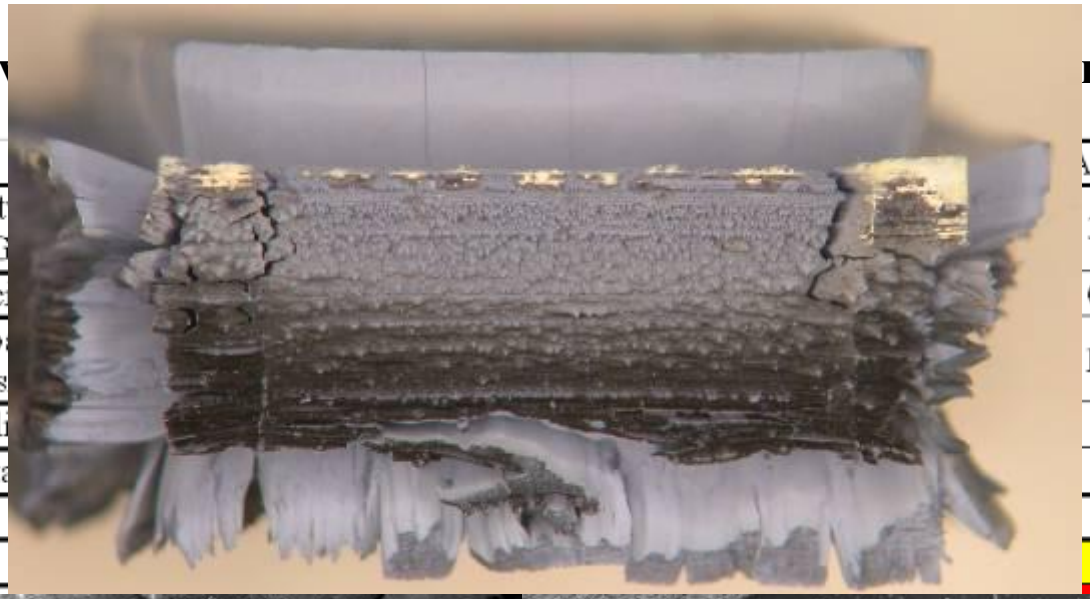


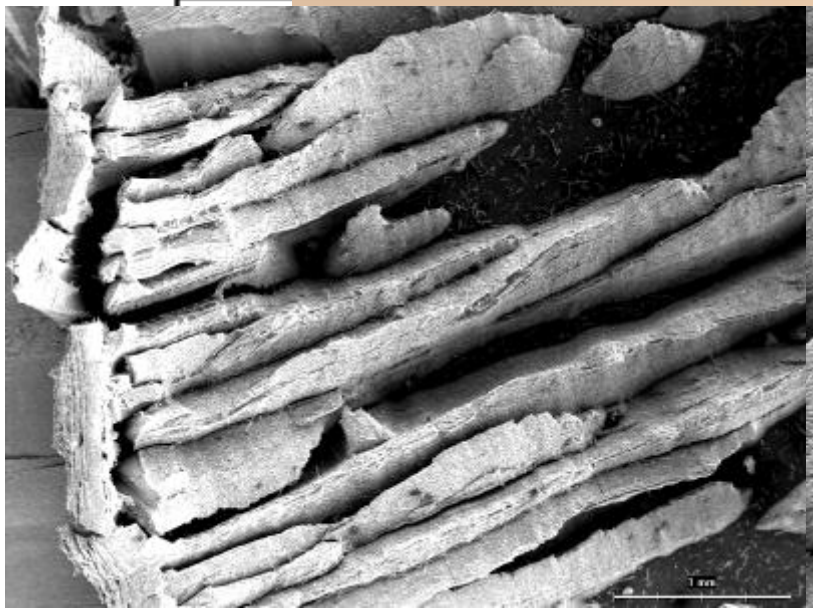


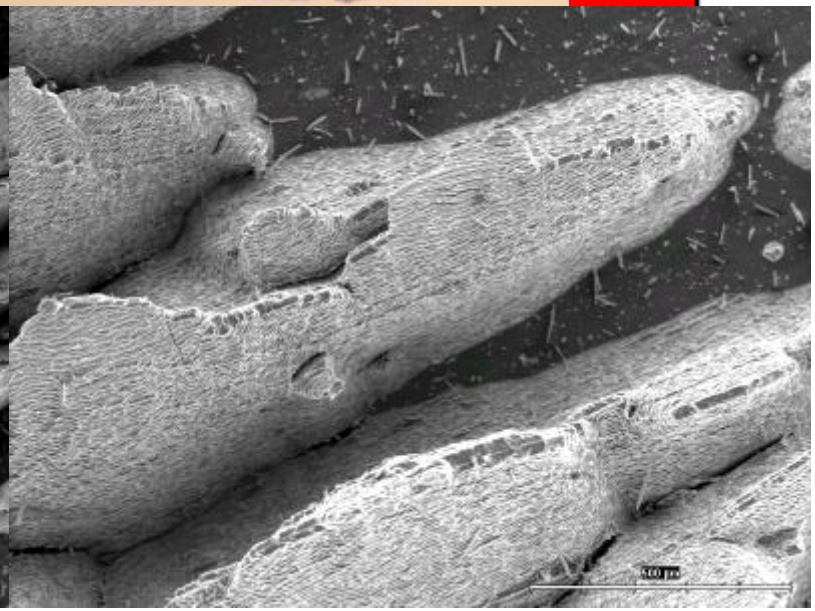
Vliv teploty na vlastnosti tenké vrstvy

Záv … **ním**

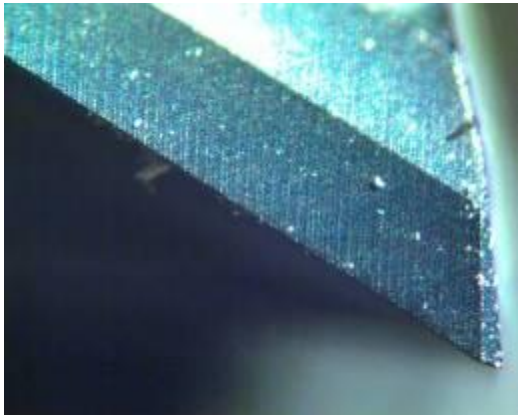
	ACo800
Mikrot HIT [G	35,2
Koefic	0,65
Veliko řezné s	1350
Trvanli	120
Teplota	55

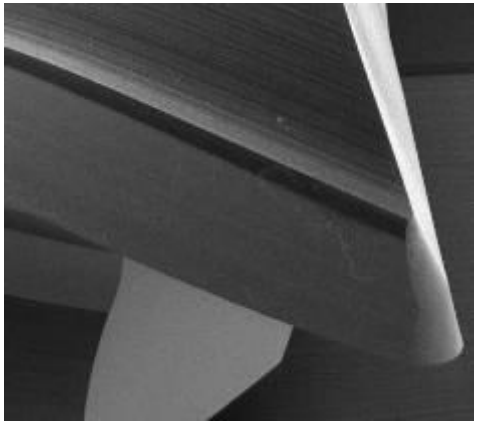


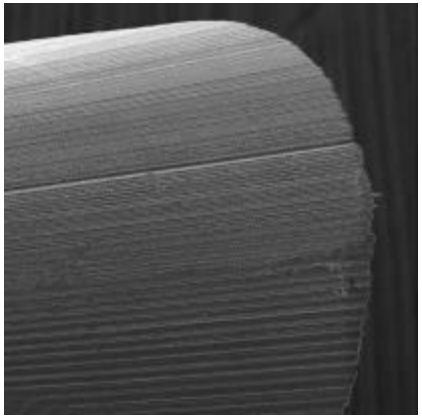


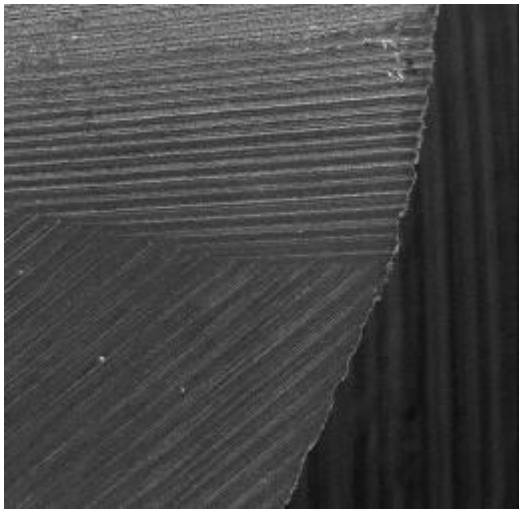


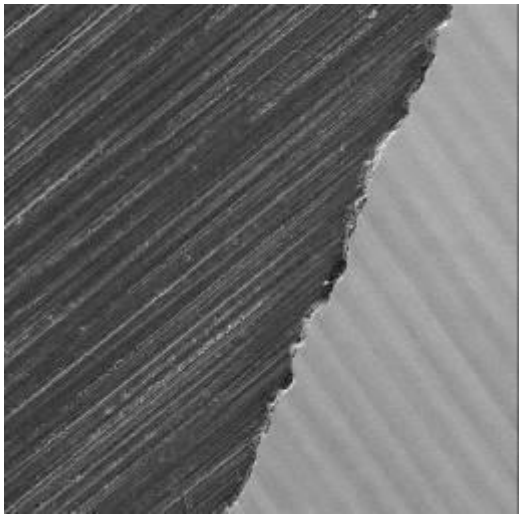
Mikrogeometrie nástroje



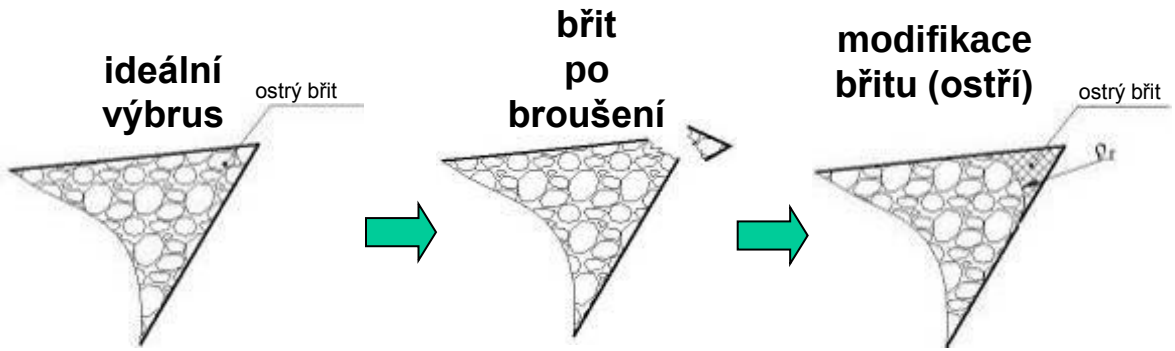


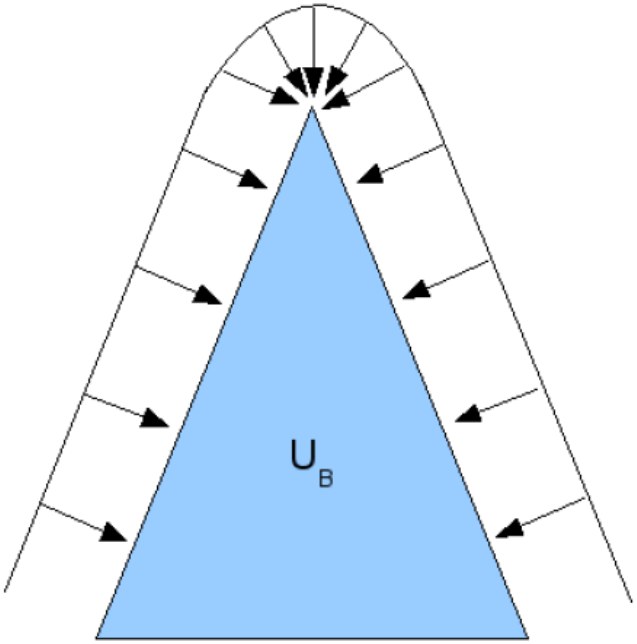


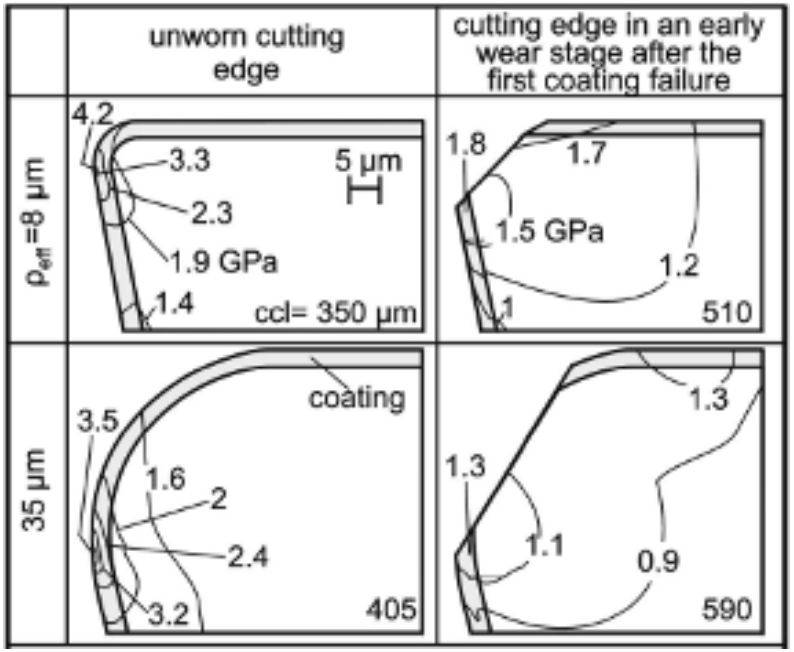




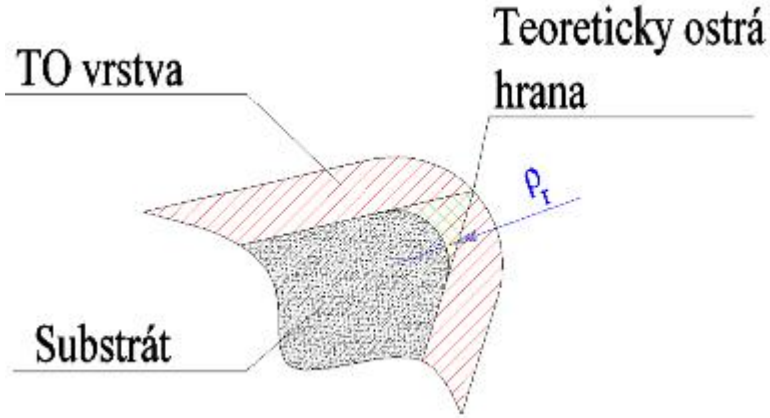
Kvalita břitu nástroje - mikrogeometrie břitu

