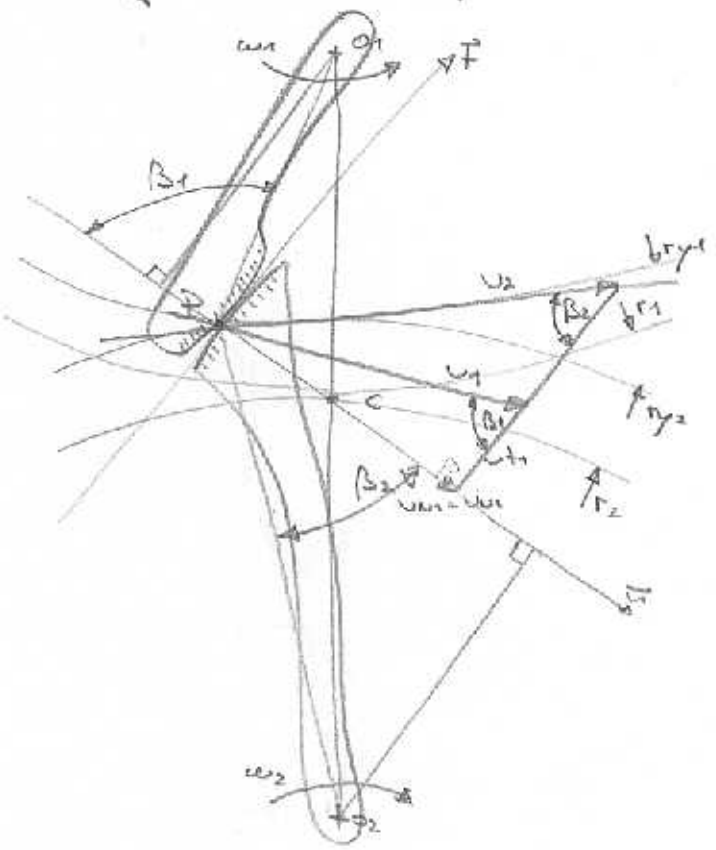
ZAKON OZOBJA

Iščemo zakonitost, ki bo povedala kakšen mora biti bok zoba, da bo vrtenje enakomerno.



$$i = \frac{\omega_1}{\omega_2} = konst$$

$$\omega_1, \omega_2 = konst$$

$$U_1 = r_{y1}\,\omega_1$$

$$U_2 = r_{y2}\,\omega_2$$

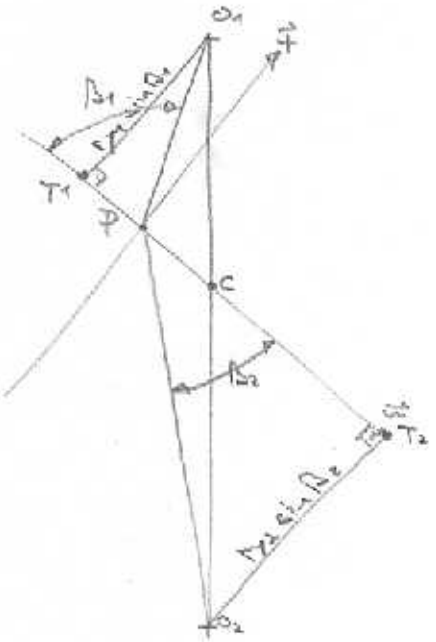
$$U_{N1} = U_1 \sin\beta_1$$

$$U_{N2} = U_2 \sin\beta_2$$

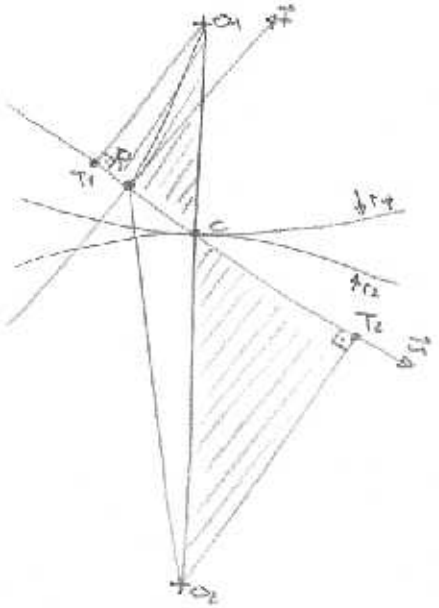
$$U_{N1} = U_{N2}$$

$$r_{y1}\,\omega_1 \sin\beta_1 = r_{y2}\,\omega_2 \sin\beta_2$$

$$\frac{\omega_1}{\omega_2} = \frac{r_{y2}\sin\beta_2}{r_{y1}\sin\beta_1} = i$$



$$i = konst = \frac{r_{y2}\sin\beta_2}{r_{y1}\sin\beta_1} = \frac{\overline{O_2T_2}}{\overline{O_1T_1}}$$



V vsaki ubrani točki mora potekati normala na boke zob skozi kinematski pol C, ki določa d_1, d_2.

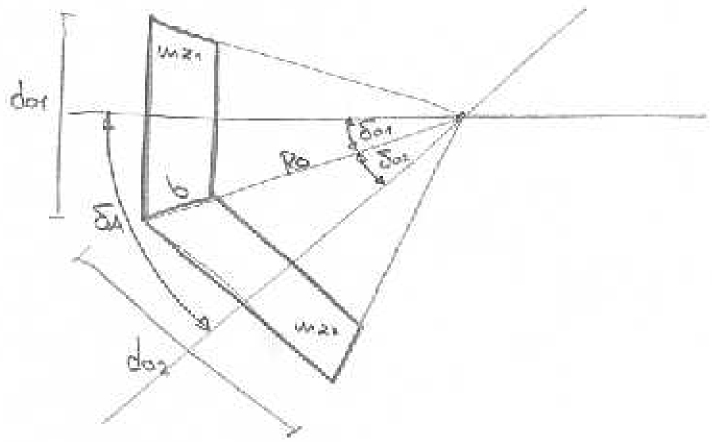
$$\triangle O_1CT_1 \sim \triangle O_2CT_2$$

$$\frac{\overline{O_2T_2}}{\overline{O_1T_1}} = konst = \frac{\overline{O_2C}}{\overline{O_1C}} = i$$

$$\overline{O_2C} + \overline{O_1C} = \overline{O_1O_2} = a$$

$$i = \frac{\overline{O_2C}}{\overline{O_1C}} = \frac{d_2}{d_1} \quad ; \quad a = \tfrac{1}{2}(d_2 + d_1) = \tfrac{1}{2}d_1(1+i)$$

Stožčasti zobniki



$d_{01} = m z_1$

$d_{02} = m z_2$

$b < 1/3 R_0$

$i = \frac{d_{02}}{d_{01}} = \frac{z_2}{z_1}$

$\delta_A = \delta_{01} + \delta_{02}$

$\frac{d_{01}}{2} = R_0 \sin \delta_{01}$

$\frac{d_{02}}{2} = R_0 \sin \delta_{02}$

$i = \frac{d_{02}}{d_{01}} = \frac{\sin \delta_{02}}{\sin \delta_{01}}$

Za $\delta_A = 90°$

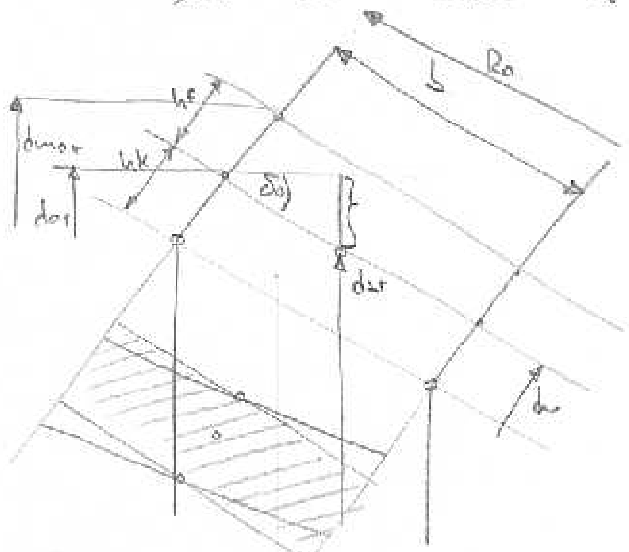
$\frac{d_{01}}{2} = R_0 \sin \delta_{01}$

