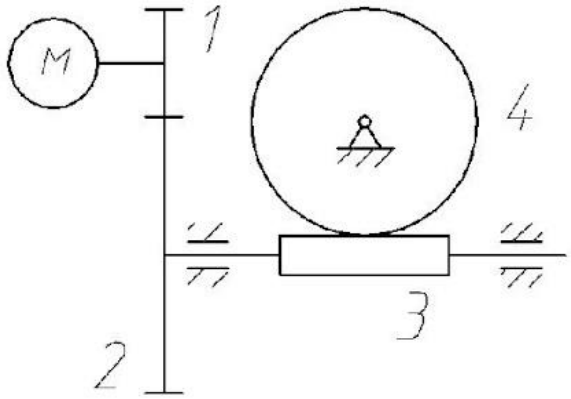
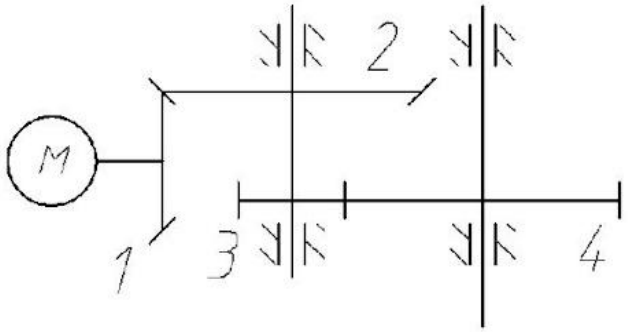
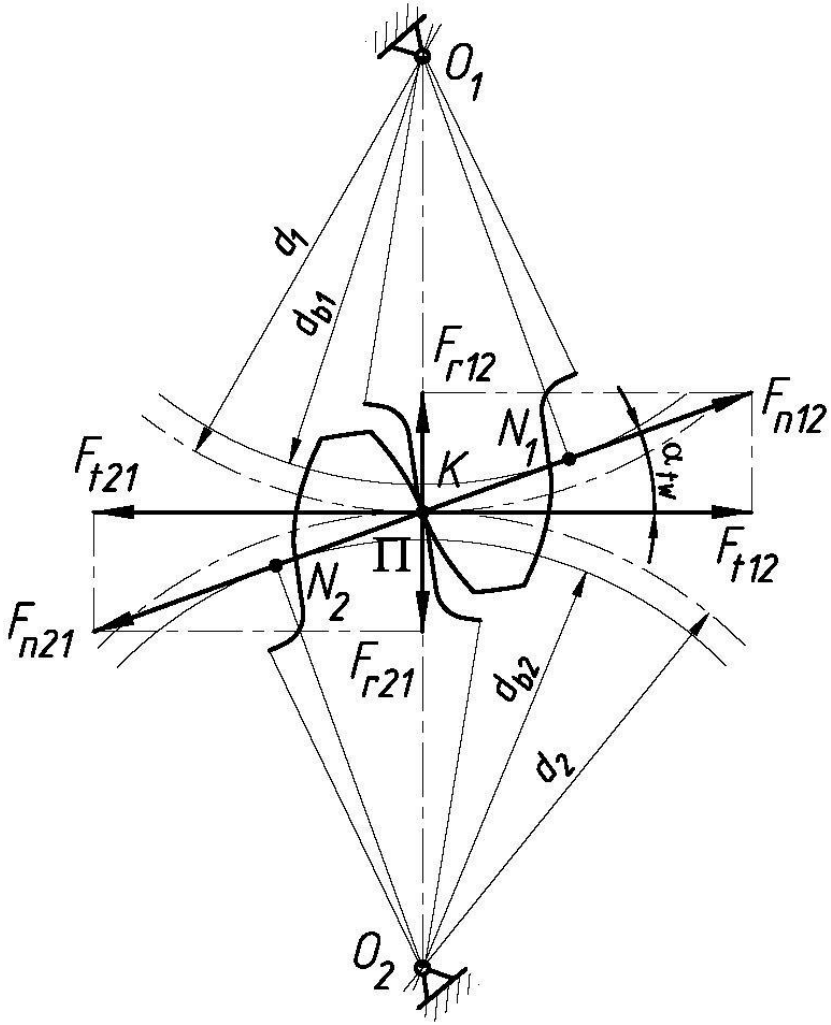
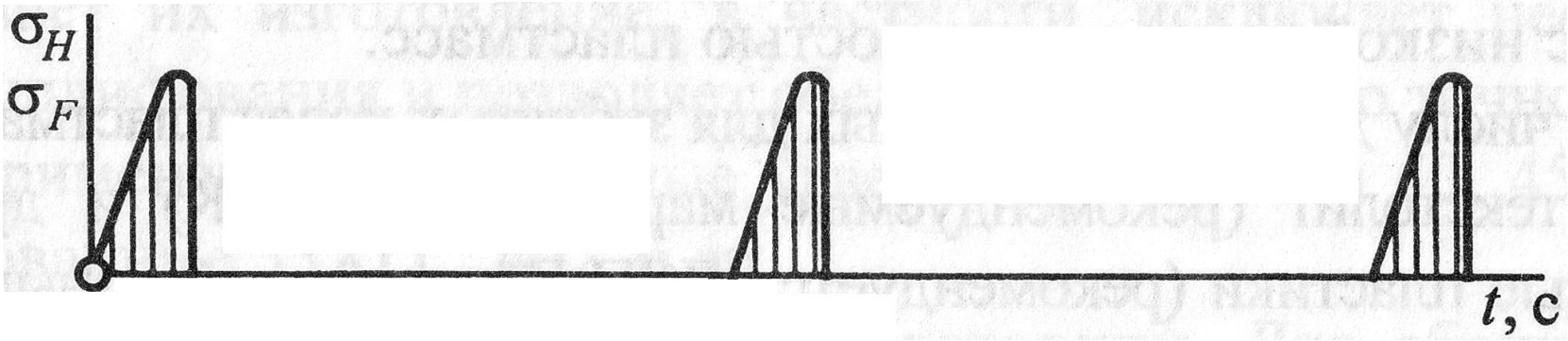
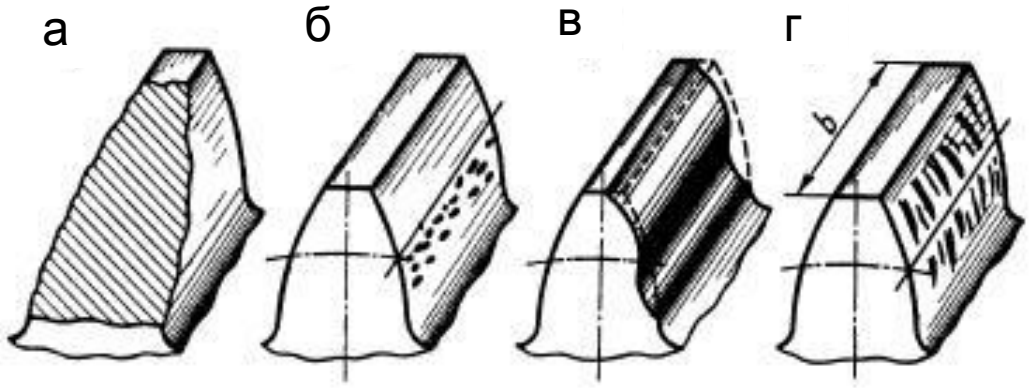

M
1
2
3
4

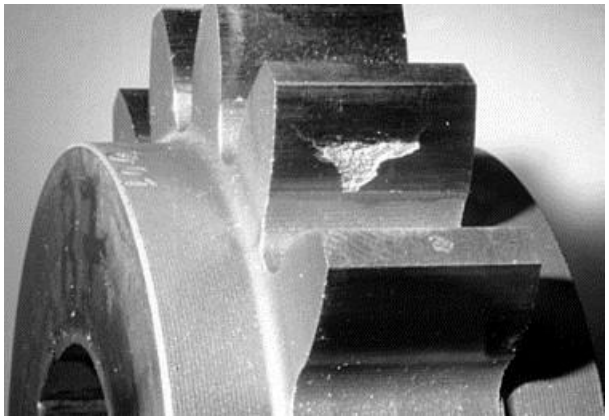

M
1
2
3
4

Название передачи	КПД	Передаточное число
Прямозубая и косозубая с внешними зубьями	0,97... 0,98	1 ÷ 10
Прямозубая с внутренними зубьями	0,97... 0,98	2 ÷ 10
Коническая	0,97... 0,98	1 ÷ 6
Червячная (в приборах)	0,65... 0,9	8 ÷ 80 (до 1000)
Планетарная	0,97... 0,98	3,2 ÷ 12,5
Волновая (кулачкового генератора волн)	0,97... 0,99 (0,8... 0,85)	80 ÷ 300
Ременная	0,92... 0,98	1 ÷ 8
Цепная	0,92... 0,98	1 ÷ 6