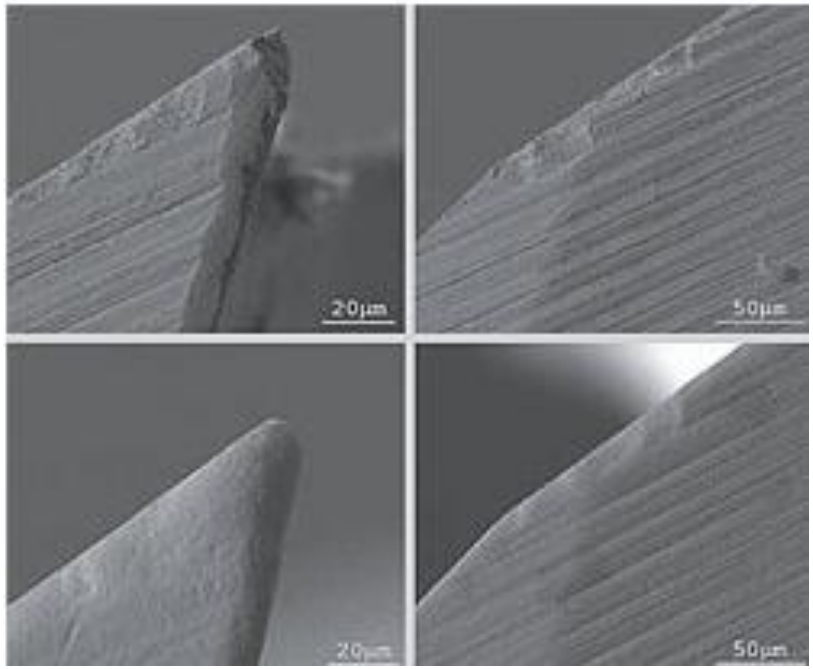


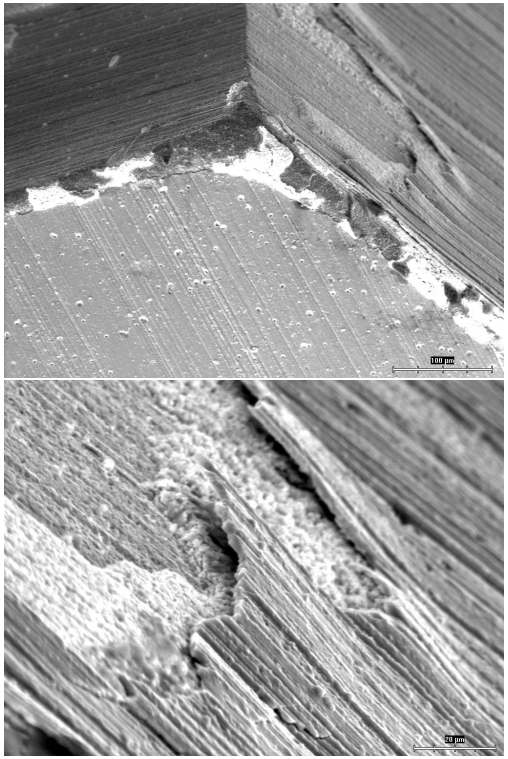




Kvalita břitu nástroje - mikrogeometrie břitu

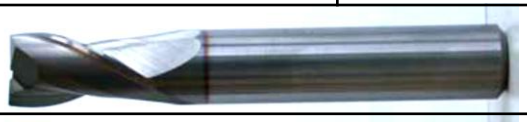




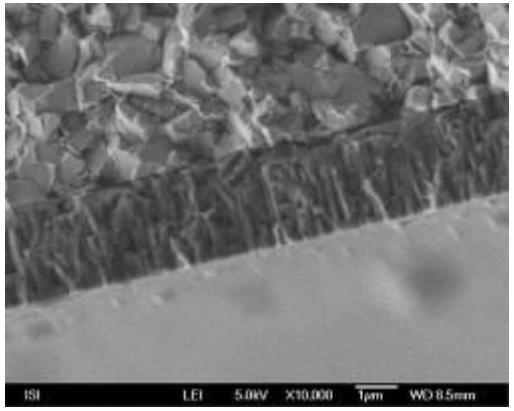


Volba řezných podmínek

Průměr frézy	10 mm
Počet břitů	2
Řezný materiál frézy	TSF 44
Tvrdost řezného materiálu	1760 HV 10
Tenká vrstva	TiAlSiN



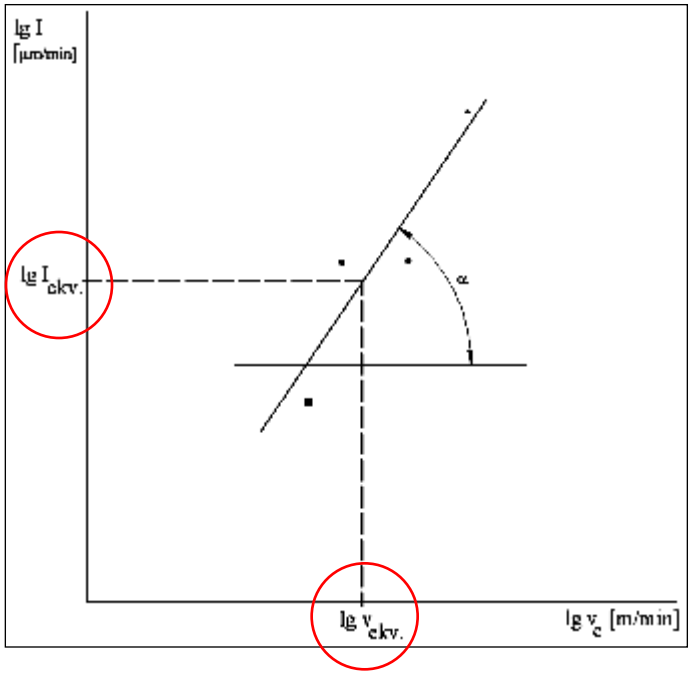
Ocel 19437										
Chemické složení [%]		C	Cr	Mn	Ni	P	S	Si	V	W
	min	1,8	11	0,20	-	-	-	0,20	0,15	0,6
	max	2,05	12,5	0,45	0,5	0,03	0,035	0,45	0,30	1



Metoda A. S. Kondratova

TEST				
posuv f [mm/ot.]	šířka řezu a_e [mm]	hloubka řezu a_p [mm]	Optimální řezná rychlost pro T = 15 min: v_{15} = 137 m/min	
0,06	0,2	3		
		Přírůstek času řezání ΔT [min]	Přírůstek opotřebení ΔVB_B [µm]	Intenzita opotřebení I [µm/min]
řezná rychlost v_{c1} [m/min]	87	4,23	7	1,65
v_{c2} [m/min]	100	3,66	15	4,09
v_{c3} [m/min]	125	6,32	31	4,9
v_{c4} [m/min]	150	6,2	35	5,6

$$I = \frac{\Delta VB}{\Delta T} \qquad I_{ekv} = \frac{\sum \Delta VB_B}{\sum \Delta T}$$

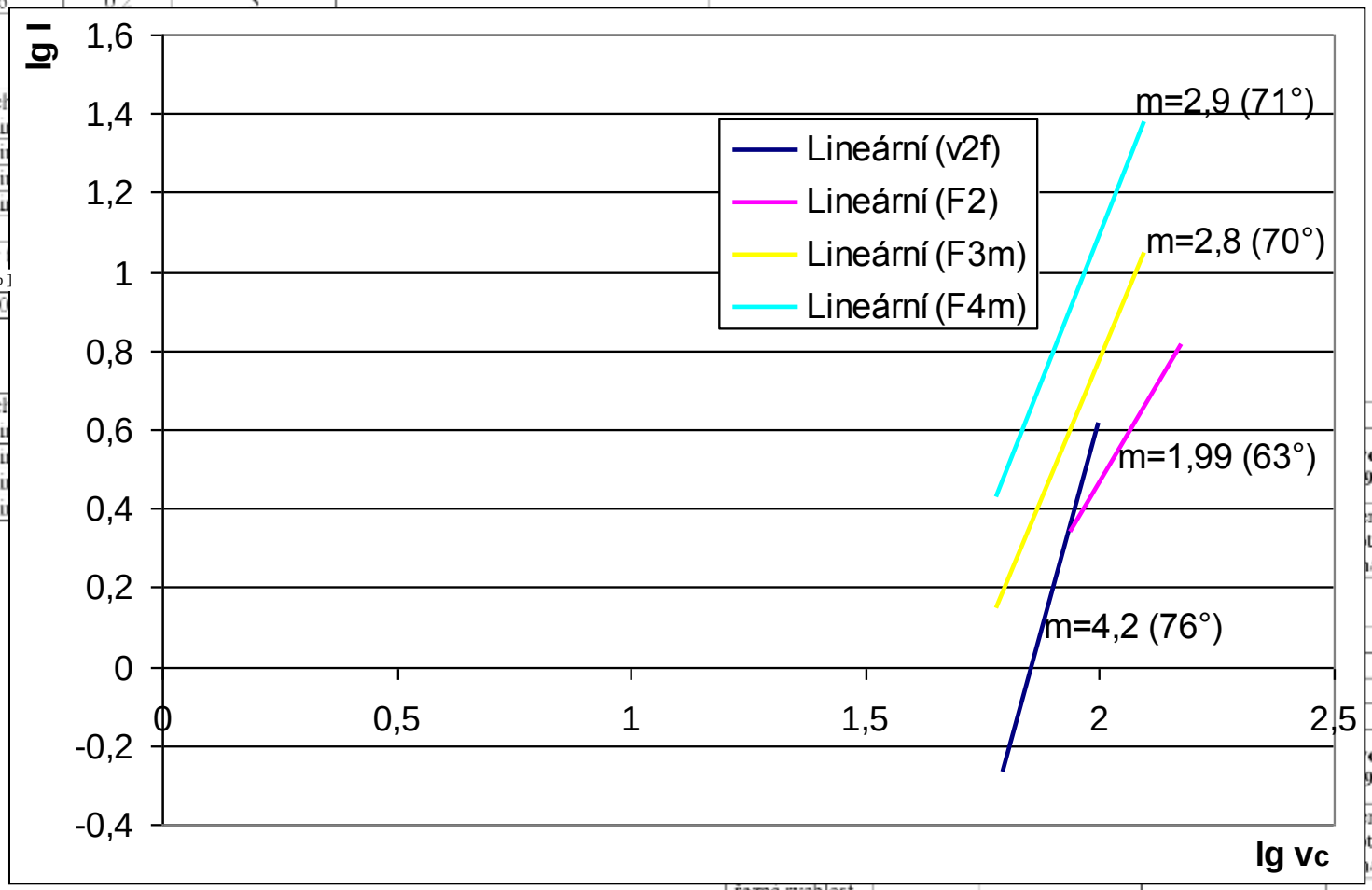


$$v_{ekv} = \frac{c_{vT}}{\sum \Delta T^{\frac{1}{m}}} \Rightarrow c_{vT} = v_{ekv} \cdot \left(\sum \Delta T\right)^{\frac{1}{m}}$$

$$\boxed{v_{15} = \frac{c_{vT}}{T^{\frac{1}{m}}}}$$

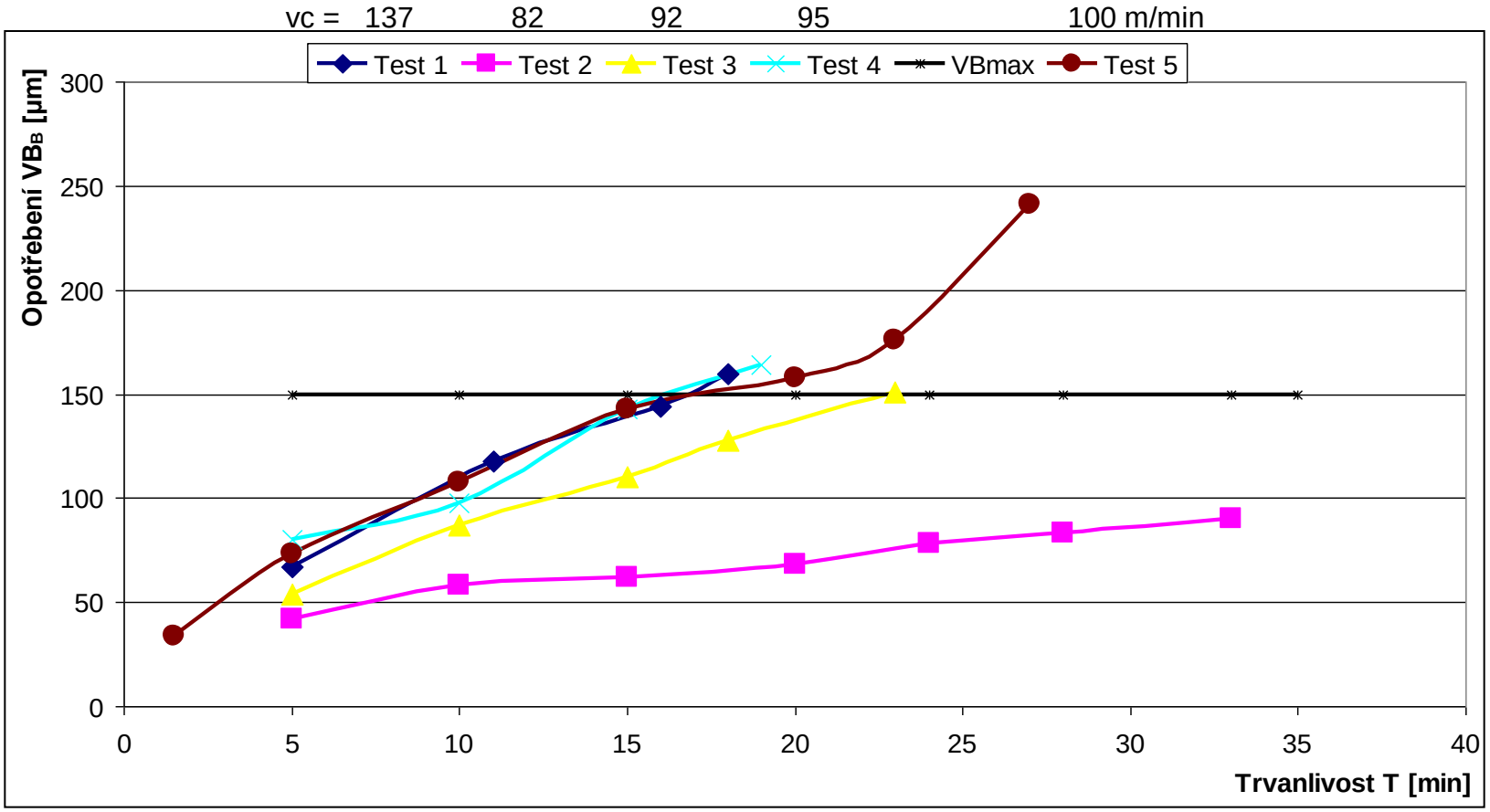
Praktické využití

TEST 1 – nástroj F2			
posuv f [mm/zub]	šířka řezu a_e [mm]	hloubka řezu a_p [mm]	Optimální řezná rychlost pro T = 15 min: v_{15} = 137 m/min
0,06	0,2	3	



řezná rychlost v_{c1} [m/min]	60	3	8	2,66
v_{c2} [m/min]	83	3,66	28	7,65
v_{c3} [m/min]	100	3,66	52	14,2
v_{c4} [m/min]	123	2,8	63	22,5

Praktické využití – dlouhodobá zkouška trvanlivosti



Řezné podmínky testu 5: v_c = 100 m/min

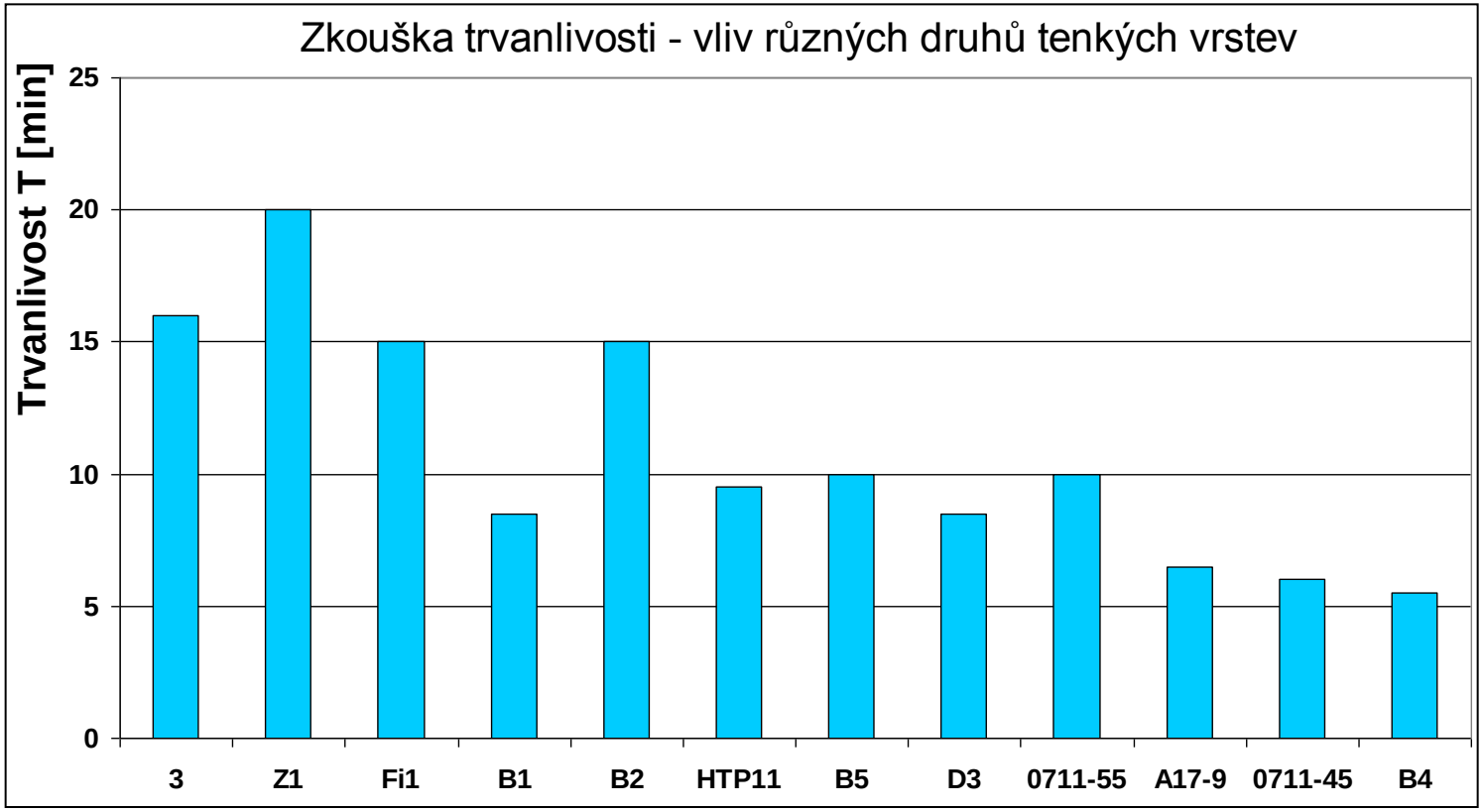
f_{ot} = 0,16 mm/ot.

