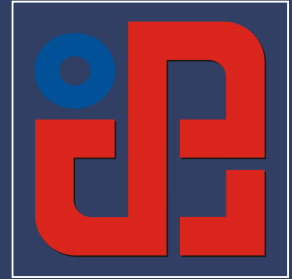




FAKULTET TEHNIČKIH NAUKA
DEPARTMAN ZA PROIZVODNO MAŠINSTVO

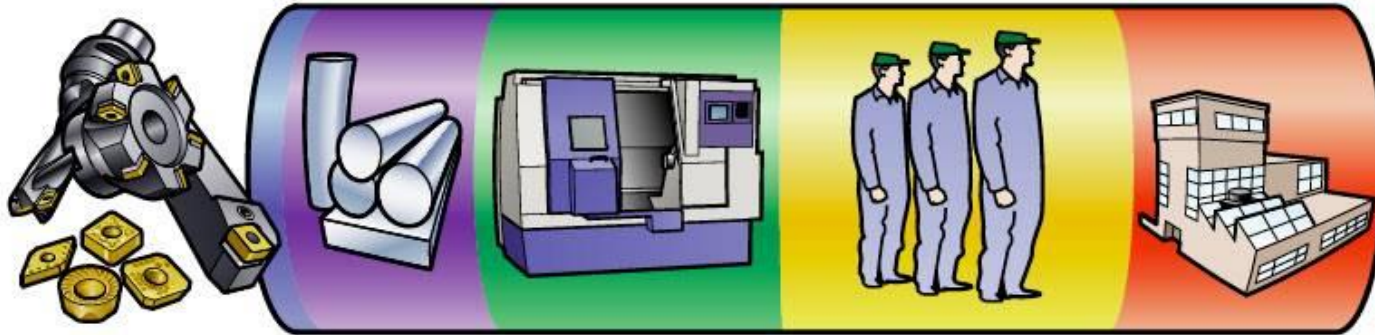


PROJEKTOVANJE I OPTIMIZACIJA TEHNOLOŠKIH PROCESA PROIZVODNJE

**VEŽBA 5: Izbor alata i režima obrade
-Sandvik Coromant**

Prof. dr Dejan Lukić

Ekonomičnost i produktivnost mašinske obrade



- **Varijabilni troškovi**

Troškovi nastali u procesu proizvodnje:

- rezni alati, potrošni materijal (3%)
- materijal radnih komada 17%

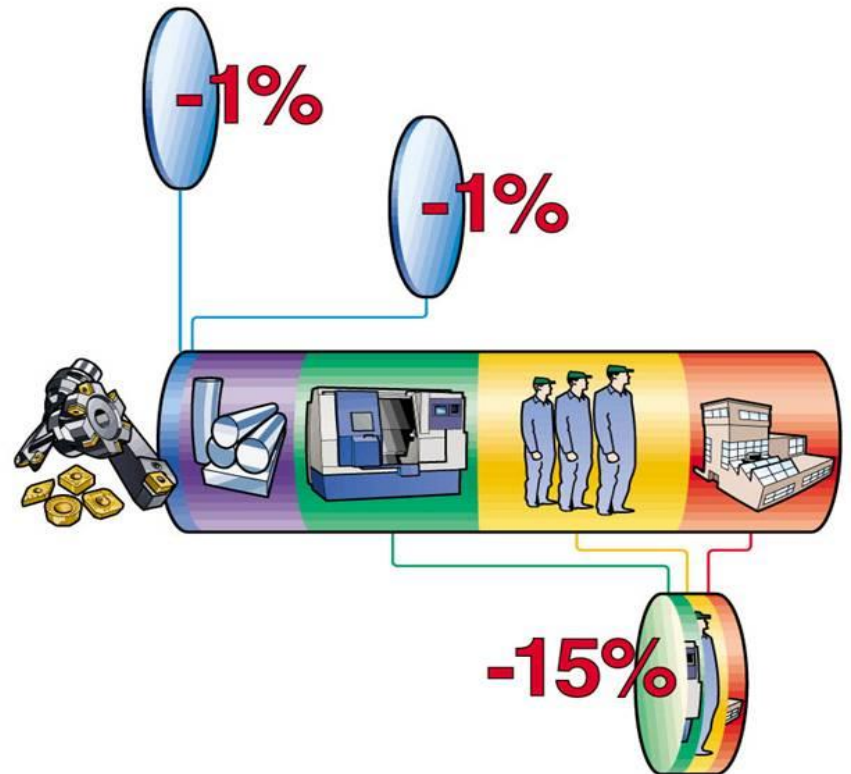
- ◆ **Fiksni troškovi**

Prateći troškovi:

- mašine i pribori (27%)
- ljudstvo (31%)
- aneksi, administracija itd. (22%)

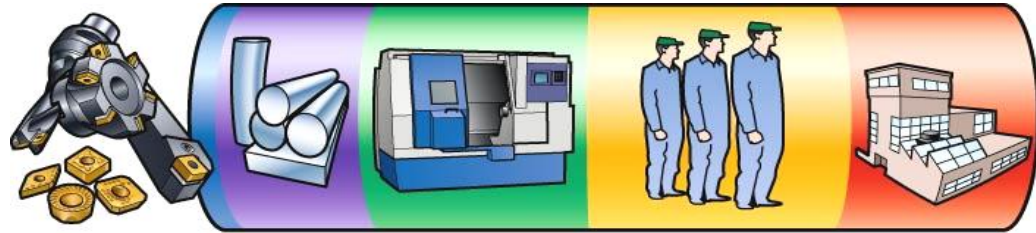
Ekonomičnost u mašinskoj obradi – troškovi, postojanost ili produktivnost

- ◆ **Snizavanje cene reznog alata:**
30% smanjenje cena reznog alata dovodi do smanjenja ukupnih troškova po komponenti samo za 1%
- ◆ **Povećanje postojanosti:**
50% povećanje postojanosti alata smanjuje ukupne troškove po komponenti za 1%
- ◆ **Povećanje režima obrade:**
20% povećanje režima obrade smanjuje ukupne troškove po komponenti za 15%



Primer ekonomičnosti mašinske obrade

Shop spends \$10,000
to make 1000 parts
Machine cost is \$10.00 per part



30%

50%

20%

Niža cena

Veća postojanost

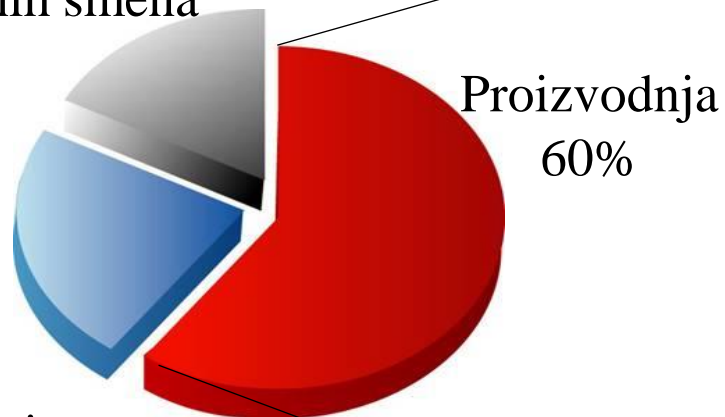
Oštriji
režimi obrade

	Today	Niža cena	Veća postojanost	Oštriji režimi obrade
Variable				
- Tooling	\$.30	\$.21	\$.20	\$.45
- Material	\$1.70	\$1.70	\$1.70	\$1.70
Fixed				
- Machinery	\$2.70	\$2.70	\$2.70	\$2.16
- Labour	\$3.10	\$3.10	\$3.10	\$2.48
- Building	\$2.20	\$2.20	\$2.20	\$1.76
Cost per part	\$10.00	\$9.91	\$9.90	\$8.55
Savings		1%	1%	15%*

* In addition to the 15% decrease in cost, there is also 20% additional capacity

Iskorišćenje Mašine alatke

Nepotpuna iskorišćenost
dodatnih smena



Praznici,
isl.



