100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

OBLIKOVANJE DEFORMIRANJEM
I
OBRADA ODVAJANJEM

Četvrto predavanje 2018/2019

FSB 100

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu

100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

Teme dosadašnjih predavanja

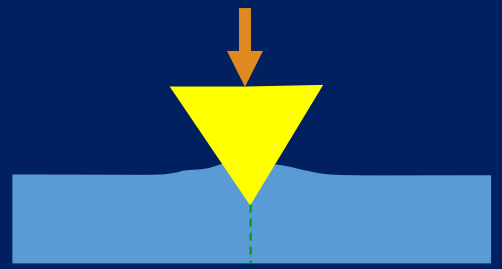
Definicija, značaj i podjela proizvodnje
Prednosti i nedostaci obrade odvajanjem
OOČ kao sustav
Postupci obrade odvajanjem čestica (DIN8580)
Gibanja
Rezni alat (osnovni oblik, materijali, prevlake, ..)
Geometrija reznoga dijela alata i sustavi ravnina
Teorija rezanja
    Formiranje odvojene čestice
    „Card” model

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

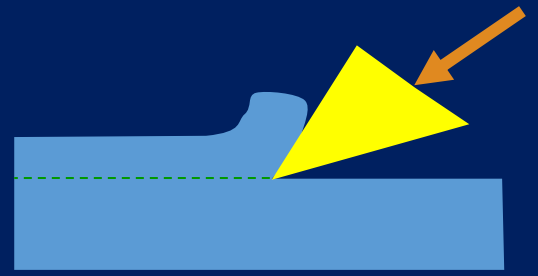
Alat- sredstvo za ooč (sredstvo za preoblikovanje pripremka (sirovca).

Osnovni oblik svih reznih alata s oštricom je klin.

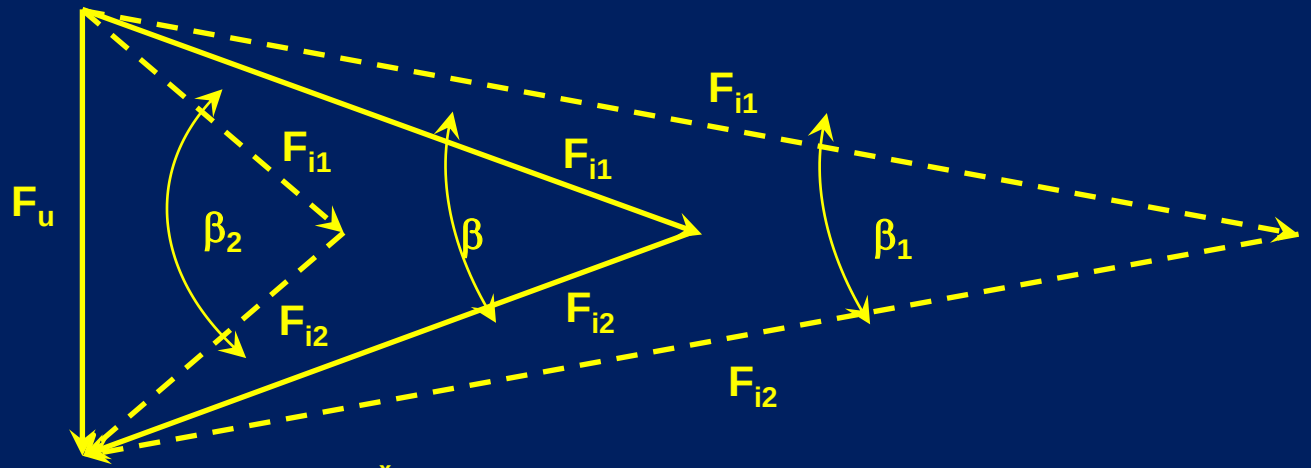
Obzirom na smjer gibanja klina razlikuje se razdvajanje i odvajanje.



Razdvajanje (sječenje)

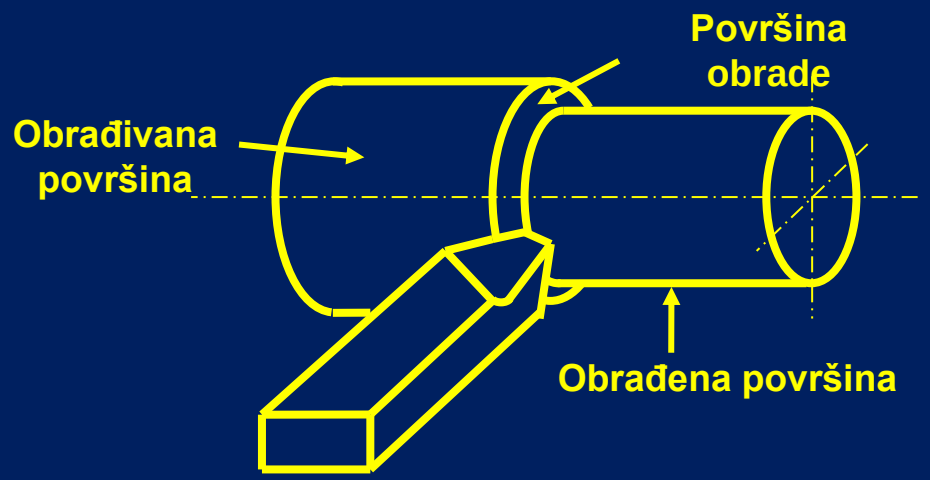


Odvajanje (rezanje)



Alat i obradak u gibanju – tokarski nož

Površine na obratku



Geometrijski elementi na reznom dijelu alata

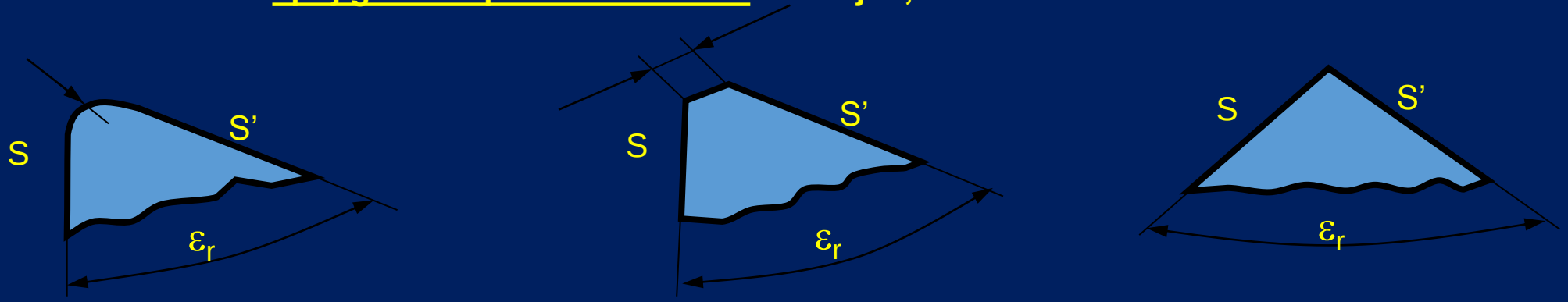
A_γ - prednja površina

A_α - stražnja površina

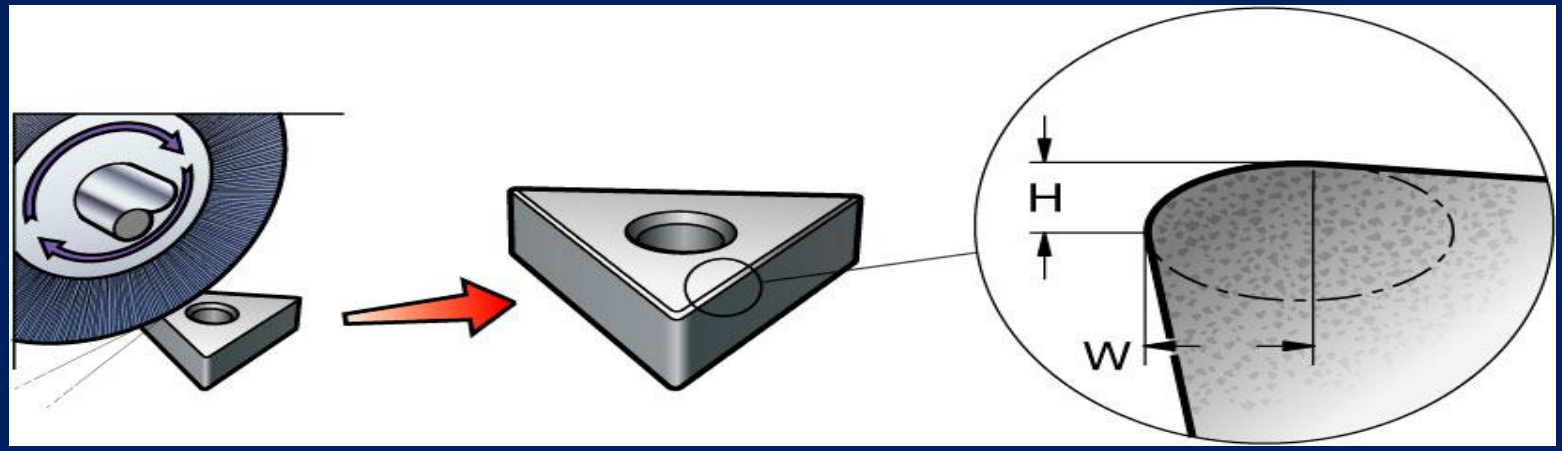
S - glavna oštrica

S' - pomoćna oštrica

Vrh alata - spoj glavne i pomoćne oštrice: zaobljen, skošen i oštar.



Oštrica alata - spoj prednje i stražnje površine alata
kao i vrh alata, najčešće je zaobljena ili ima skošenje (u μm)



Tehnološki (geometrijski) kutovi

a) za orjentaciju prednje i stražnje površine (mogu se mjeriti u više ravnina pa ovisno o tome imaju odgovarajući indeks)

γ – **prednji kut (kut prednje površine)** - kut između $A\gamma$ i P_r;

β – **kut klina** – kut između $A\gamma$ i $A\alpha$;

α – **stražnji kut (kut stražnje površine)** – kut između A_α i P_s;

Za kutove vrijedi izraz: $\alpha_x + \beta_x + \gamma_x = 90°$

b) kutovi za orjentaciju rezne oštrice

κ_r – **kut namještanja glavne oštrice** – mjeri se između ravnina P_s i P_f, a u ravnini P_r

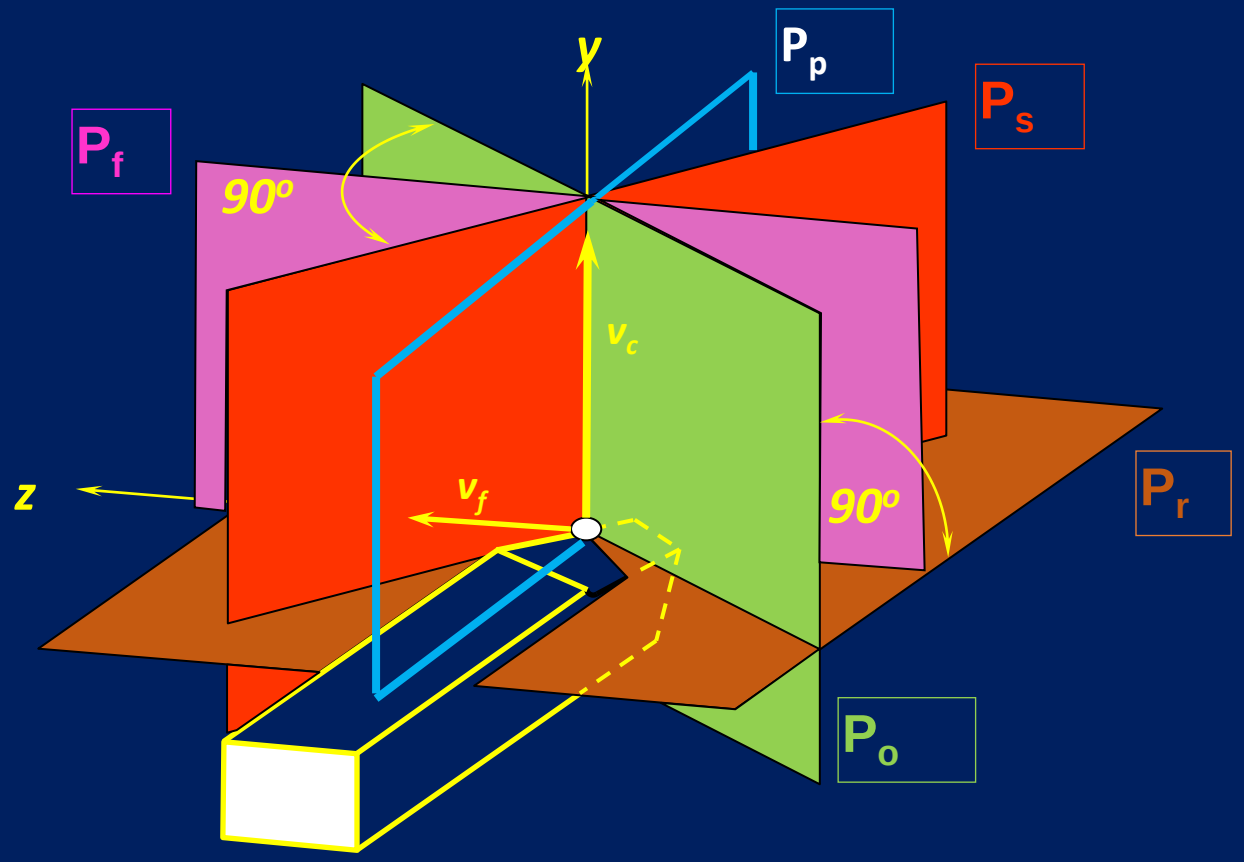
κ_r' – **kut namještanja pomoćne oštrice** – mjeri se između ravnina $P_{s'}$ i P_f, a u ravnini P_r

ε_r – **vršni kut alata** – mjeri se između P_s i $P_{s'}$, a u ravnini P_r

Za kutove vrijedi izraz: $\kappa_r + \kappa_r' + \varepsilon_r = 180°$;

λ_s - **kut nagiba glavne oštrice** – mjeri se između oštrice i ravnine P_r, a u ravnini P_s