a_p = 3 mm

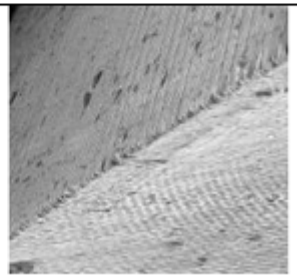
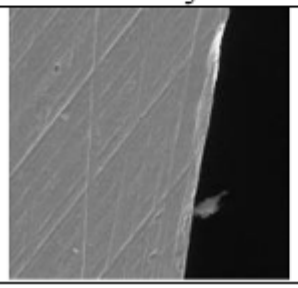
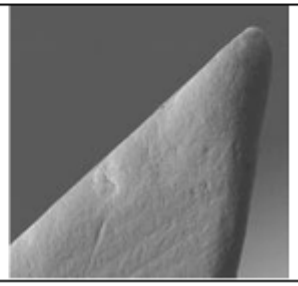
a_e = 0,5 mm

Praktické využití – ověření řezných podmínek

Řezná rychlost	v_c = 100 m/min
Posuv na otáčku	f_{ot} = 0,16 mm/ot.
Hloubka řezu:	a_p = 3 mm
Šířka řezu:	a_e = 0,5 mm
Řezné prostředí:	ZA SUCHA

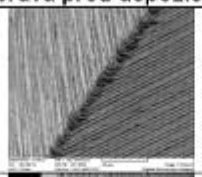
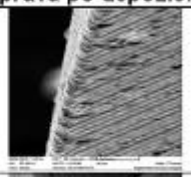
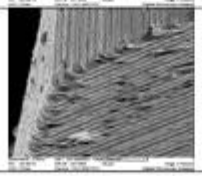
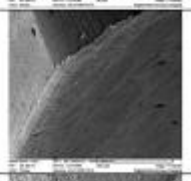
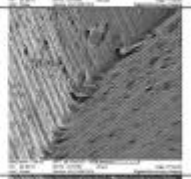
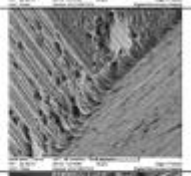
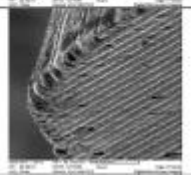
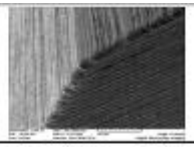
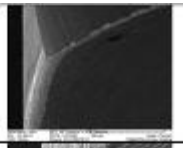
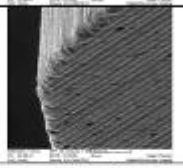
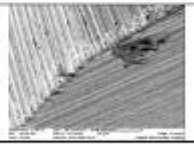
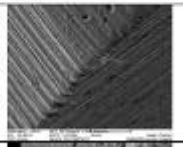
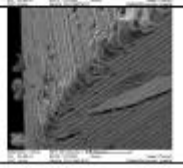


Kvalita břitu nástroje - mikrogeometrie břitu

	Ruční leštění	**Kartáčování**	**Omílání v granulátech**
Kvalita	Nejlepší	Střední	Dobrá
Reprodukovatelnost	Závisí na pracovníkovi	Dobrá	Dobrá
Flexibilita	Vysoká	Střední	Dobrá
Produktivita	Nízká	Střední	Střední
Cena	Plat pracovníka	Střední	Střední
Jiné	Pouze pro malé firmy	Nepoužitelné pro závitníky	Univerzální použití
Povrchu po úpravě	Odstranění hrubých nerovností	Povrch upravený, vznik rýh	Téměř bez nových defektů
Foto povrchu			

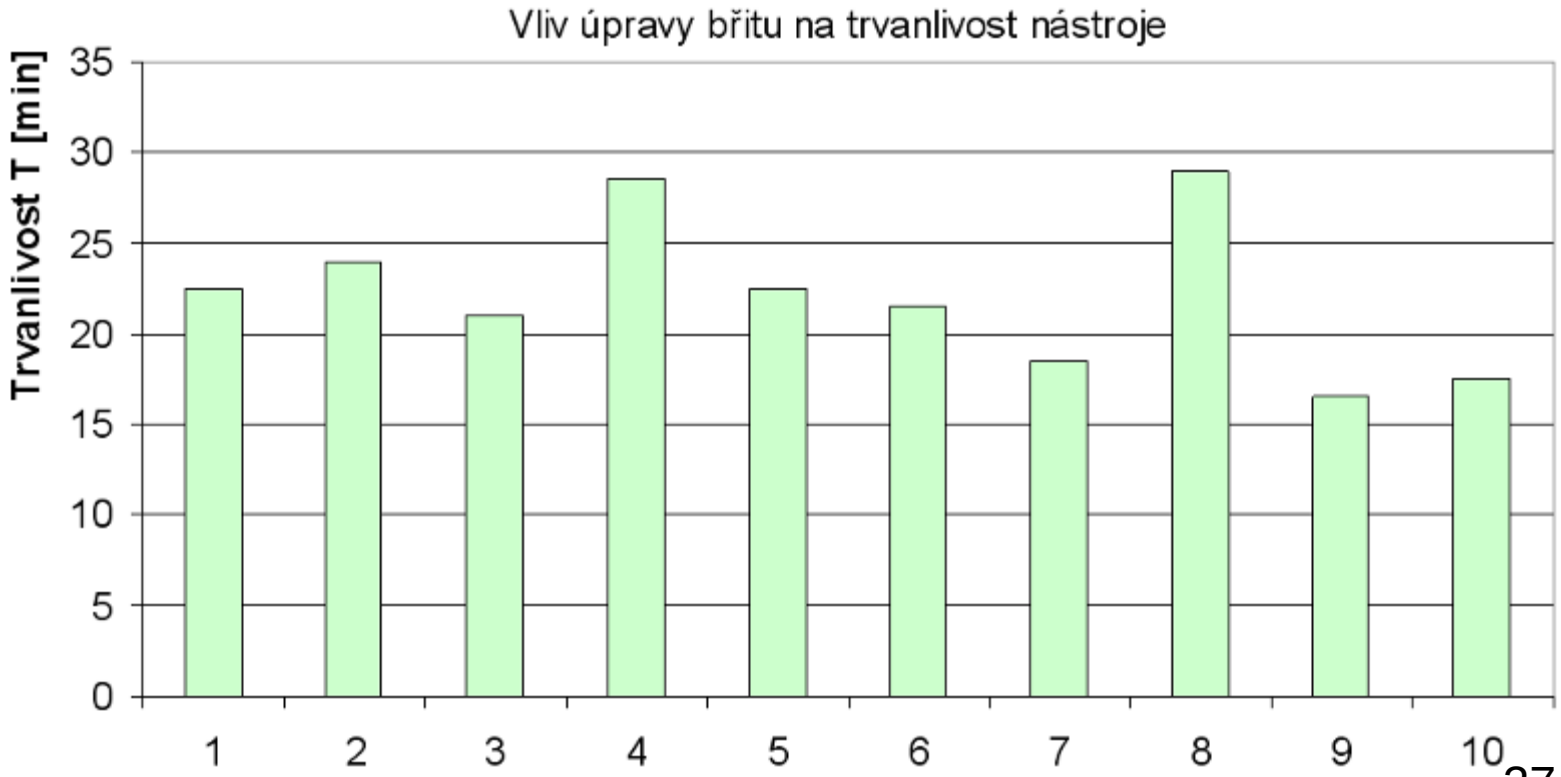
Kvalita břitu nástroje - mikrogeometrie břitu

Varianta	úprava před depozicí	úprava po depozici
1	žádná	žádná
2	žádná	kartáč15"
3	žádná	OTEC 2'
4	žádná	OTEC 1'
5	žádná	OTEC 2' hrubý
6	OTEC 2'	kartáč 15"
7	OTEC 2'	OTEC 1' hrubý
8	OTEC 2'	žádná
9	OTEC 30"	OTEC 2'
10	OTEC 30"	OTEC 1' hrubý

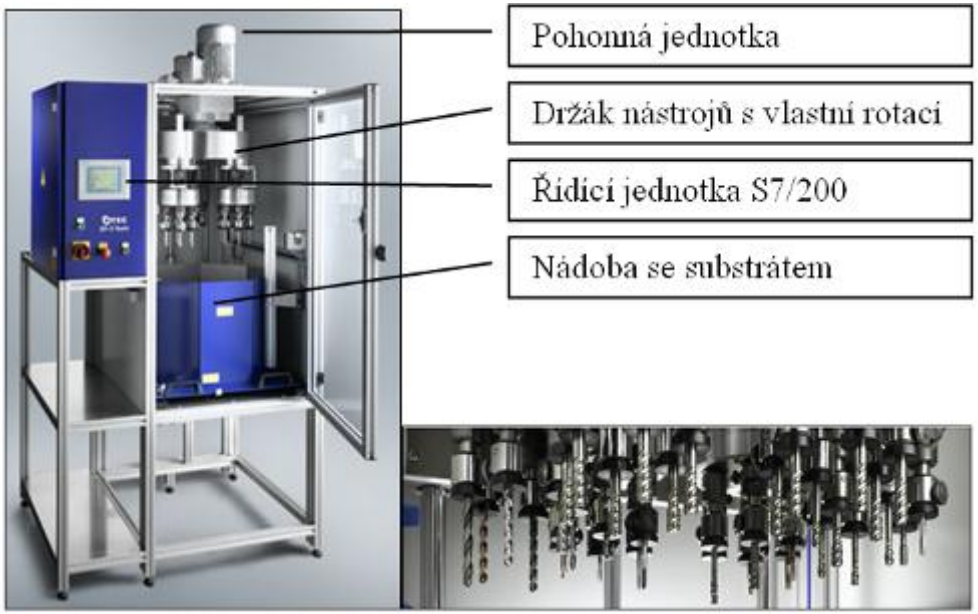
Varianta	úprava před depozicí	úprava po depozici
1		
2		
3	žádná	
4	žádná	
5	žádná	
6		
7	OTEC 2'	
8	OTEC 2'	žádná
9		
10	OTEC30"	

Kvalita břitu nástroje - mikrogeometrie břitu

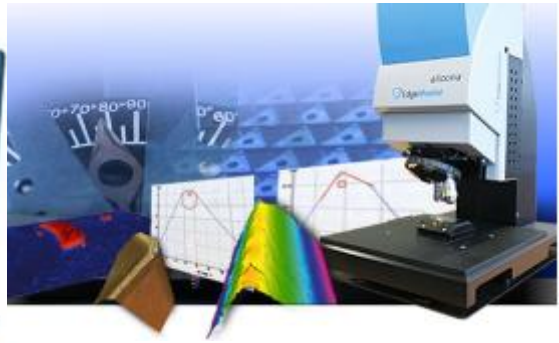
Varianta	úprava před depozicí	úprava po depozici
1	žádná	žádná
2	žádná	kartáč15"
3	žádná	OTEC 2'
4	žádná	OTEC 1'
5	žádná	OTEC 2' hrubý
6	OTEC 2'	kartáč 15"
7	OTEC 2'	OTEC 1' hrubý
8	OTEC 2'	žádná
9	OTEC 30"	OTEC 2'
10	OTEC 30"	OTEC 1' hrubý

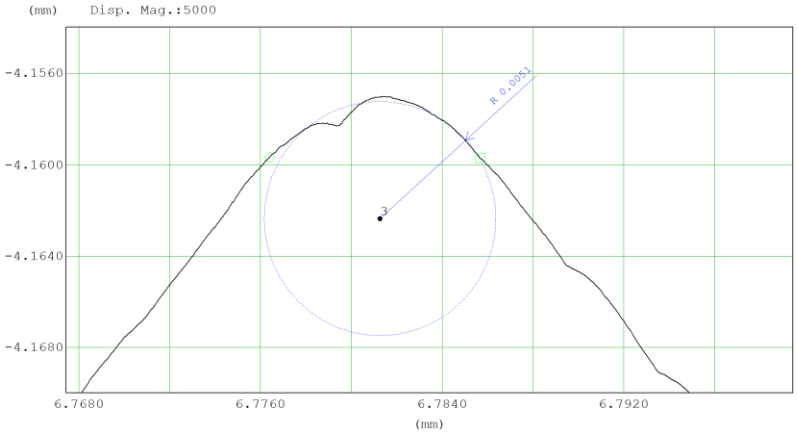


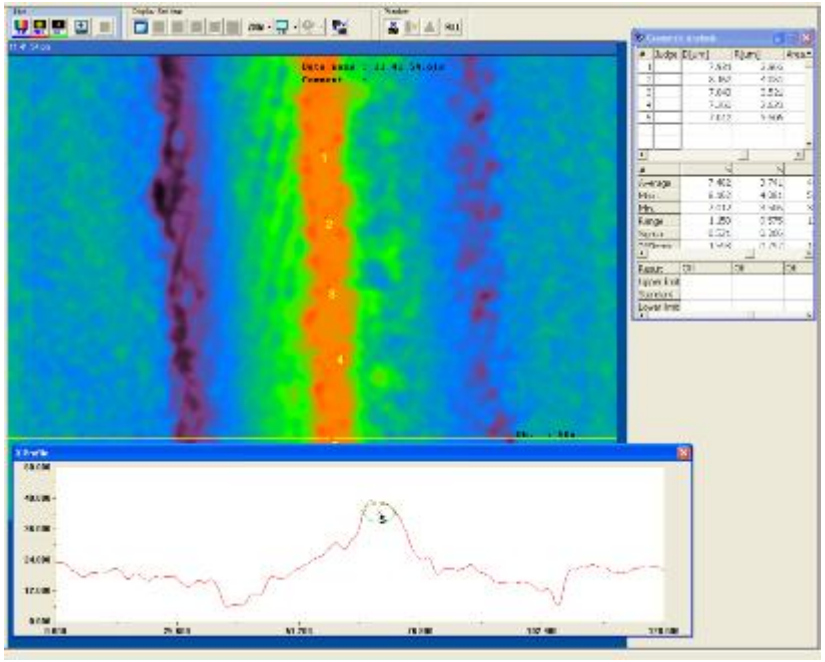
Kvalita břitu nástroje - mikrogeometrie břitu