Mašinska obrada 20%

Izmena alata 10%

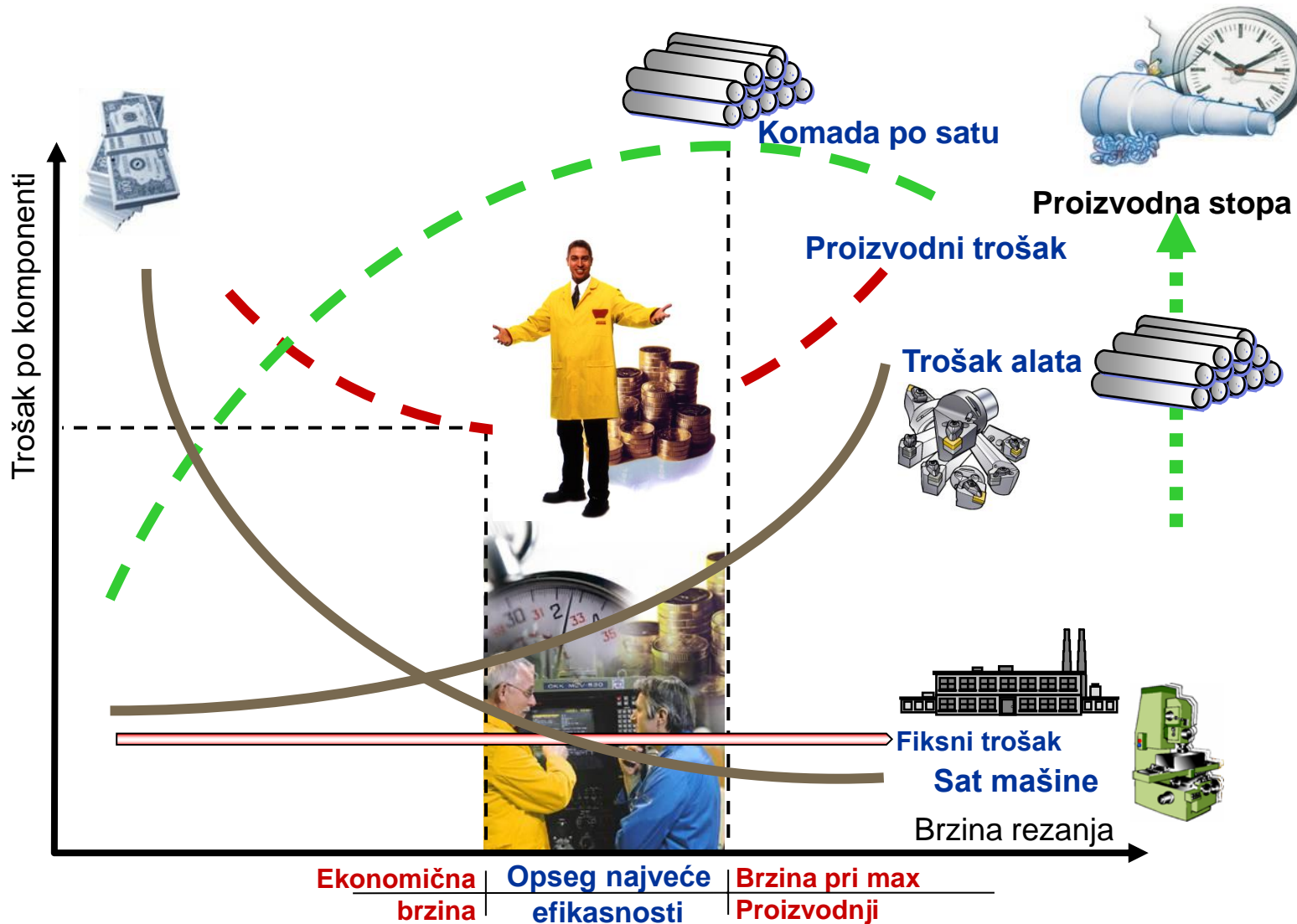
Podešavanje i
umeravanje 10%

Zastoji 10%

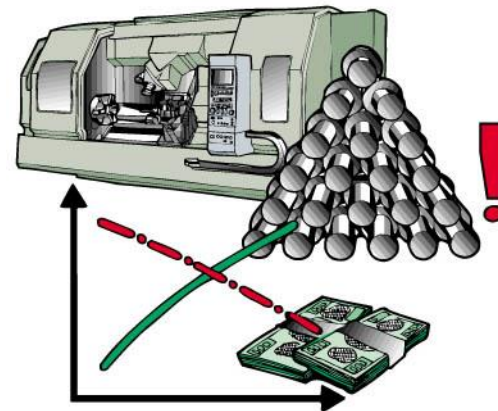
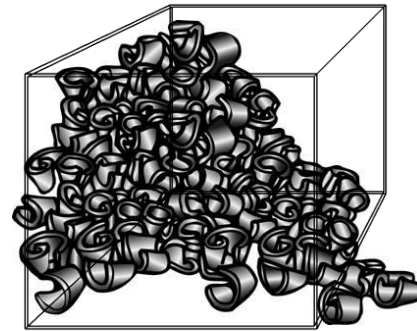
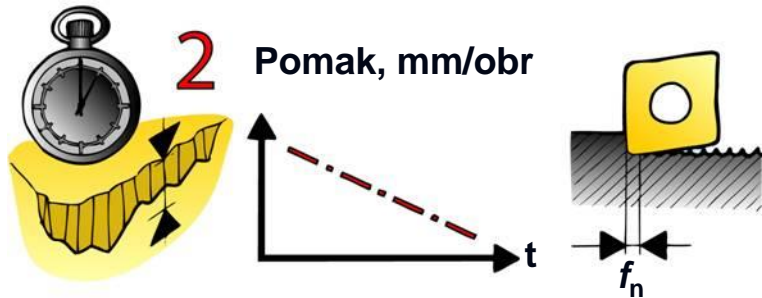
Zamena radnog
predmeta 10%

Ekonomičnost u mašinskoj obradi

- Režimi obrade i troškovi



Povećanje produktivnosti



Kako povečati produktivnost



- ◆ Definirati **materijal i tvrdoću HB** ili zateznu čvrstoću N/mm^2
- ◆ Izabrati adekvatnu **geometriju**
- ◆ Izabrati adekvatni **kvalitet pločice**
- ◆ Koristiti preporučene **režime obrade** ili kompenzovati vrednost režima prema vašim potrebama
- ◆ **Korektna primena** alata može povećati produktivnost za najmanje 20%

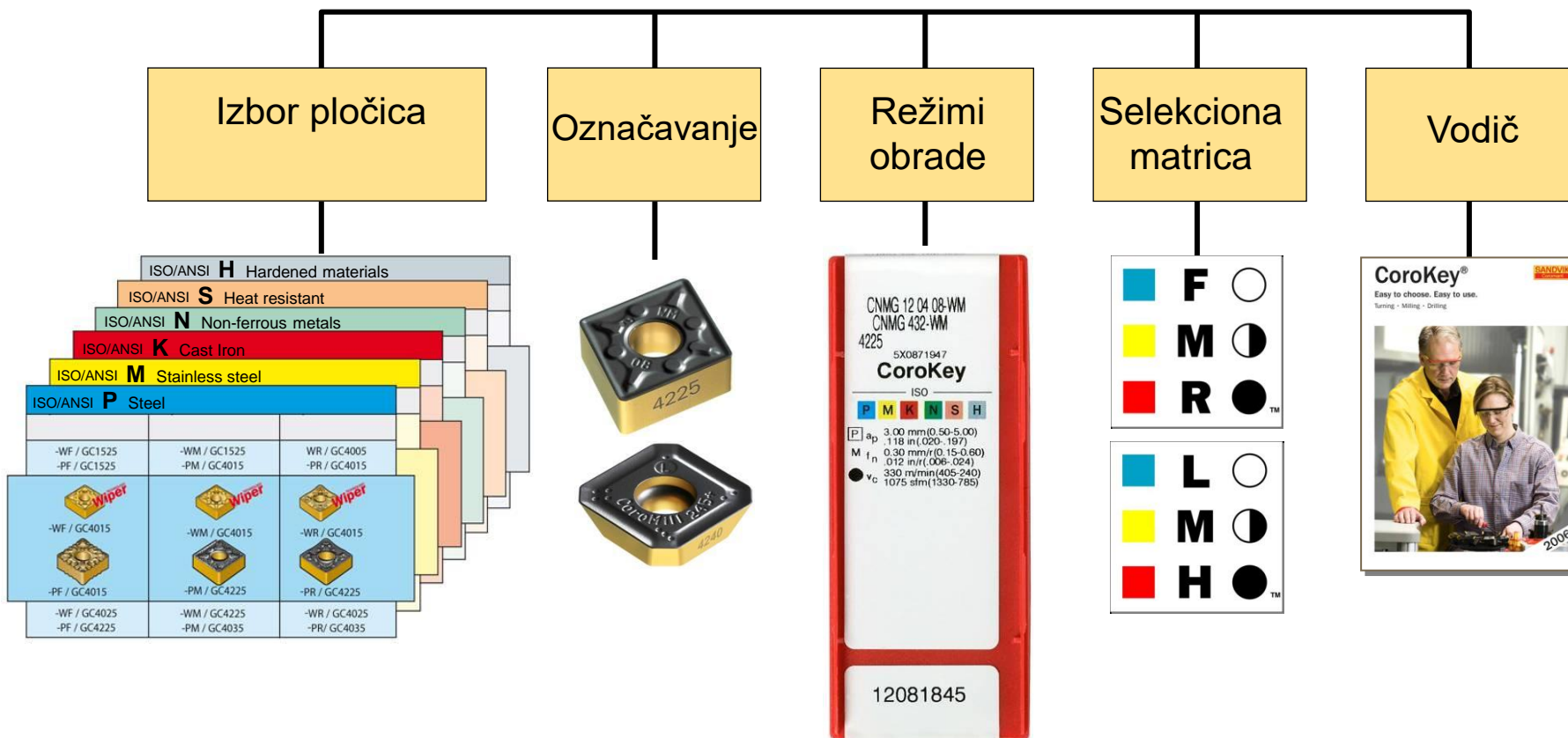
Saveti za povećanje veka alata pri mašinskoj obradi

- ◆ Brzine i pomaci unutar preporučenih parametara.
- ◆ Iskoristite sve raspoložive rezne ivice na pločici.
- ◆ Odgovarajuća veličina radijusa pločice u odnosu na dubinu rezanja.
- ◆ Izaberite pravu kombinaciju veličine radijusa i geometrije.
- ◆ Primenite istosmerno umesto suprotnosmernog glodanja kad god je moguće.
- ◆ Potrošene pločice se mogu koristiti za obaranje ivica.