Tehnološki koordinatni sustav



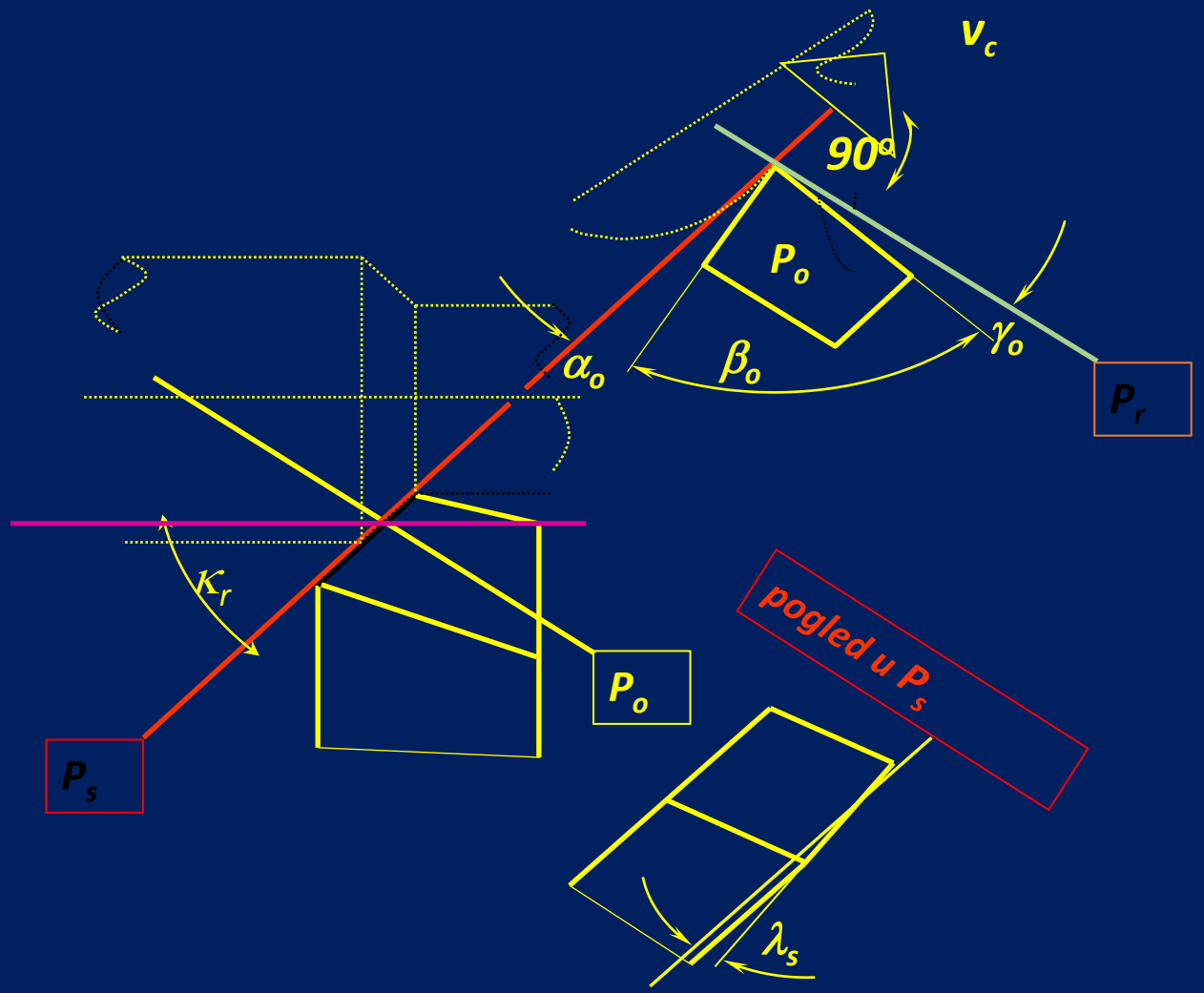
P_r - osnovna ravnina: okomita na v_c u promatranoj točki oštrice i okomita ili paralelna na neku površinu ili os alata, bitnu za izradu, oštrenje ili kontrolu alata

P_s - ravnina rezanja: okomita na P_r i paralelna s tangentom na oštricu u promatranoj točki štrice

P_f - ravnina kretanja: okomita na P_r i paralelna s pravcem posmičnog gibanja u promatranoj točki oštrice

P_o - ortogonalna ravnina: okomita na P_r i P_s

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb



A_γ ?

A_α ?

općenito:

$\alpha + \beta + \gamma = 90^o$

$\kappa_r + \kappa_r' + \varepsilon_r = 180°$;

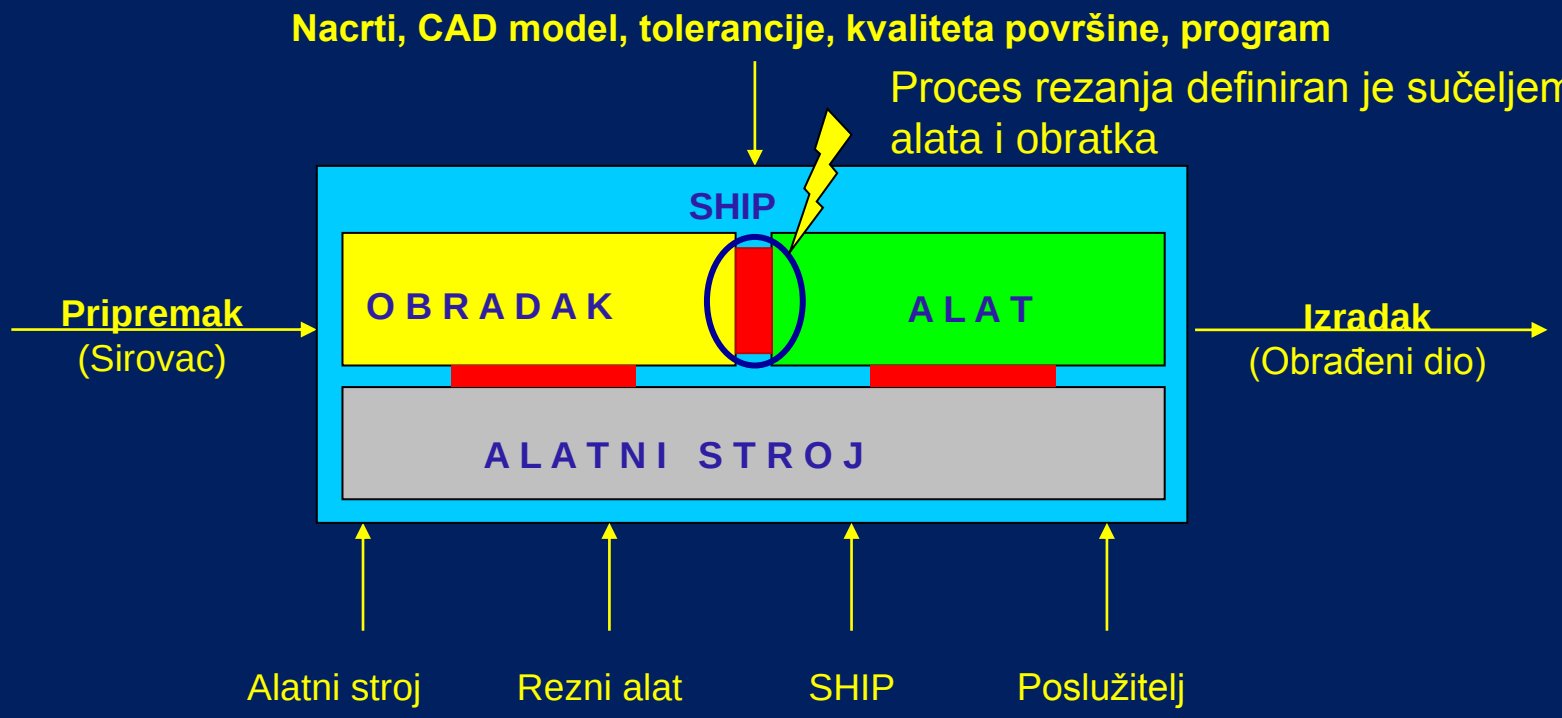
kut	mjeri se između	u ravnini
napadni kut κ_r	P_s i P_f	P_r
kut vrha alata ε_r	P_s i P_s'	P_r
kut nagiba oštrice λ_s	P_r i s	P_s
prednji kut γ_0	A_γ i P_r	P_0
kut klina β_0	A_γ i A_α	P_0
stražnji kut α_0	P_s i A_α	P_0

Prepoznavanje osnovnih geometrijskih parametara kod složenijih alata (svrdla, glodala)

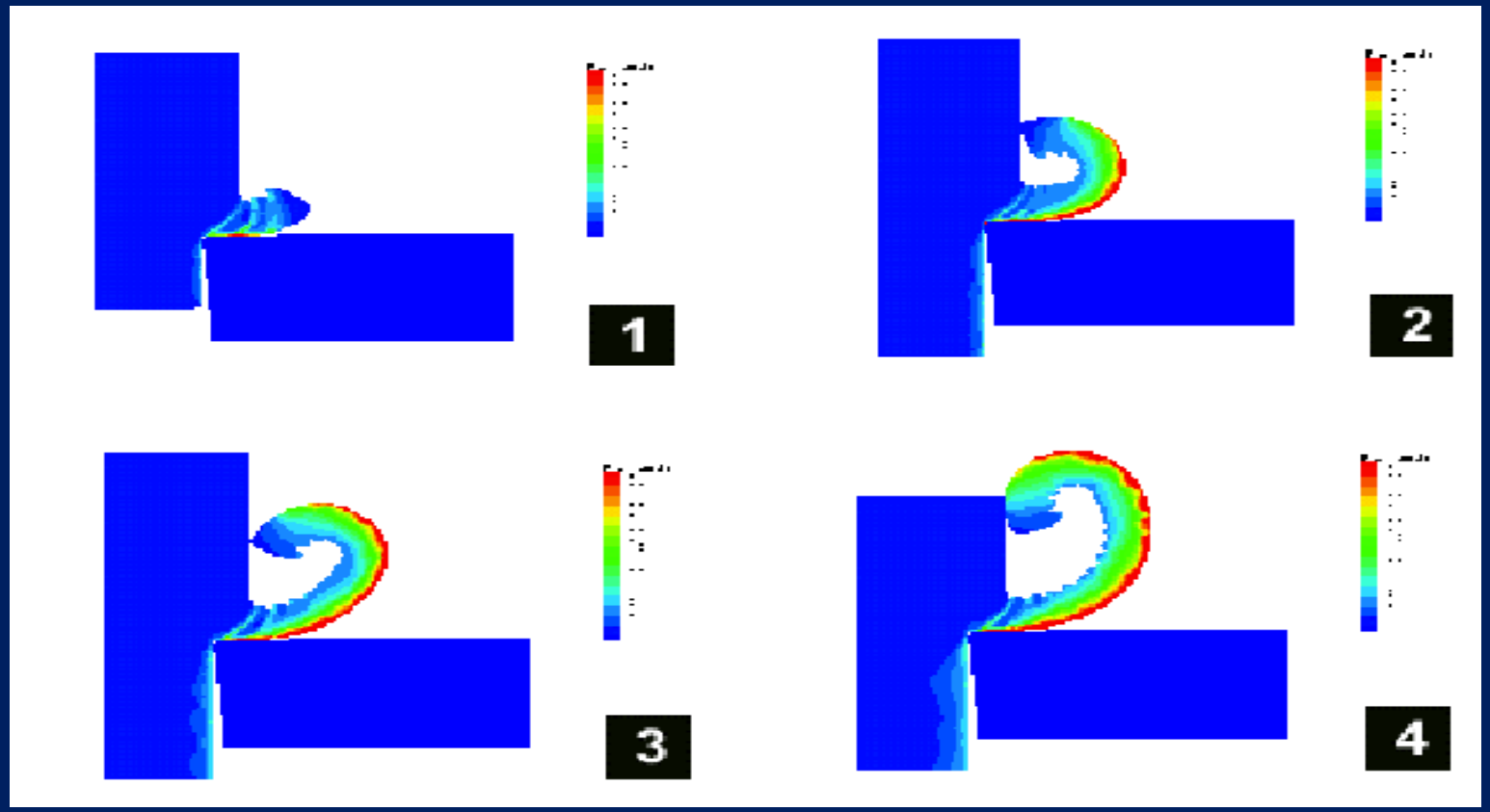
100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

Teorija rezanja

Teorija rezanja je znanstvena disciplina kojom se nastoji objasniti utjecaj uvjeta obrade na tijek formiranja odovojene čestice, sile, naprezanja i deformacije koje se javljaju pri obradi.