O_1
d_1
d_{b1}
F_{r12}
F_{n12}
N_1
F_{t21}
K
α_{tw}
F_{t12}
П
N_2
F_{n21}
F_{r21}
d_{b2}
d_2
O_2

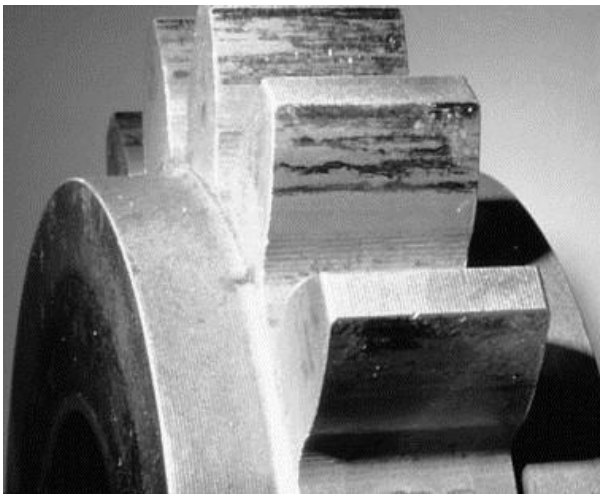

σ_H
σ_F
t, с



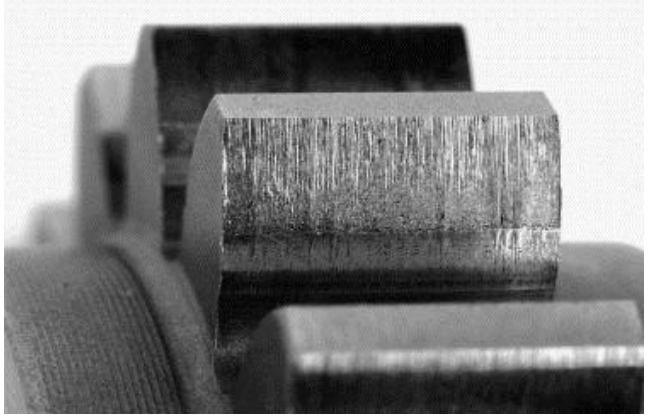


а – поломка, б – выкрашивание,

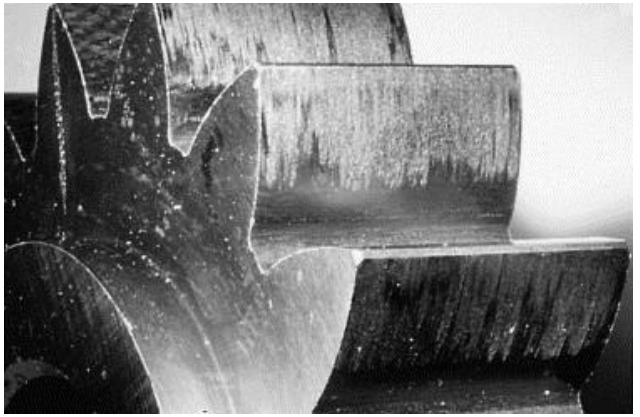
в – износ, г – заедание



б



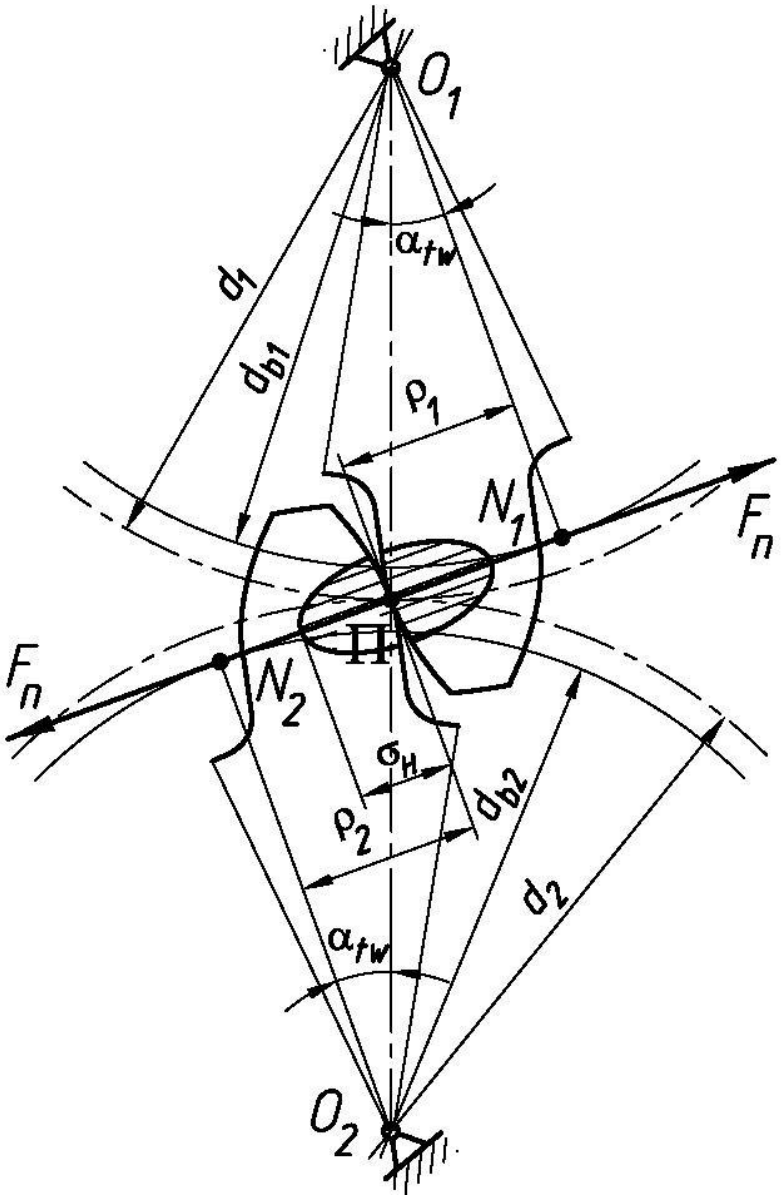
в



г

$$\sigma_H \leq \sigma_{HP}$$

$$\sigma_F \leq \sigma_{FP}$$



$$\rho_1 = \frac{d_1}{2}\sin\alpha_{tw}$$

$$\rho_2 = \frac{d_2}{2}\sin\alpha_{tw}$$

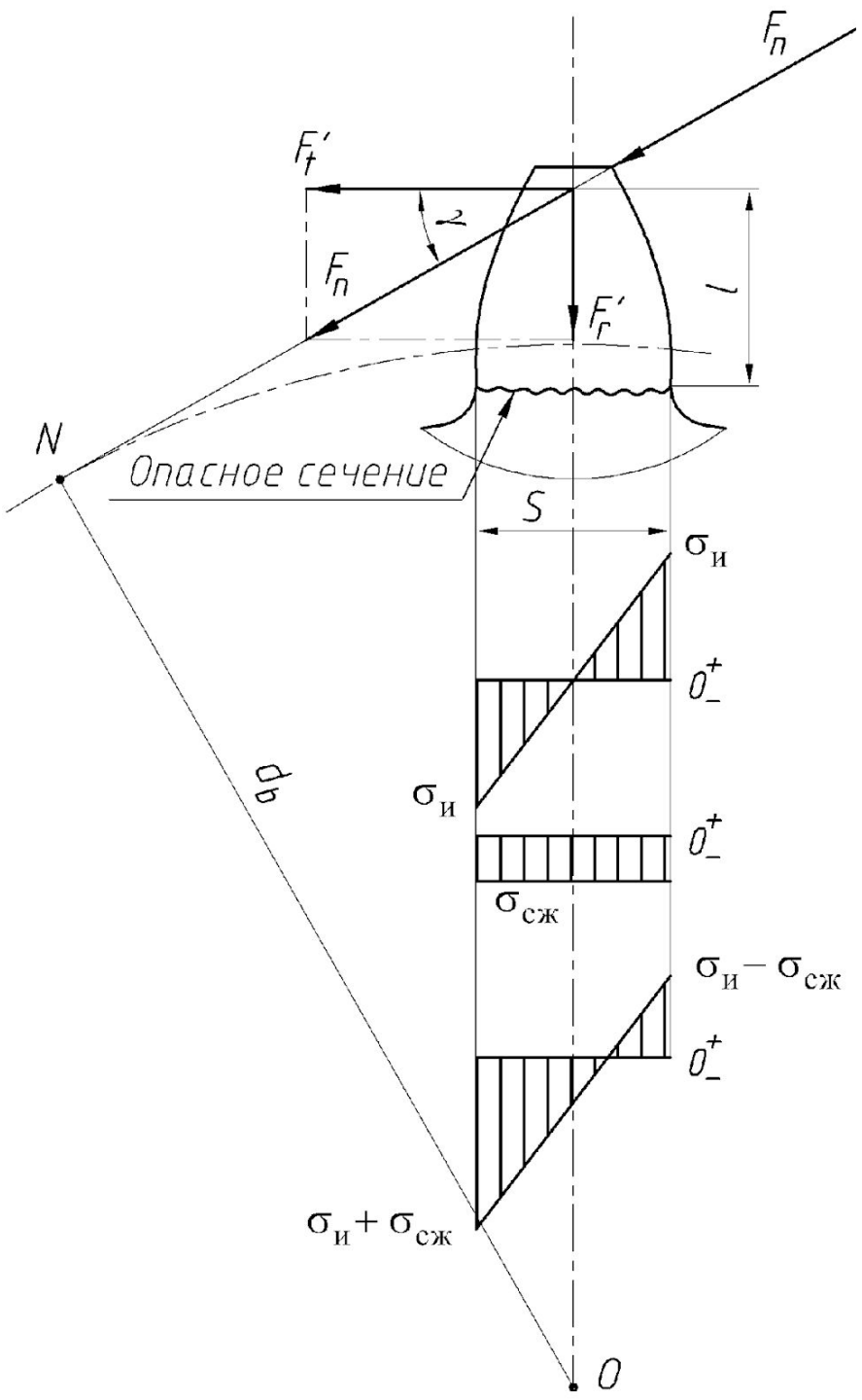
$$\sigma_{\max} = \sqrt{\frac{1}{\pi\rho_{\text{пр}}}\frac{F_n}{l}\frac{E_1E_2}{E_1\left(1-\mu_2^2\right)+E_2\left(1-\mu_1^2\right)}}$$