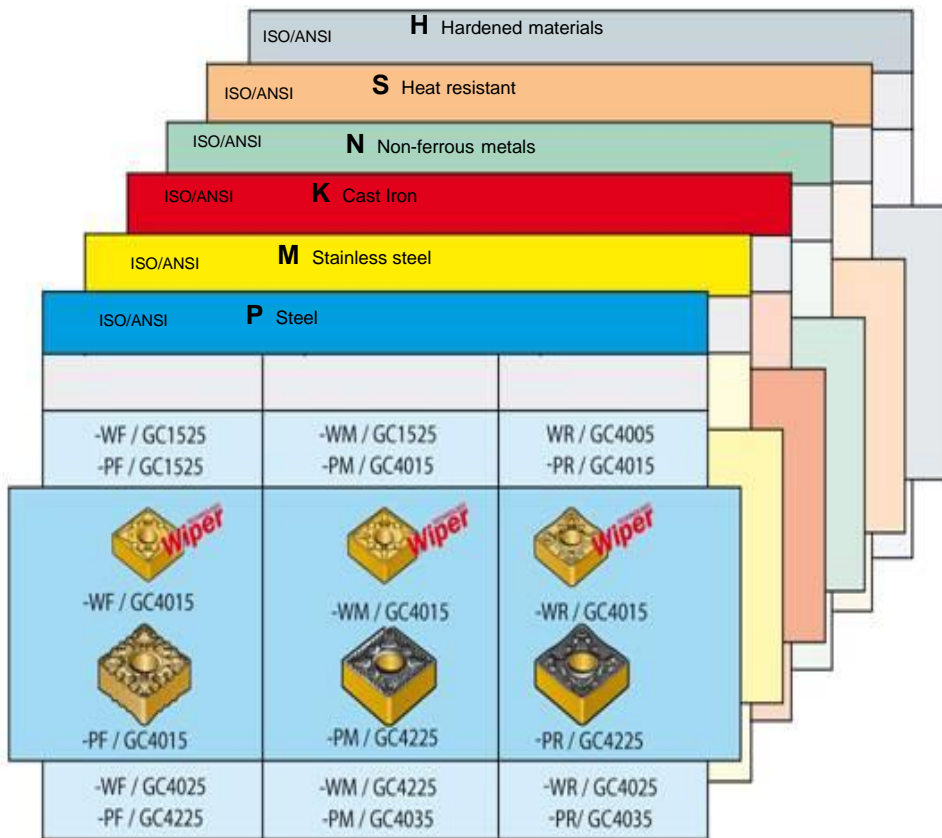


Dobra stabilnost = Uspešan proces rezanja

CoroKey® koncept kamen temeljac



Izbor geometrije i kvaliteta



Dominantna oblast primene

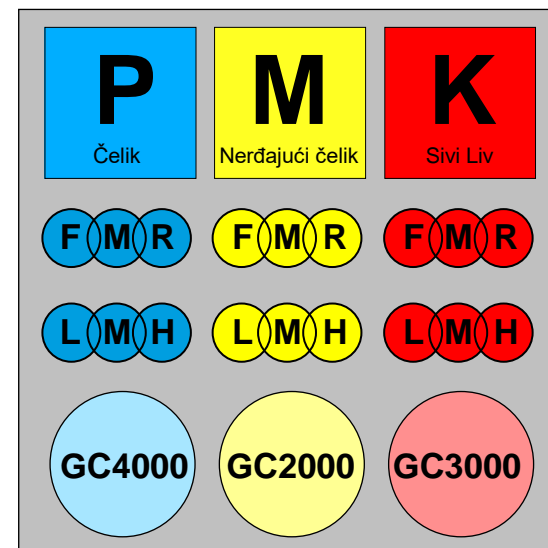
Materijali

Izbor geometrije

Kvaliteti

Struganje

Glodanje



Materijali obradka



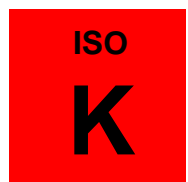
Čelik

Referentni materijal:
nisko legirani čelici,
CMC 02.1 / 180 HB



Nerđajući čelik

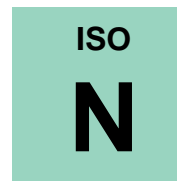
Referentni materijal:
Austenitni nerđajući čelik,
CMC 05.21 / HB 180



Liv

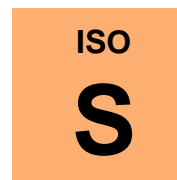
Referentni materijal :
Sivi liv, CMC 08.2/HB 220
Nodularni liv,
CMC 09.2 / HB 250

NEW



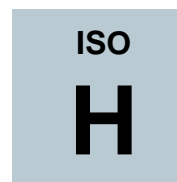
Legure Aluminijuma

Referentni materijal :
Liven, nežaren
CMC 30.21 / HB75



Vatrootporne Legure

Referentni materijal:
Na bazi Ni, Ti
CMC 20.22 / 350 HB

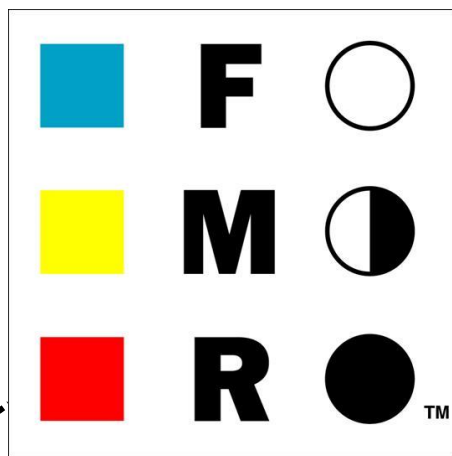


Kaljeni čelik

Referentni materijal:
Kaljen i cementiran,
CMC 04.1 / HRC 60

Materijal obradka - Vrsta primene - Uslovi obrade

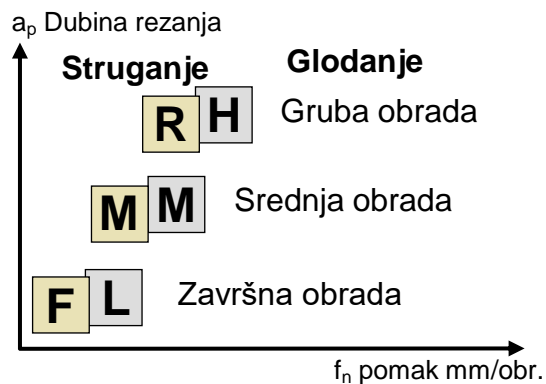
CoroKey®



1 Materijali obradka

- ISO P** Čelici
- ISO M** Nerđajući čelici
- ISO K** Sivi livovi

2 Tip aplikacije



3 Uslovi obrade

- = **Dobri uslovi**
Kontinualan rez.
Stabilni uslovi
- ◐ = **Prosečni uslovi**
- = **Teški uslovi**
Isprekidani rez; teška i gruba obrada. Vibracije

Materijal obradka- Vrsta primene- Uslovi obrade

1. Materijal obradka



ČELIK
Referentni materijal: Niskolegirani čelik,
CMC02.1/HB 180



NERĐAJUĆI ČELIK
Referentni materijal: Austenitni nerđajući
čelik, CMC 05.21/HB 180



SIVI LIV
Referentni materijal: Sivi liv, CMC 08.2/HB 220
Nodulami liv, CMC 09.2/HB 250



Aluminijumske legure
Referentni materijal: Liveni, nežaren, CMC
30.21/HB 75



Vatrootpome legure
Referentni materijal: Ni bazirane, CMC 20.22/
HB 350

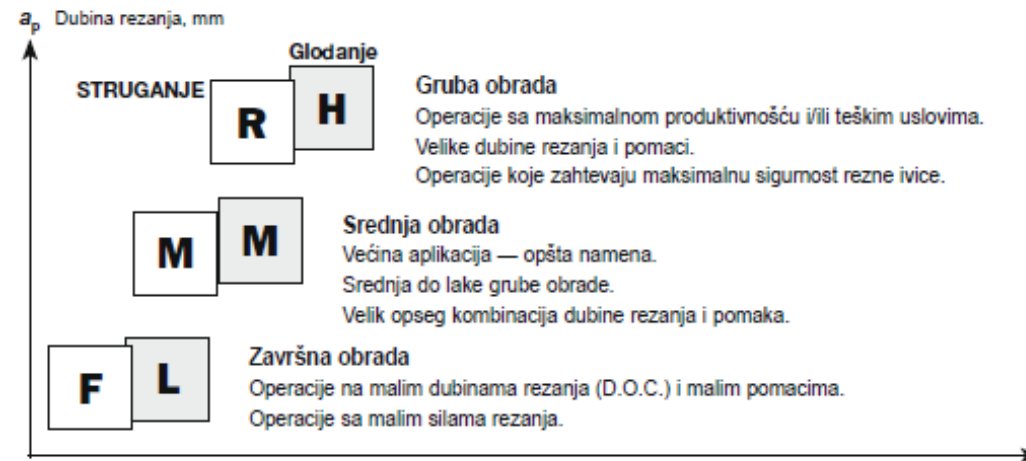


KALJENI MATERIJALI
Referentni materijal: Kaljeni čelik, CMC 04.1/
HRC 60

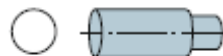
Sandvik Coromant će postepeno uvoditi novu klasifikaciju materijala sa MC kodovima i zameniti postojeći CMC kodni sistem.