$\frac{d_{02}}{2} = R_0 \sin(90 - \delta_{01})$

$= R_0 \cos \delta_{01} =$

$= R_0 [\sin 90 \cos \delta_{01} - \cos 90 \sin \delta_{01}]$

$i = \frac{d_{02}}{d_{01}} = \frac{2R_0 \cos \delta_{01}}{2R_0 \sin \delta_{01}} = \frac{1}{\frac{\sin \delta_{01}}{\cos \delta_{01}}} = \frac{1}{tg\, \delta_{01}}$



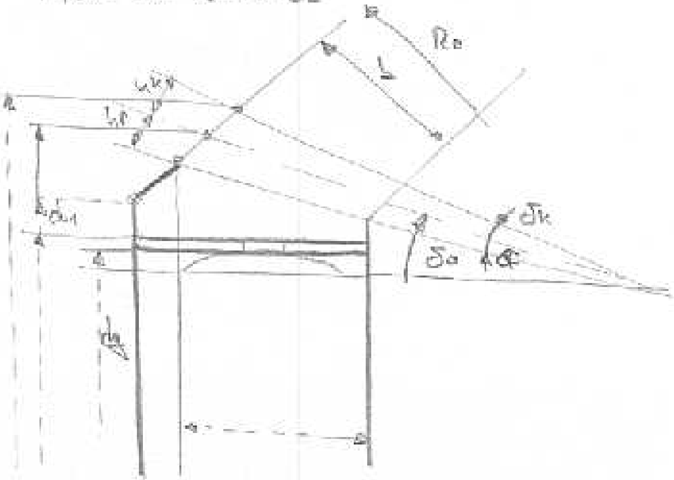
$d_{sr} = d_{01} - 2 \frac{b}{2} \sin \delta_0$