$$\rho_{\text{пр}} = \frac{\rho_2\rho_1}{\rho_2 \pm \rho_1}$$

$$\mu_1 = \mu_2 \approx 0{,}3$$

$$E_1 = E_2 = 2{,}1\cdot 10^5 \text{ МПа} \qquad \alpha_{tw} = 20^{\circ}$$

$$a_w \geq 49{,}5(u \pm 1)\sqrt[3]{\frac{T_2K_H}{\sigma_{HP}^2u^2\psi_{ba}}}$$



$$M = F_t' l = F_n \cos\gamma l$$

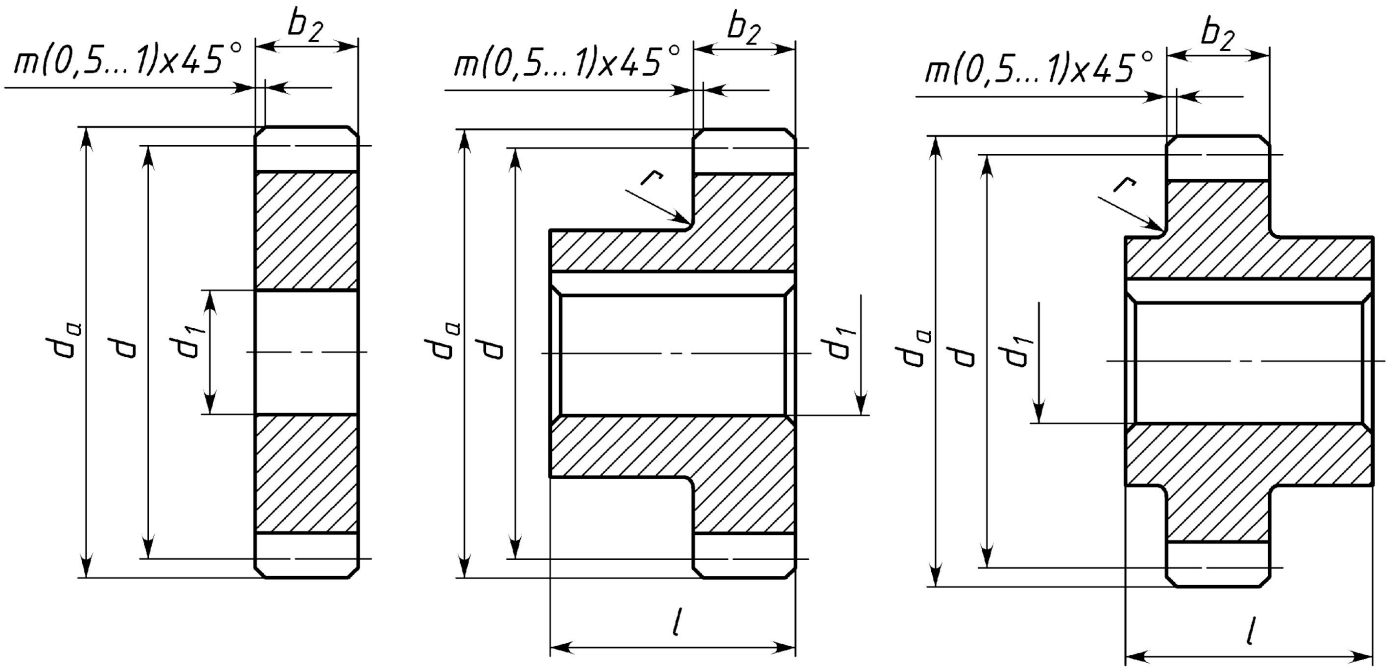
$$F_r' = F_n \sin\gamma$$

$$\sigma_и = \frac{M}{W} \qquad \sigma_{сж} = \frac{F_r'}{A}$$

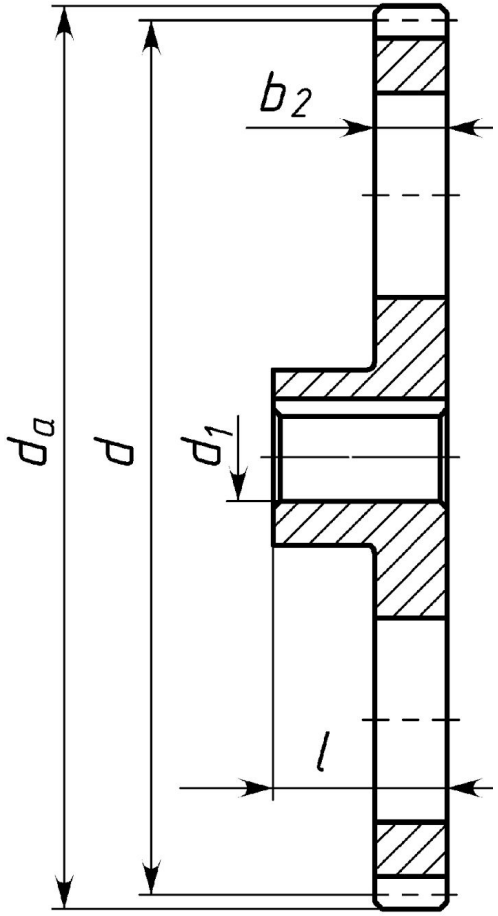
$$W = \frac{bS^2}{6} \qquad A = bS$$

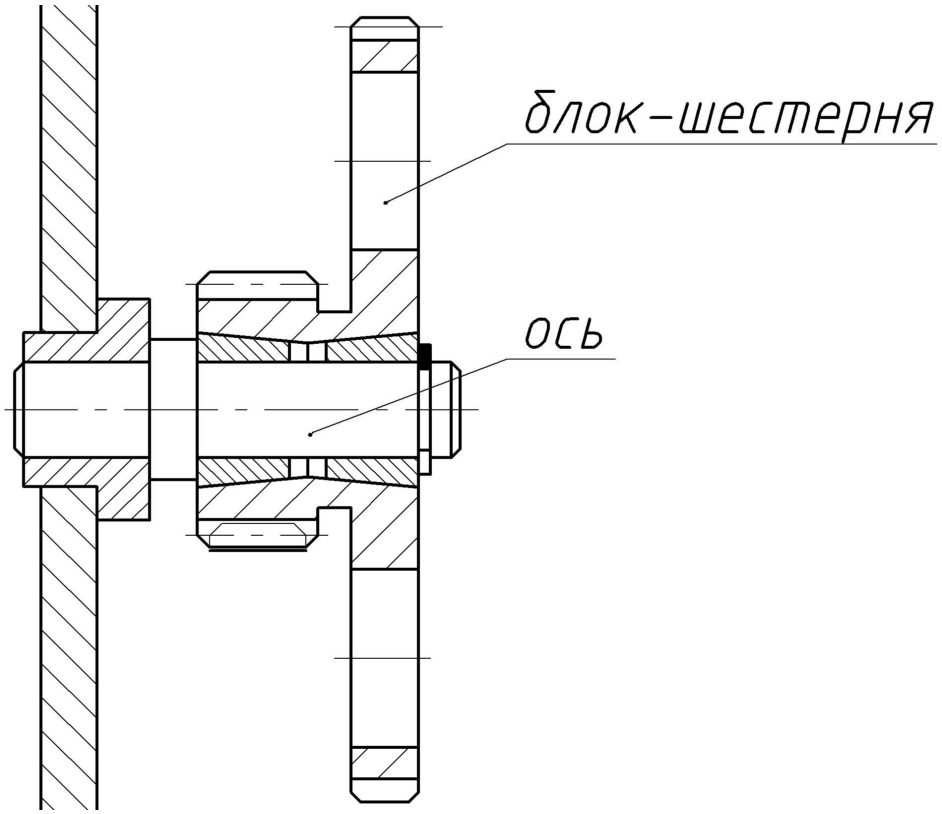