MC kodovi, sa daljim podgrupama će pružati određenije preporuke režima obrade u poređenju sa CMC klasifikacijama materijala.

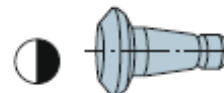
2. VRSTA PRIMENE (STRUGANJE / GLODANJE)



3. Uslovi obrade



Dobri uslovi
Neprekidni rezovi. Velike brzine rezanja. Predobrađena površina.
Odlično stezanje komponente. Mali prepusti.

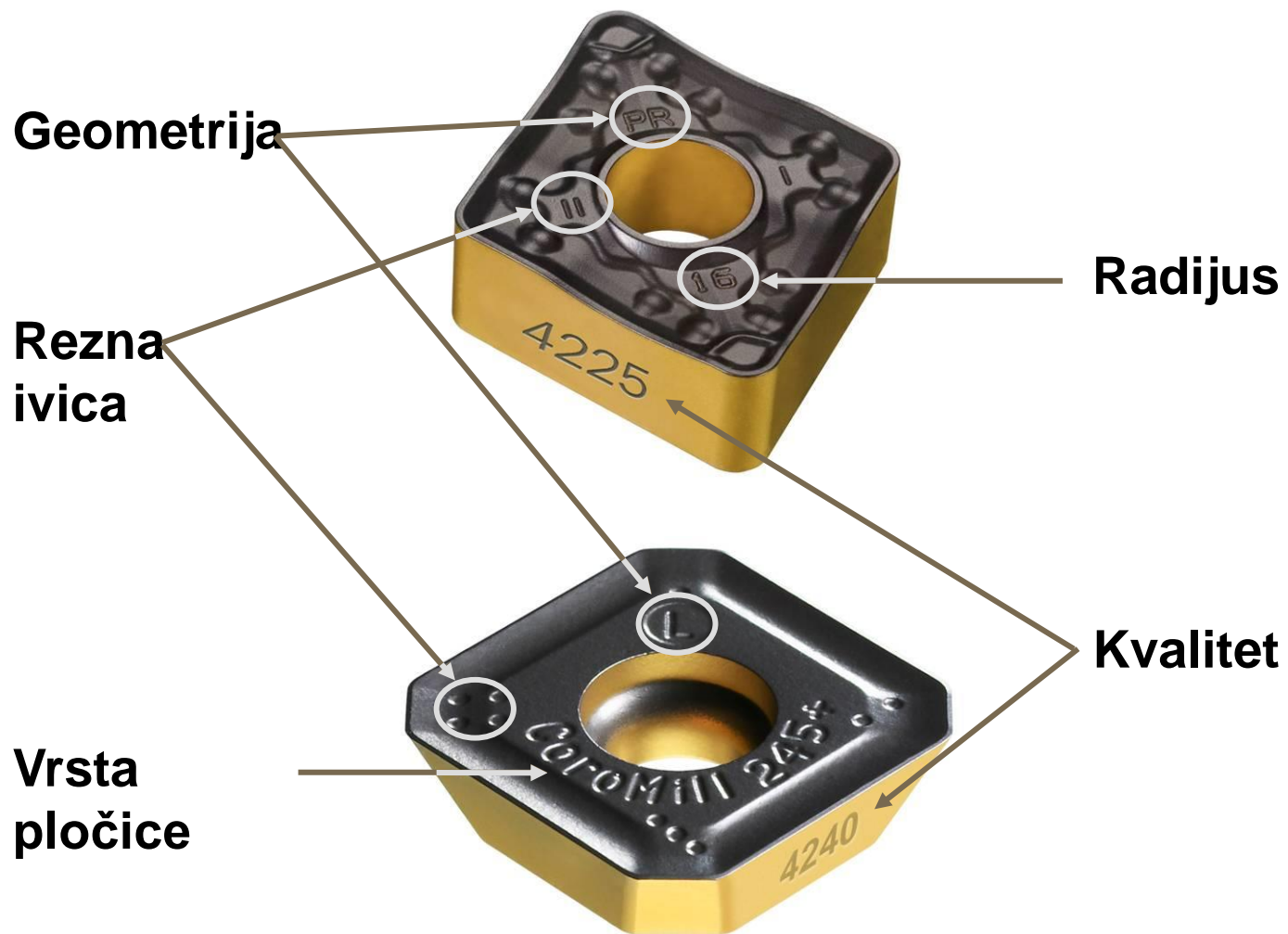


Prosečni uslovi
Promenljiva dubina rezanja. Srednje brzine rezanja. Odlivak ili otkovak.
Dobro stezanje komponente.



Teški uslovi
Prekinuti rezovi. Male brzine rezanja. Gruba kora na obradku.
Slabo stezanje komponente.

Označavanje pločica



Režimi obrade na nalepnici kutije pločica i u vodiču CoroGuide

- ◆ Materijal obaradka:
 - P, M, K
 - N, S, H
- ◆ Radno područje za geometriju:
 - F, M, R (Struganje)
 - L, M, H (Glodanje)
- ◆ Uslovi obrade za izbor kvaliteta:
 - Tri simbola
- ◆ Polazne vrednosti za:
 - dubinu rezanja a_p
 - pomak f_n
- ◆ Radno područje za :
 - dubinu rezanja a_p
 - pomak f_n



Izbor alata za struganje i režima obrade

SPOLJAŠNJA OBRADA

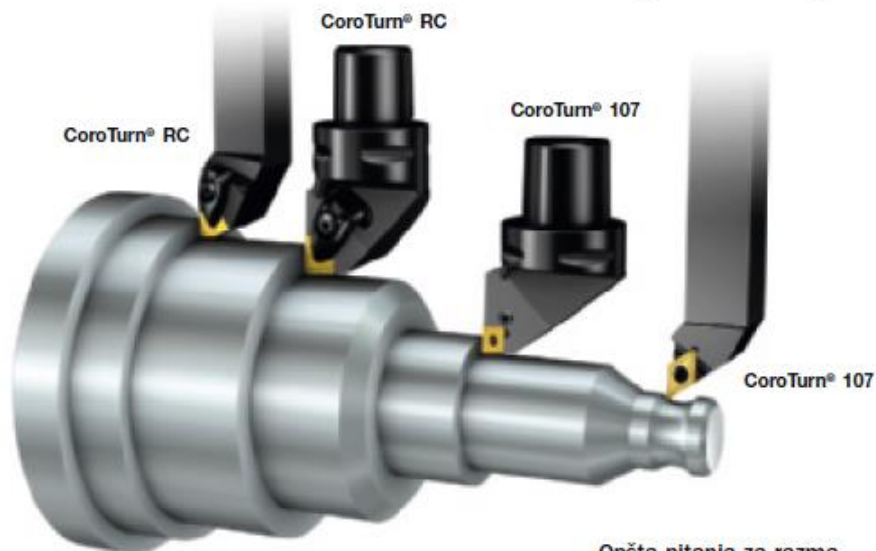


CoroTurn® RC

- Spoljašnja obrada, od grube do završne obrade

CoroTurn® 107

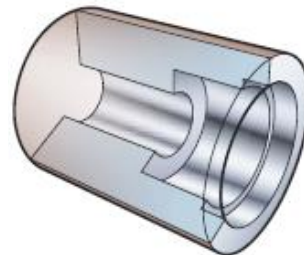
- Spoljašnja obrada malih, dugačkih i vitkih komponenti



Opšta pitanja za razmatranje

Koristiti napadni ugao manji od 90° ako je moguće da bi se smanjili udari i sile

UNUTRAŠNJA OBRADA

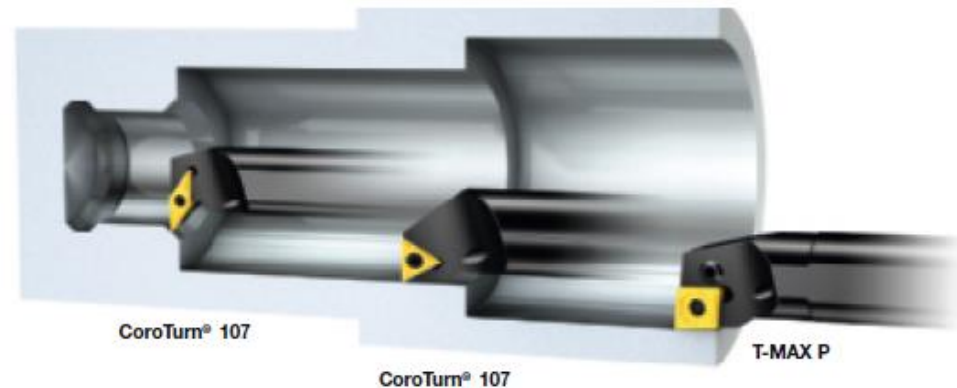


CoroTurn® 107

- Prvi izbor za unutrašnju obradu malih i srednjih otvora i u slučajevima dugačkih prepusta

T-MAX P

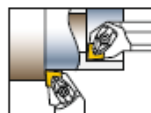
- Unutrašnja obrada velikih otvora sa kratkim prepustima alata u stabilnim uslovima.