$m_{sr} = \frac{d_{sr}}{z}$

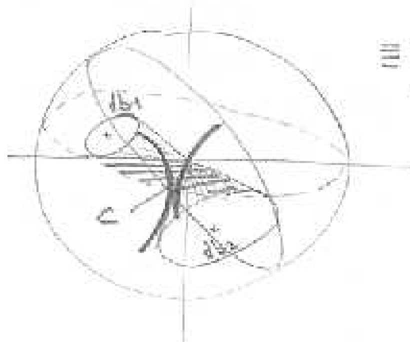
$d_v = \frac{d_{sr}}{\cos \delta_0}$

$z_v = \frac{d_v}{m_{sr}}$ virtualno

Mere za surovec

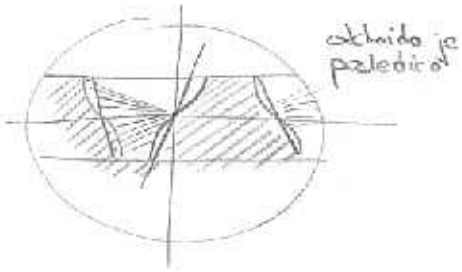


Krogelne evolvente

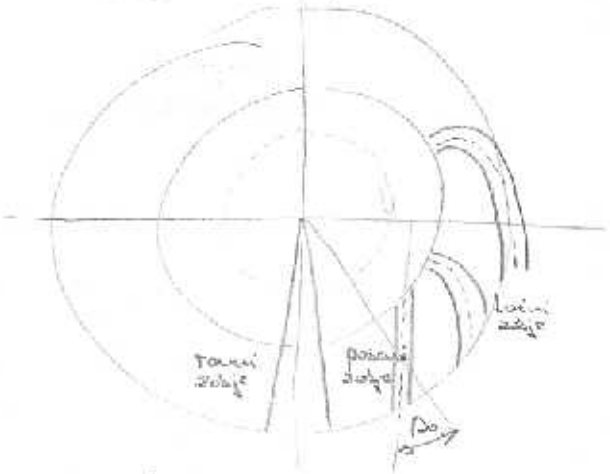


≡ ravnina tangira obodna osnova stožca

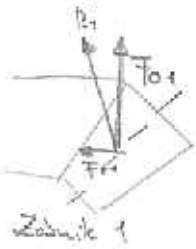
Plani zobnik

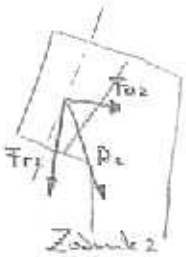


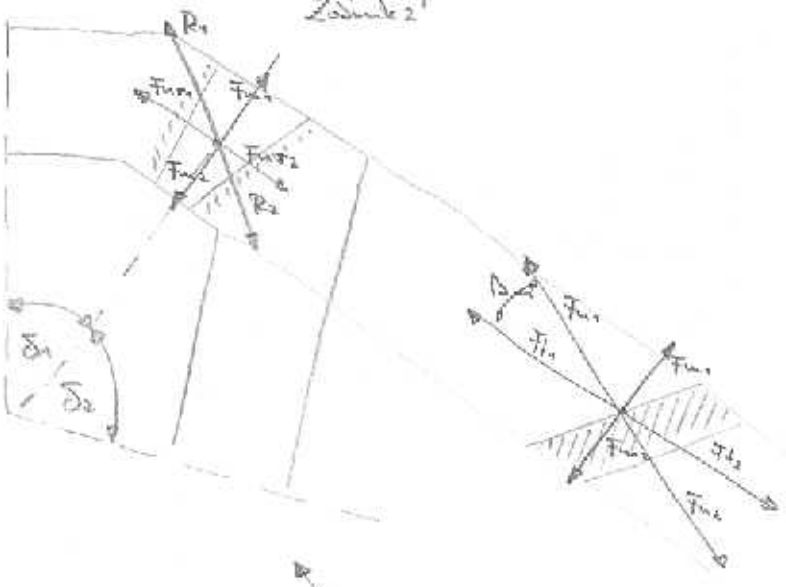
Različni zobje

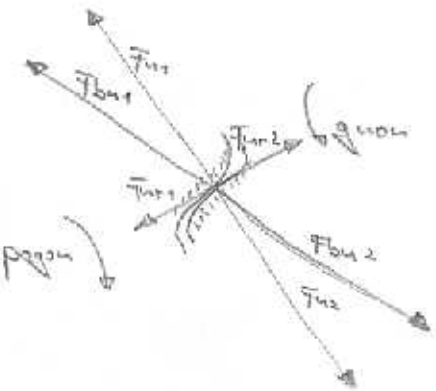


Sile na stožčasti zobnik s poševnim ozobjem





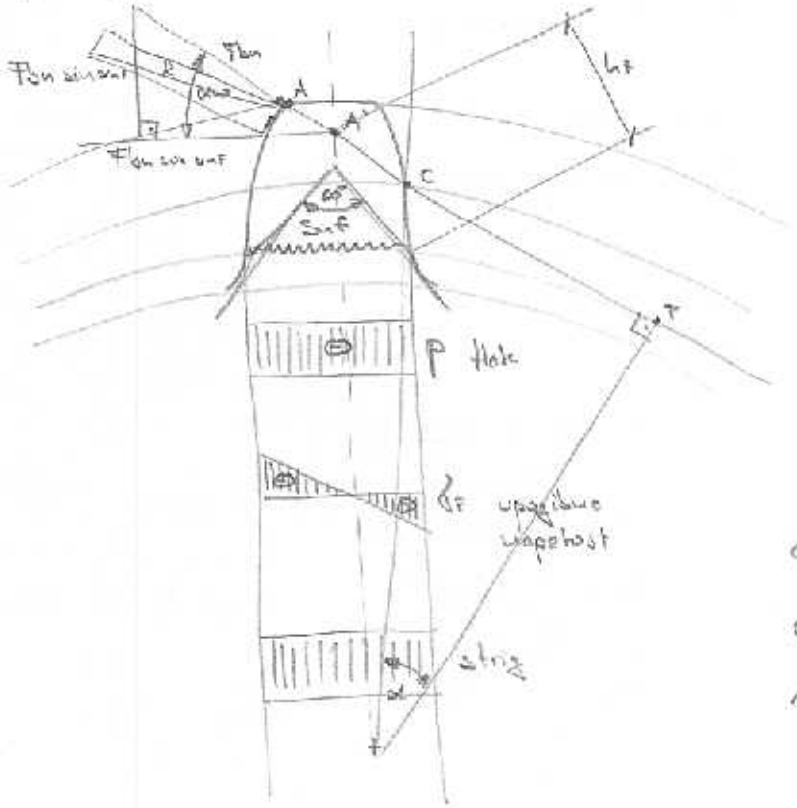




OSNOVE ZA PRERAČUN ZOBNIKOV

DIN 3990

- prelom v korenu
- bočni tlak
- segrevanje
- mikropitting



$$\sigma_{xp} = \frac{F_{tn}\,\sin\alpha_{nF}}{s_{nF}\,b}$$

$$\sigma_{up} = \frac{F_{tn}\,\cos\alpha_{nF}\,h_F}{s_{nF}^2\,b/6}$$

$$\tau_b = \frac{F_{tn}\,\cos\alpha_{nF}}{b\,s_{nF}}$$

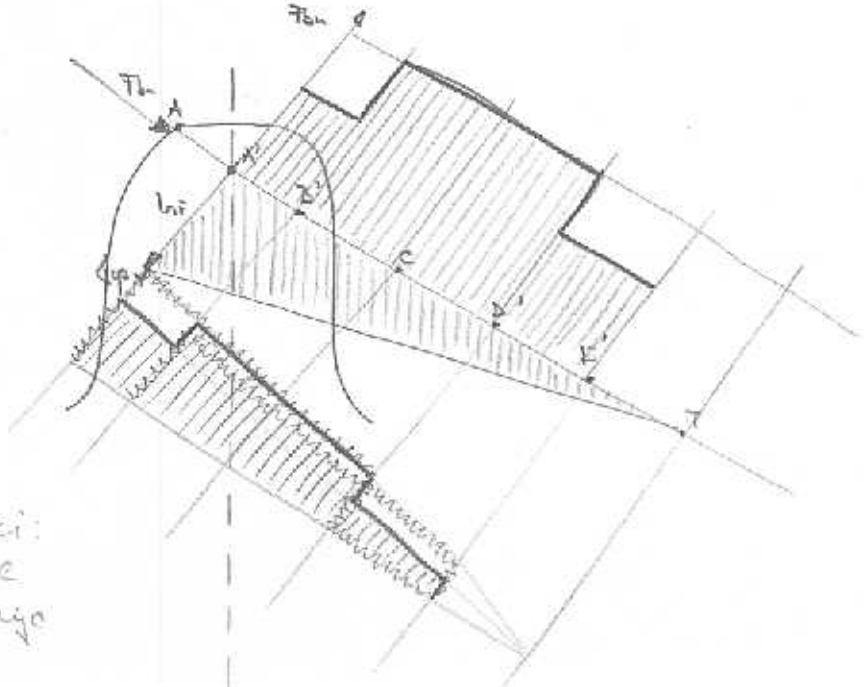
R = Ftn ... zunanja sila

snF - debelina v korenu

b ... širina

Za merila uporabimo samo upogibno napetost. Mip najbolj prispeva

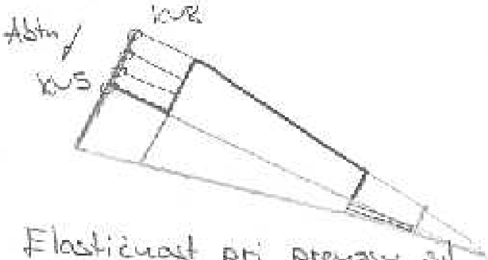
Porazdelitve sil vzdolž abitnice



Vzpeki:
- delitve
- obitnice

Abtn napake v delitvi

Kvaliteta kv

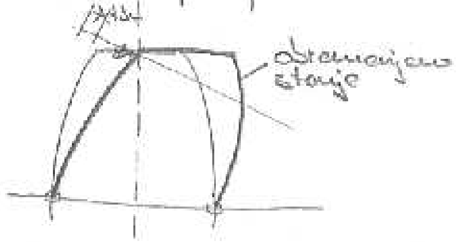


kv 6 ... male napake

kv 9 ... slabša obdelava

F ... fino

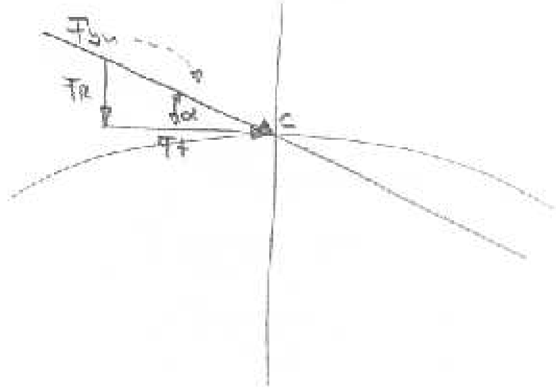
Elastičnost pri prenosu sil



Abtn - napaka izdelave

$\frac{F_{bn}}{b}$ ... obteženo, kompenzira elastičnost

Kontrola na upogib



b ... širina zobnika

$$\sigma_F = \frac{F_{bn} \cos \alpha_{NF} \, h_F}{s_{NF}^2 \; b/6}$$

$M_{t1} = F_{bn} \, r_{b1}$ $\qquad M_t = F_t \, d_{01}/2 = F_t \, d_1/2$

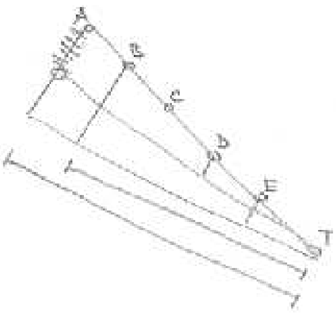
$M_{t2} = F_{bn} \, r_{b2}$

$F_{bn} = F_t \, d_1/d_{01} \rightarrow \frac{1}{\cos \alpha}$

σ_F ... napetost v korenu

$$\sigma_F = \frac{F_t \cos \alpha_{NF} \left(\frac{h_{NF}}{m}\right)}{\cos \alpha \left(\frac{s_{NF}}{m}\right)^2 b/6 \; m} = \frac{F_t}{b m} \left[\frac{6 \cos \alpha_{NF} \left(\frac{h_{NF}}{m}\right)}{\cos \alpha \left(\frac{s_{NF}}{m}\right)^2} \right] = f\left[m, z_1, z_2, i, x_1, x_2 \right]$$

Y_F ... faktor, ki ga najdemo v tabelah



$\sigma_{FB} = \sigma_{FA} \, 1/\varepsilon_\alpha$

ε_α ... stopnja prekritja

$\sigma_F = \frac{F_t}{b\,m}\; Y_F\; Y_\varepsilon\; K_{F\alpha}\; K_{F\beta}\; Y_\beta\; K_I\; K_v$

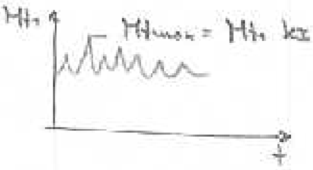
$\sigma_F \leq \sigma_{dop}$

$\sigma_{dop} = \frac{\sigma_{FLim}\; K_{FA}\; K_{FK}}{S_F}$

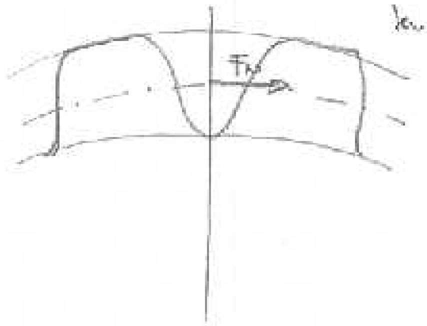
S_F ... faktor varnosti

σ_{FLim} ... statično, malociklično, zasano, TDT

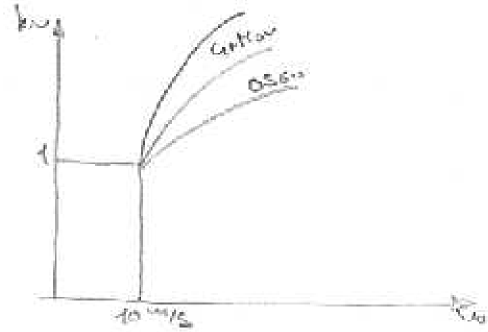
- K_I ... faktor sunkov



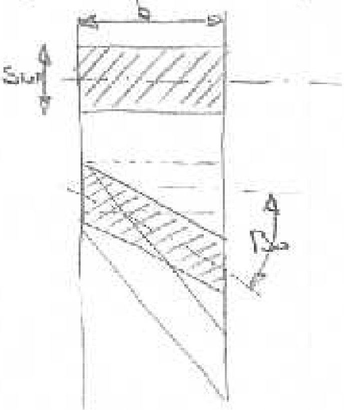
- K_v ... povečanje sile zaradi notranjih sunkov