Možnosti monitoringu mikrogeometrie břitu nástroje

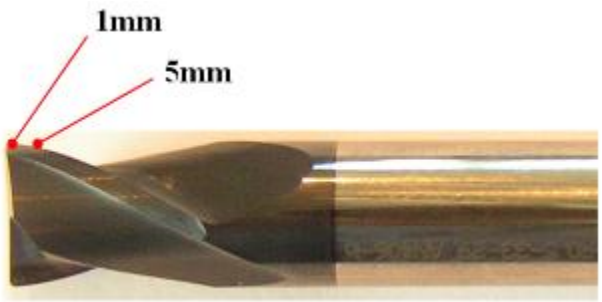


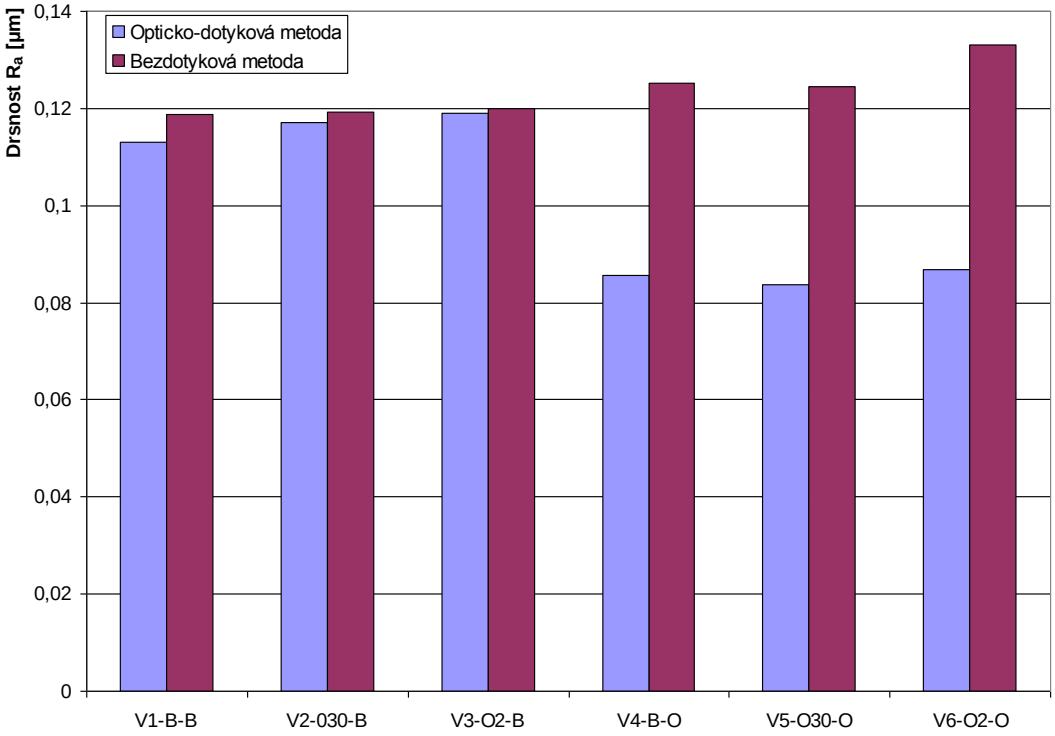


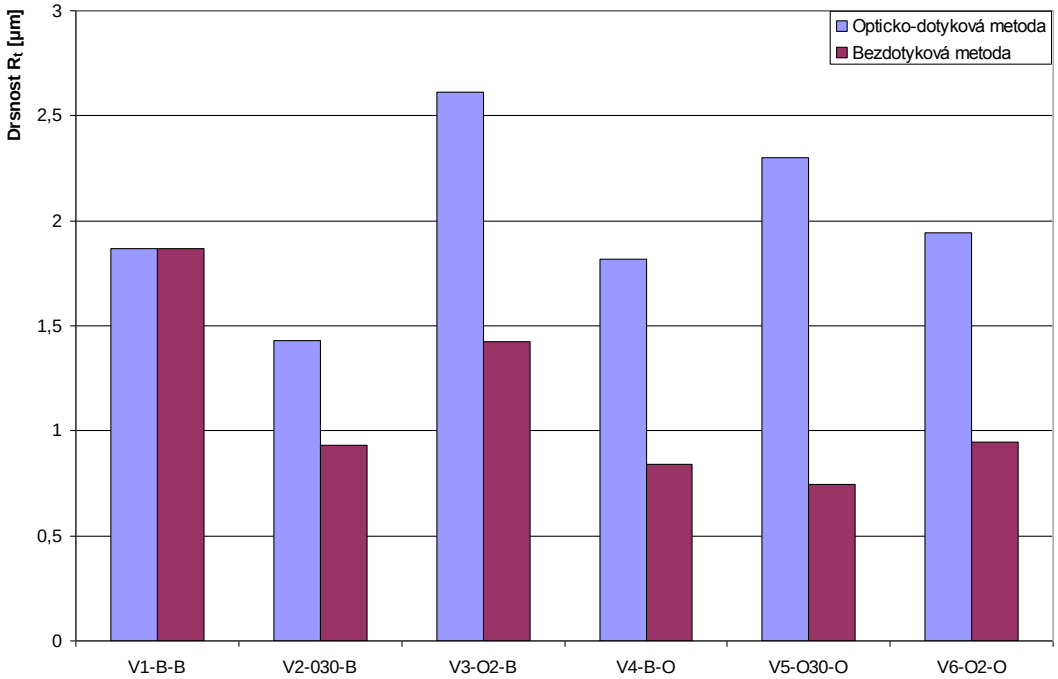


Možnosti monitoringu mikrogeometrie břitu nástroje

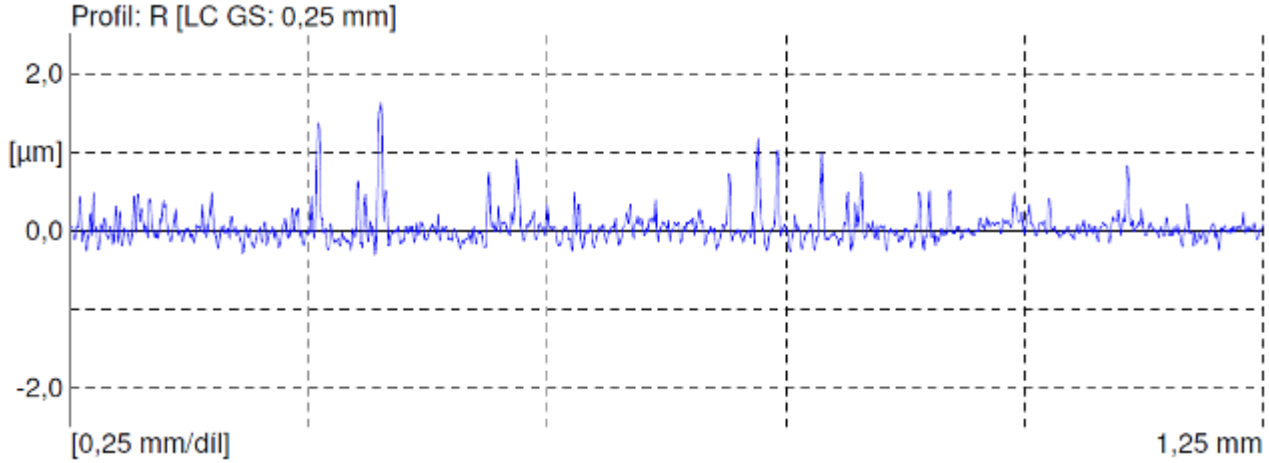
Varianta	Označení	Úprava před depozicí	Úprava po depozici
1	V1-B-B	bez úpravy	bez úpravy
2	V2-O30-B	OTEC 30 s	bez úpravy
3	V3-O2-B	OTEC 2 min	bez úpravy
4	V4-B-O	bez úpravy	OTEC
5	V5-O30-O	OTEC 30s	OTEC
6	V6-O2-O	OTEC 2min	OTEC

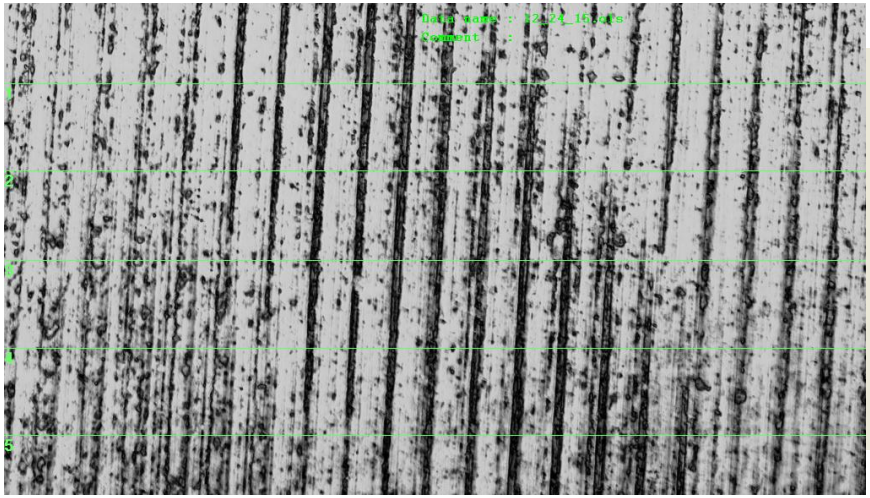


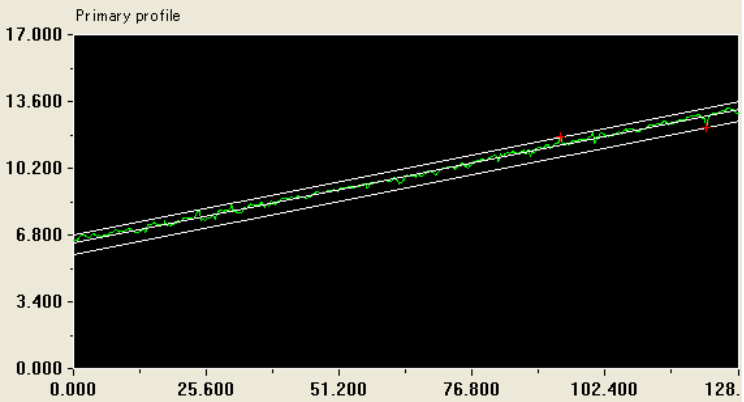

Drsnost Ra [µm]
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
Opticko-dotyková metoda
Bezdotyková metoda
V1-B-B
V2-030-B
V3-O2-B
V4-B-O
V5-O30-O
V6-O2-O


Drsnost Rt [µm]
3
2,5
2
1,5
1
0,5
0
Opticko-dotyková metoda
Bezdotyková metoda
V1-B-B
V2-030-B
V3-O2-B
V4-B-O
V5-O30-O
V6-O2-O

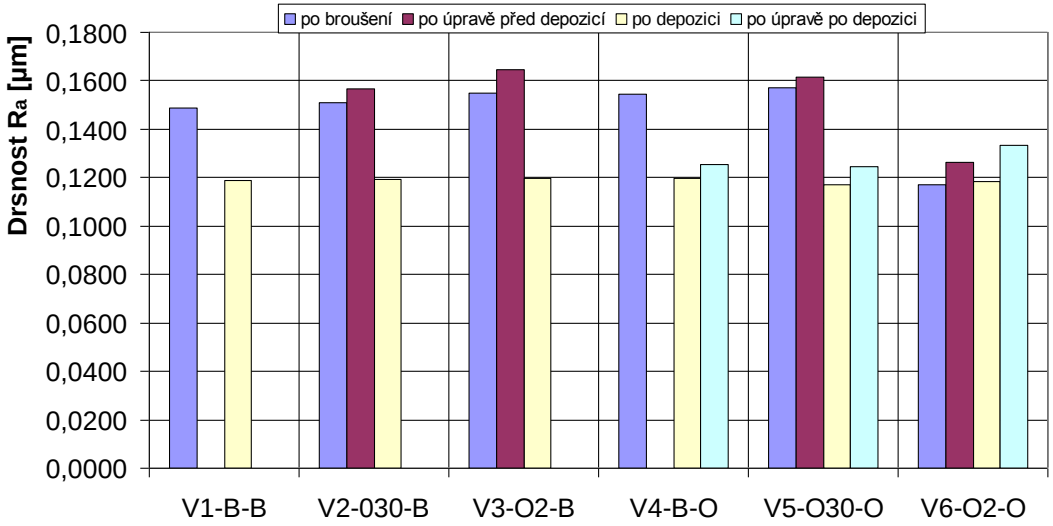
Možnosti monitoringu mikrogeometrie břitu nástroje