Opšta pitanja za razmatranje

Koristiti napadni ugao manji od 90° ako je moguće da bi se smanjili udari i sile.

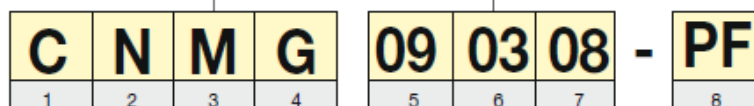
Koristićenje najvećih nosača i najmanjeg mogućeg prepusta za maksimalnu stabilnost.



Alati za struganje

Sistem označavanja za pločice i nosače alata
Izvod od ISO 1832—1991

PLOČICA



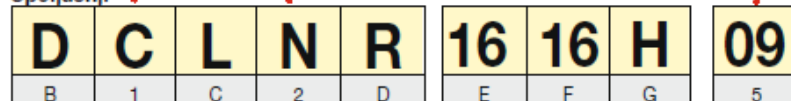
1. Oblik pločice

5. Veličina pločice = Dužina rezne ivice

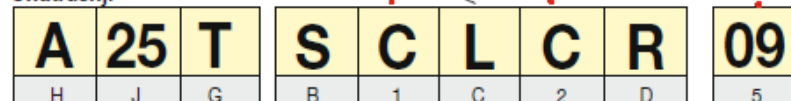
2. Leđni ugao pločice

NOSAČI ALATA

Spoljašnji

C3-
A

Unutrašnji



Prečnik nosača

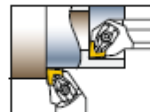
S = Nosač od punog čelika
A = Nosač sa otvorima za hlađenje

Tip nosača

Coromant Capto®
Veličina prihvata

Alati za struganje

Sistem označavanja za pločice i nosače alata
Izvod od ISO 1832—1991



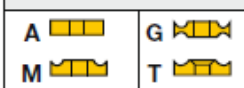
1. OBLIK PLOČICE



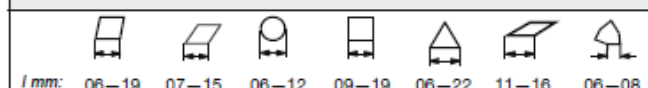
2. LEĐNI UGAO PLOČICE



4. TIP PLOČICE



5. VELIČINA PLOČICE = DUŽINA REZNE IVICE



7. RADIJUS VRHA PLOČICE

	04	$r_e = 0.4$	Prvi izbor radijusa vrha pločice:	
	08	$r_e = 0.8$	T-MAX P	CoroTurn 107
	12	$r_e = 1.2$	ZAVRŠNA	08
	16	$r_e = 1.6$	SREDNJA	08
	24	$r_e = 2.4$	GRUBA OBRADA	12
				08

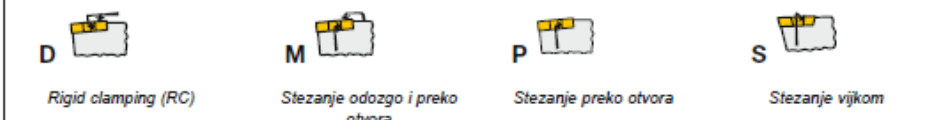
8. OZNAKA GEOMETRIJE - OPCJA PROIZVOĐAČA

Proizvođač može dodati dva simbola u kod opisujući geometriju pločice i sl.

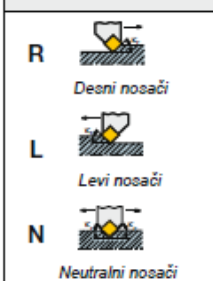
-PF = ISO P Završna obrada

-MR = ISO M Gruba obrada

B. SISTEM STEZANJA



D. ORJENTACIJA ALATA



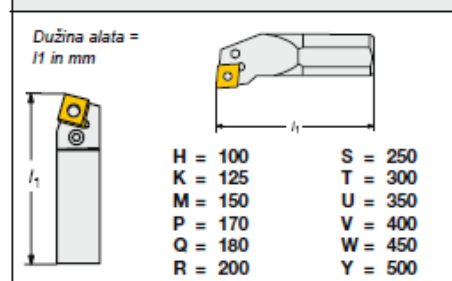
E. VISINA NOSAČA



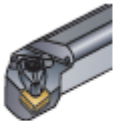









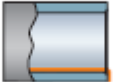

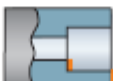
F. ŠIRINA ALATA



G. DUŽINA ALATA











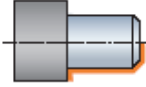
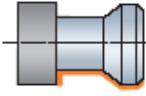

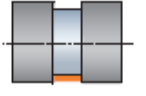
Preporuke za izbor drške alata i sistema stezanja kod unutrašnjeg struganja

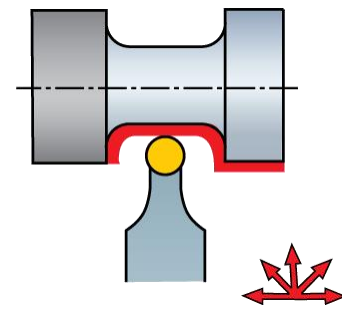
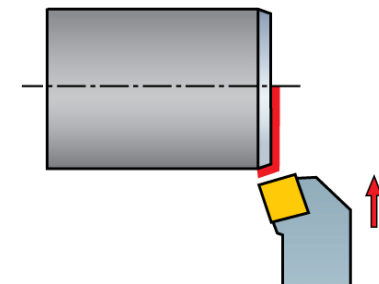
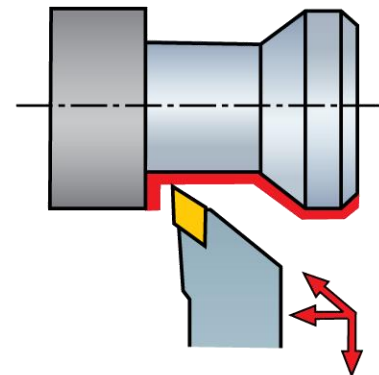
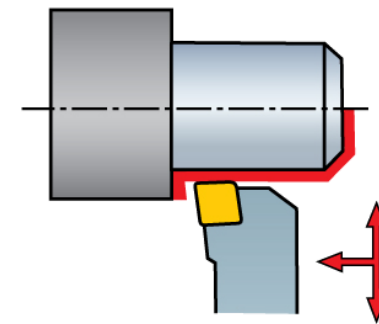
Tooling system	Negative inserts			Positive inserts		Ceramic and CBN inserts	
	CoroTurn RC	T-MAX P		CoroTurn 107	CoroTurn 111	T-MAX	
Clamping system	 Rigid clamp design 	 Lever clamp design 	 Wedge clamp design 	 Screw clamp design 		 Top clamp design 	
Operation	Longitudinal turning/ facing 	●●	●●	●	●●	●●	●
	Profiling 	●	●		●●	●●	
	Facing 	●	●		●●	●	●

●● = Recommended toolholder system

● = Alternative

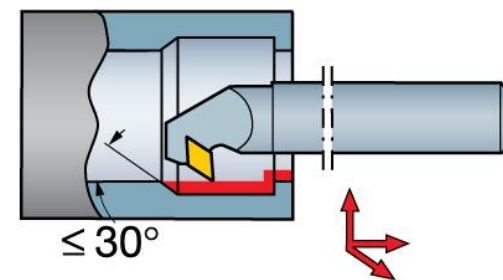
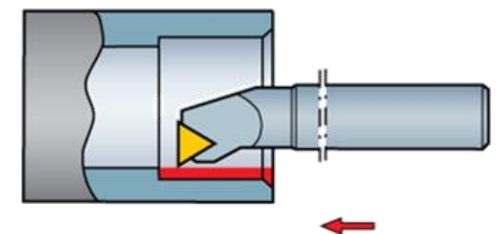
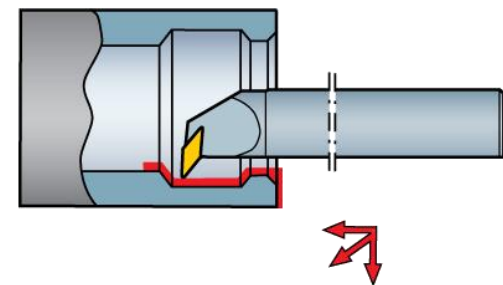
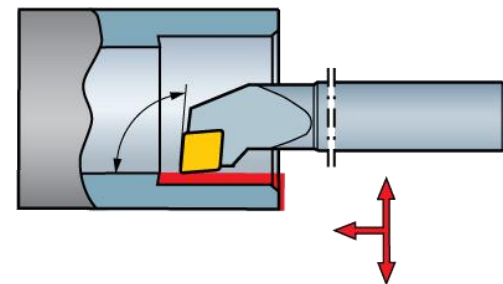
Preporuke za izbor vrste rezne pločice za spoljašnje struganje

Spoljašnje struganje	80°	55°	-	90°	60°	80°	35°	55°
								
	++	+	+	+	+	+		+
		++	+		+		+	+
	+	+	+	++	+	+		+
			++		+			



Preporuke za izbor vrste rezne pločice za unutrašnje struganje

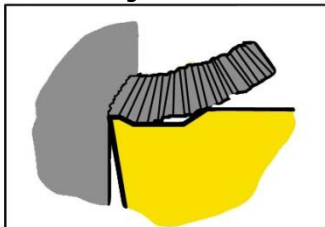
Unutrašnje strugane	80°	55°	-	90°	60°	80°	35°	
	+	+	+	+	++	+		
		++			+		+	
	++	+	+		+	+		



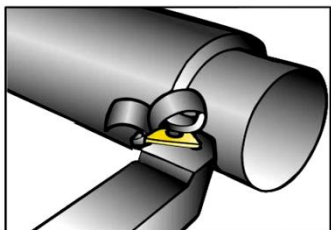
CoroKey[®] - Lako struganje

Lako za izbor. Lako za korišćenje.