$$\sigma_F = \sigma_и - \sigma_{сж}$$

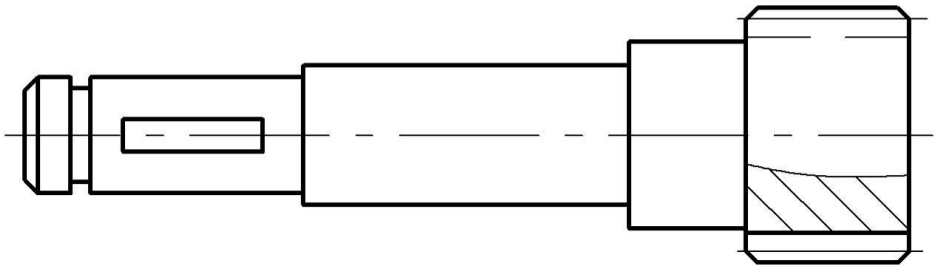
$$\sigma_F = \frac{F_t K_F Y_F}{bm}$$

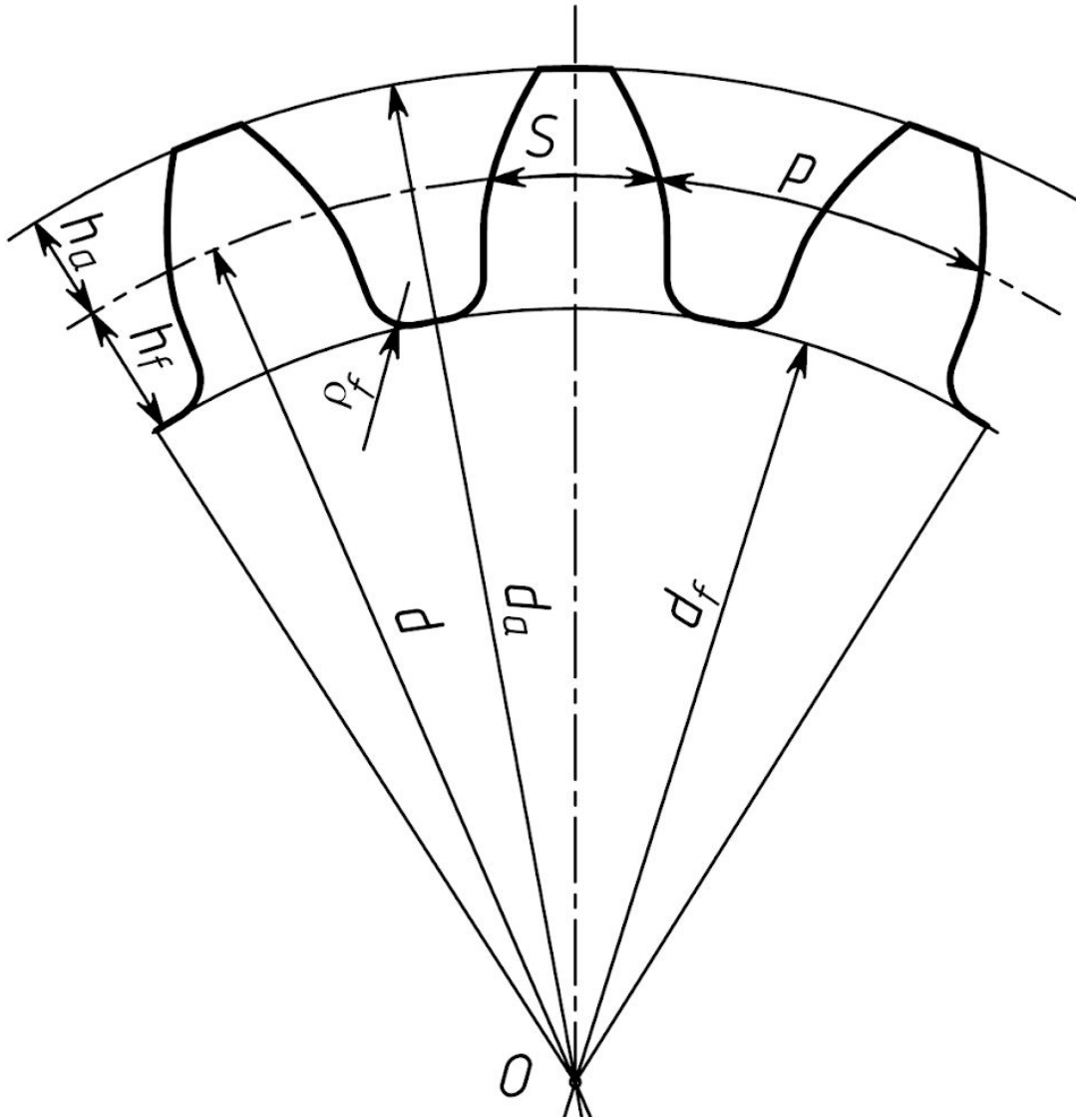


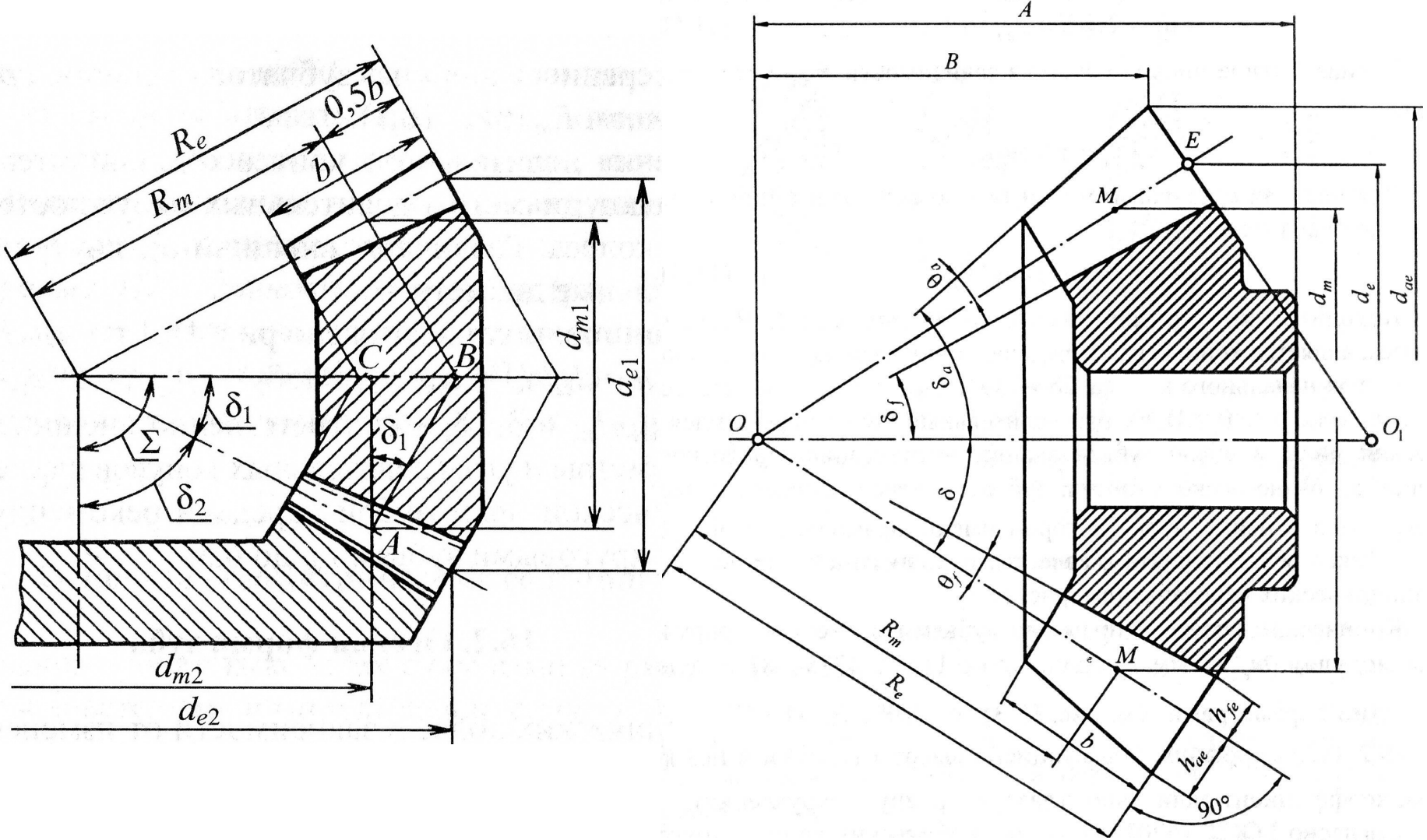
а б в


b_2
d_a
d
d_1
l


блок-шестерня
ось




S
p
h_a
h_f
ρ_f
p
p_p
d_f
O



Значения среднего модуля m_m	Формула для h_{fe}
$0,1 \le m_m < 0,3$	$1,4m_{te}$
$0,3 \le m_m < 0,5$	$1,35m_{te}$
$0,5 \le m_m < 1$	$1,25m_{te}$
$m_m \ge 1$	$1,2m_{te}$

$$0{,}418\sqrt{\frac{F_n K_H}{b\vartheta_H}\frac{1}{\rho_{пр}}\frac{2E_1E_2}{E_1+E_2}} \le \sigma_{HP}$$