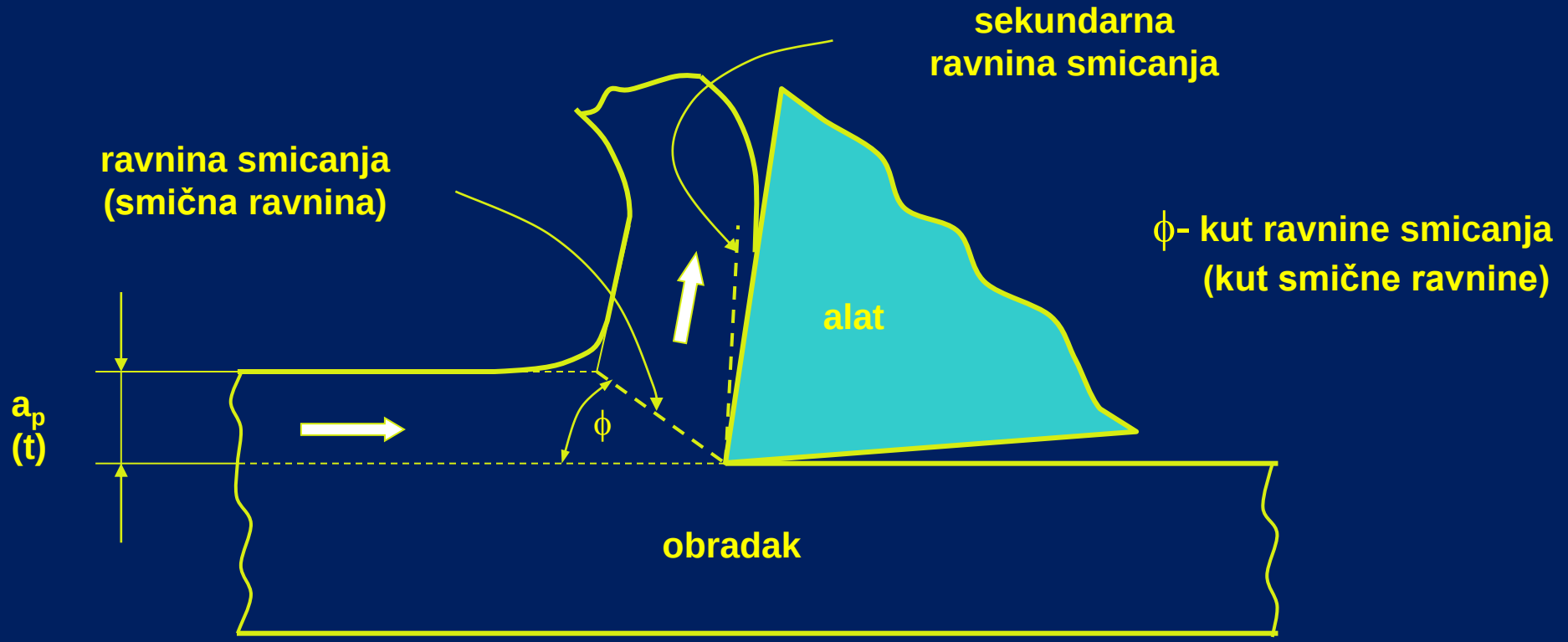


Formiranje odvojene čestice - simulacija



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

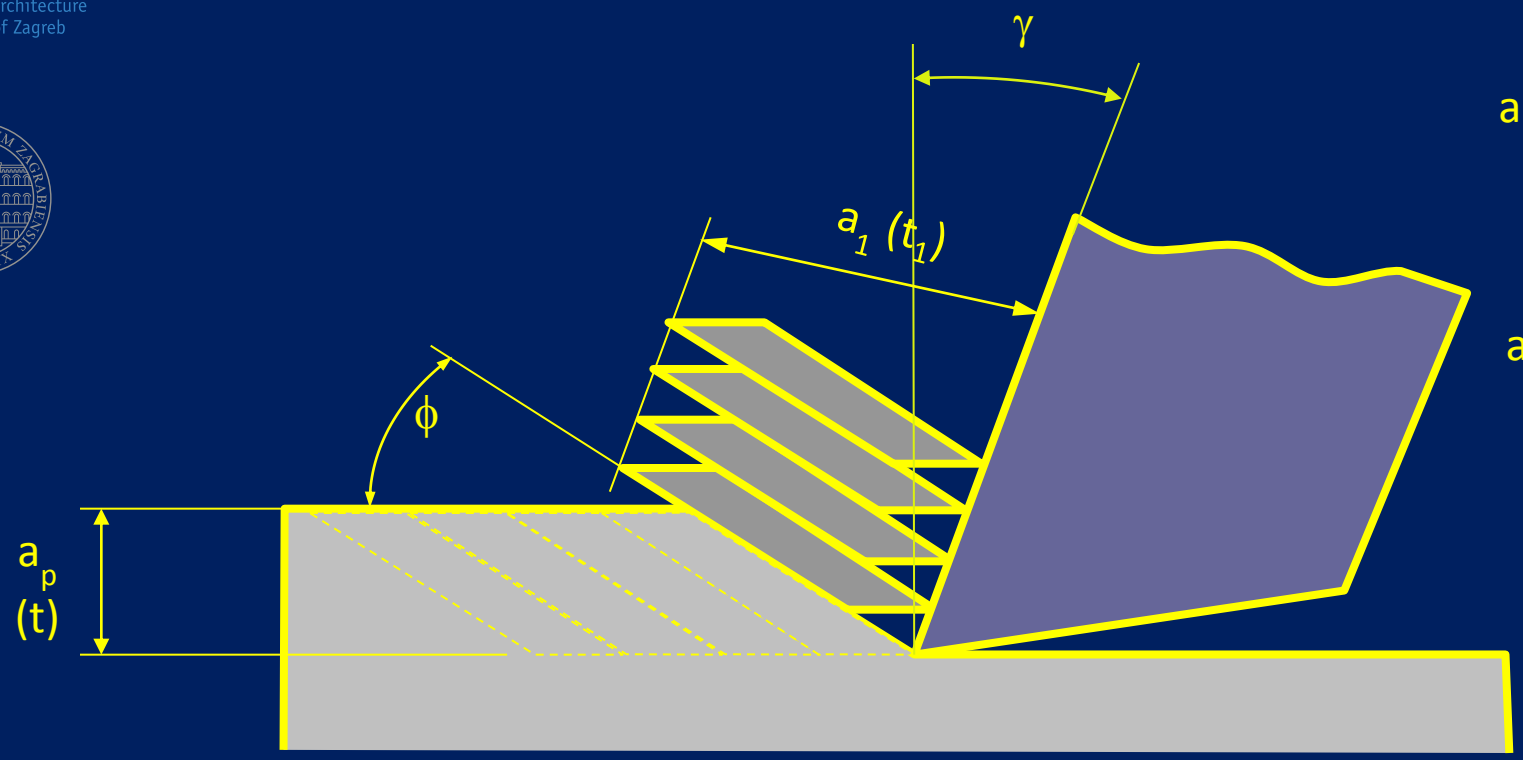
Plastična deformacija i formiranje odvojene čestice – ravninski prikaz



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model"

"Card model" - model elementarnih lamela i jedne smične ravnine



a_p - dubina obrade (dubina rezanja)
(debljina nedeformiranog sloja)

a_1 - debljina odvojene čestice

Često se umjesto oznaka

a_p i a_1,

u literaturi koriste oznake

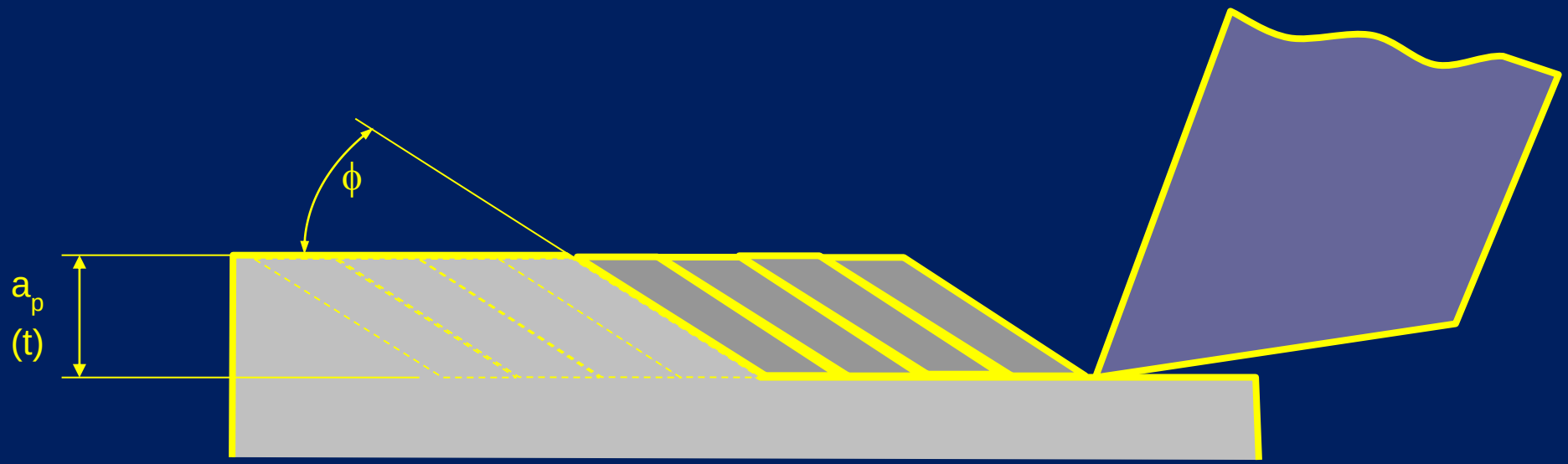
t i t_1

t – debljina (thickness)

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model" – model elementarnih lamela

a_p - dubina obrade
(debljina nedeformiranog sloja)

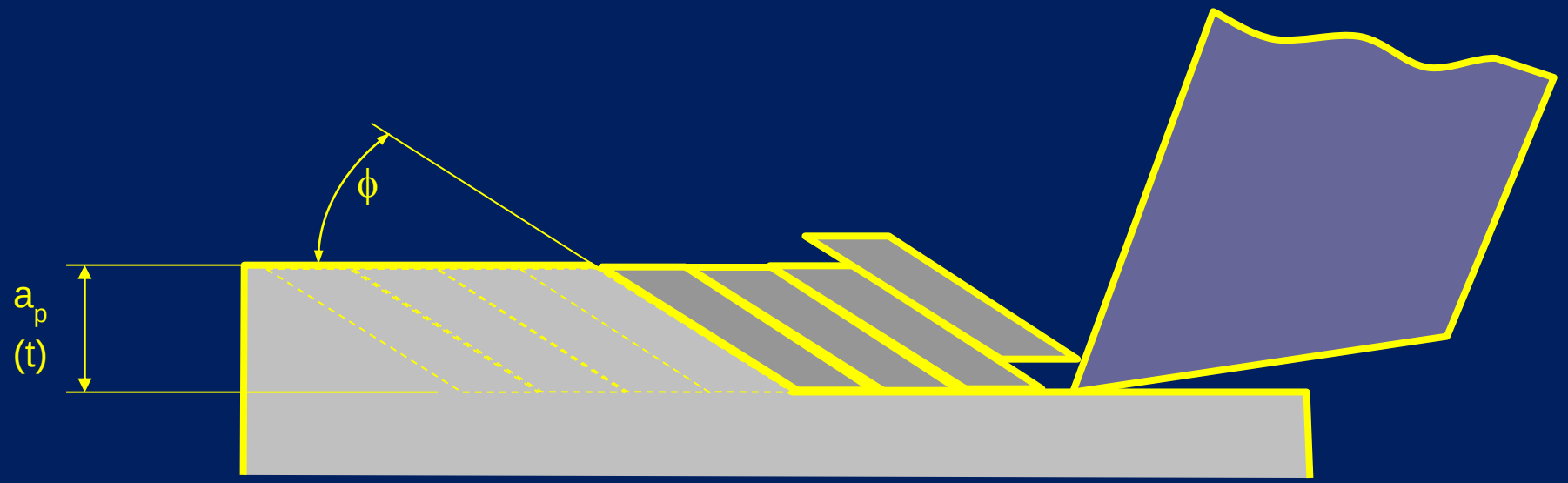


Kako u primjeni ostvariti, ili se što više približiti ortogonalnom rezanju ?

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model" – model elementarnih lamela

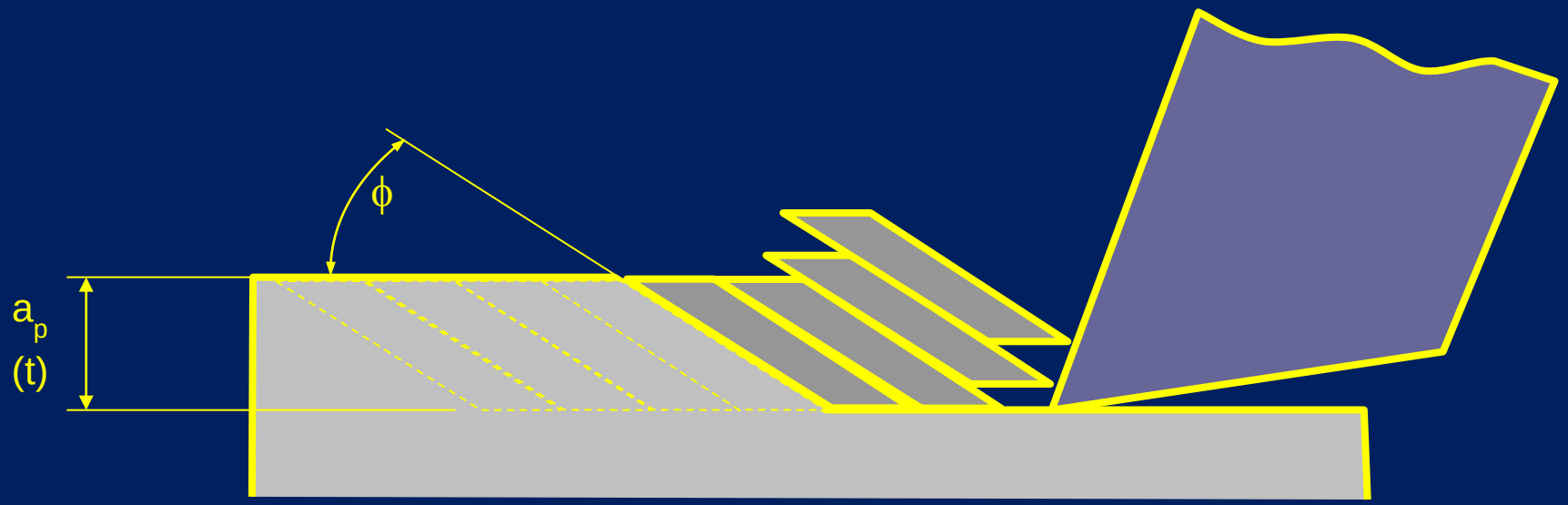
a_p - dubina obrade
(debljina nedeformiranog sloja)



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model" – model elementarnih lamela