Materijal

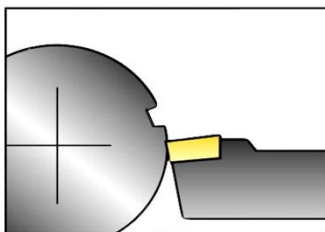


Oblast primene



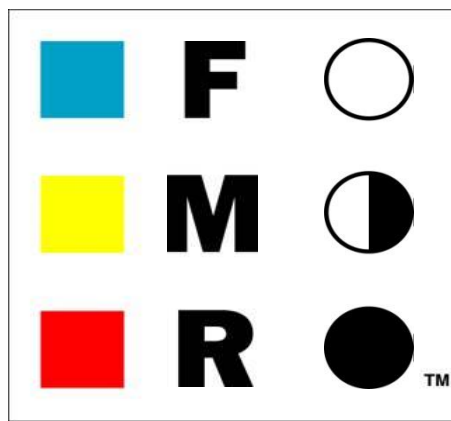
F-fina
M-srednja
R-gruba

Uslovi obrade



Dobri ○
 Prosečni ◐
 Teški ●

Materijal obrade
 Oblast primene
 Uslovi obrade

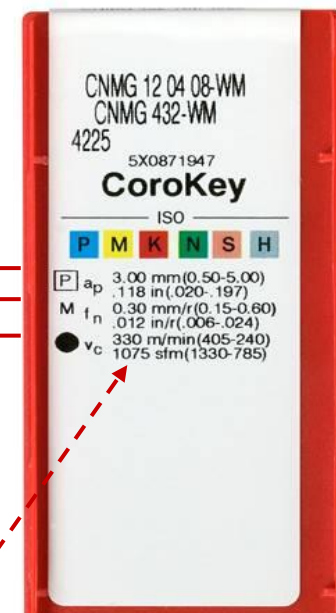


a_p Dubina rezanja (mm, inch)

f_n Pomak (mm/obr)

v_c Brzina rezanja (m/min)

Režimi obrade za rezu pločicu. Startna vrednost i područje primene.



Kompenzacija brzine rezanja usled razlike u tvrdoći materijala

◆ Postojanost

- Svi režimi obrade su dati za postojanost $T=15$ min
- 15 min tool life = Factor 1.0
- Za ostale vrednosti T se koristi korekcionni faktor

◆ Tvrdoća

- Svi režimi obrade su dati na osnovu referentne tvrdoće
- E.g ISO P HB 180 = Factor 1.0
- Za ostale vrednosti tvrdoće materijala koristiti korekcionni faktor

Higher metal removal

If you want to change the cutting speed to obtain higher metal removal rates the new cutting speed values can be calculated from the following table.

Tool life (Mins.)	10	15	20	25	30	45	60
Correction factor	1,11	1,0	0,93	0,88	0,84	0,75	0,70

Example: If the recommended cutting speed (v_c) = 225 m/min. a tool life of 10 minutes gives you $225 \times 1,11 \approx 250$ m/min

ISO/ ANSI	CMC ⁽¹⁾	HB ⁽²⁾	Reduced hardness				Increased hardness				
			-60	-40	-20	0	+20	+40	+60	+80	+100
P	02.1	HB ⁽²⁾ 180	1,44	1,25	1,11	1,0	0,91	0,84	0,77	0,72	0,67
M	05.21	HB ⁽²⁾ 180	1,42	1,24	1,11	1,0	0,91	0,84	0,78	0,73	0,68
K	08.2	HB ⁽²⁾ 220	1,21	1,13	1,06	1,0	0,95	0,90	0,86	0,82	0,79
	09.2	HB ⁽²⁾ 250	1,33	1,21	1,09	1,0	0,91	0,84	0,75	0,70	0,65
N	30.21	HB ⁽²⁾ 75				1,05	1,0	0,95			
S	20.22	HB ⁽²⁾ 350				1,12	1,0	0,89			
H	04.1	HRC ⁽³⁾ 60				1,07	1,0	0,97			

Primer kompenzacije brzine rezanja od tvrdoće materijala obradka

♦ M.O Čelik ISO P 02.1

- Reference hardness HB= 180
- 15 min postojanost = Faktor 1.0
- Use correction factor for other values according to the table

♦ Materijal obradka

- DIN 42CrNiMo4
- Zatezna čvrstoća 900N/mm²
- 900N/mm² = HB 266
- vrednost prikazana u tabeli

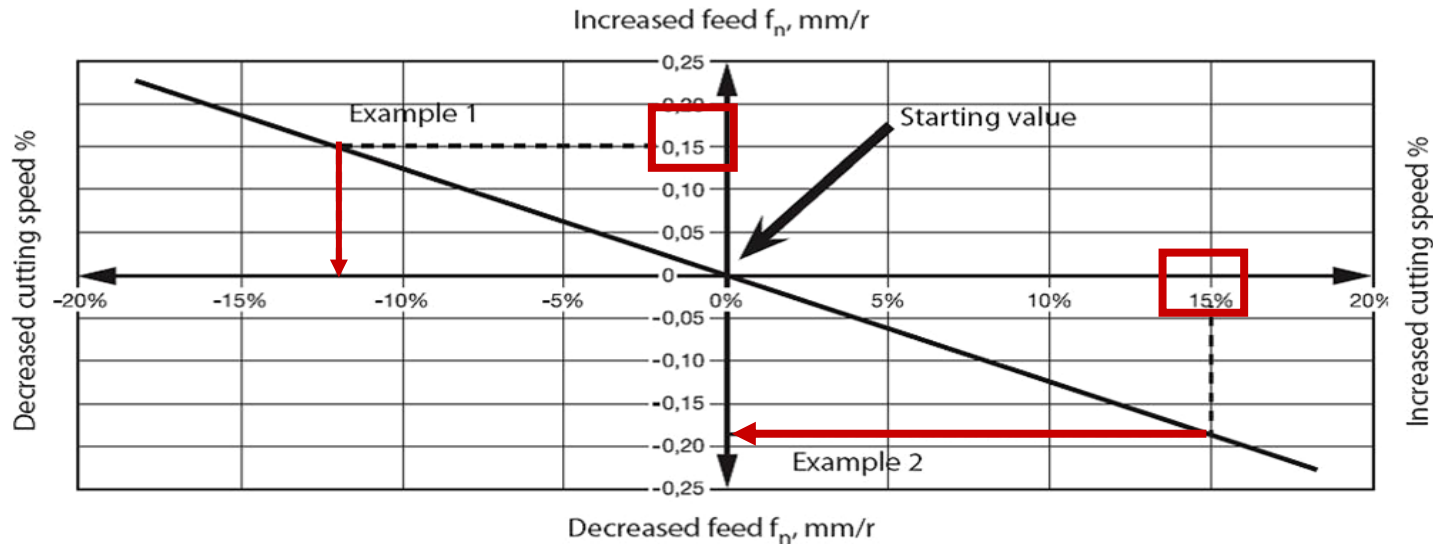
♦ Faktor korekcije za tvrdoću

- HB 266-180 = +86
- Faktor korekcije brzine $v_c = 0.70$
- Redukcija brzine za 70%

ISO/ ANSI	CMC ¹⁾	HB ²⁾	← Reduced hardness					Increased hardness →				
			-60	-40	-20	0	+20	+40	+60	+80	+100	
P	02.1	HB ²⁾ 180	1,44	1,25	1,11	1,0	0,91	0,84	0,77	0,72	0,67	
M	05.21	HB ²⁾ 180	1,42	1,24	1,11	1,0	0,91	0,84	0,78	0,73	0,68	
K	08.2	HB ²⁾ 220	1,21	1,13	1,06	1,0	0,95	0,90	0,86	0,82	0,79	
	09.2	HB ²⁾ 250	1,33	1,21	1,09	1,0	0,91	0,84	0,75	0,70	0,65	
N	30.21	HB ²⁾ 75				1,0	0,95					
S	20.22	HB ²⁾ 350				1,0	0,89					
H	04.1	HRC ³⁾ 60				1,0	0,97					