$$E_1 = E_2 = 2{,}1\cdot 10^5 \text{ МПа} \qquad \alpha_w = 20^\circ$$

$$d_{e2} \ge 95{,}8\sqrt[3]{\frac{T_2 K_H u}{(1-K_{be})K_{be}\vartheta_H \sigma_{HP}^2}}$$

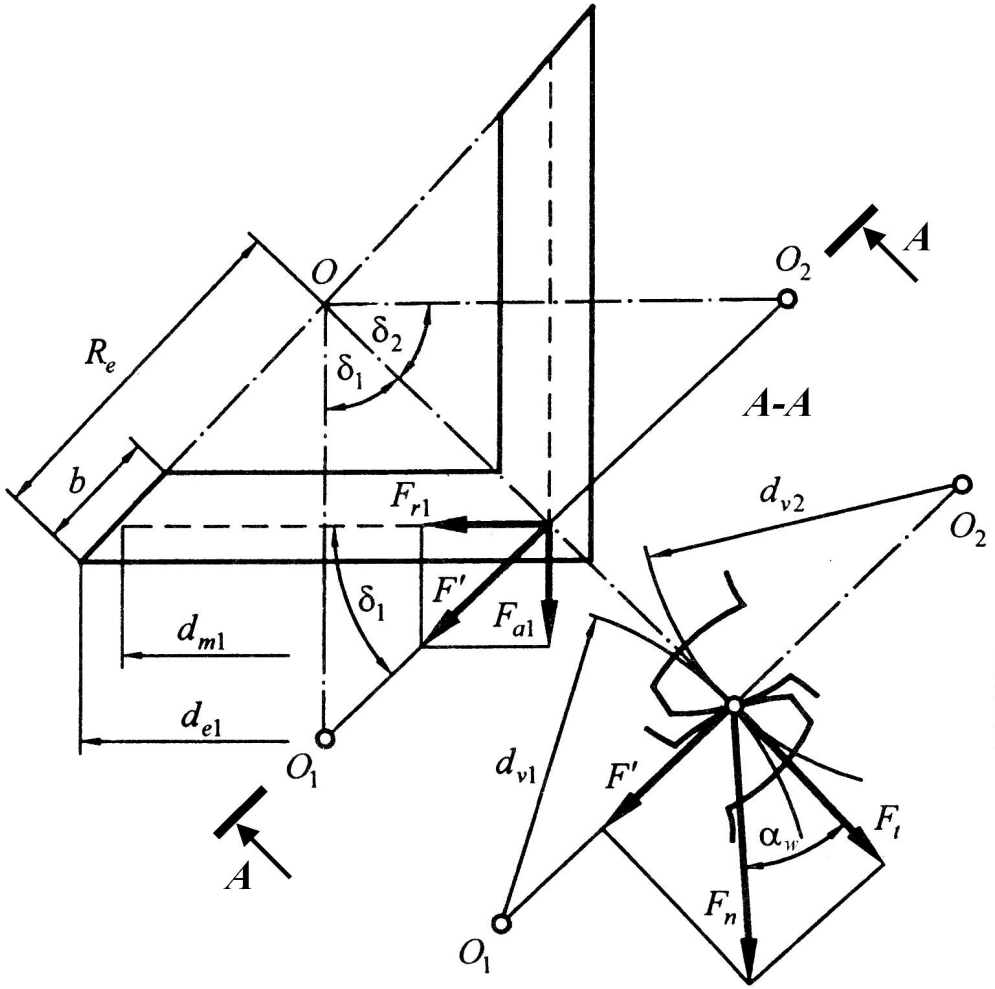
$$\sigma_F \leq \sigma_{FP}$$

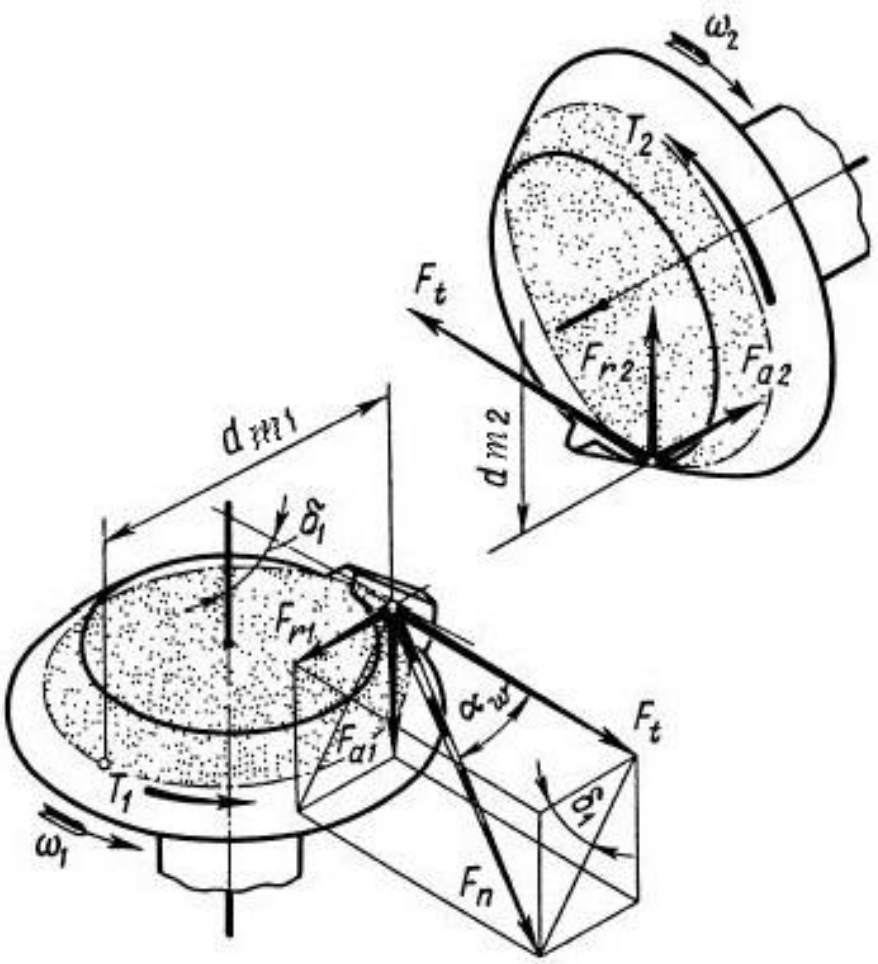
$$\sigma_F = \frac{F_t K_F Y_F}{b m_m \vartheta_F}$$

$$F_t = \frac{2T}{d_e\left(1-0{,}5K_{be}\right)} = \frac{2T}{m_{te} z\left(1-0{,}5K_{be}\right)}$$

$$m_m = m_{te}\left(1-0{,}5K_{be}\right)$$

$$\frac{2TK_F Y_F}{b m_{te}^2 z\left(1-0{,}5K_{be}\right)^2 \vartheta_F} \leq \sigma_{FP}$$