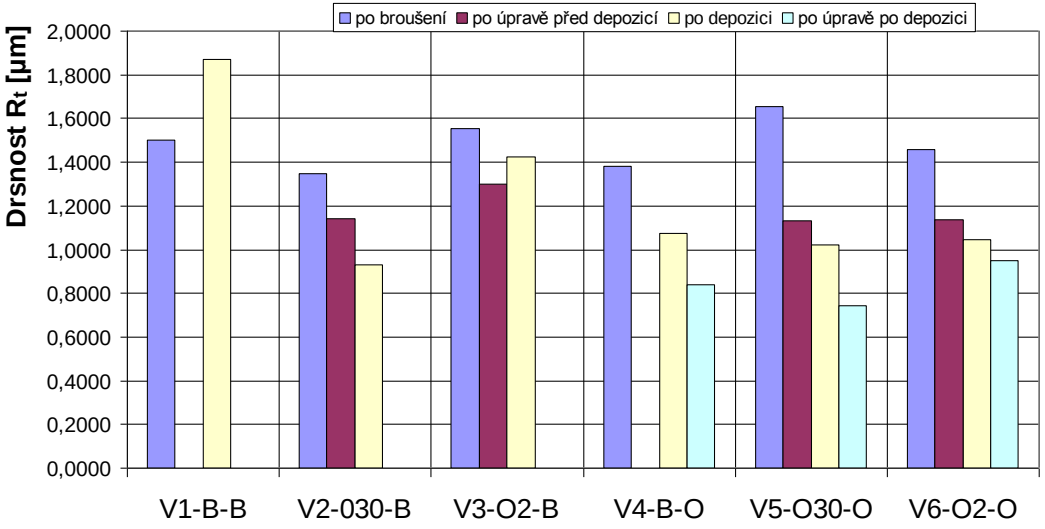




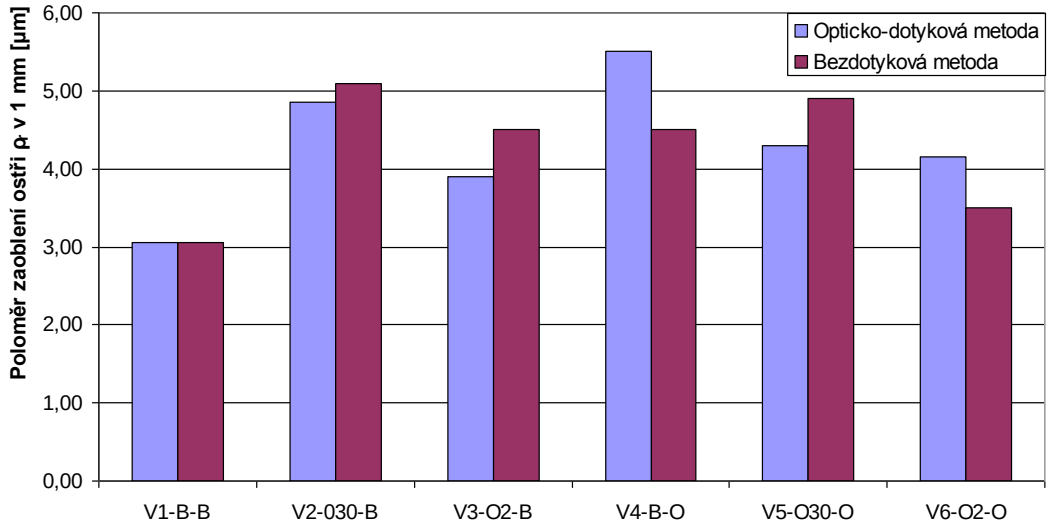


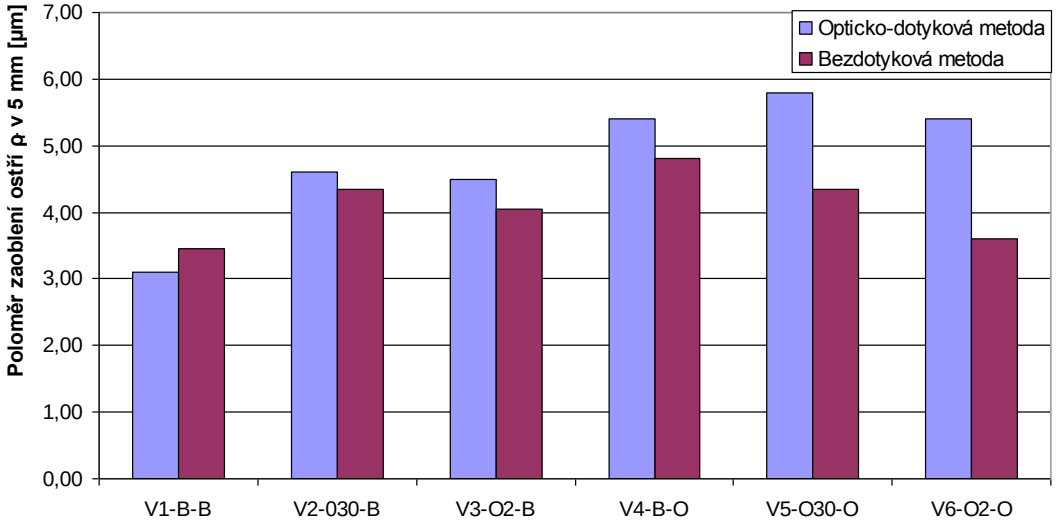
Vývoj drsnosti v závislosti na úpravě





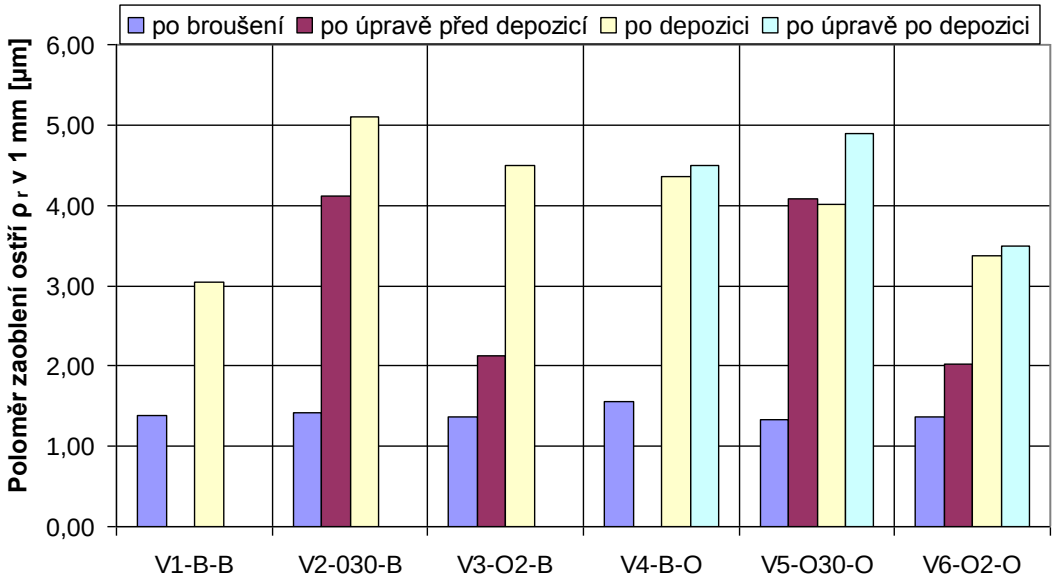
Možnosti monitoringu mikrogeometrie břitu nástroje

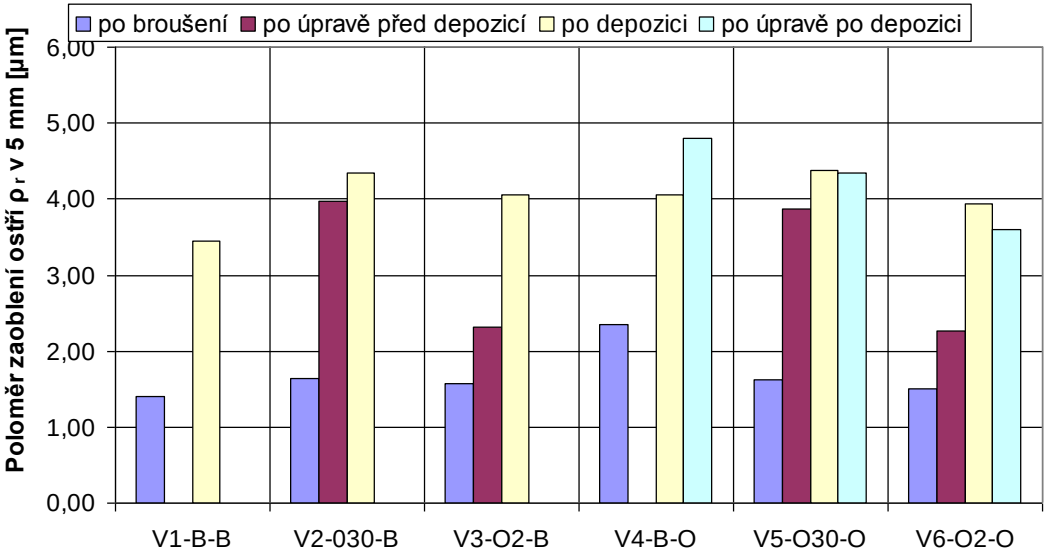




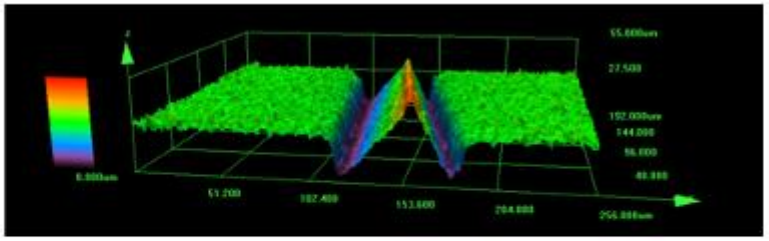
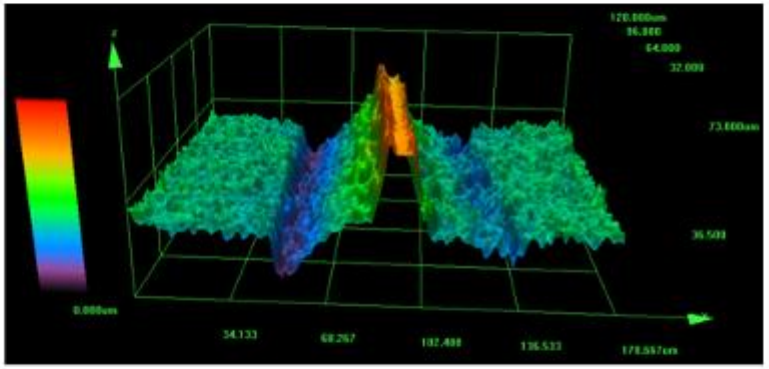
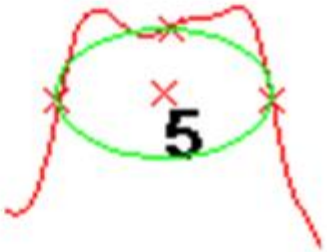
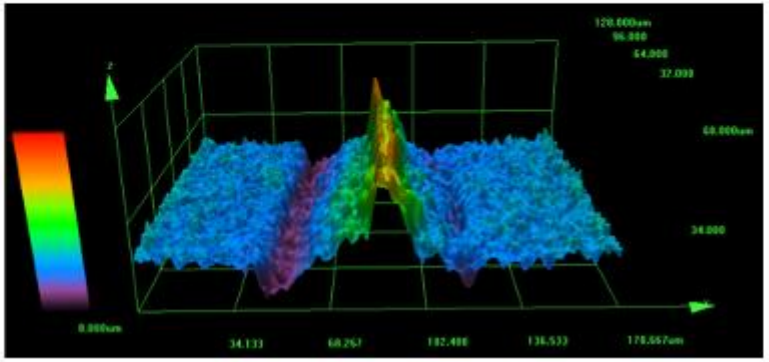
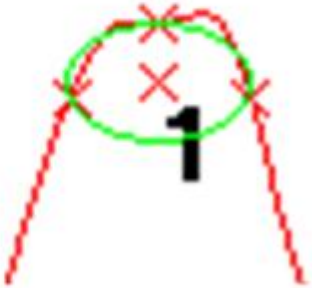
Možnosti monitoringu mikrogeometrie břitu nástroje

Vývoj poloměru zaoblení břitu v závislosti na úpravě

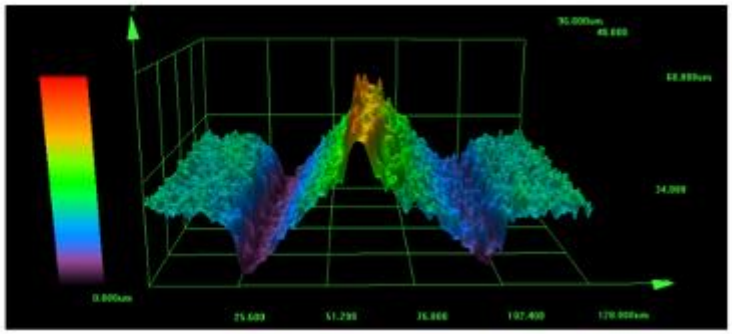
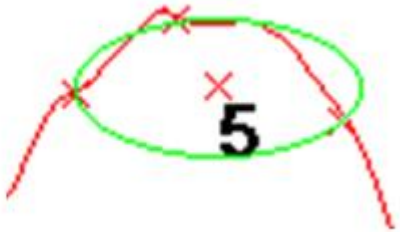
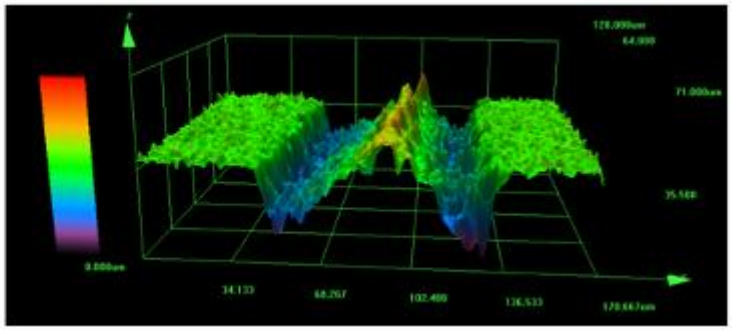
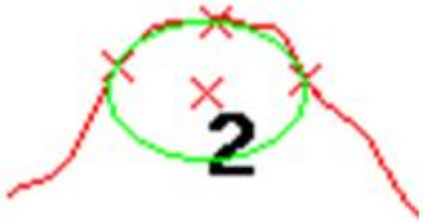




Možnosti monitoringu mikrogeometrie břitu nástroje

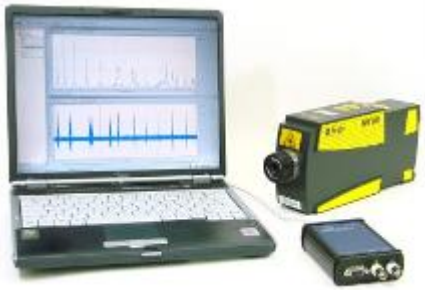
	3D obraz břitu	Křivka profilu břitu
Po broušení- **Obr. 1**		
Úprava 30 s – **Obr. 2**		
Úprava 2 min – **Obr. 3**		

Možnosti monitoringu mikrogeometrie břitu nástroje

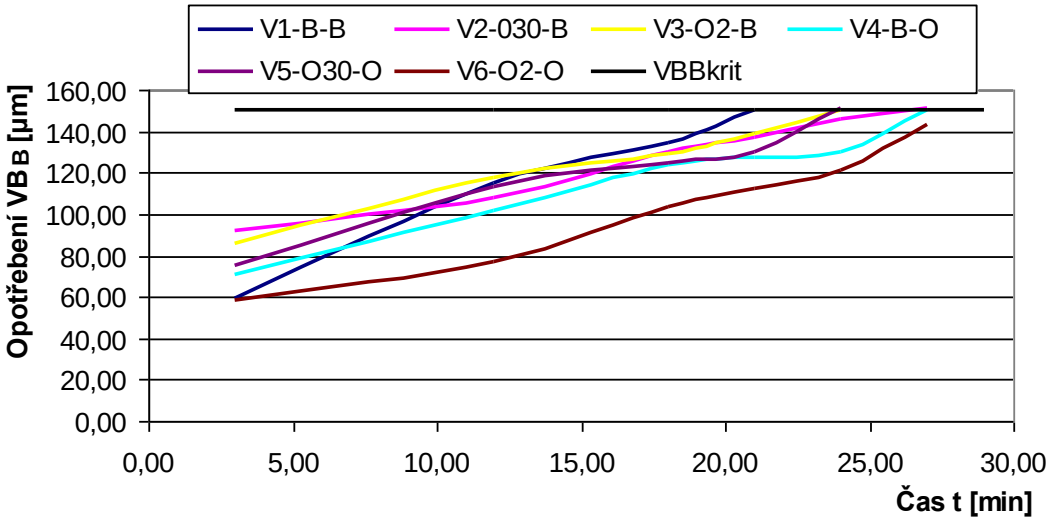
Po depozici vrstvou – **Obr. 4**		
Úprava po depozici – **Obr. 5**		