Tensile strength N/mm ²	Vickers HV	Brinell HB	Rockwell	
			HRC	HRB
255	80	76.0	-	-
270	85	80.7	-	41.0
285	90	85.5	-	48.0
305	95	90.2	-	52.0
320	100	95.0	-	56.2
350	110	105	-	62.3
385	120	114	-	66.7
415	130	124	-	71.2
450	140	133	-	75.0
480	150	143	-	78.7
510	160	152	-	81.7
545	170	162	-	85.0
575	180	171	-	87.5
610	190	181	-	89.5
640	200	190	-	91.5
660	205	195	-	92.5
675	210	199	-	93.5
690	215	204	-	94.0
705	220	209	-	95.0
720	225	214	-	96.0
740	230	219	-	96.7
770	240	228	20.3	98.1
800	250	238	22.2	99.5
820	255	242	23.1	-
835	260	247	24.0	(101)
850	265	252	24.8	-
865	270	257	25.6	(102)
900	280	266	27.1	-
930	290	276	28.5	(105)
950	295	280	29.2	-
965	300	285	29.8	-
995	310	295	31.0	-

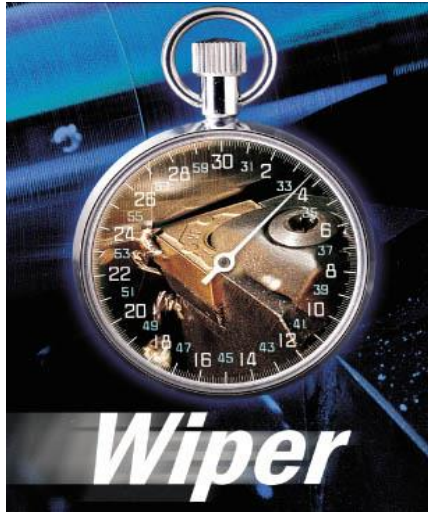
Kompensacija brzine rezanja i pomaka kod struganja



- ◆ Kako se vrši kompensacija režima obrade
 - Preporučeni režimi obrade su bazirani za postojanost $T=15$ min
- ◆ Primer 1
 - Povećanje pomaka $f_n=0.3$ mm/rev na 0.45 mm/rev = $+0.15$ mm/r
 - Rezultira smanjenjem brzine rezanja za 12% od preporučene vrednosti
- ◆ Primer 2
 - Povećanje brzine za +15% sa 345 m/min na 400 m/min
 - Rezultira smanjenjem pomaka za 0.18 mm/r od preporučene vrednosti

Wiper tehnologija

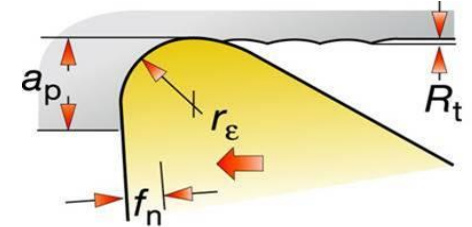
Zašto koristiti Wiper?



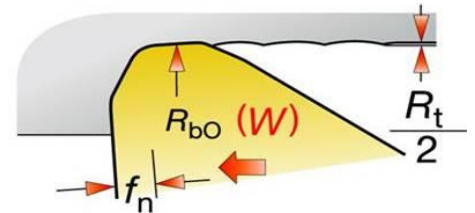
Prepolovite vaše vreme proizvodnje korišćenjem Wiper pločica

- Wiper pločice kombinuju odličnu ekonomičnost mašinske obrade sa visokim kvalitetom obrađene površine

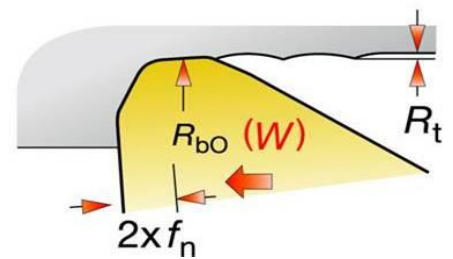
Standardni radijus



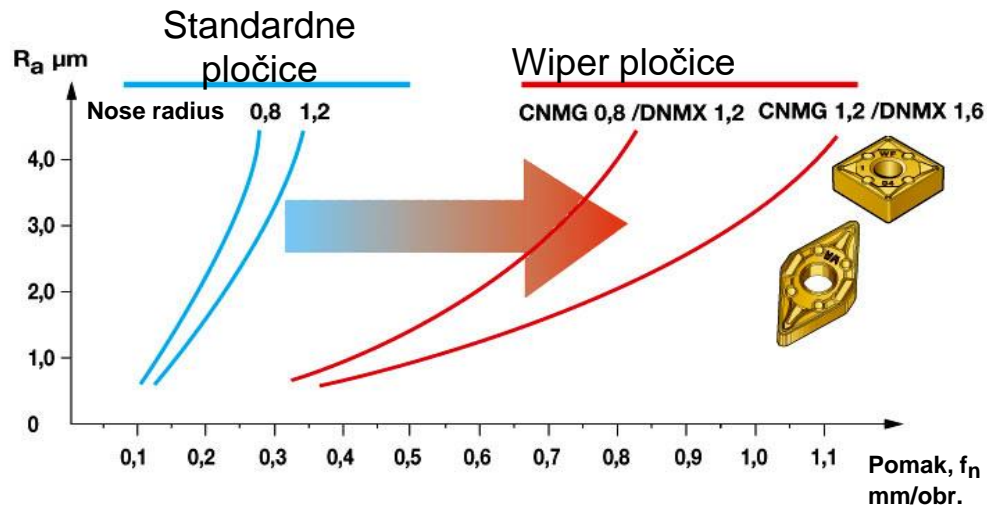
Wiper radijus
isti pomak



Wiper radijus
Dva puta veći pomak

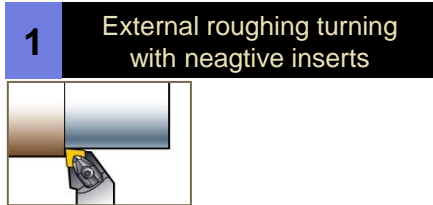


Kvalitet obr.
površine



1. Correct answer: Turning

External roughing turning with negative inserts



Tools and cutting data

Material: 42CrMo4 (DIN)

Hardness: HB 220

Steel  CMC = 02.1

Toolholder: **DCLNR 2525M 12 alt. Coromant Capto® C4**

Insert: **CNMG 120412**

Geometry: **-PR**

Grade: **GC4225**

Cutting depth (a_p): **4.0 mm**

Number of passes: **2**

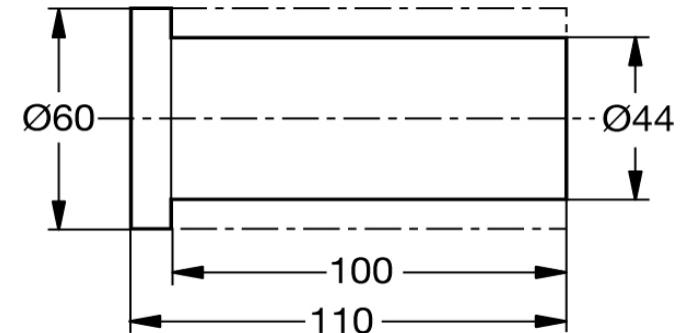
Feed (f_n): **0.4 mm/rev**

Cutting speed (v_c): **305 m/min**

Hardness compensating factor: **0.84**

Hardness compensated cutting speed (v_c): **256 m/min**

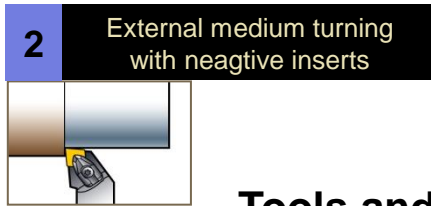
Revolution (n) **1567 rev/min (calculate on dia 52 mm)**



For video, click on picture above

2. Correct answer: Turning

External medium turning with negative inserts



Material: 42CrMo4 (DIN)

Hardness: HB 220

Steel **P** CMC = 02.1

Tools and cutting data

Toolholder: **DCLNR 2525M 12 alt. Coromant Capto® C4**

Insert: **CNMG 120408**

Geometry: **-PM**

Grade: **GC4225**

Cutting depth (a_p): **3.0 mm**

Number of passes: **1**

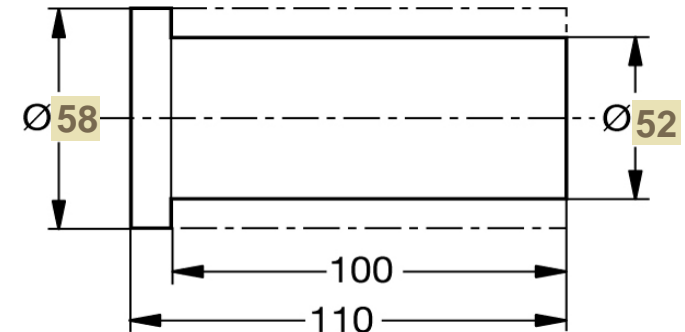
Feed (f_n): **0.3 mm/rev**

Cutting speed (v_c): **345 m/min**

Hardness compensating factor: **0.84**

Hardness compensated cutting speed (v_c): **290 m/min**

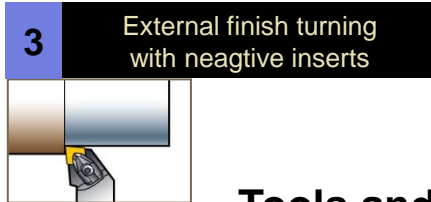
Revolution (n) **1775 rev/min (calculate on dia 52 mm)**