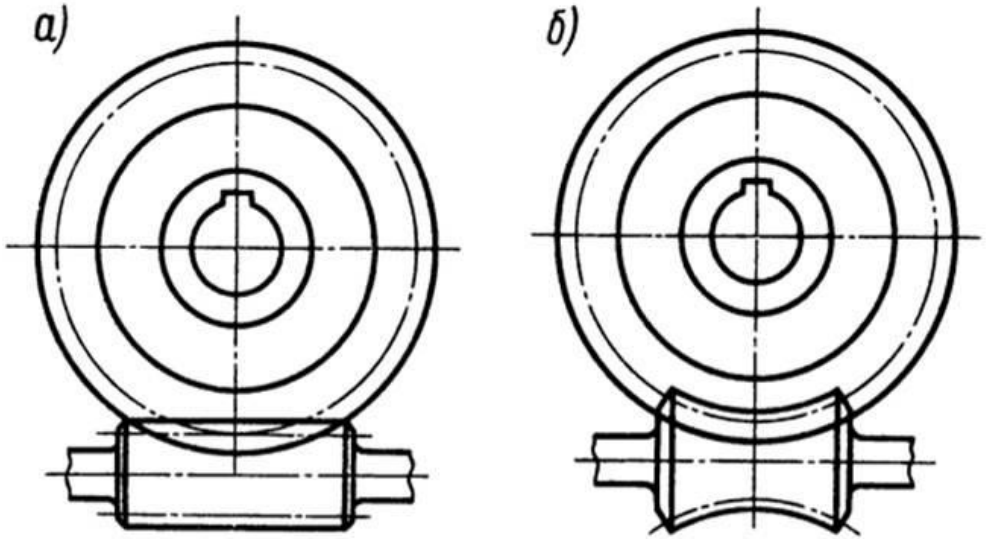


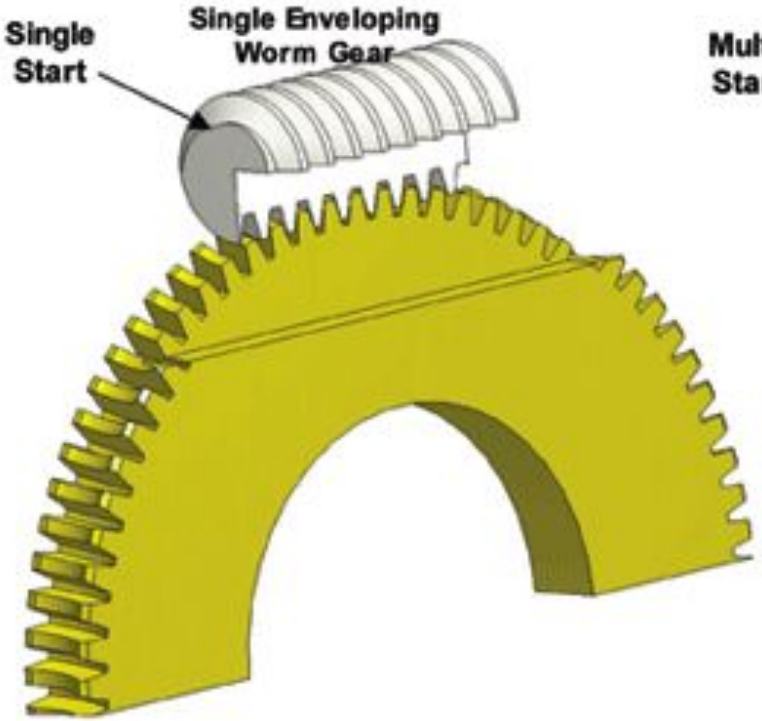


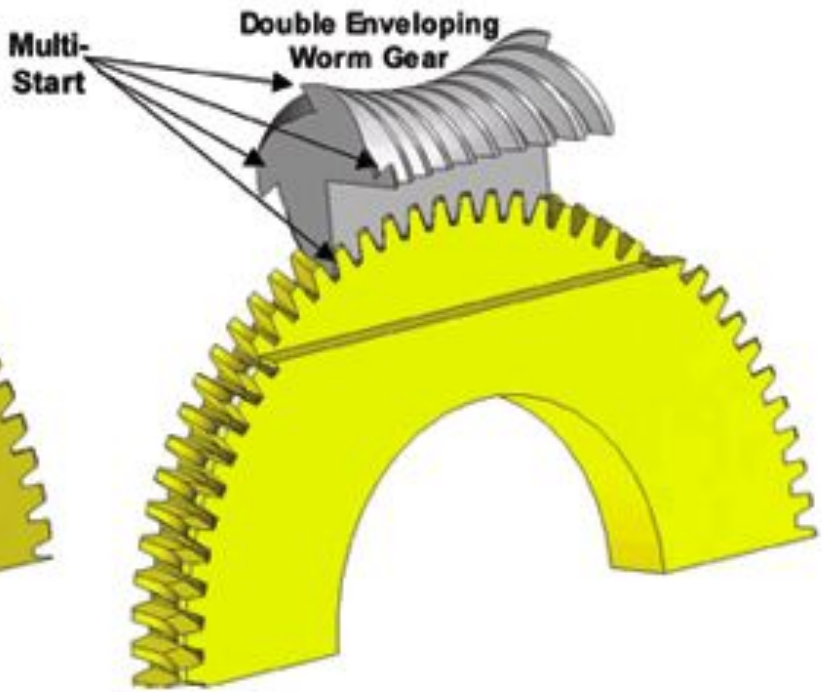
$$F_t = \frac{2T_1}{d_{m1}} = \frac{2T_2}{d_{m2}} = \frac{2T_1}{d_{e1}(1-0{,}5K_{be})} = \frac{2T_2}{d_{e2}(1-0{,}5K_{be})} \qquad F' = F_t \operatorname{tg}\alpha_w$$

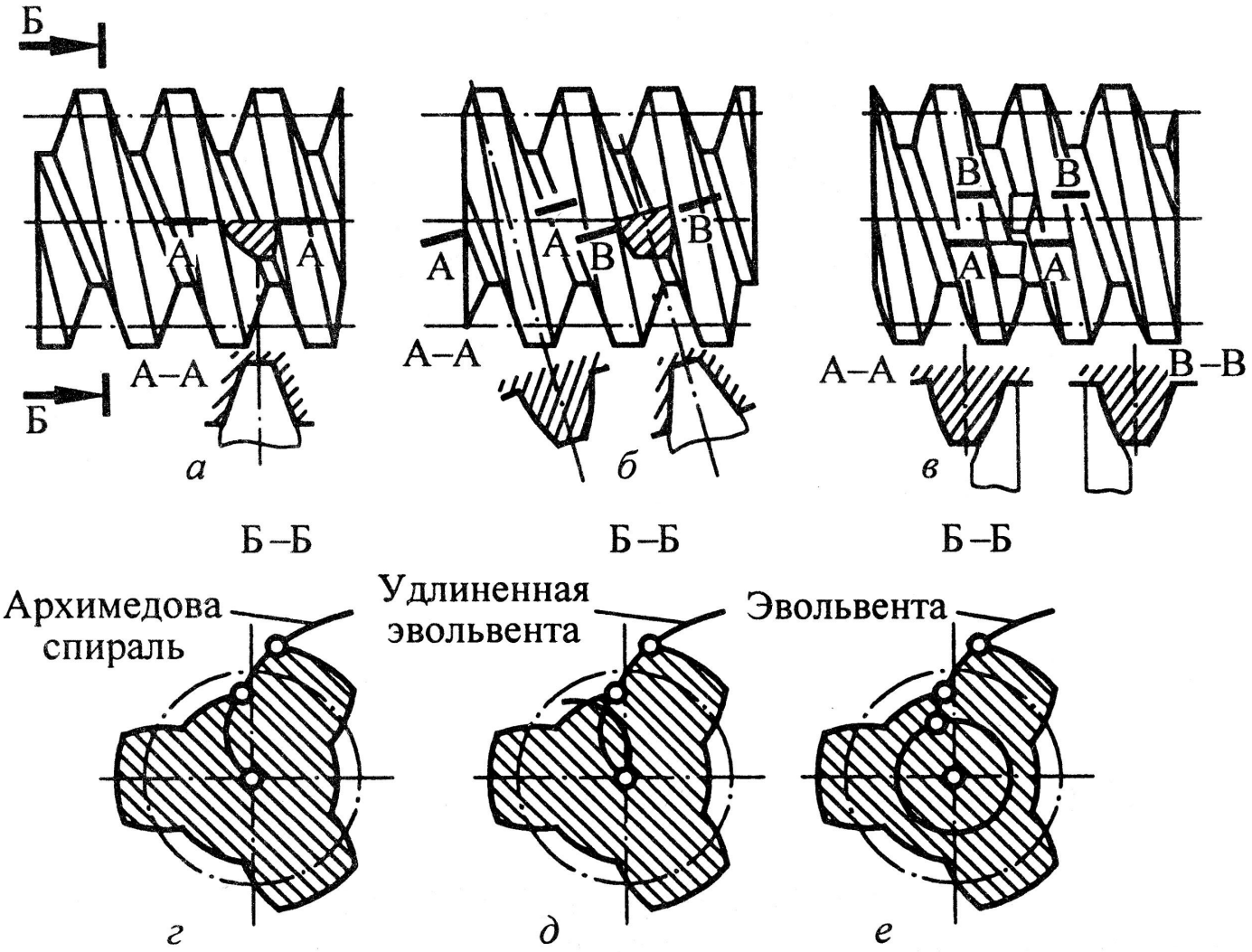
$$F_{r1} = F'\cos\delta_1 = F_t \operatorname{tg}\alpha_w \cos\delta_1 \qquad F_{r2} = -F_{a1}$$