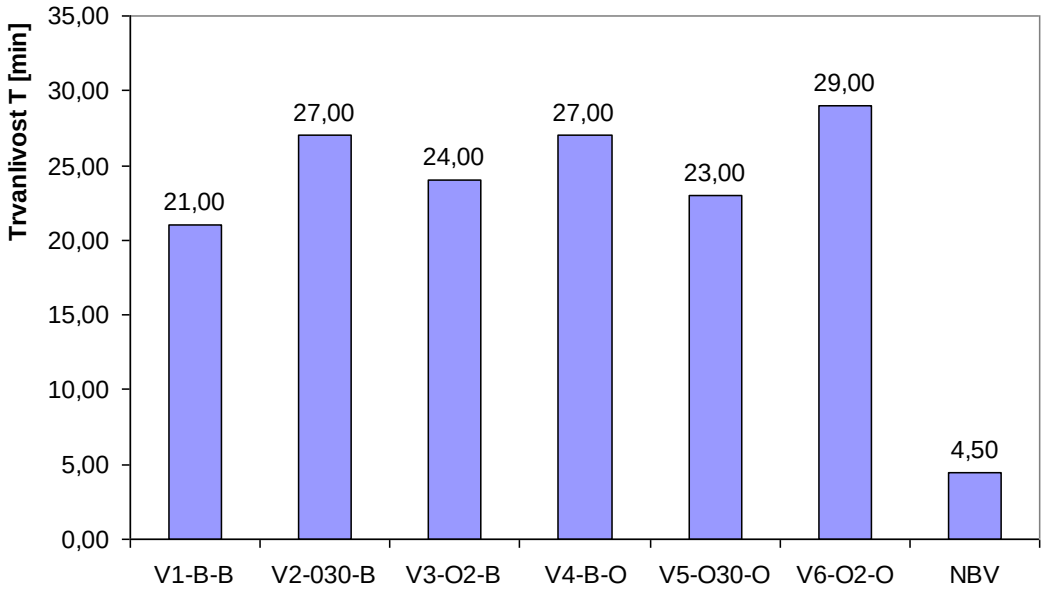
Vliv mikrogeometrie na řezný proces

Použité vybavení

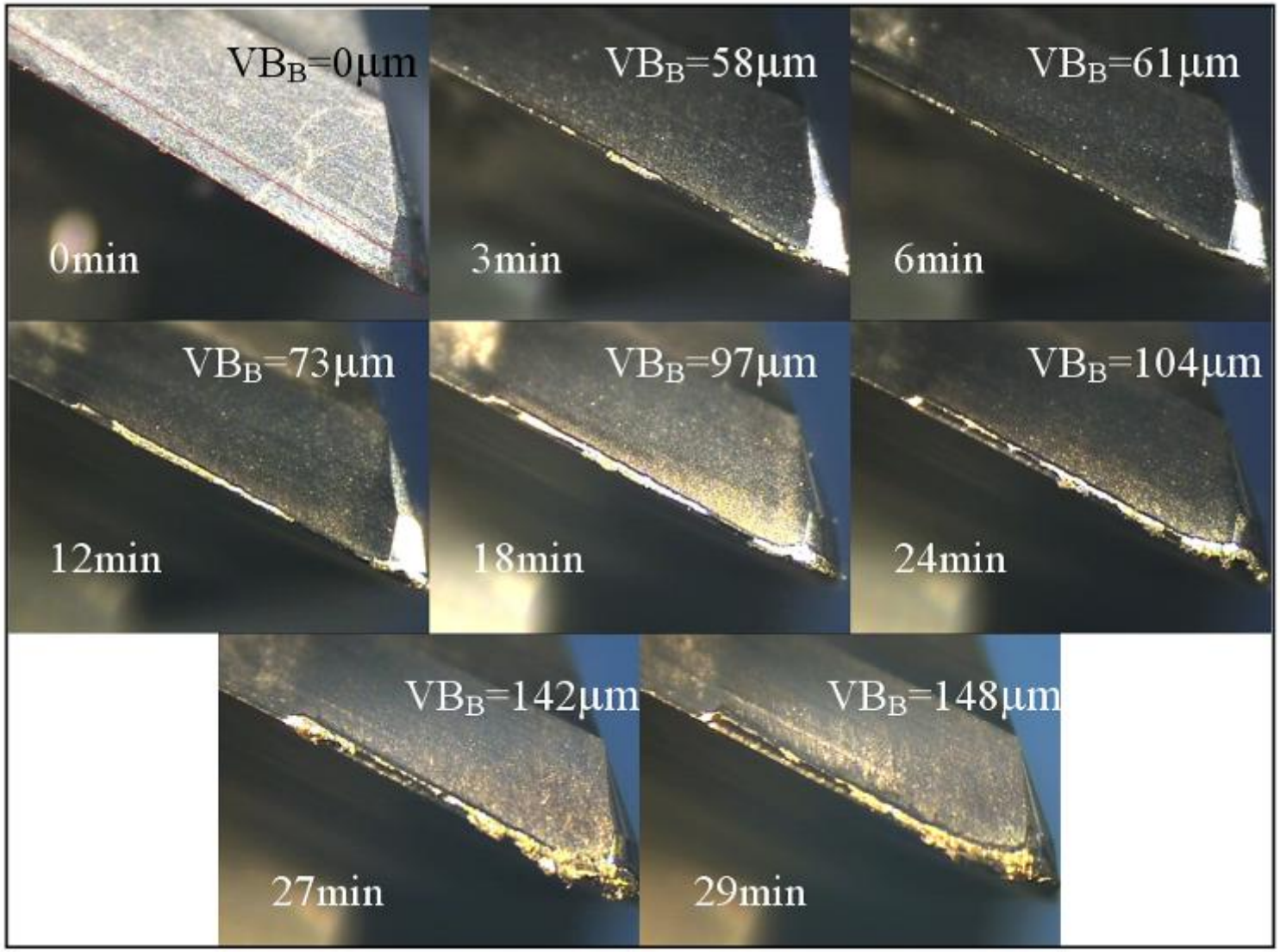


Vliv mikrogeometrie na řezný proces

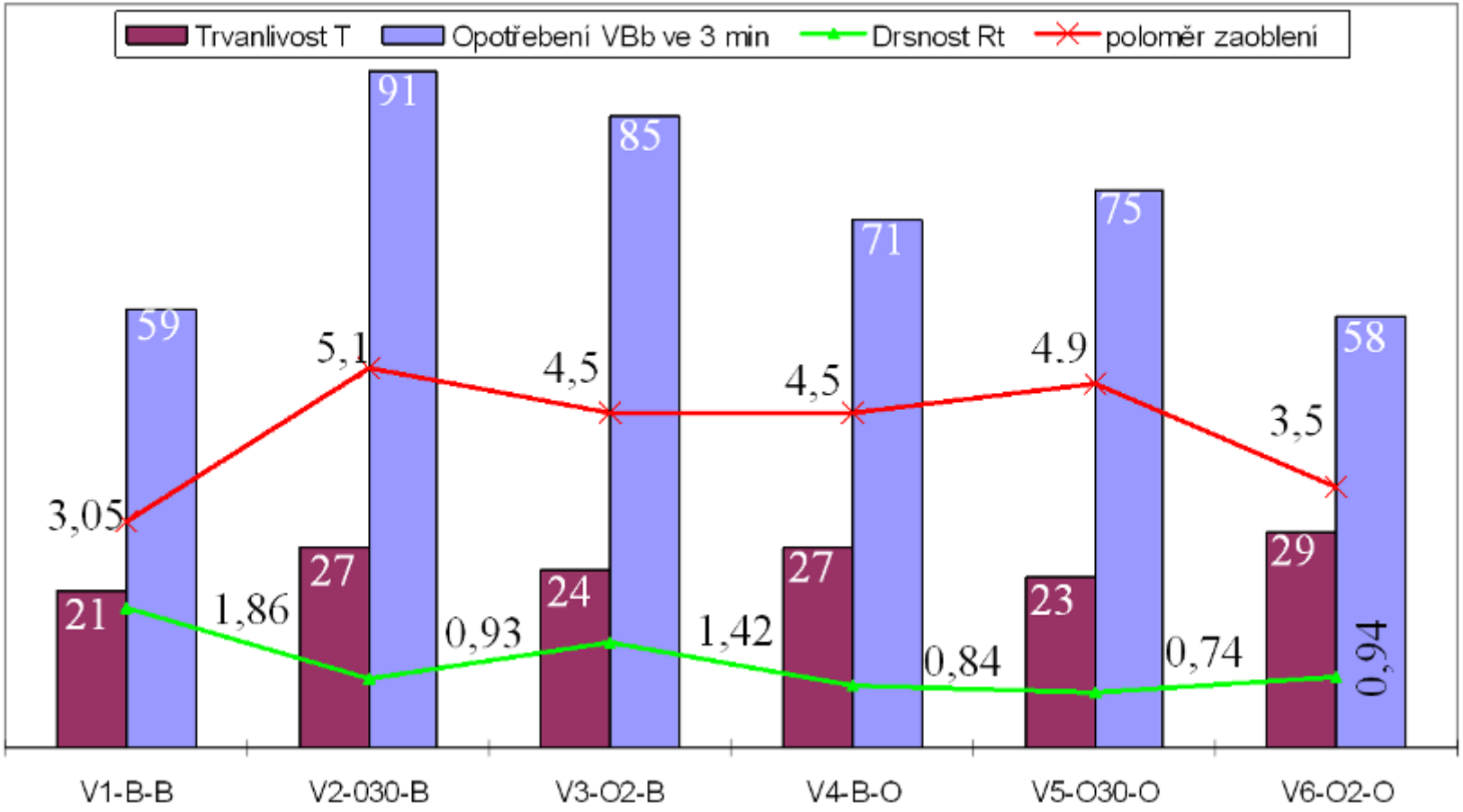




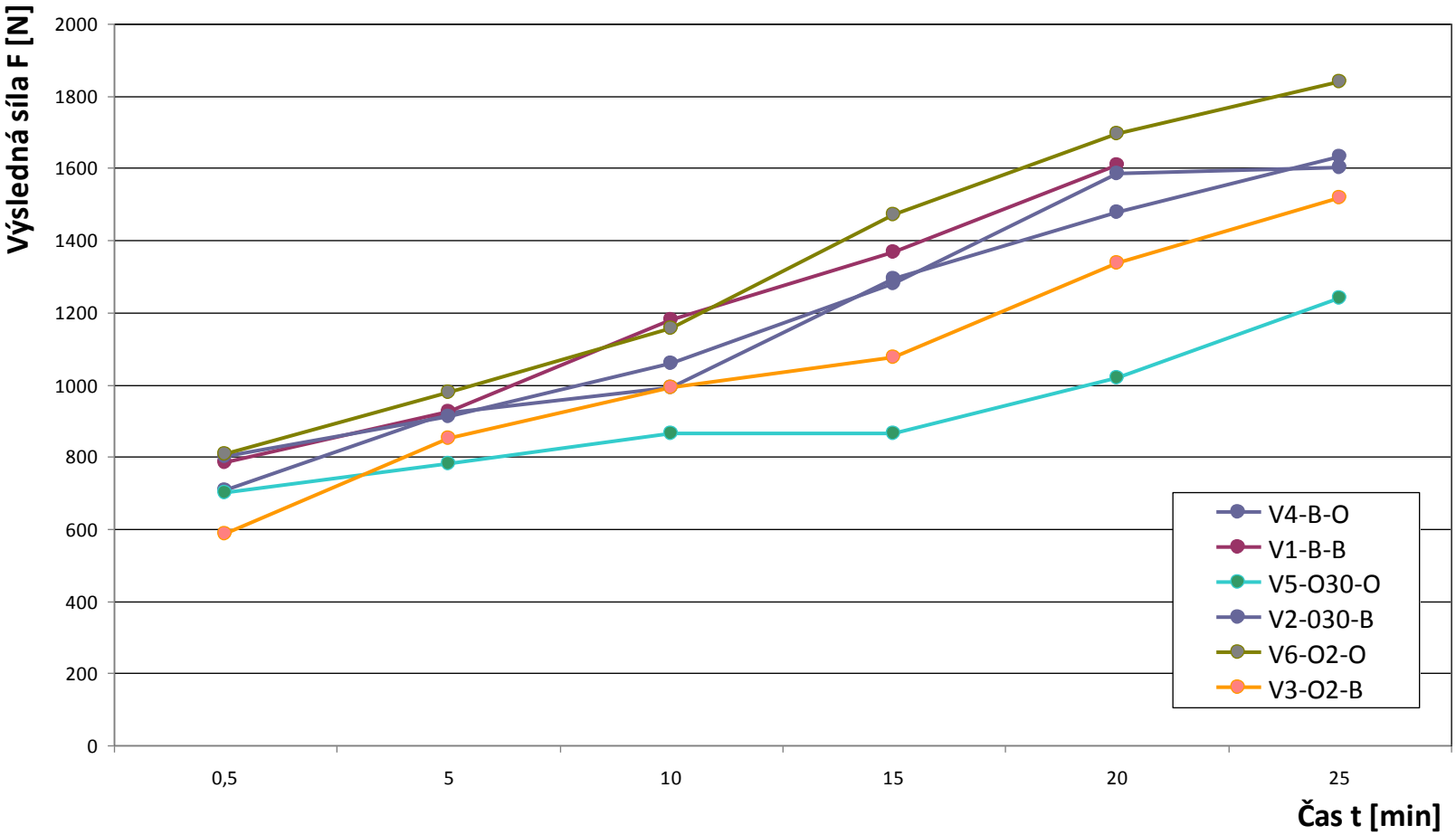
Vliv mikrogeometrie na řezný proces



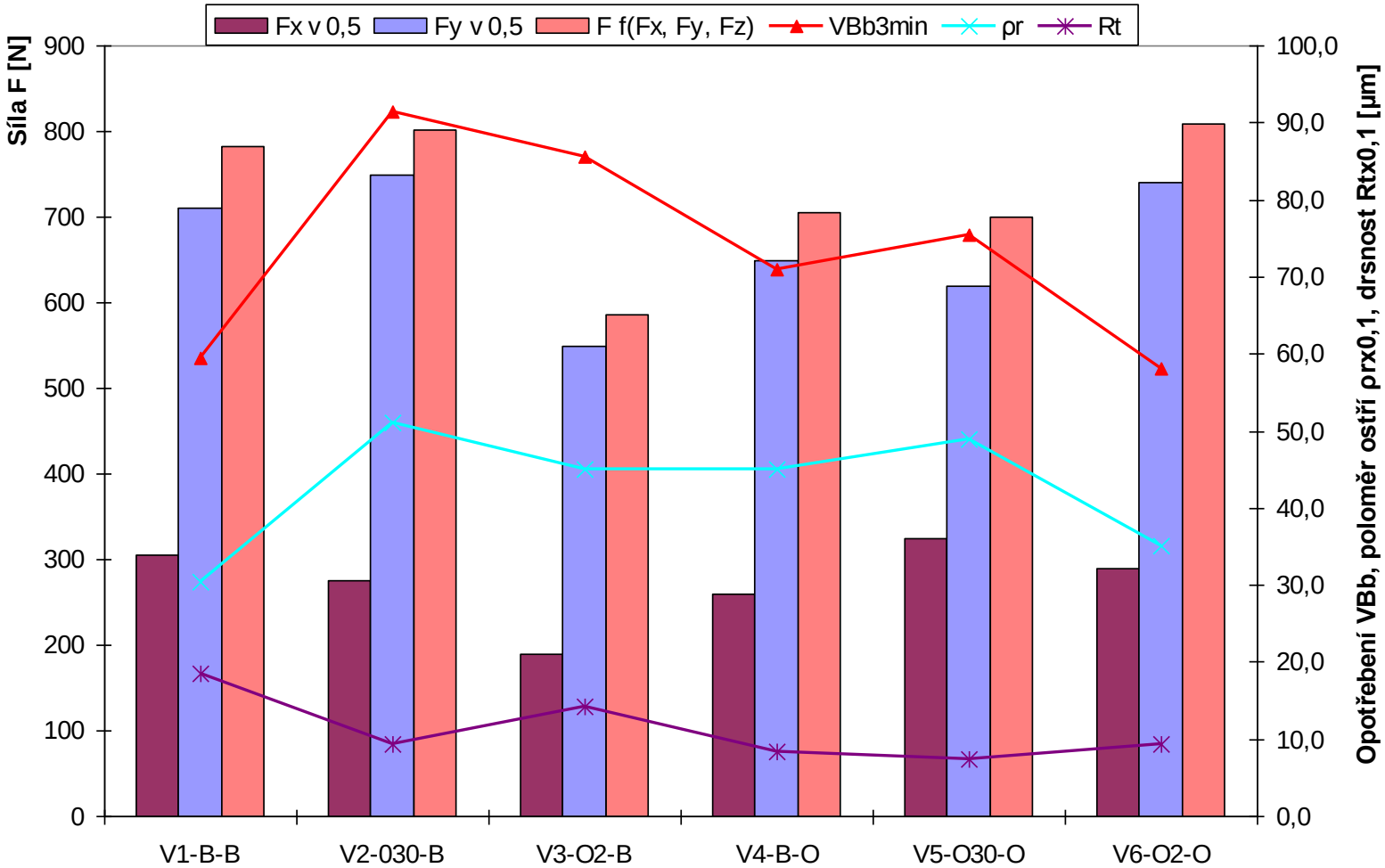
Vliv mikrogeometrie na řezný proces

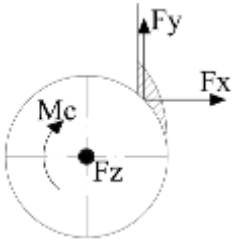


Vliv mikrogeometrie na řezný proces

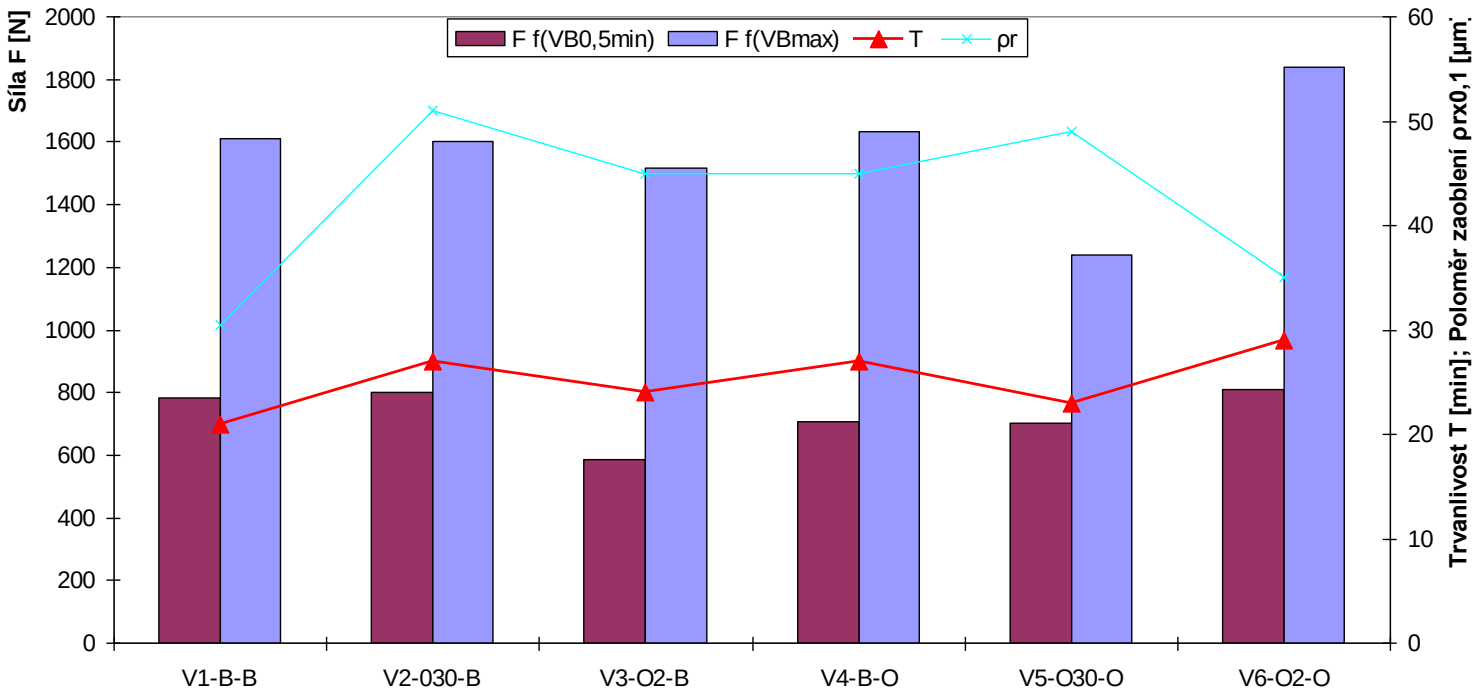


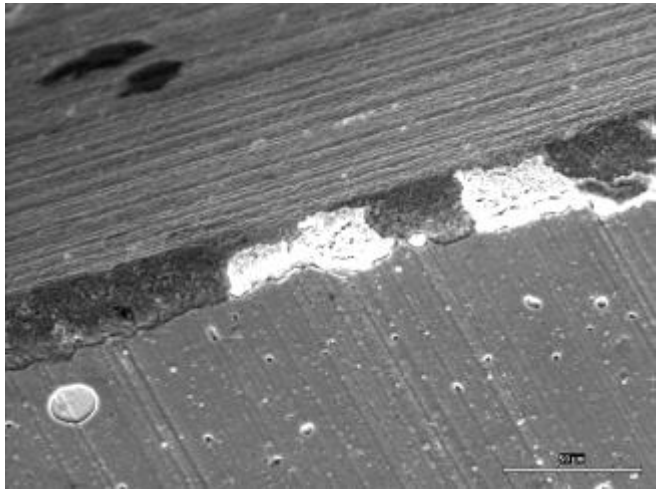
Vliv mikrogeometrie na řezný proces



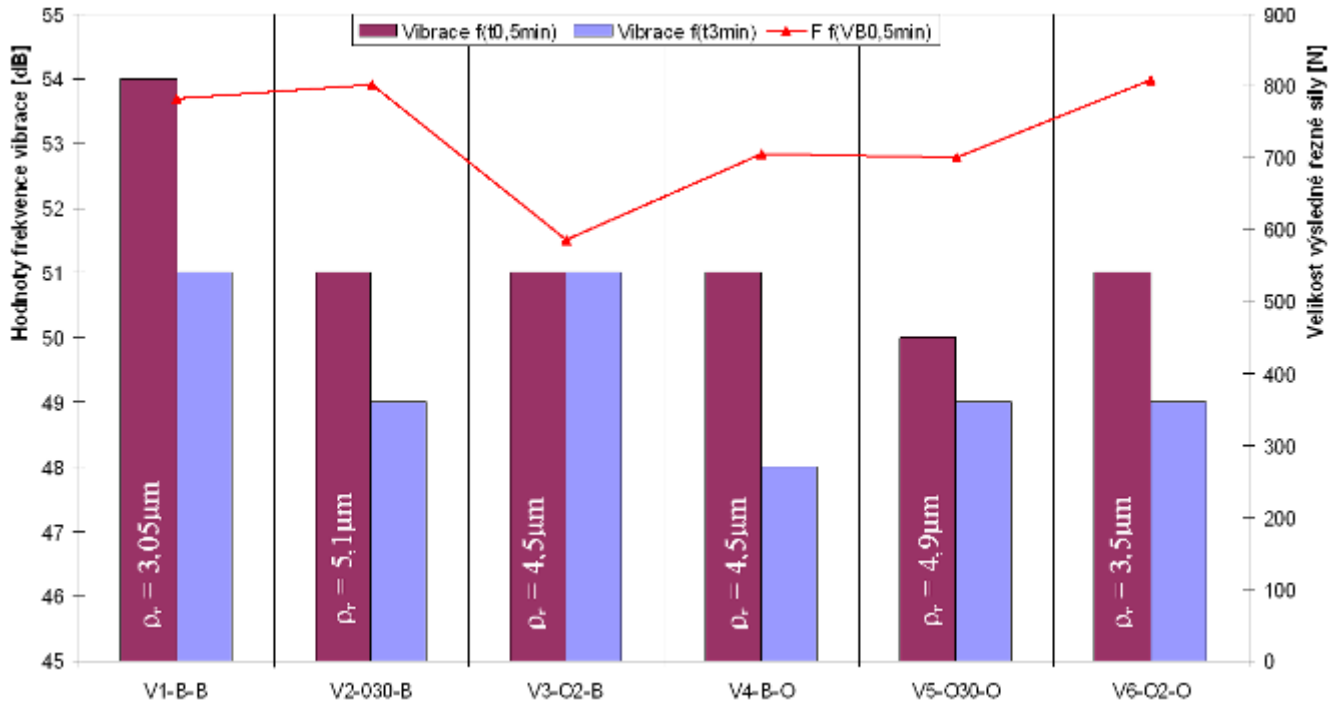


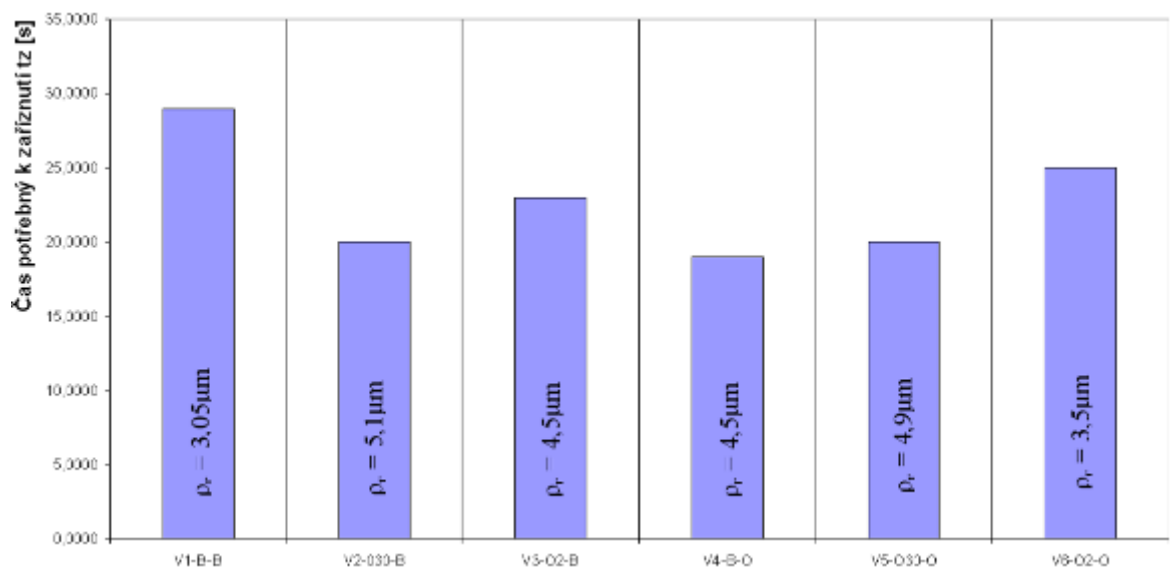
Vliv mikrogeometrie na řezný proces



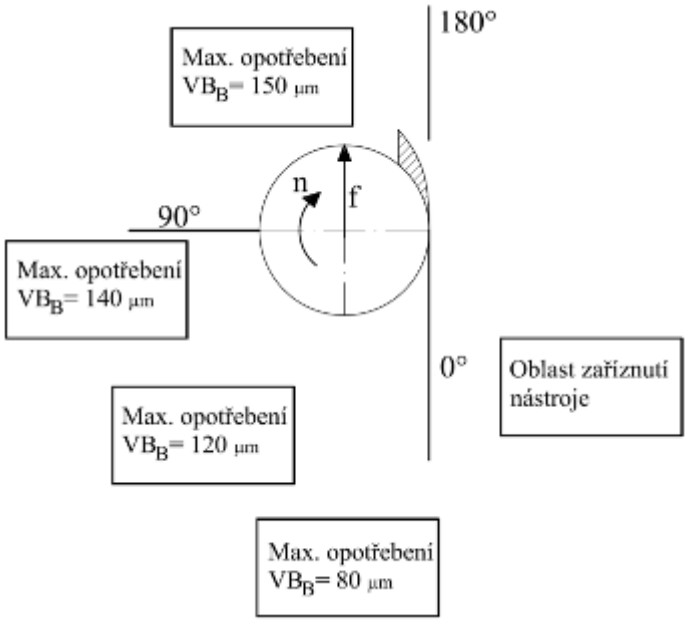