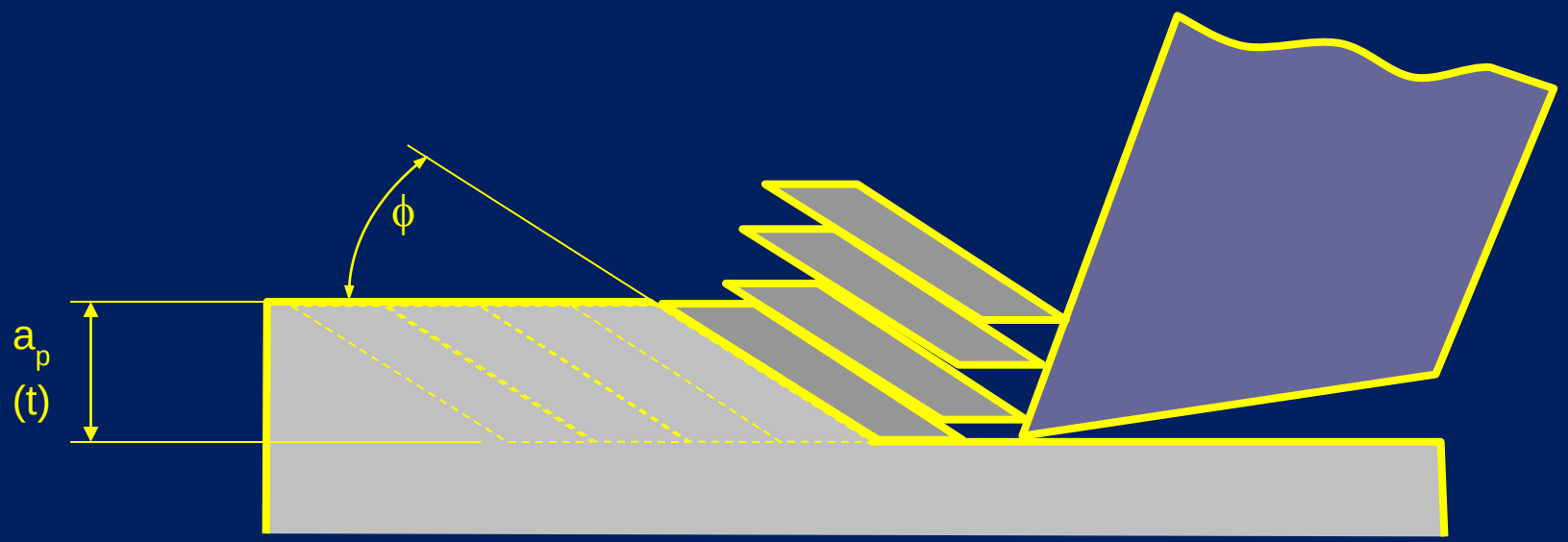
a_p - dubina obrade
(debljina nedeformiranog sloja)



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model" – model elementarnih lamela

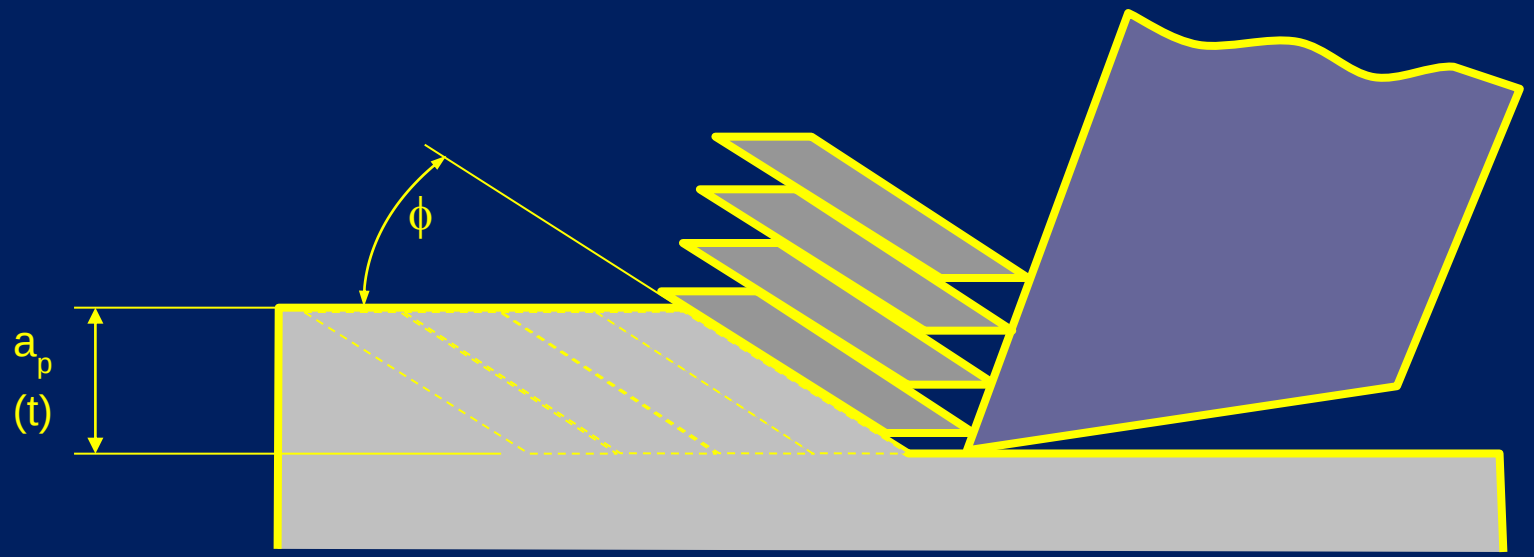
a_p - dubina obrade
(debljina nedeformiranog sloja)



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model" – model elementarnih lamela

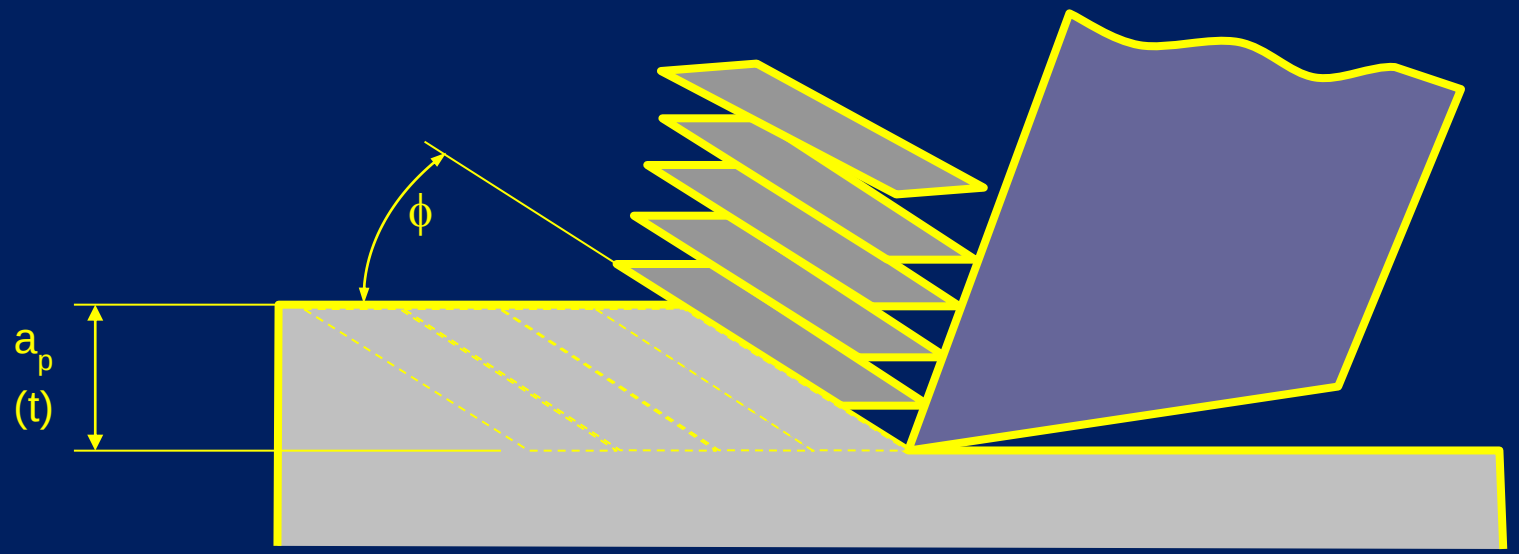
a_p - dubina obrade
(debljina nedeformiranog sloja)



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model" – model elementarnih lamela

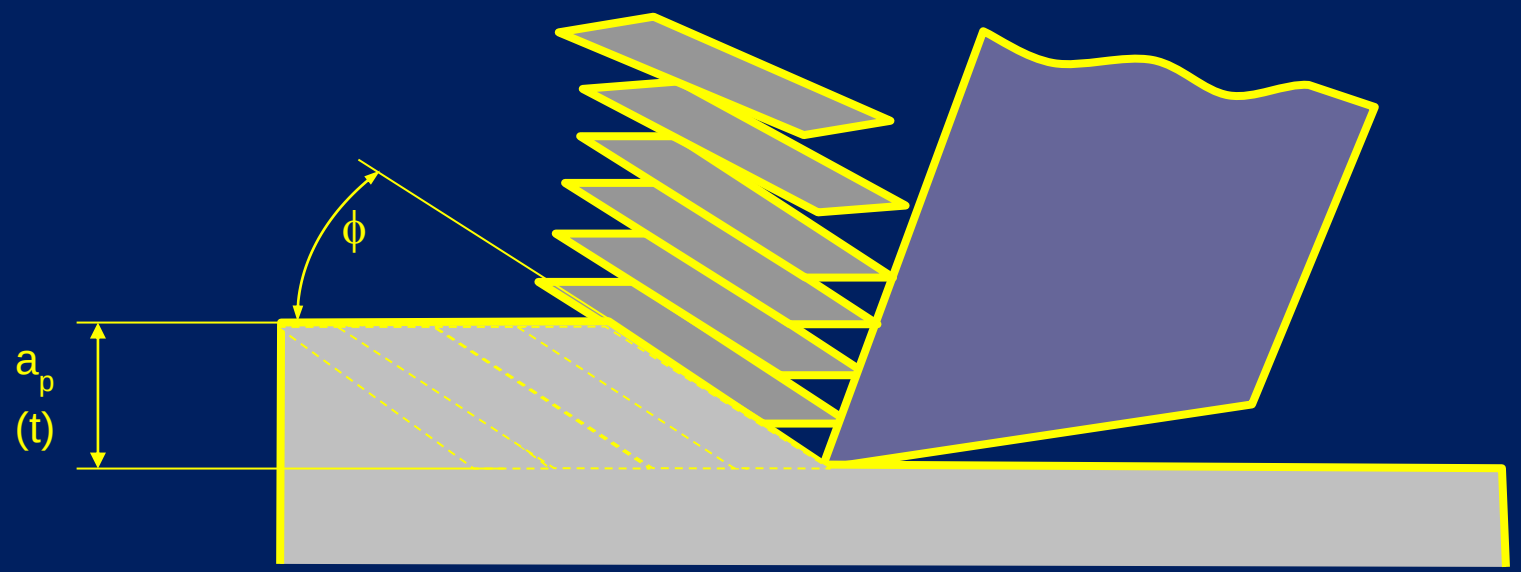
a_p - dubina obrade
(debljina nedeformiranog sloja)



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

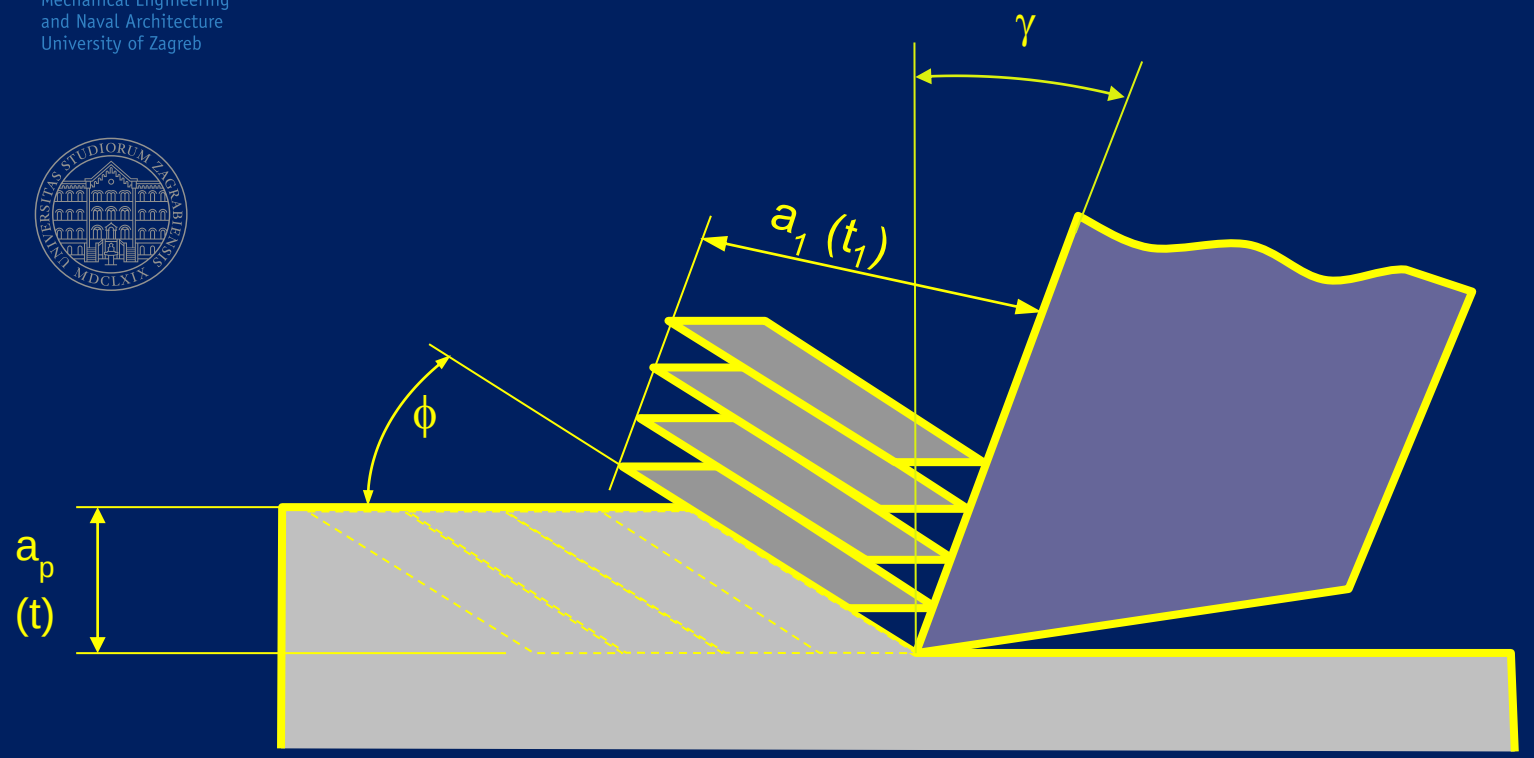
"Card model" – model elementarnih lamela

a_p - dubina obrade
(debljina nedeformiranog sloja)