$K_v > 1$

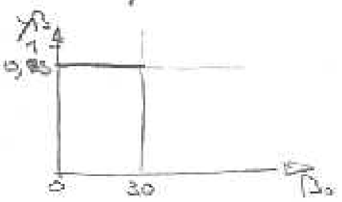


- Y_β ... faktor za poševnost

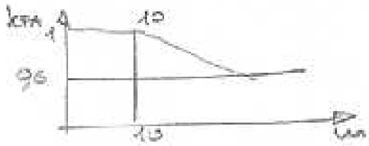


KOREKCIJSKI FAKTORJI

Tbn $Y_\beta = f(\beta_0)$



- K_{FA} ... odvisnost velikosti modula



K_A ... koeficient obratovanja

- K_{FK} ... mikrozarezni vpliv

Poboljšan je bolj občutljiv na zareze

R_t ... hrapavost površine

- $K_{F\beta}$ ... korekcijski koeficient porazdelitve sil po širini zoba

- $K_{F\alpha}$ ... korekcijski koeficient porazdelitve sil na zobe

$K_{F\alpha} = \varepsilon_\alpha g_L \quad ; \; g_L = \frac{F_{bn1}}{F_{bn2}} = f\left[A_{tbn}, \frac{F_t}{b}, E\right]$

$0,5 \leq g_L \leq 1$

- Y_ε ... korekcijski koeficient prekritja

$\sigma_{FB} = \sigma_{FA} \; 1/\varepsilon_\alpha \rightarrow 1/Y_\varepsilon$

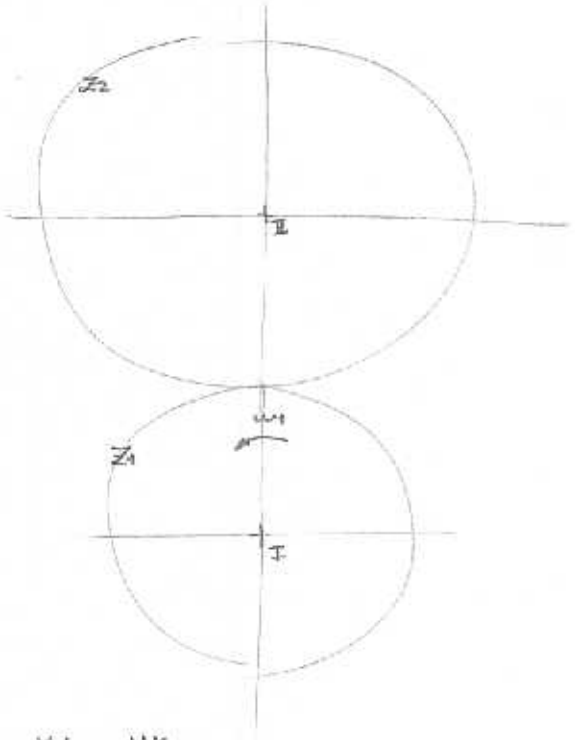
$Y_\varepsilon = 0,25 + 0,75 \frac{\cos^2\beta_0}{\varepsilon_\alpha}$

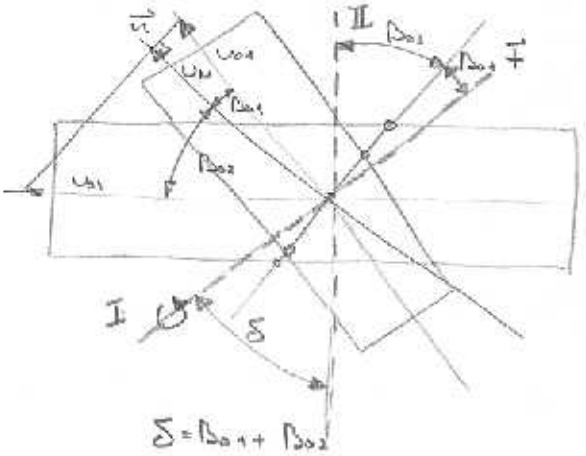
β_0 ... kot poševnosti

- Y_F ... oblikovni koeficient

Glej list 1 za Y_F ki je v tabeli kot $f[m, z_1, z_2, i, x_1, x_2]$

VIJČNA GONILA





$$i = \frac{\omega_1}{\omega_2} = \frac{\omega_{t1}}{\omega_{t2}}$$

$$v_{01} = r_{01}\,\omega_1$$

$$v_{02} = r_{02}\,\omega_2$$

$$v_{t1} = \checkmark$$

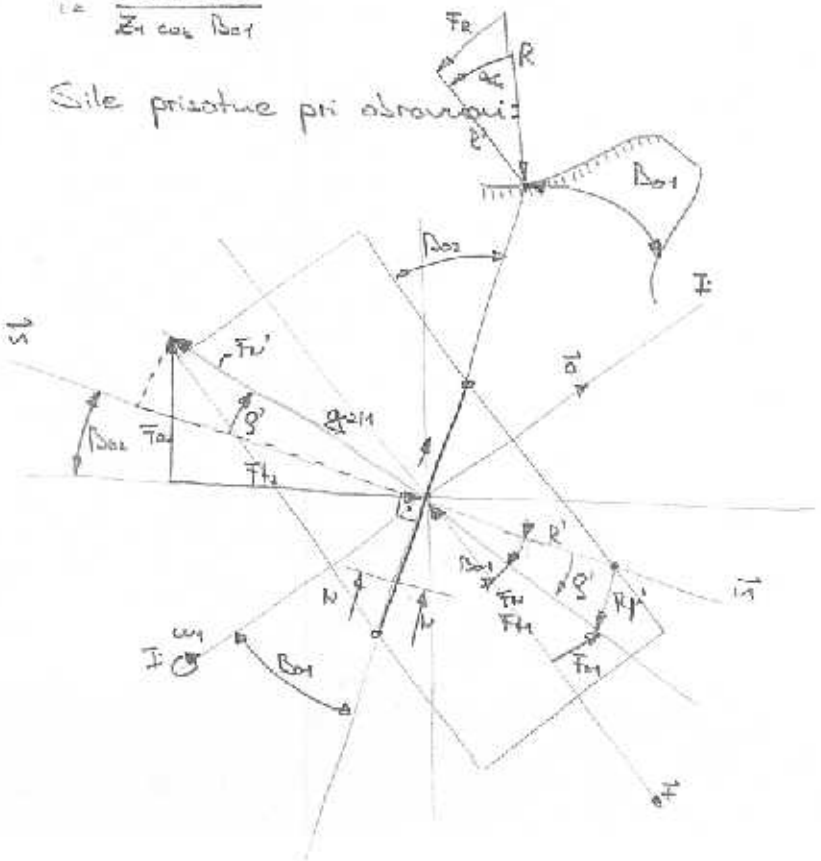
$$v_{t2} = v_{01}\,\frac{\cos\beta_{01}}{\cos\beta_{02}}$$

$$\frac{v_{01}}{v_{02}} = \frac{\cos\beta_{02}}{\cos\beta_{01}} = \frac{r_{01}\,\omega_1}{r_{02}\,\omega_2} = i\,\frac{r_{01}}{r_{02}}$$

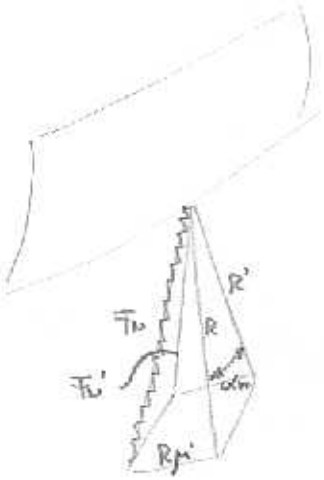
$$i = \frac{r_{02}}{r_{01}}\,\frac{\cos\beta_{02}}{\cos\beta_{01}} = \frac{z_2\,\omega_2}{z_1\,\omega_1}\,\frac{\cos\beta_{02}}{\cos\beta_{01}}$$

$$i = \frac{z_2\cos\beta_{02}}{z_1\cos\beta_{01}}$$

Sile prisotne pri obravnavi:



$\vec{o}$ ... obsiolna sila



$\rho' = \frac{\rho}{\cos\rho}$ ... torni kotlični

F_u' = skupna rezultirajoča sila, s katero utiri odrivajo

$$F_{t1} = \frac{2M_{tr}}{d_r}$$

$$F_{o1} = F_{t1} \operatorname{tg}(\beta_{o1} - \rho')$$

$$F_u' = \frac{F_{t1}}{\cos(\beta_{o1} - \rho')}$$

$F_u \rightarrow 2$

$$F_{t2} = F_u \cos(\beta_{o2} + \rho')$$

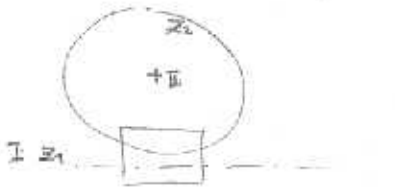
$F_R = R \sin\alpha_w$

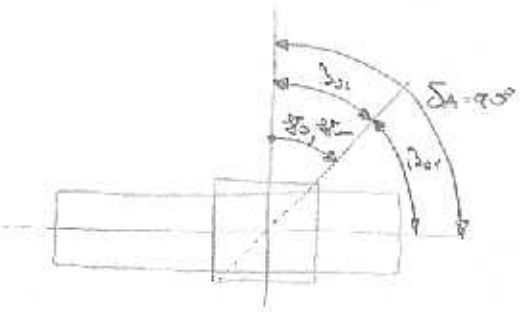
$$F_{r2} = \frac{F_{t1}\cos(\beta_{o2} + \rho')}{\cos(\beta_{o1} - \rho')}$$

$$\eta = \frac{P_2}{P_1} = \frac{F_{t2}}{F_{t1}} \frac{v_2}{v_1} = \frac{\cos(\beta_{o2} + \rho')}{\cos(\beta_{o1} - \rho')} \frac{\cos\beta_{o1}}{\cos\beta_{o2}}$$ Izkoristek

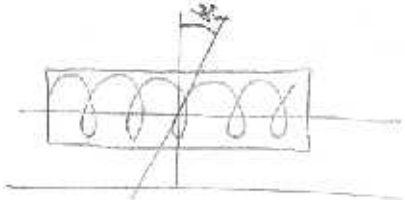
F_u ... telesna diagonala

$\delta = 90°$ Polzasto gonilo





$\beta_{o1} + \beta_{o2} = 90°$



T dol do

$$\eta = \frac{\cos(\beta_{o2} + \rho')}{\cos(\beta_{o1} - \rho')} \frac{\cos\beta_{o1}}{\cos\beta_{o2}}$$

$\beta_{o1} = 90 - \beta_{o2}$

$\beta_{o2} = \psi_m$

$$\eta_{RT} = \frac{\operatorname{tg}\psi_m}{\operatorname{tg}(\psi_m + \rho')}$$

$$\eta_{TP} = \frac{\operatorname{tg}(\psi_m - \rho')}{\operatorname{tg}\psi_m}$$

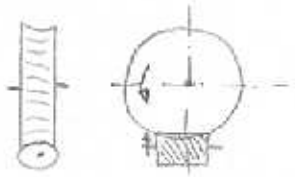
$$i = \frac{z_2}{z_1} = \frac{\cos\beta_{02}}{\cos\beta_{01}} = \frac{z_2}{z_1} = \frac{1}{\tan\varphi_{12}}$$

$d_{01} = m z_1$

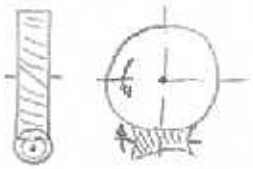
$$m = \frac{m_n}{\cos\beta_{01}}$$

Oblike:

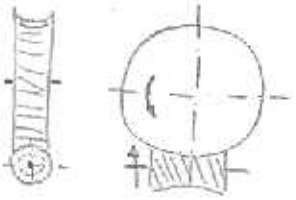
- Polžasto kolo s cilindričnim polžem



- Globoidno obliko

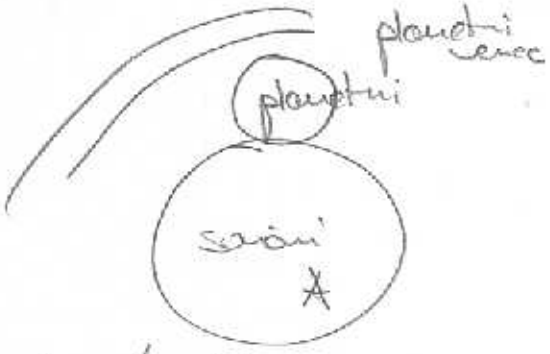


- Polžasto kolo in polžasto globoidno obliko
  Osi se prekrivajo

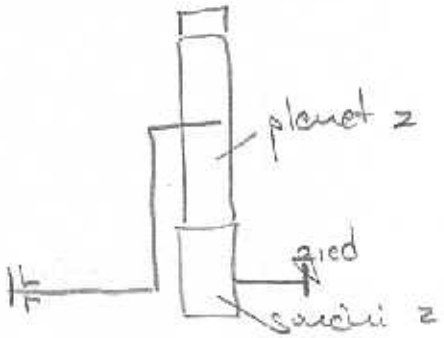


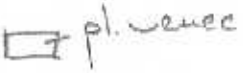
- Dober izkoristek
- Globoko pouličnje
- Lepe evolvente
- Dolg zob, kolo bronasto

- Planetno gonilo se sestoji iz sonca, planetnih vencev in planetov, ki se vrtijo okoli centralne osi



Planetno / pretok energije preko planetnika sestavljeno





- Stabilno gonilo je od planetnega veliko lažje
- Planetno gonilo za veliko prestavno razmerje / ne toliko za velike moči

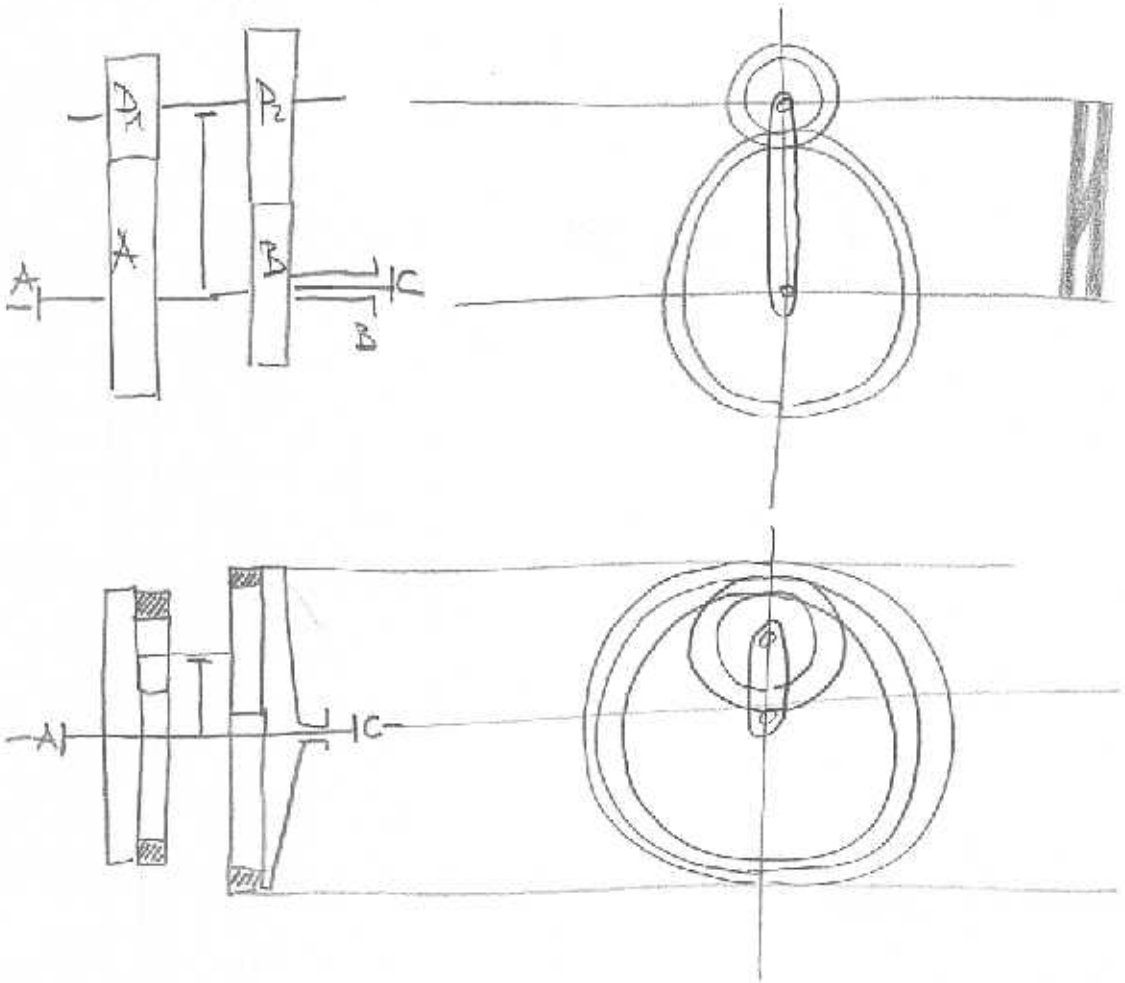
Notranja prestava: Razmerje med turažami dveh vrtečih se gredeh pri mirujoči tretji