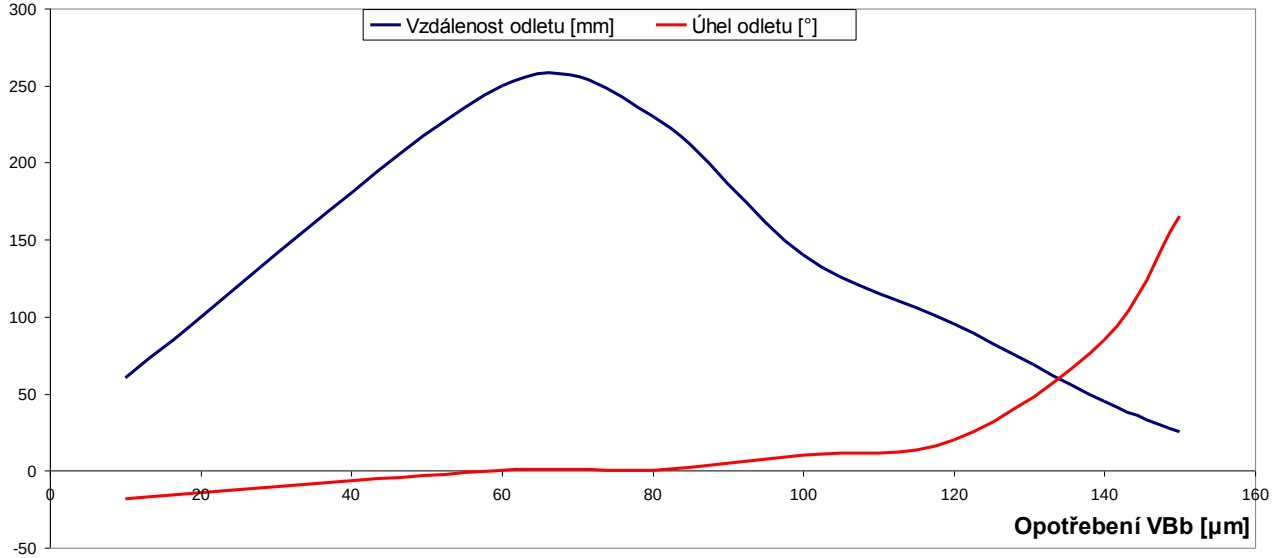
Vliv mikrogeometrie na řezný proces



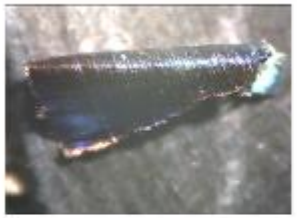
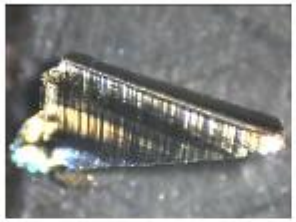
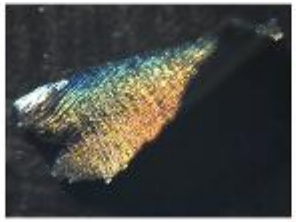
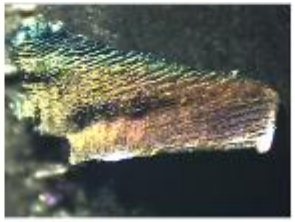
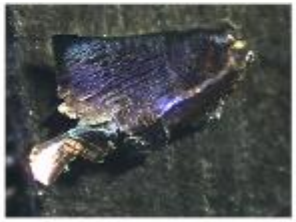


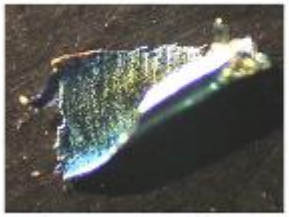
Vliv mikrogeometrie na řezný proces



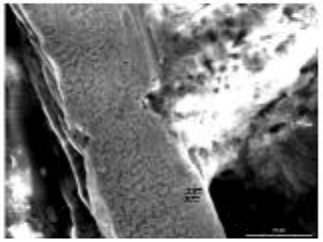
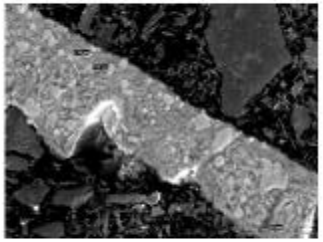
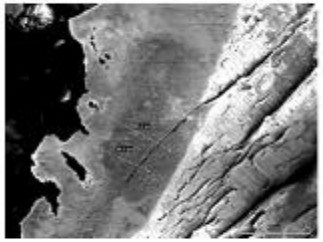
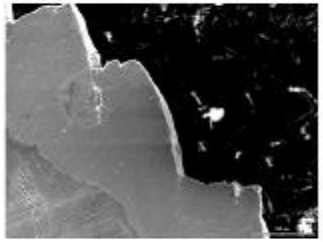


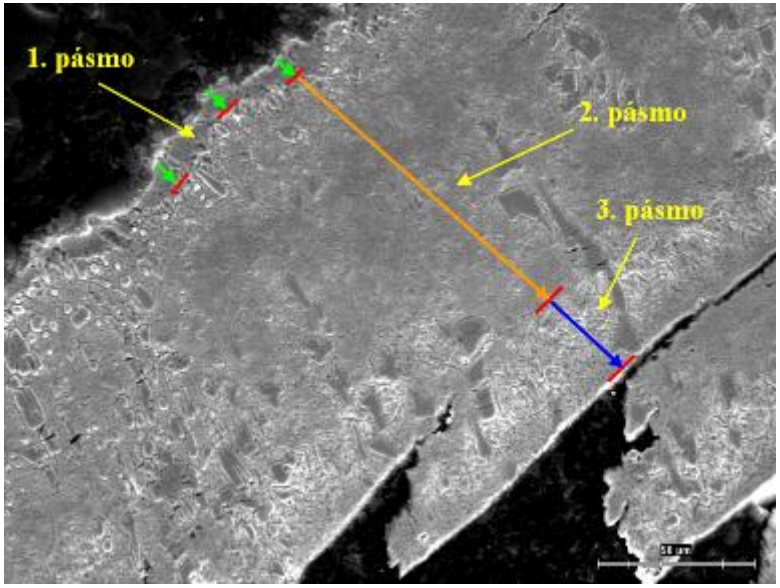
Vliv mikrogeometrie na řezný proces

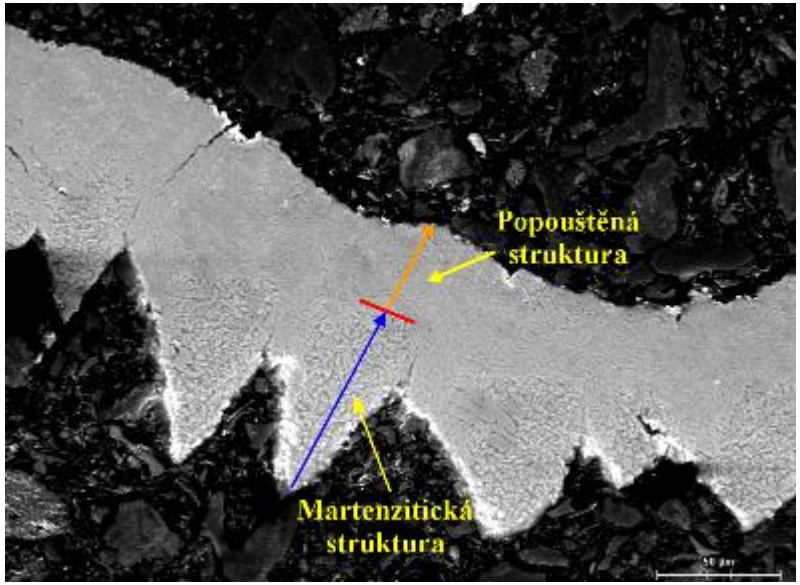
	3 min	12 min	24 min	33 min
Pohled A				
Pohled B				