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

"Card model" – model elementarnih lamela



a_p (t) - dubina obrade (dubina rezanja, debljina odvajanog sloja ili debljina nedeformriane čestice)

a_p (t_1) - debljina odvojene čestice

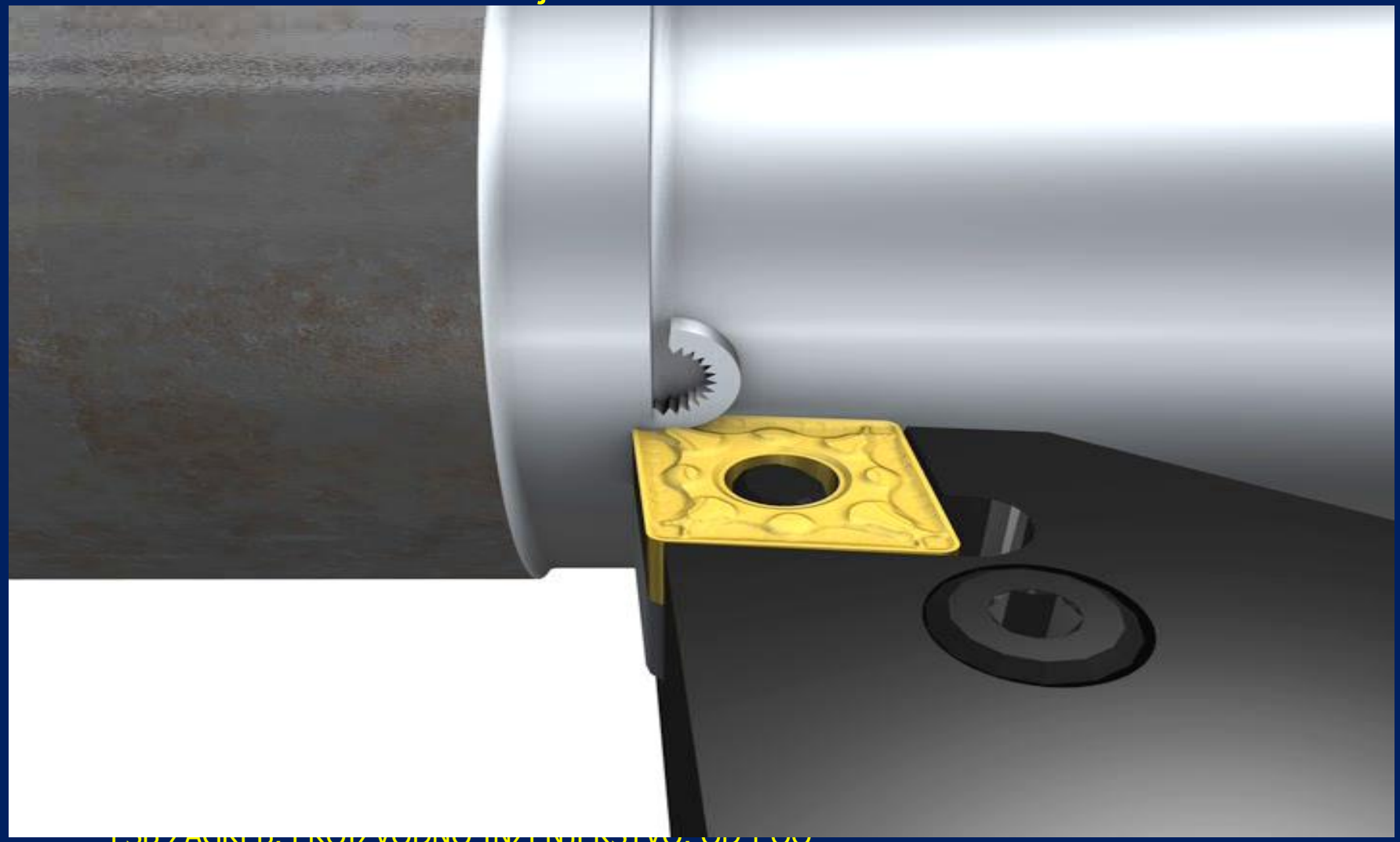
U literaturi se češće koriste oznake

t i t_1 (eng. thickness)

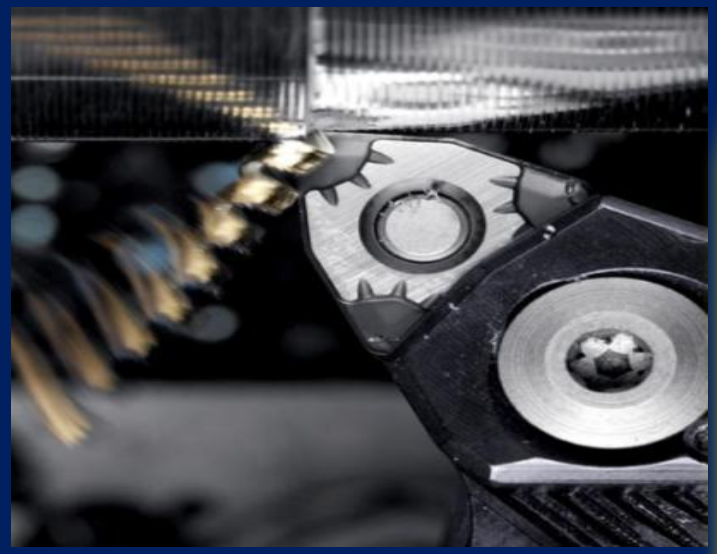
t – debljina nedeformiranog sloja

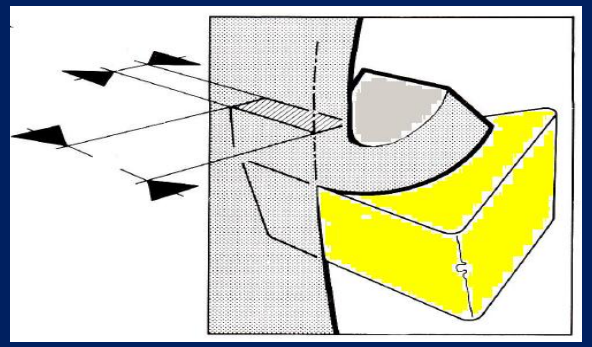
t_1 – debljina deformirane čestice

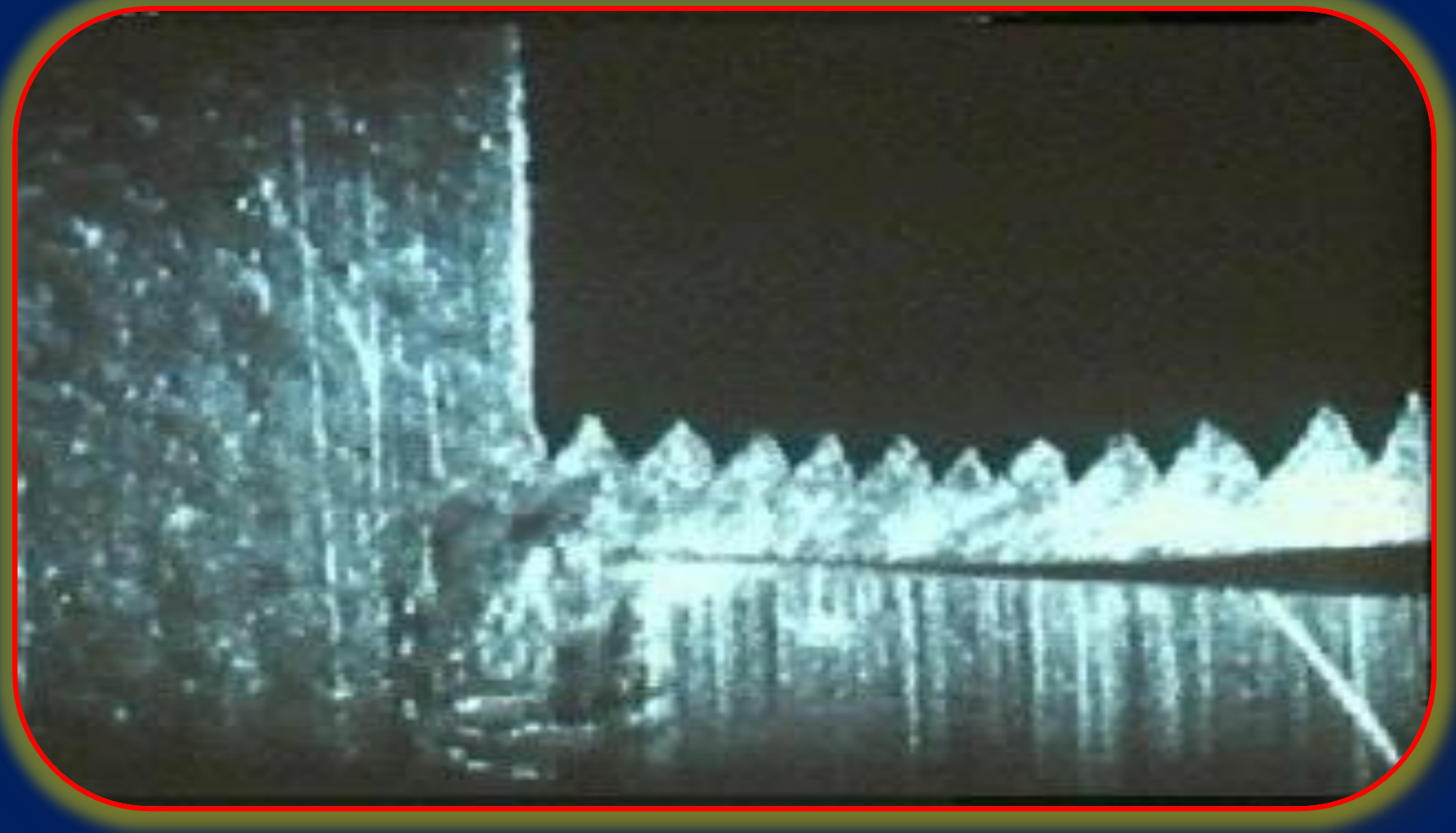
Formiranje čestica - film



OBLIKOVANJE DEFORMIRANJEM I OBRADA ODVAJANJEM
Obrada odvajanjem







Ortogonalno rezanje

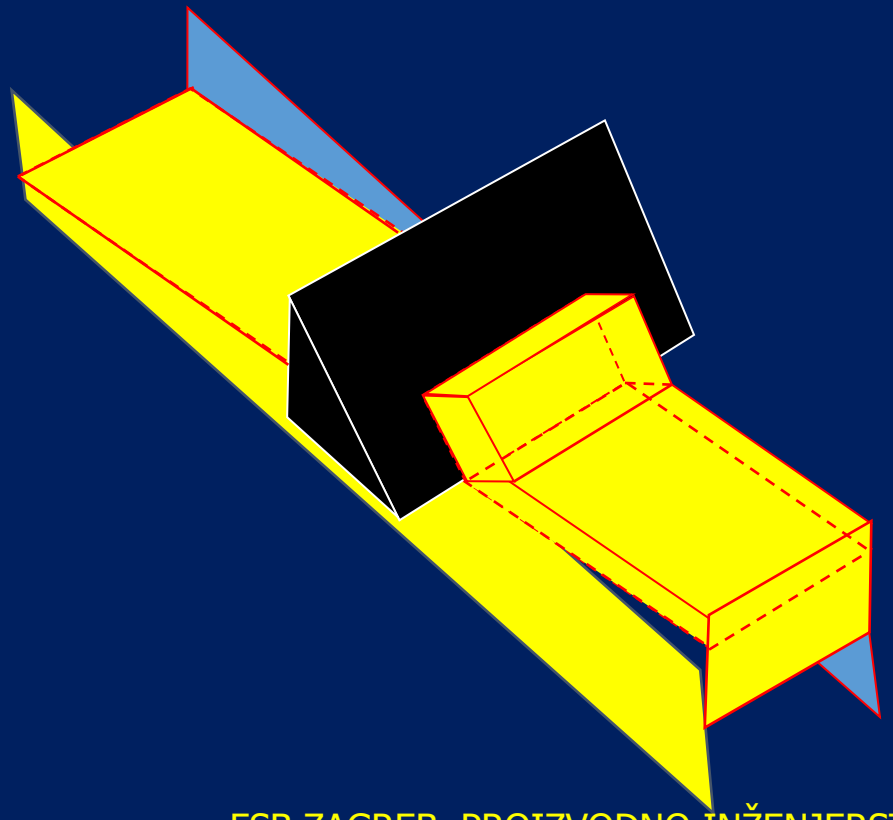
Zbog jednostavnosti i preglednosti, za istraživanja u teoriji rezanja se najčešće koristi ortogonalno rezanje.

Osnovne pretpostavke (preduvjeti) ortogonalnog rezanja:

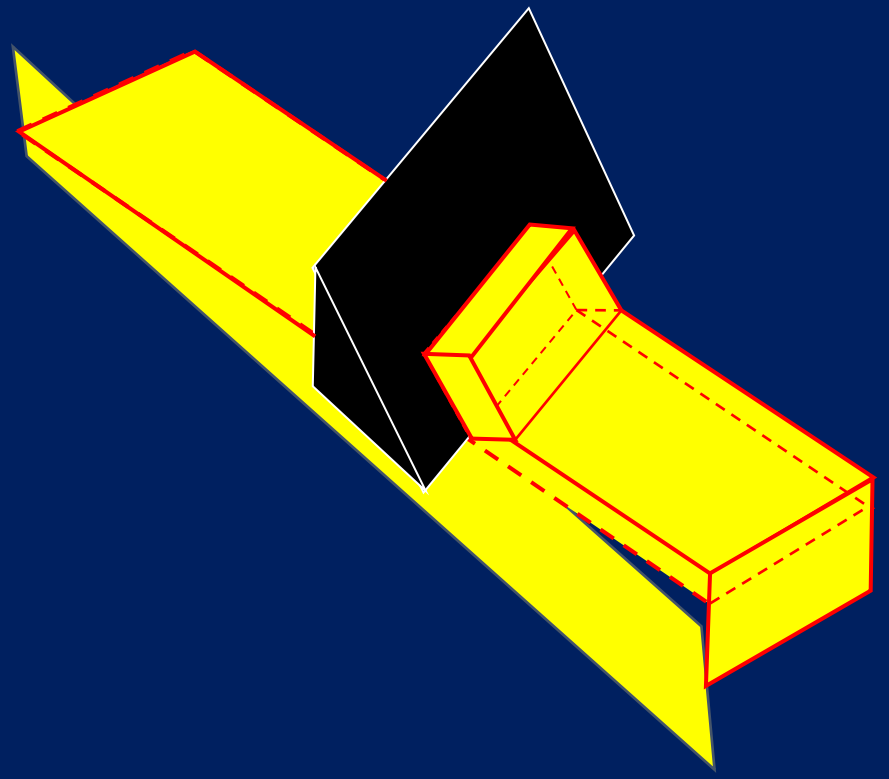
- konstantni parametri obrade (v_c, f, a_p)
- glavna oštrica je okomita na brzinu rezanja i na posmičnu brzinu (ako postoji);
- jednolika raspodjela naprezanja;
- smicanje se događa u ravnini;
- nema trenja na stražnjoj površini alata;
- glavna oštrica je šira od širine obrade.