$$F_{a1} = F'\sin\delta_1 = F_t \operatorname{tg}\alpha_w \sin\delta_1 \qquad F_{a2} = -F_{r1}$$


а)
б)


Single
Start
Single Enveloping
Worm Gear


Multi-
Start
Double Enveloping
Worm Gear



архимедов червяк

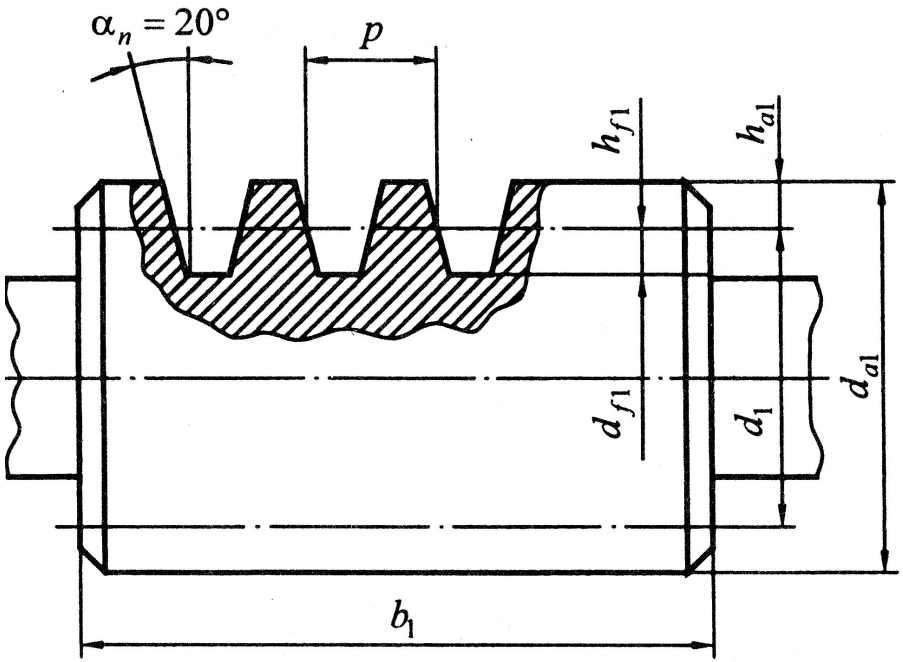
ZA

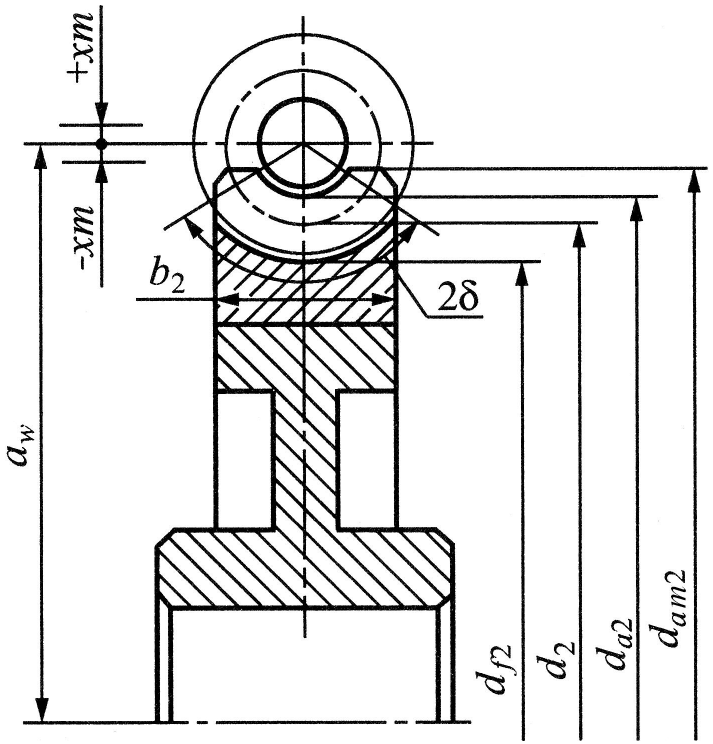
конволютный червяк

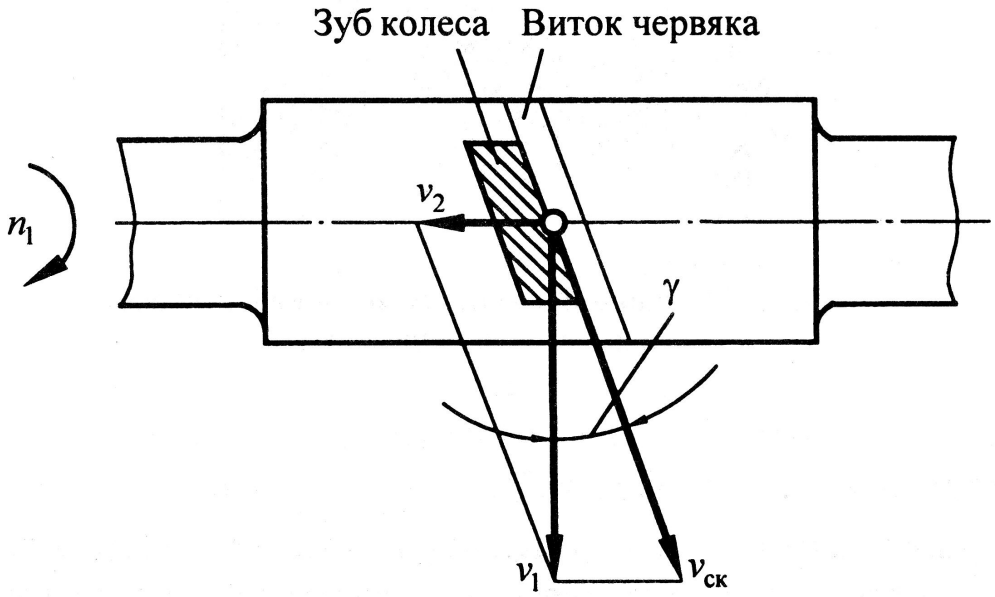
ZN

эвольвентный червяк

ZJ


$\alpha_n = 20°$
p
h_{f1}
h_{a1}
d_{f1}
d_1
d_{a1}
b_1


$+xm$
$-xm$
b_2
2δ
a_w
d_{f2}
d_2
d_{a2}
d_{am2}

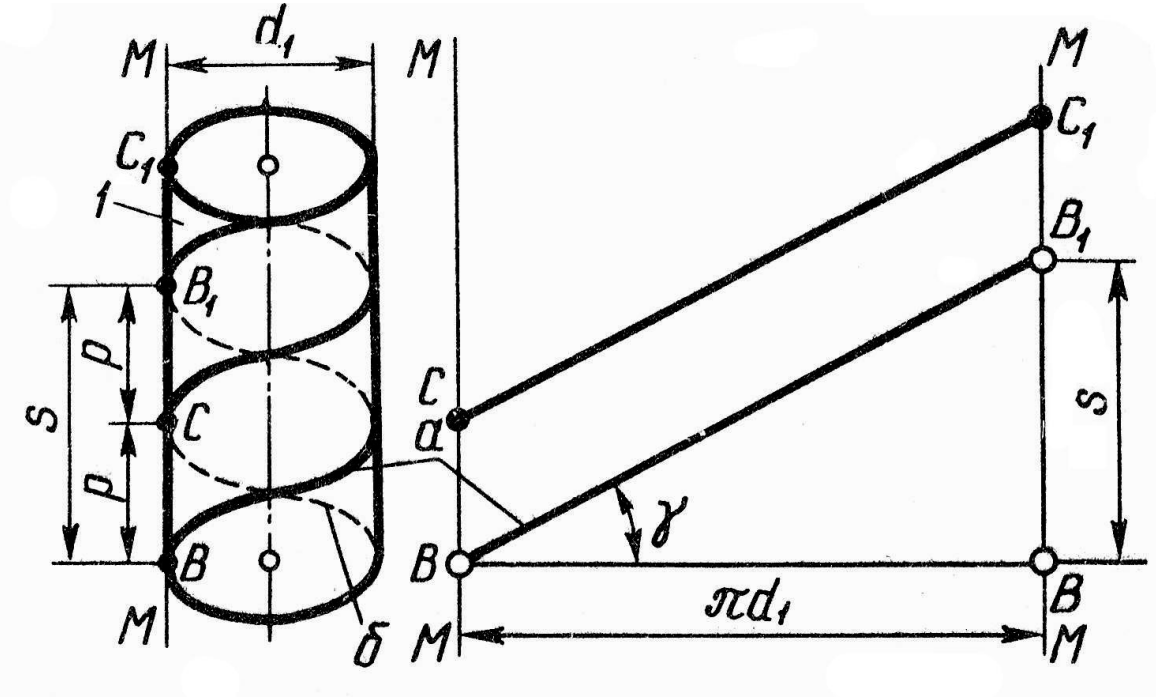


$$v_{ск} = \sqrt{v_1^2 + v_2^2} = \frac{v_1}{\cos\gamma}$$

$$v_1 = \pi n_1 d_{w1}$$

$$v_2 = \pi n_2 d_2$$

$$\gamma < 30^{\circ}$$



$$s = z_1 p$$

$$\gamma = \operatorname{arctg}\frac{s}{\pi d_1} = \operatorname{arctg}\frac{z_1 p}{\pi d_1} = \operatorname{arctg}\frac{z_1 m}{d_1} = \operatorname{arctg}\frac{z_1}{q}$$

$$0{,}418\sqrt{\frac{F_n K_H}{l_\Sigma}\frac{1}{\rho_{пр}}\frac{2E_1E_2}{E_1+E_2}} \le \sigma_{HP}$$

$$E_1 = 2{,}1\cdot 10^5 \text{ МПа} \qquad E_2 = 0{,}9\cdot 10^5 \text{ МПа}$$