For video, click on picture above

3. Correct answer: Turning

External finish turning with negative inserts



Tools and cutting data

Material: 42CrMo4 (DIN)

Hardness: HB 220

Steel **P** CMC = **02.1**

Toolholder: **DCLNR 2525M 12 alt. Coromant Capto® C4**

Insert: **CNMG 120404**

Geometry: **-PF**

Grade: **GC4215**

Cutting depth (a_p): **0.4 mm**

Number of passes: **1**

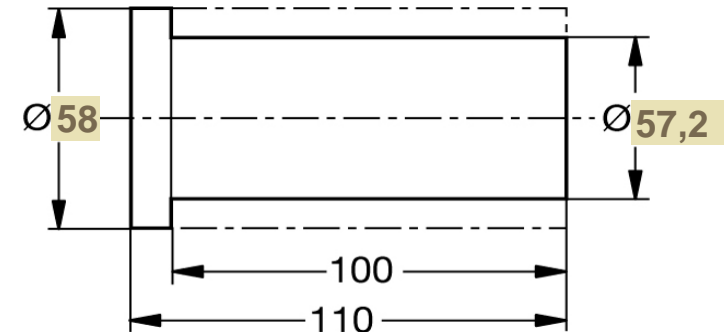
Feed (f_n): **0.15 mm/rev**

Cutting speed (v_c): **515 m/min**

Hardness compensating factor: **0.84**

Hardness compensated cutting speed (v_c): **433 m/min**

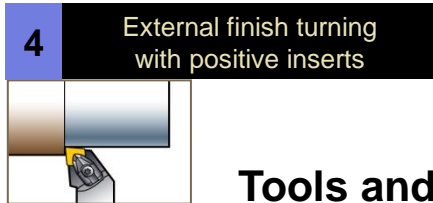
Revolution (n) **2420 rev/min (calculate on dia 57 mm)**



For video, click on picture above

4. Correct answer: Turning

External finish turning with positive inserts



Tools and cutting data

Material: 2350 (SS)

Hardness: HB 200

Stainless steel **M** CMC = **05.21**

Toolholder: **SCLCR 2020K 09 alt. Coromant Capto® C4**

Insert: **CCMT 09T304**

Geometry: **-MF**

Grade: **GC2015**

Cutting depth (a_p): **0.4 mm**

Number of passes: **1**

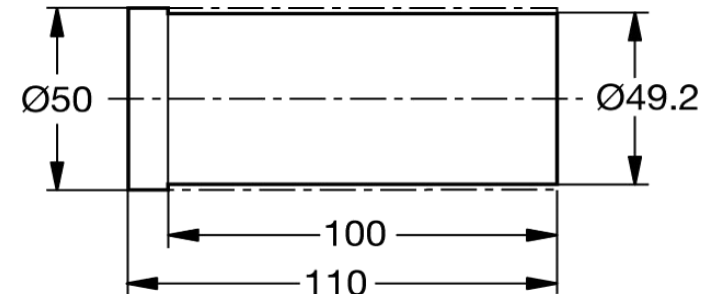
Feed (f_n): **0.11 mm/rev**

Cutting speed (v_c): **290 m/min**

Hardness compensating factor: **0.91**

Hardness compensated cutting speed (v_c): **264 m/min**

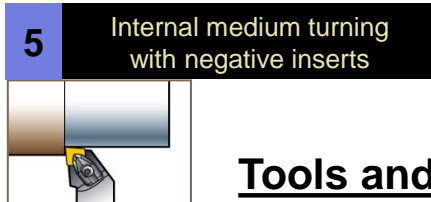
Revolution (n) **1715 rev/min (calculate on dia 49 mm)**



For video, click on picture above

5. Correct answer: Turning

Internal medium turning with negative inserts



Material: 42CrMo4 (DIN)

Hardness: HB 220

Steel



CMC = 02.1

Tools and cutting data

Toolholder: **S25T-PCLNR 12 alt. Coromant Capto® C4**

Insert: **CNMG 120408**

Geometry: **-PM**

Grade: **GC4225**

Cutting depth (a_p): **3.0 mm**

Number of passes: **1**

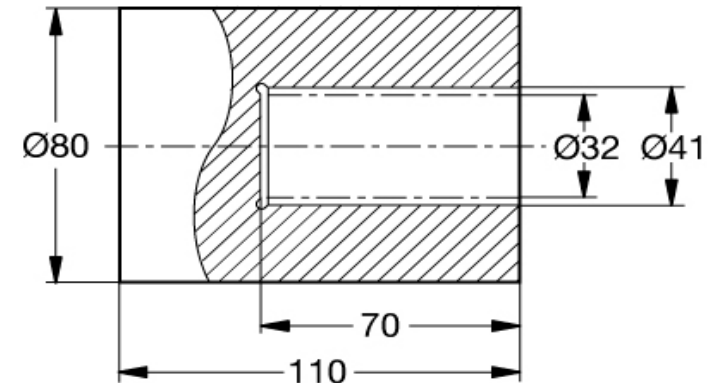
Feed (f_n): **0.3 mm/rev**

Cutting speed (v_c): **345 m/min**

Hardness compensating factor: **0.84**

Hardness compensated cutting speed (v_c): **290 m/min**

Revolution (n) **2637 rev/min (calculate on dia 35 mm)**

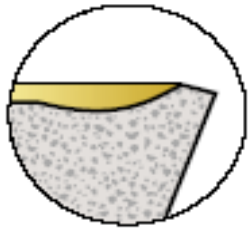


For video, click on picture above

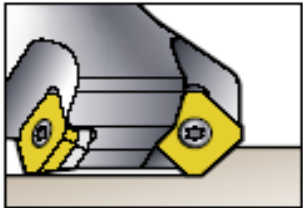
CoroKey[®] - Lako glodanje

Lako za izbor. Lako za korišćenje

Materijal

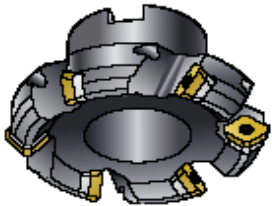


Oblast primene



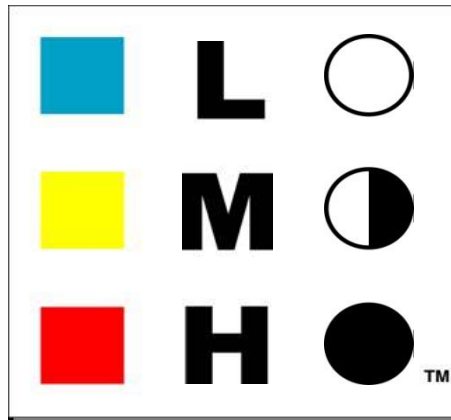
L- laka
M- srednja
H- teška

Uslovi obrade



Dobri ○
 Prosečni ◐
 Teški ●

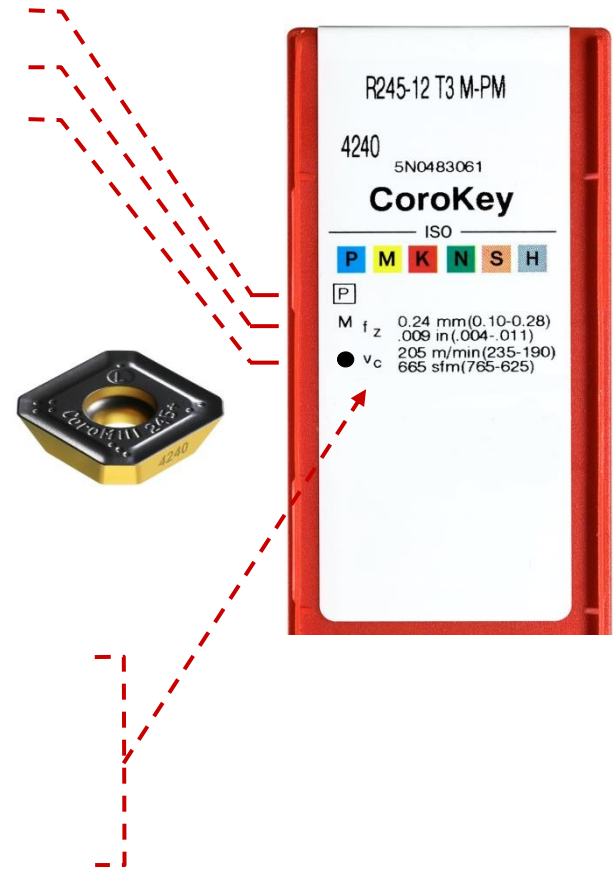
Materijal obradka
 Oblast primene
 Uslovi obrade



f_z Pomak/zubu
 (mm)

v_c Brzina rezanja
 (m/min)

Režimi obrade za reznu pločicu. Startne vrednosti.



CoroMill® pločice za glodanje

Geometrija