Ortogonalno rezanje

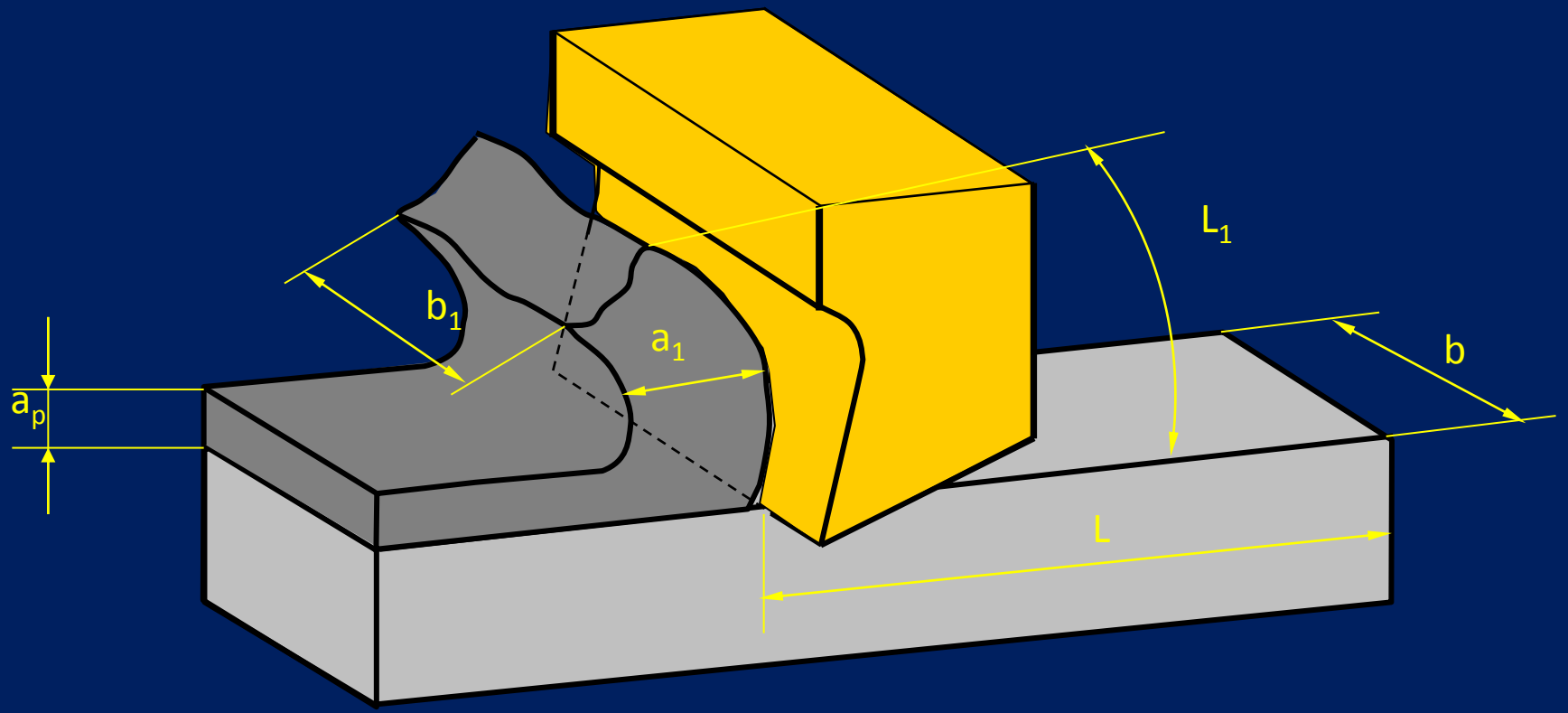
Oortoganlno rezanje



Koso rezanje



Koeficijenti deformacije



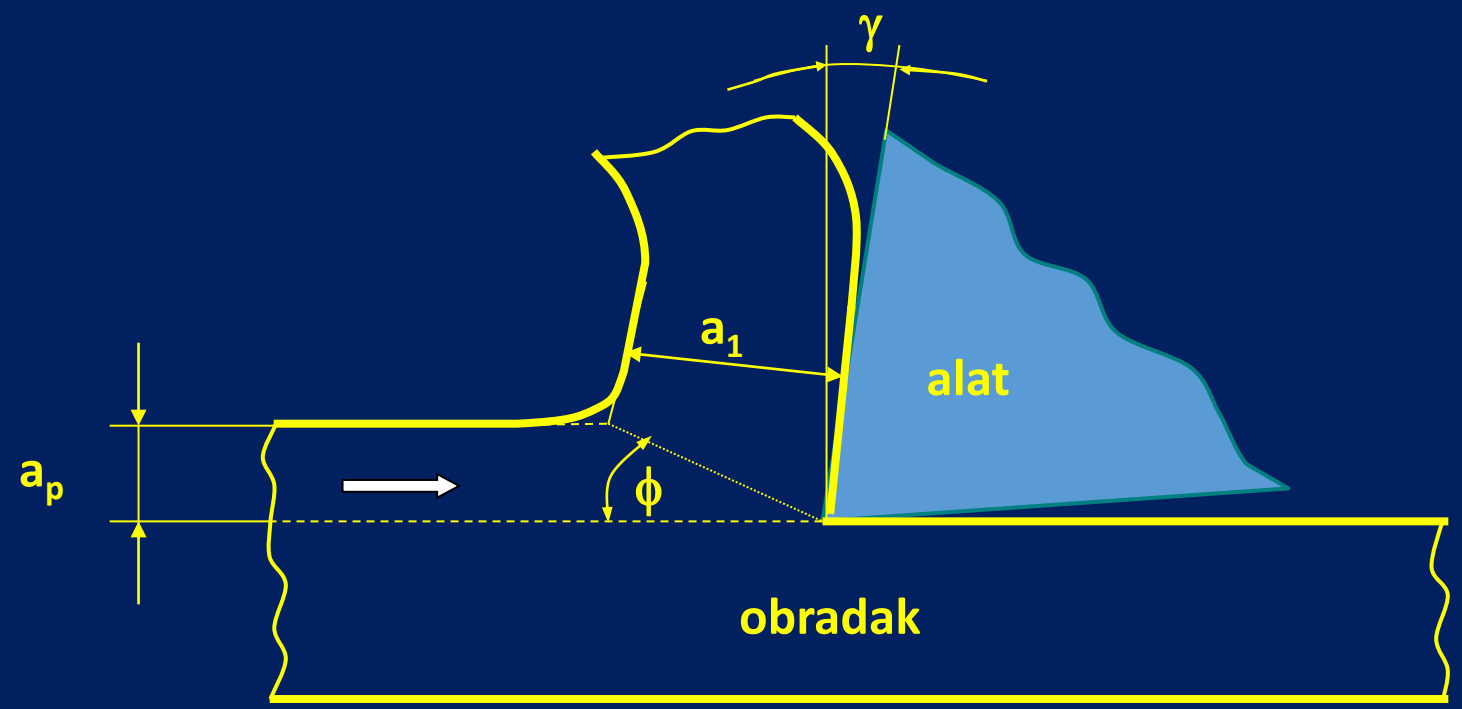
$$\theta_a = \frac{a_1}{a_p}$$

$$\theta_b = \frac{b_1}{b} \approx 1$$

$$\theta_L = \frac{L}{L_1}$$

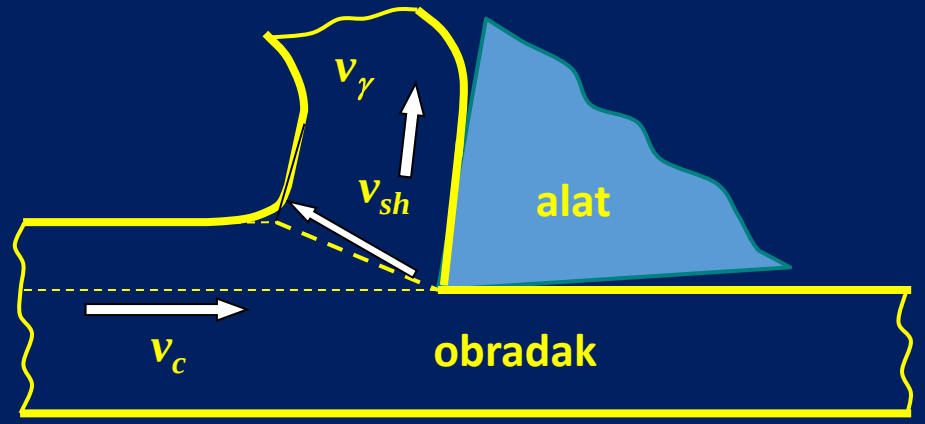
$$a_p b L = a_1 b_1 L_1 \rightarrow \frac{a_1}{a_p} = \frac{L}{L_1}$$

Koeficijent deformacije u ravnini



$$\theta_a = \frac{a_1}{a_p} = \frac{x sin\left(\frac{\pi}{2} - \emptyset + \gamma\right)}{x sin\emptyset} = \frac{cos(\emptyset - \gamma)}{sin\emptyset} = \frac{cos\gamma}{tg\emptyset} + sin\gamma \rightarrow \phi$$

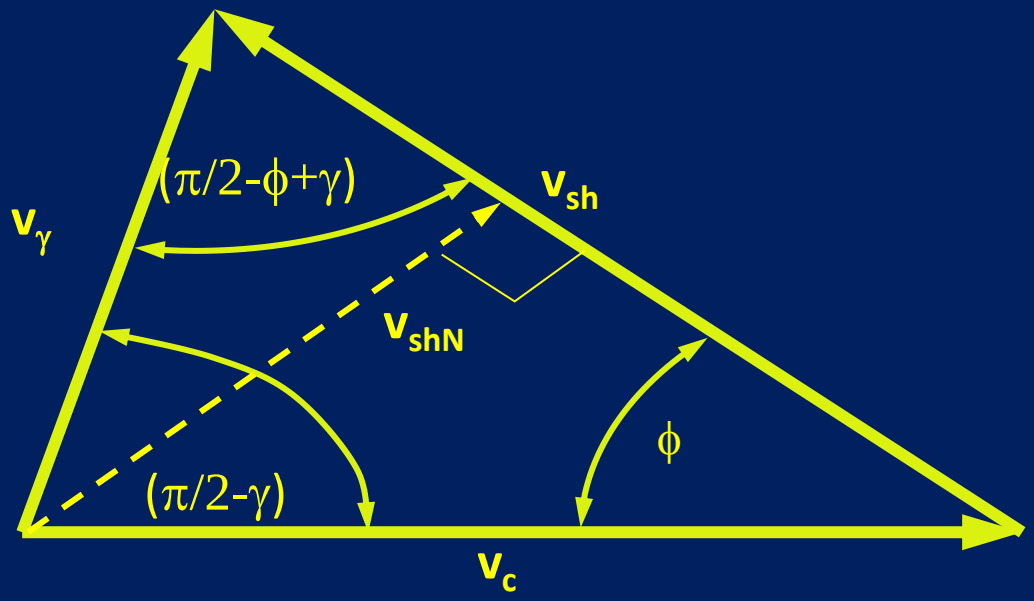
Kinematika procesa - brzine u zoni rezanja (trokut brzina)



$$v_{sh} = v_c \frac{cos\gamma}{\cos(\emptyset - \gamma)}$$

$$v_\gamma = v_c \frac{sin\emptyset}{\cos(\emptyset - \gamma)}$$

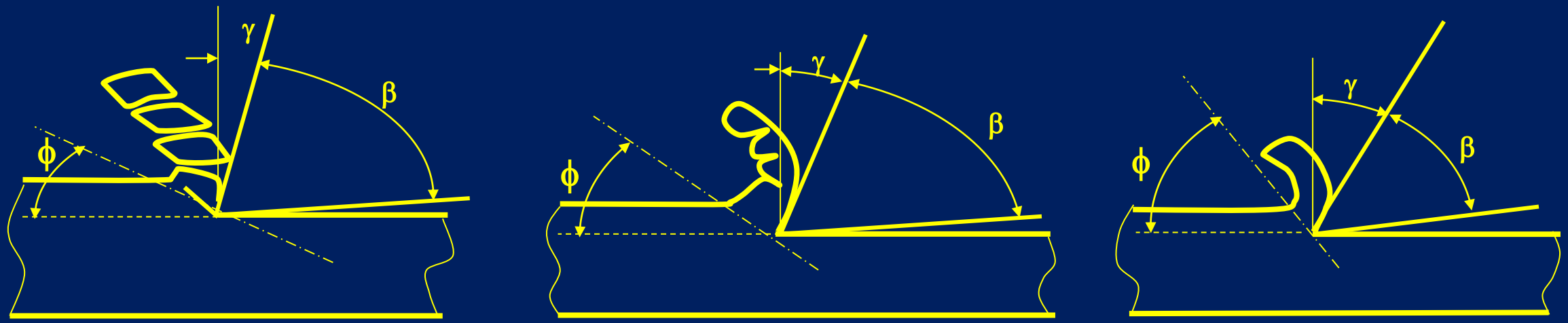
$$v_{shN} = v_c sin\emptyset$$



$$\frac{v_c}{sin\left(\frac{\pi}{2} - \emptyset + \gamma\right)} = \frac{v_{sh}}{sin\left(\frac{\pi}{2} - \gamma\right)} = \frac{v_\gamma}{sin\emptyset}$$

Ove brzine su istog reda veličine !