- 3 možne

Zunanja prestava: Razmerje med turažami dveh od treh notranjih se gredi

1) Stabilno prestava: Mirujoče planetno gred

2,3) Miruje sončno gred ali planetni venec → planetno prestava



Gredi - tisti deli po katerih se dovaja / odvaja energija

u_A, u_B, u_C ... turaje gredi ABC

M_A, M_B, M_C ... momenti (vrtilni) A, B, C

P_A, P_B, P_C ... moč

$i_{A/B} = \frac{u_A}{u_B}$ stabilno prestavo $u_C = 0$ / $i_{B/A} = \frac{u_B}{u_A}$ reciprocost

$i_{A/C} = \frac{u_A}{u_C}$ planetno prestavo $u_B = 0$

$i_{B/C} = \frac{u_B}{u_C}$ planetno prestavo $u_C = 0$

Razmerje + (pozitivno) če se vrtita gredi v isto smer

Negativno (-) za nasprotno smer

u ... turaje, če 3 gredi rotirajo

v ... turaje če 2 gredi rotirata

$K_{A/C} = \frac{u_A}{u_C}$ Prestava med A, C če se tudi B vrti

Razmerje moči

$\varepsilon_{A/B} = -\frac{P_A}{P_B}$; recimo $P_A = M_A\, n_A \pi/30$

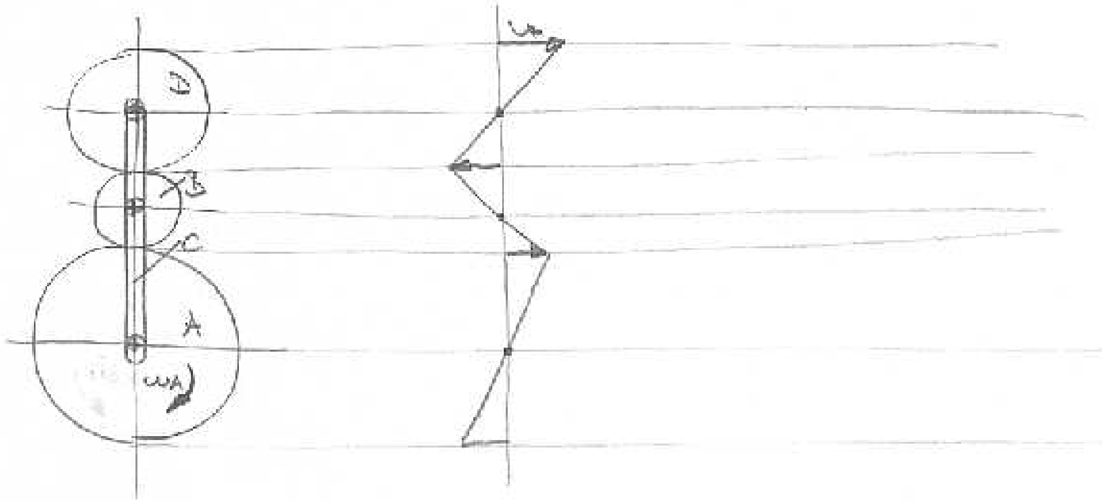
$\varepsilon_{A/B} = -\frac{M_A}{M_B}\, i_{A/B}$ ($\frac{n_A}{n_B}$)

Izstopna moč je vedno manjša od izstopne zaradi izgub

Moč pozitivna, če imamo v gredi delujoč vrtilni moment v smeri vrtenja gredi

Sila in obodna hitrost enako usmerjeni moč dovajamo

Ročica C miruje



Jalova moč
kotalna moč je večja od dovedene

Schwampovo pravilo

$i_{A/B} = 1 - i_{A/C} = \frac{1}{1 - i_{B/C}}$

$i_{B/C} = 1 - i_{B/A} = \frac{1}{1 - i_{C/A}}$ $i_{A/B} \cdot i_{B/C} \cdot i_{C/A} = -1$

$i_{CA} = 1 - i_{C/B} = \frac{1}{1 - i_{B/A}}$ $i_{A/B} = -i_{A/C}\, i_{C/B}$

Stabilna prestava

$i_{A/B} = 1$ pogon/odgon gred se vrtita enako sklopko

$i_{A/B} = -1$ enako hitro vendar v nasprotni smeri

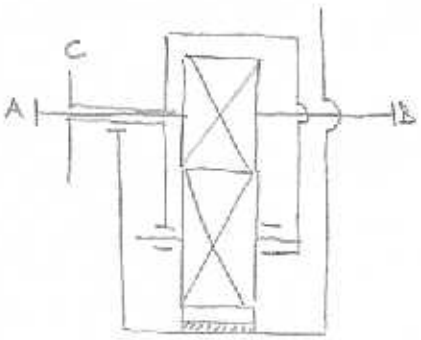
$i_{A/B} = \frac{Z_B}{Z_A}$; $i_{B/C} = \frac{Z_C}{Z_B}$

$i_{CA} = -\frac{Z_A}{Z_C}$

$i_{A/C} = \frac{Z_2 Z_3}{Z_1 Z_4}$

Sumarna gred – vsota momentov
– pri mirovanju da ugotoviš
Diferenčni gredi prestava ostalih dveh
– nasprotni minus

PLANETNA GONILA



$\left.\begin{matrix} u_A \\ u_B \\ u_C \end{matrix}\right\}$ vrtilne prestave

$\left.\begin{matrix} \omega_A \\ \omega_B \\ \omega_C \end{matrix}\right\}$ kotne prestave

Dosedamo:

$i_{A/B} = \frac{u_A}{u_B} = \frac{z_B}{z_A}$

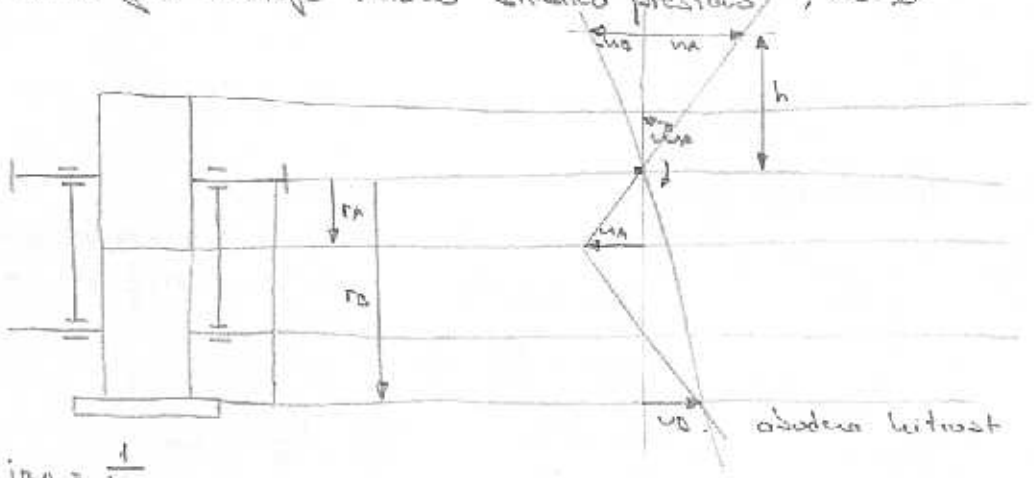
$i_{BC} = \frac{u_B}{u_C}$

$i_{CA} = \frac{u_C}{u_A}$

C planetno gred

AB sončno gred

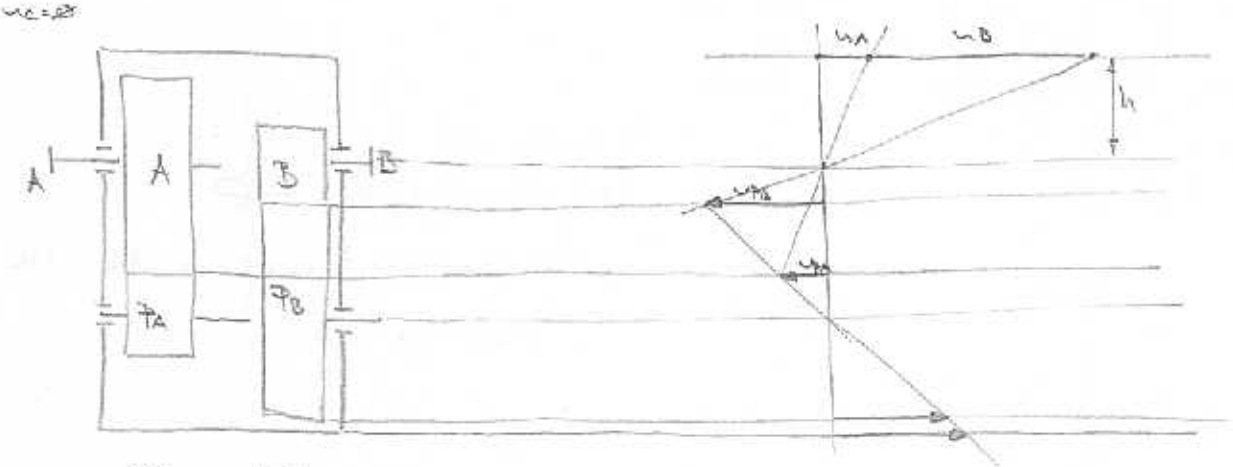
Če planetno gred miruje imamo stabilno prestavo, $u_C = 0$



$i_{A/B}$; $i_{BA} = \frac{1}{i_{A/B}}$

$\boxed{i_{A/B} = -\frac{u_A}{u_B}}$ Negativno stabilno prestavo

$u_C = 0$



$u_{PA} = \frac{u_A}{h} = \frac{u_A}{\omega_A z_A}$

$u_{PB} = \frac{u_B}{\omega_A z_A} = \frac{u_{PB}}{\omega_{PB} z_{PB}}$

$i_{A/B} = \frac{u_A}{u_B} = \frac{z_A}{z_A} \cdot \frac{z_B}{z_{PB}}$

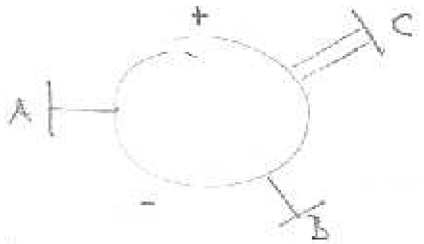
$\frac{u_{PB}}{\omega_B} \frac{1}{z_B} = \frac{u_B}{h}$

A	B	C	
n_A	n_B	$n_C = 0$	$i_{A/B} = \frac{n_A}{n_B}$
	$n_B = 0$		
$-n_B$	$-n_B$	$-n_B$	$i_{A/C} = \frac{n_A - n_B}{n_B}$
			$i_{A/C} = 1 - i_{AB}$
$n_A = 0$			
$-n_A$	$-n_A$	$-n_A$	$i_{B/C} = \frac{n_B - n_A}{-n_A} = 1 - \frac{n_B}{n_A}$
			$i_{B/C} = 1 - i_{B/A}$
			$i_{C/B} = \frac{1}{1 - i_{B/A}}$