$$367{,}96\sqrt{\frac{\cos^2\gamma}{\sin 2\alpha_n}\frac{z_2 T_2 K_H}{q d_2^3}} \le \sigma_{HP}$$

$$\gamma \approx 10^{\circ} \qquad \alpha_n = 20^{\circ}$$

$$d_2 \ge 58{,}9\sqrt[3]{\frac{T_2 K_H z_2}{q\sigma_{HP}^2}}$$

$$\cos^2\gamma$$

$$\sigma_F \le \sigma_{FP}$$

$$F_{t2}/\cos\gamma$$

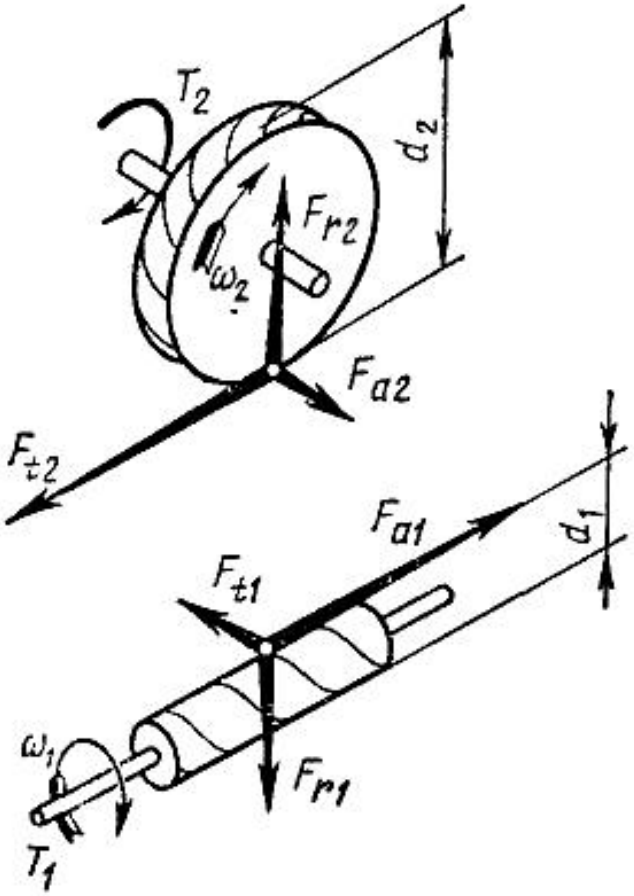
$$\sigma_F = \frac{F_{t2}K_F Y_{F2}}{\cos\gamma l_\Sigma m_n}\cos^2\gamma = \frac{F_{t2}K_F Y_{F2}}{l_\Sigma m_n}\cos\gamma$$

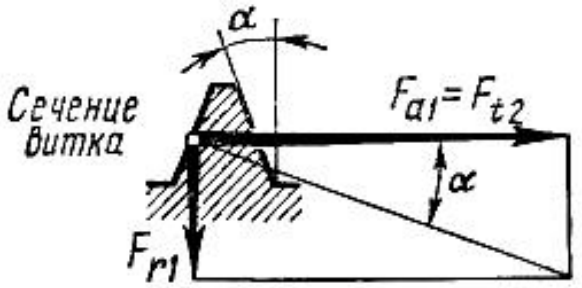
$$\frac{1{,}5T_2 K_F Y_{F2}\cos\gamma}{qm^3 z_2} \le \sigma_{FP}$$

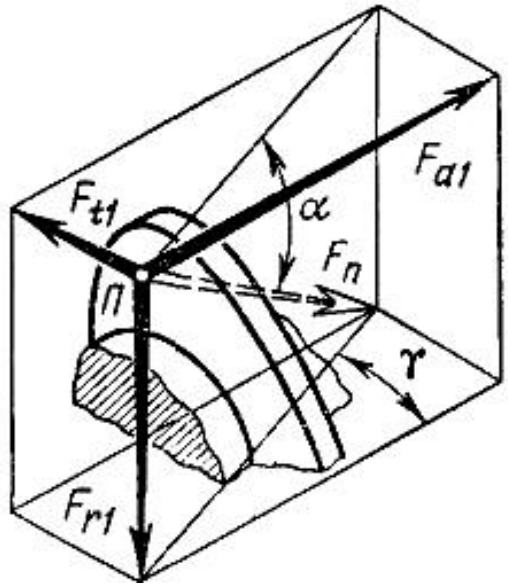
$$\sigma_{FP} = \left(0{,}25\sigma_т + 0{,}08\sigma_в\right)$$

$$\sigma_{FP} = 0{,}1\sigma_в$$

z_{v2}	20	24	26	28	30	32	35	37	40	45	50	60	80	100	150	300
Y_{F2}	1,98	1,88	1,85	1,80	1,76	1,71	1,64	1,61	1,55	1,48	1,45	1,40	1,34	1,30	1,27	1,24







$$F_{t2} = F_{a1} = \frac{2T_2}{d_2} \qquad F_{t1} = F_{a2} = \frac{2T_1}{d_1} \qquad F_{r1} = F_{r2} = F_{t2}\,\mathrm{tg}\alpha_n$$

$$F_n = \frac{F_{a1}}{\cos\gamma\cos\alpha_n} = \frac{F_{t2}}{\cos\gamma\cos\alpha_n}$$