Vrste odvojene čestice



a) **b)** **c)**

a) - lomljena (elementarna) odvojena čestica; **obrađena površina ?**

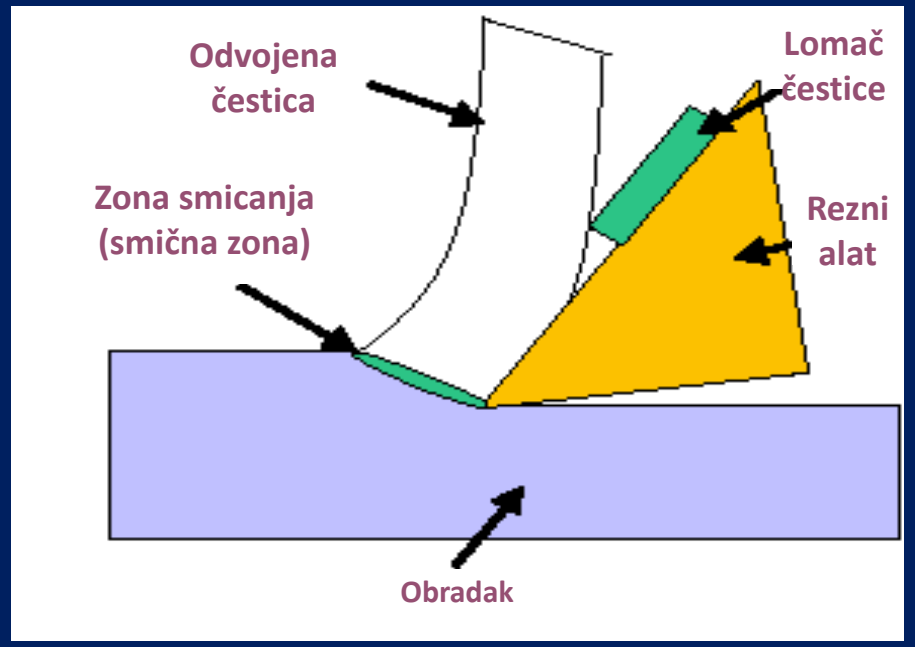
b) - nasječena odvojena čestica (više lamela zajedno); **obrađena površina ?**

c) - tekuća (kontinuirana) odvojena čestica; **obrađena površina ?**

Utjecaj debljine, kuta prednje površine i brzine rezanja na oblik o.č.

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

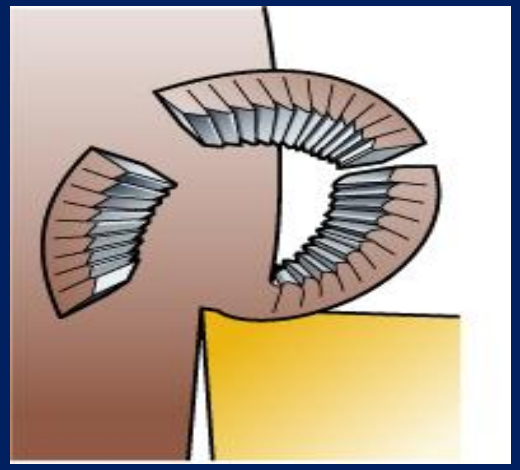
Oblici odvojene čestice – vanjski i integrirani lomači



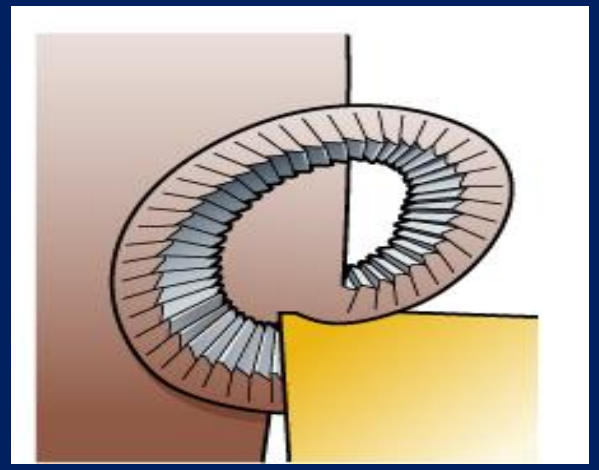
vanjski lomači

integrirani lomači

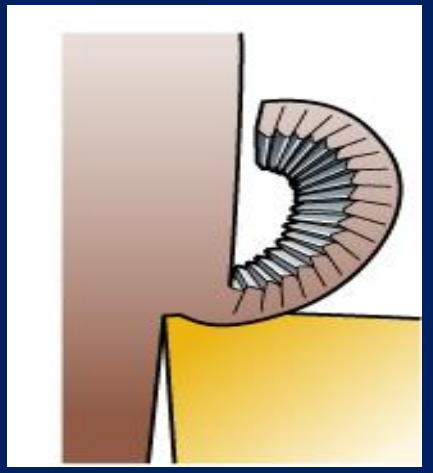
Lom odvojene čestice



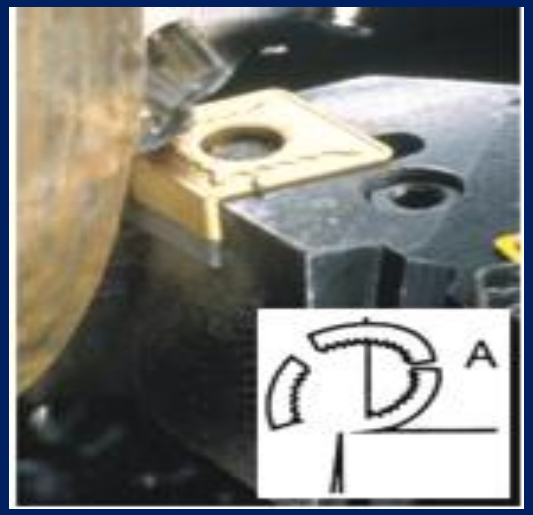
A Samo-lom

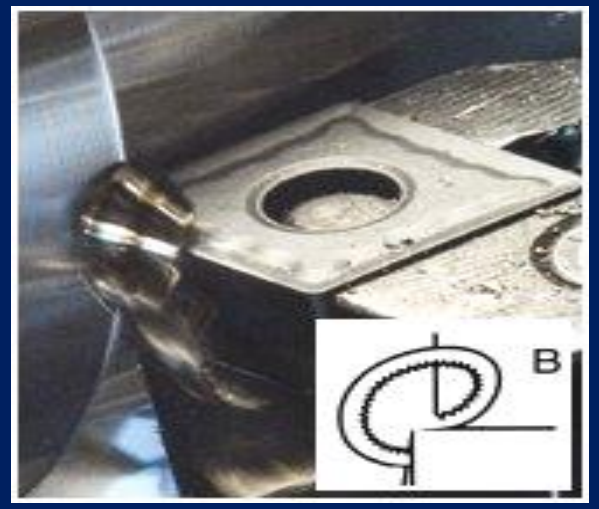


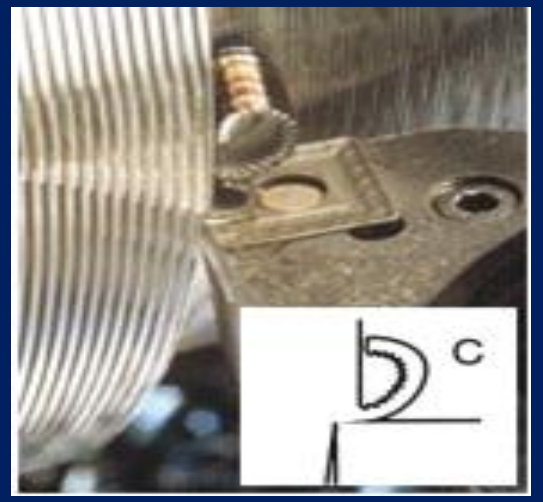
B Lom na alatu



C Lom na obratku








Lom odvojene čestice na obratku

Lom odvojene čestice na alatu


K
Cast iron
Samo-lom

Odvojene čestice kod glodanja

U kojim uvjetima se može formirati kontinuirana odvojena čestica ?

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

Utjecaj parametara obrade na oblik odvojene čestice

$$g = \frac{a_p}{f}$$

vitkost

odvojene čestice

Utjecaj brzine rezanja i kuta prednje površine.

Turning: Chip Breaking

Material : XC48

Tool: PCLNL 2525-M12

CNMM120416-R7

CNMG120412-R3

CNMG120412-M5

CNMG120408-F2

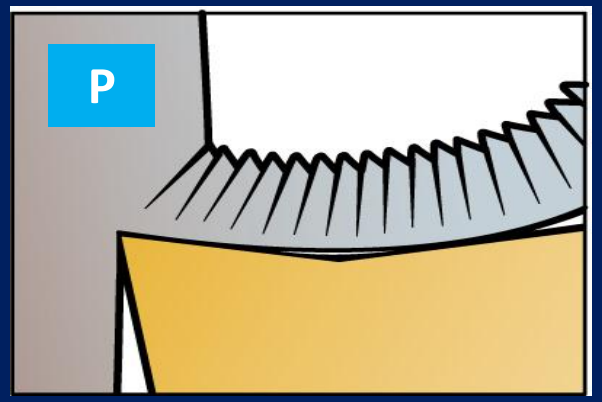
Safety

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu

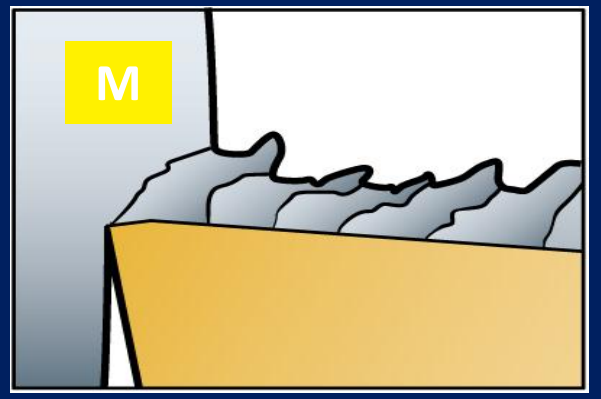
Primjeri formiranja čestice pod utjecajem posmaka