$$i_{A/B} \cdot i_{B/C} \cdot i_{C/A} = -1$$

$$-\frac{n_A}{n_B} \cdot \frac{n_B}{n_C} \cdot \frac{n_C}{n_A} = -1$$

Wolfovo shema planetnog gonila



Sumarna grad je uspoređi −0

$$M_B = i_{A/B} M_A \cdot$$

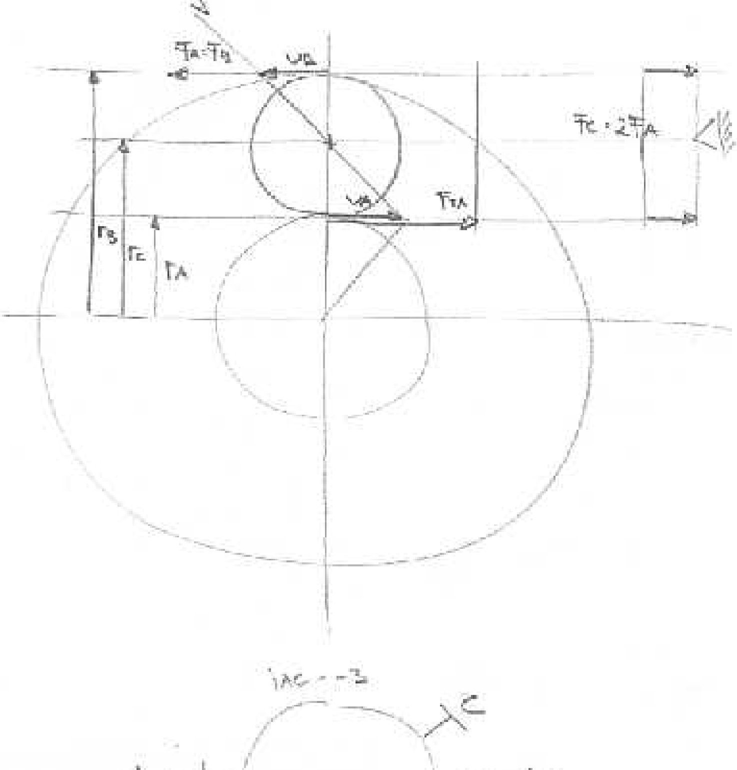
$$i_{AB} = -\frac{z_B}{z_A} = -4$$

$P_A = n_A M_A$

$P_B = n_B M_B$

$$\frac{n_A}{n_B} = \frac{M_B}{M_A} = -i_{A/B}$$

Sastavanje momenata

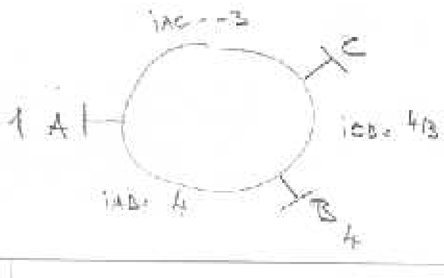


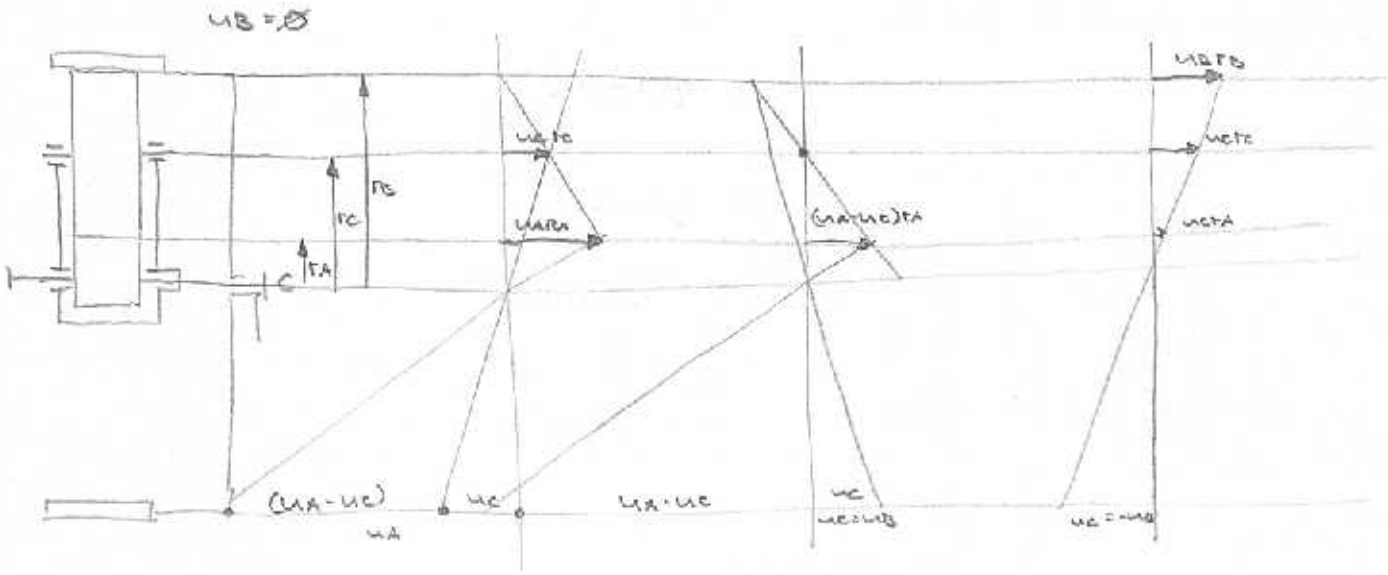
Fi obodna sila

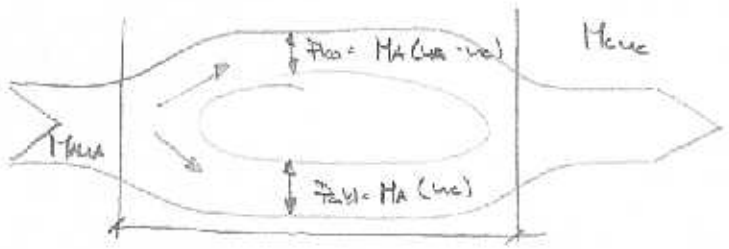
$$M_C = 2F_A r_C = 2F_A \frac{r_A + r_B}{2}$$

$$= F_A (r_A + r_B) = F_A r_A + F_A r_B = M_A + M_B \frac{r_B}{r_A}$$

$$= M_A + M_B i_{BA}$$

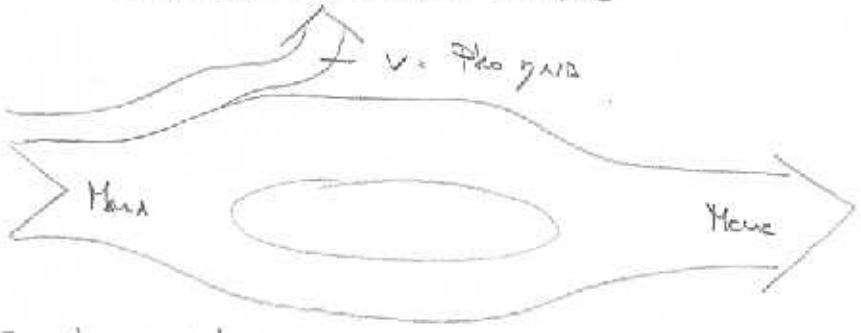






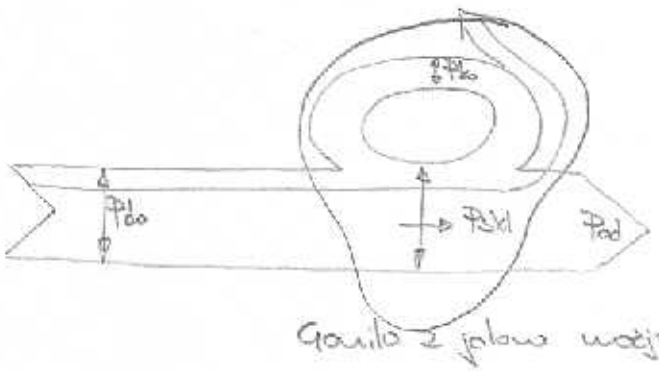
$p_{dj} = M_{AUA}$ = kotalno vrtež + sklopno vrtež

$= M_A (u_A - u_C) + M_A u_C = M_{CUC}$



η_{AVB} ... izkoristek stabilnega gonila

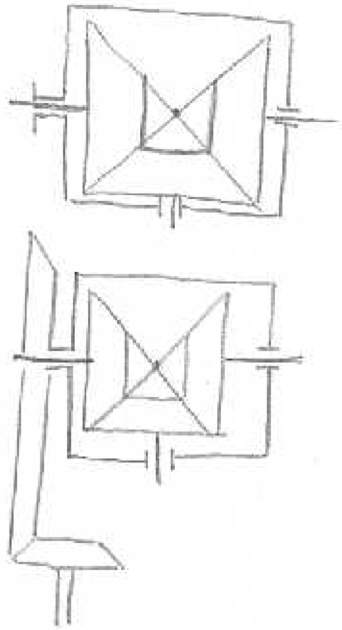
Gonilo z jalovo vodjo

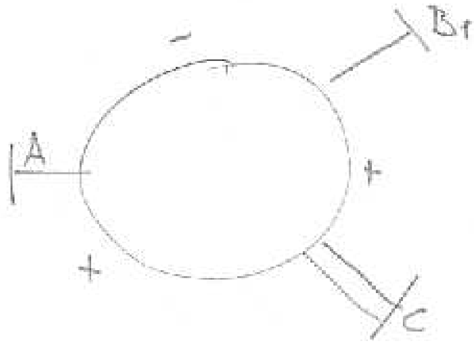


Gonilo z jalovo vodjo

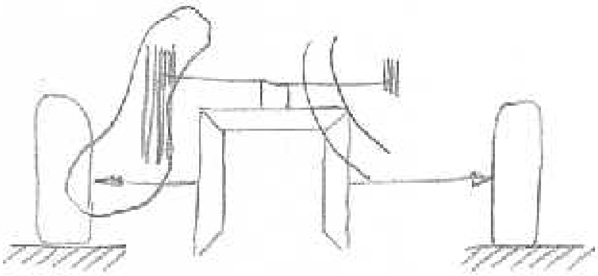
Automobilski diferencial

- Kotno gonilo
- sprememba smeri vrtenja vrtilnega gibanja



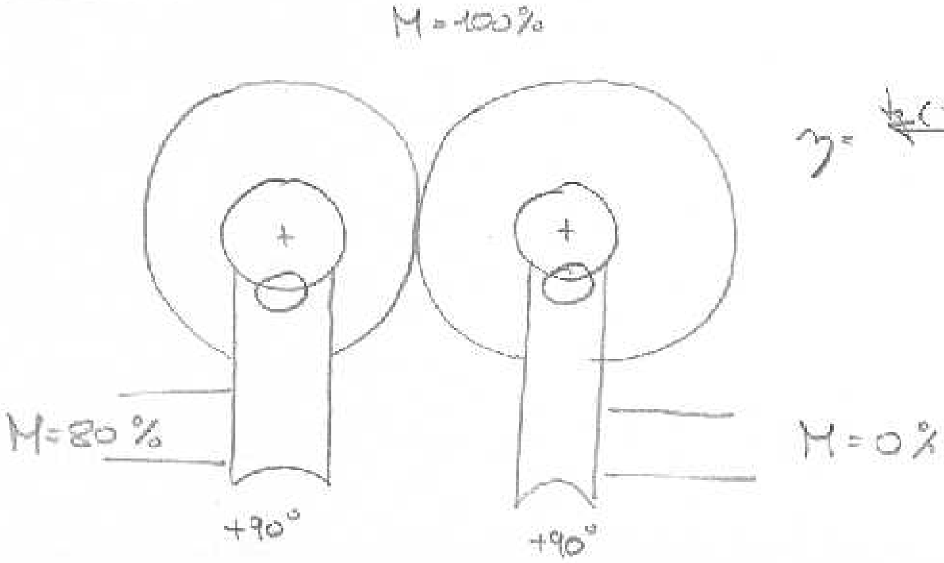


Samozaporni diferencial



Nesimetričen prenos moči zaradi dveh tornih sklopk

Torsenov diferencial



$$\eta = \frac{tg(\gamma_m - \rho')}{tg\,\gamma_m}$$

Notranje krožne moči povečajo tok moči

Dvojno planetno gonilo