V1-B-B	V2-O30-B	V4-B-O
V5-O30-O	**V6-O2-O**	
		v čase t = 3 min

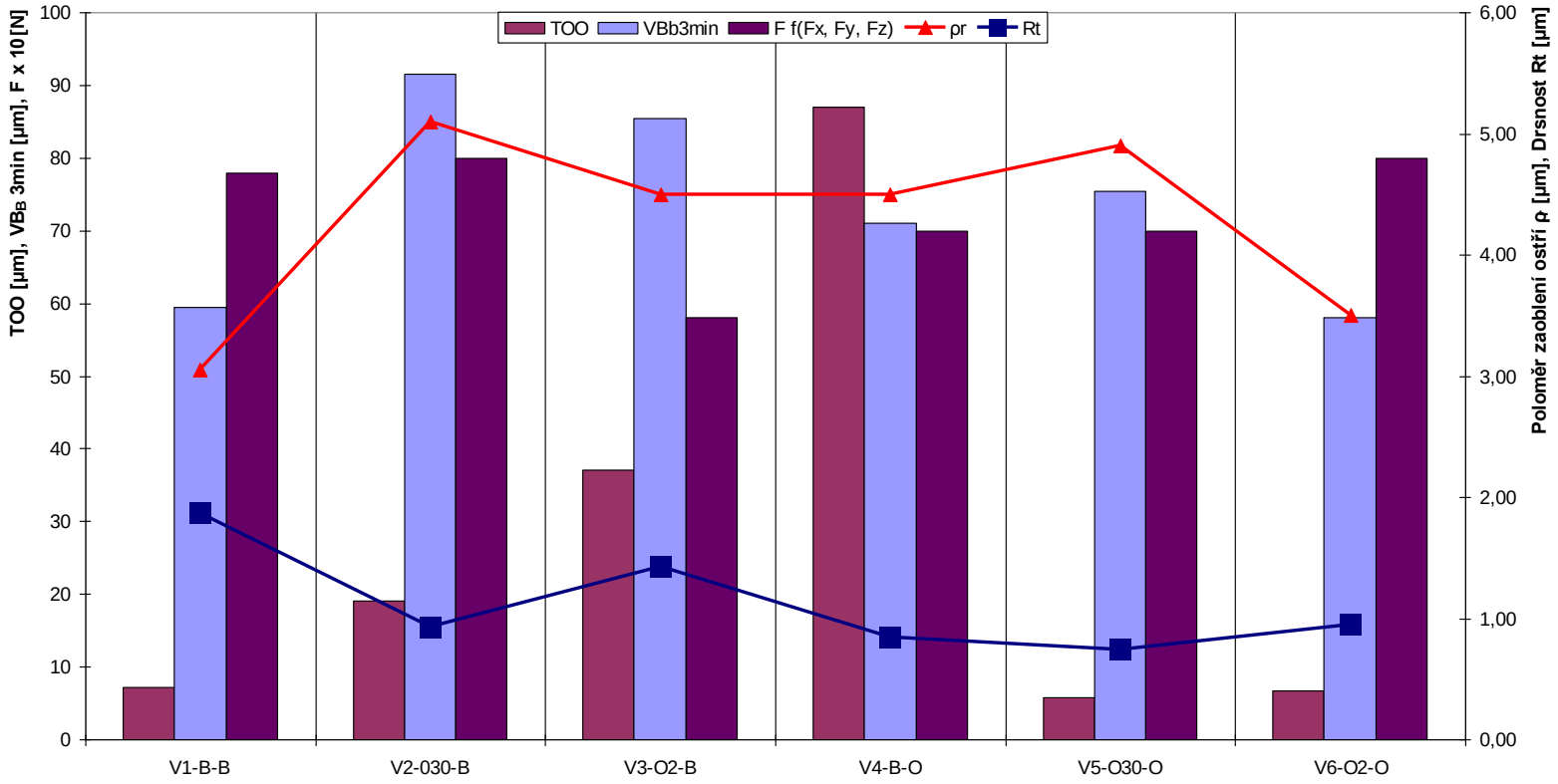
Vliv mikrogeometrie na řezný proces

	3 min	12 min	24 min	33 min
Met. výbrus				
TOO	6,9 µm	15,4 µm	53,1 µm	53,4 µm

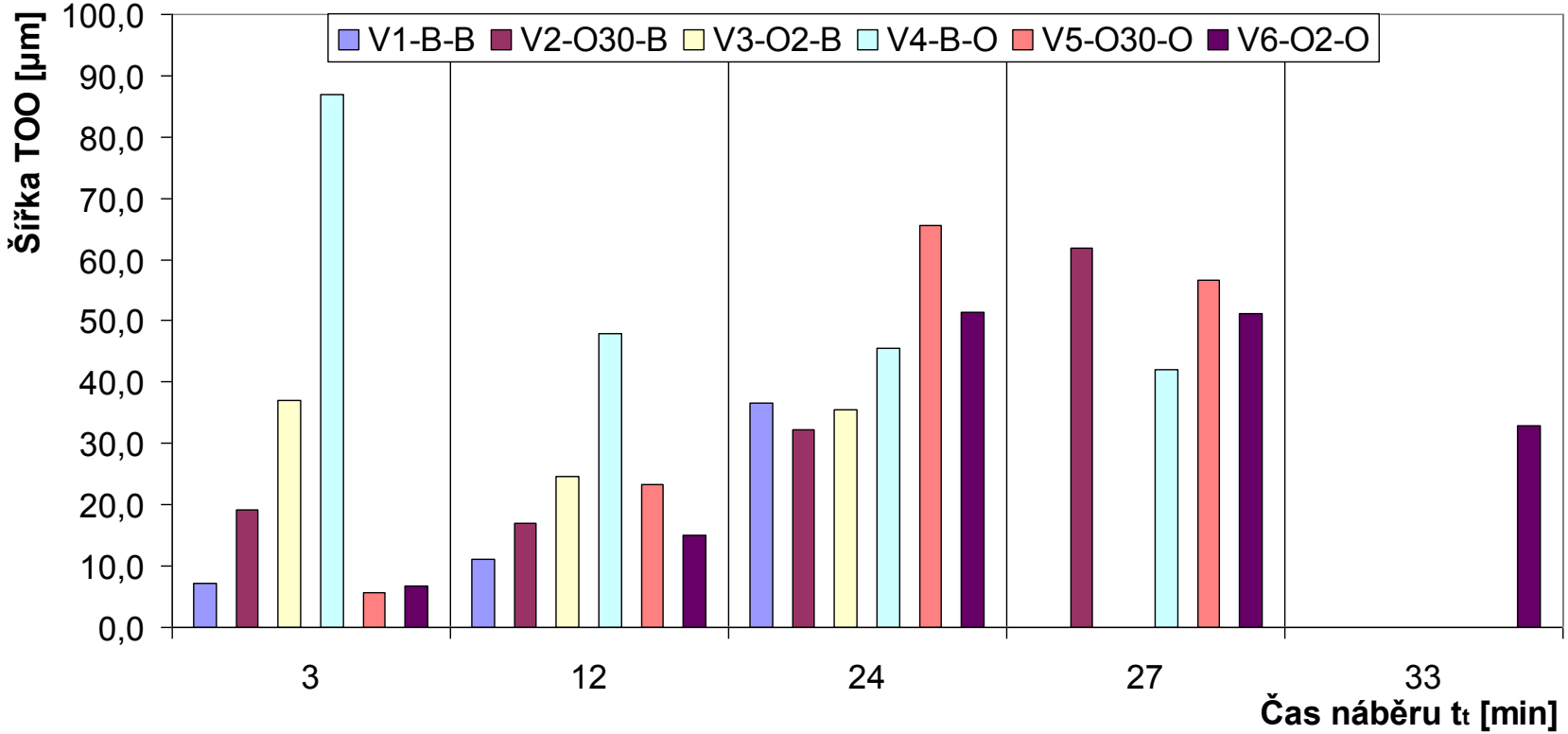


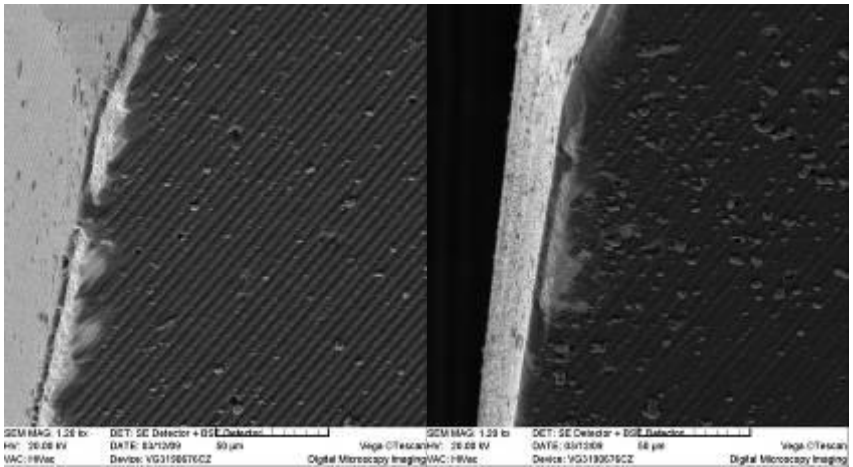


Vliv mikrogeometrie na řezný proces



Vliv mikrogeometrie na řezný proces





nástroj V4-B-O

Technicko – ekonomické hodnocení

	V1-B-B	V2-O30-B	V3-O2-B	V4-B-O	V5-O30-O	V6-O2-O
Suma	**16**	**23**	**24**	**21**	**27**	**26**
Pořadí	**VI.**	**IV.**	**III.**	**V.**	**I.**	**II.**

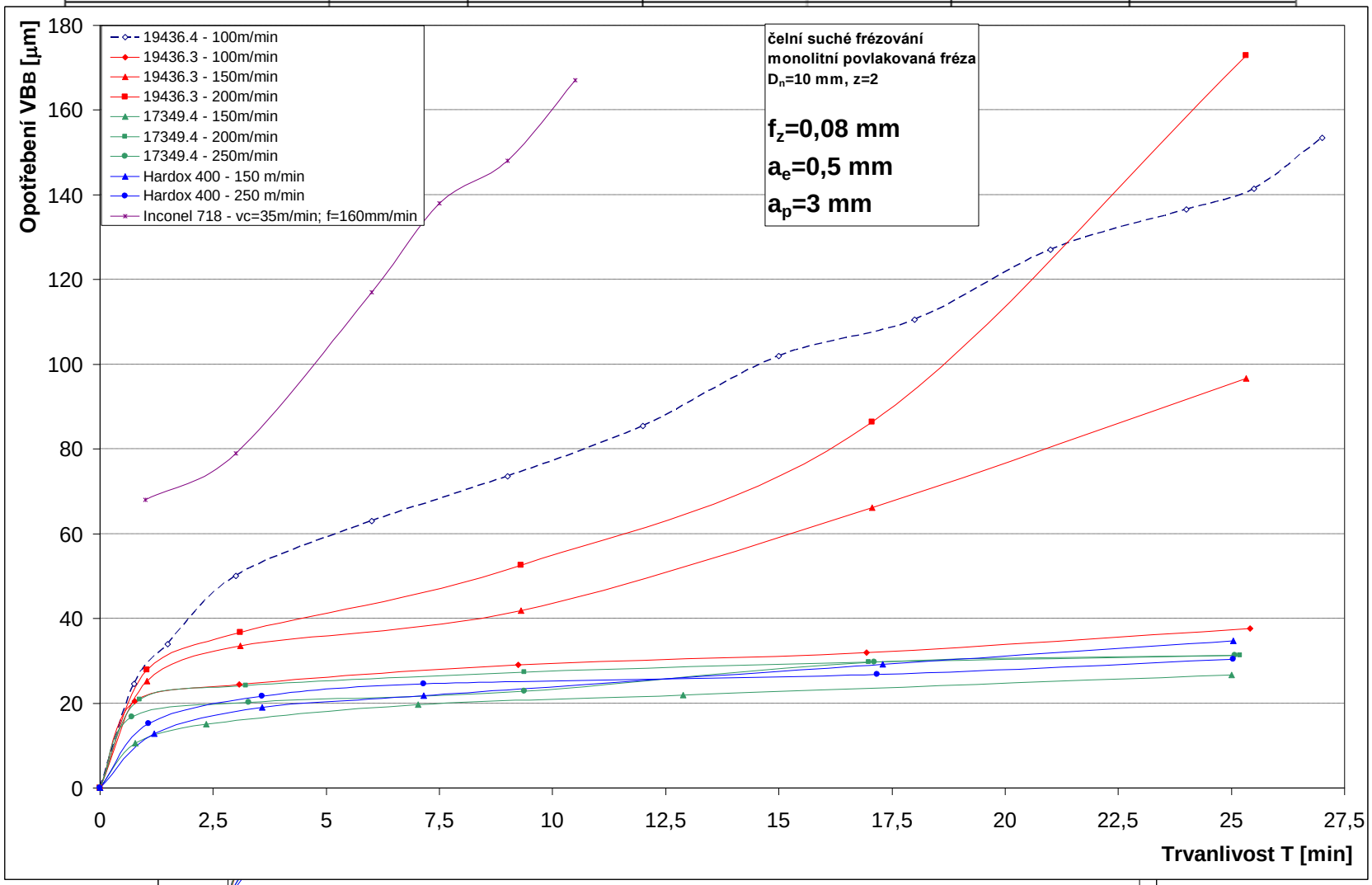
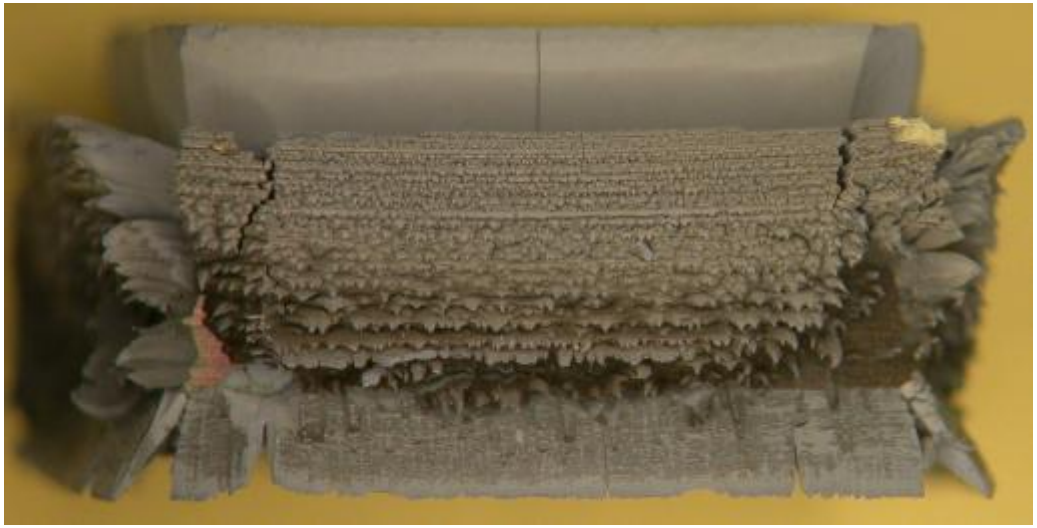
Sumarizující tabulka

Varianta nástroje	**V1-B-B**	**V2-O30-B**	**V3-O2-B**	**V4-B-O**	**V5-O30-O**	**V6-O2-O**
Obrobená vzdálenost [mm]	247	170	196	162	170	213

Varianta nástroje	**V1-B-B**	**V2-O30-B**	**V3-O2-B**	**V4-B-O**	**V5-O30-O**	**V6-O2-O**
Cena nástroje [Kč]	300					
Úprava před depozicí [Kč]	0	15	20	0	15	20
Depozice [Kč]	45					
Úprava po depozici [Kč]	0	0	0	20	20	20
Celková cena nástroje [Kč]	345	360	365	365	380	385

Vliv mikrogeometrie na řezný proces

Varianta nástroje	V1-B-B	V2-O30-B	V3-O2-B	V4-B-O	V5-O30-O	V6-O2-O



Děkuji za pozornost