- Lijevo: posmak f=0,1 mm/okr
- Desno: posmak f=0,3 mm/okr

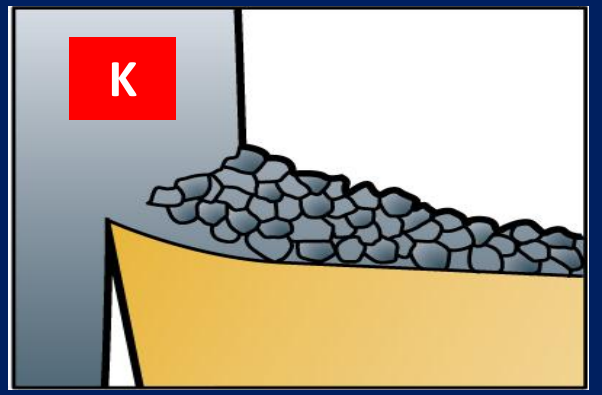
Oblici odvojene čestice – SANDVIK



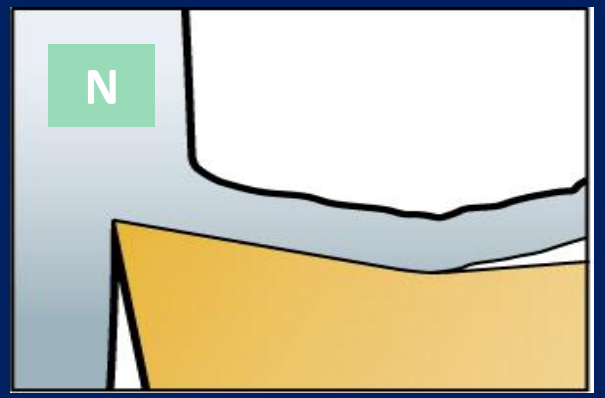
Čelik



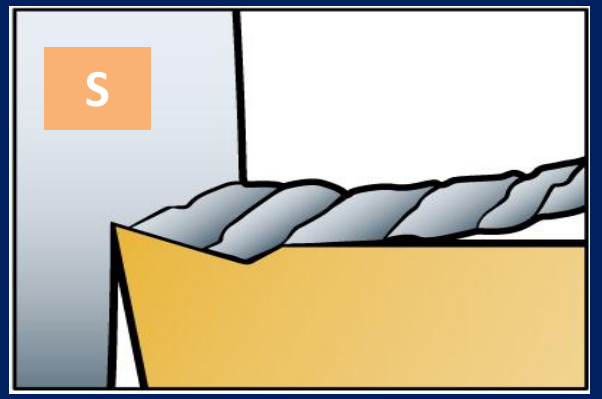
Nehrđajući čelik



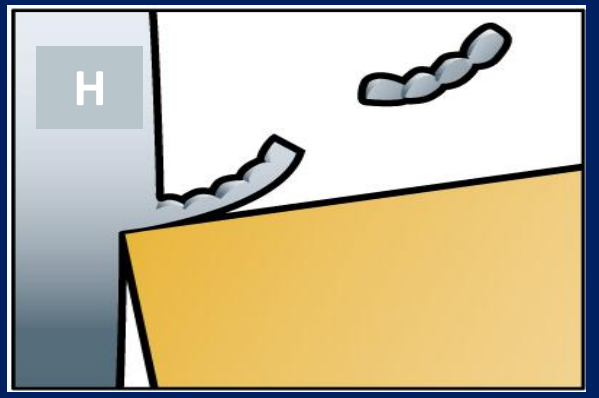
Lijevano željezo



Aluminij



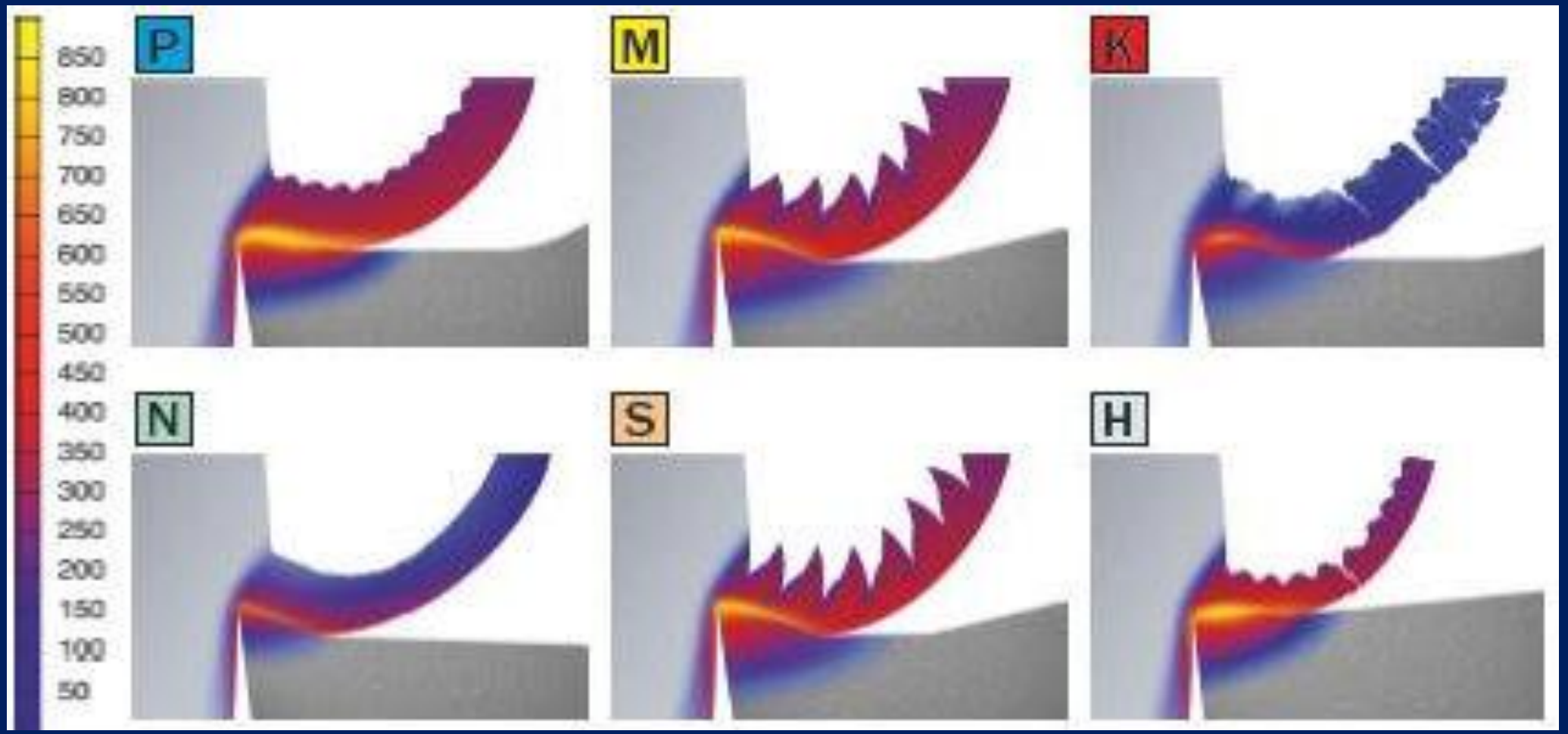
Vatrootporne slitine



Kaljeni čelik

100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

Temperature u presjeku pri obradi različitih materijala alatom od TM

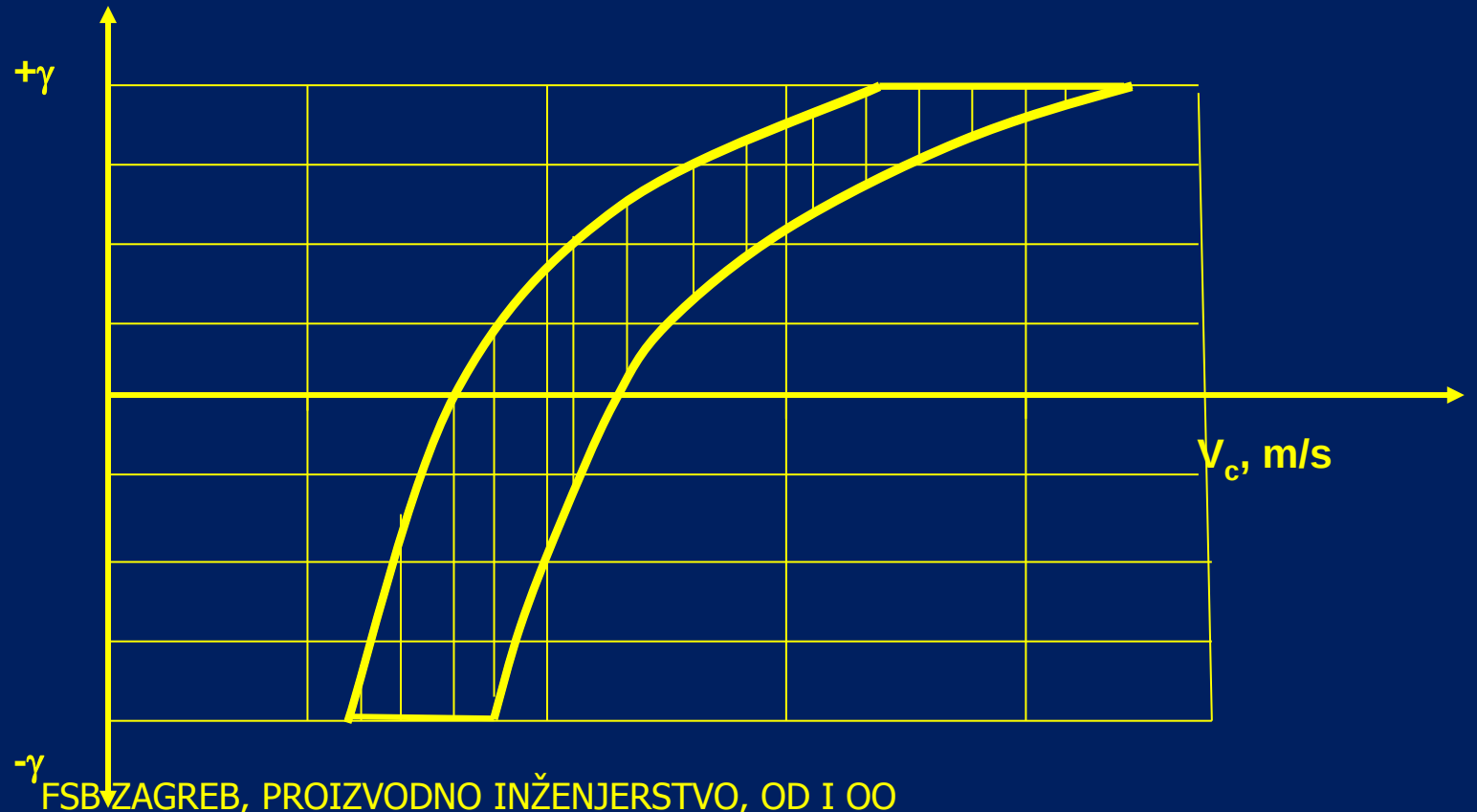


100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

Područje stvaranja naljepka (naslage)

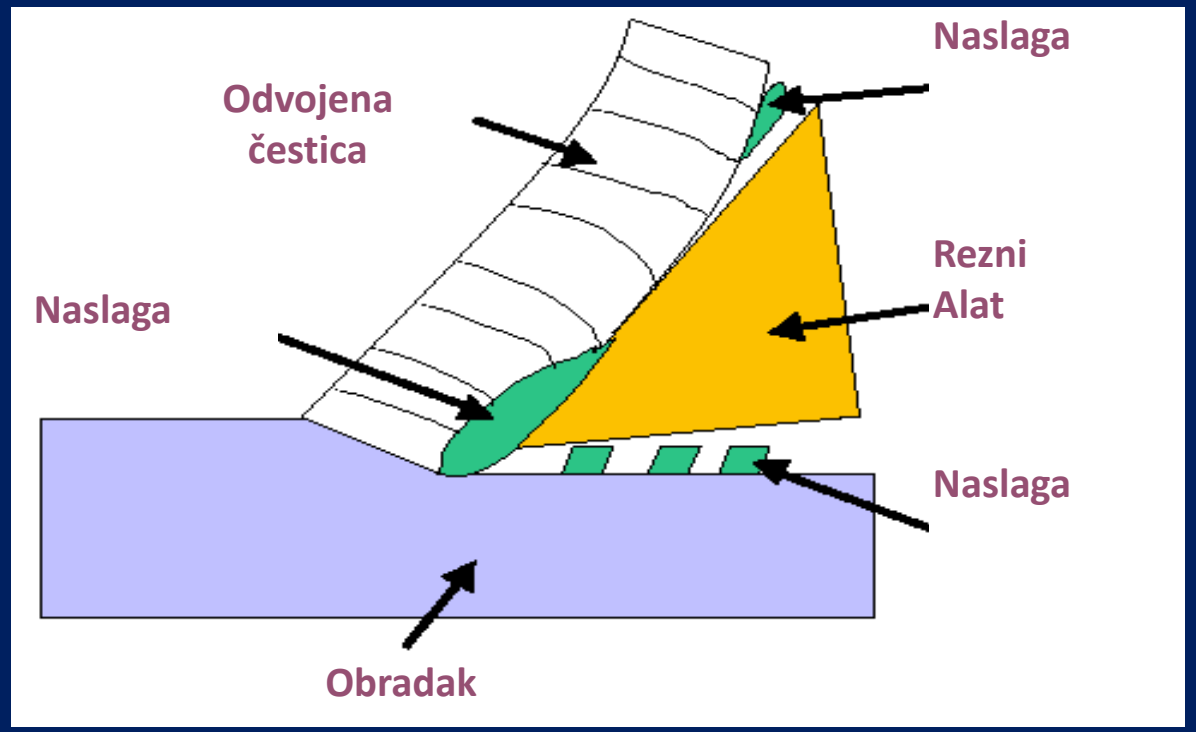
U kojim uvjetima nastaje naljepak ?

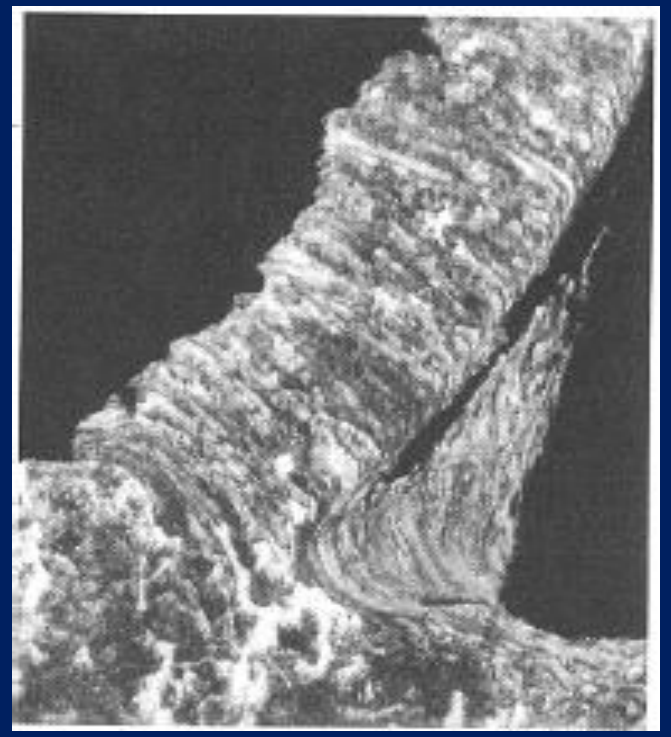
BUE



100 godina Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu
100 Years of Faculty of Mechanical Engineering and Naval Architecture University of Zagreb

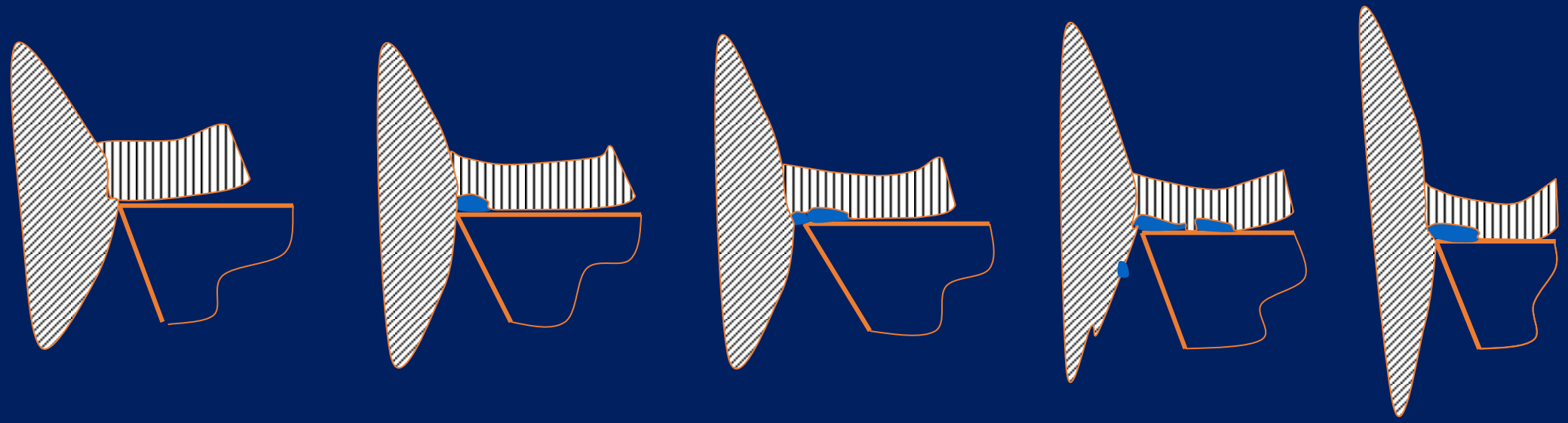
Naslaga (naljepak) na prednjoj površini alata - BUE





Stvaranje naslage (naljepka) – BUE - film

Naslaga – BUE – faze nastajanja



Formiranje i kidanje naljepka

Naljepak kod obrade Al - posljedice na alatu i obratku