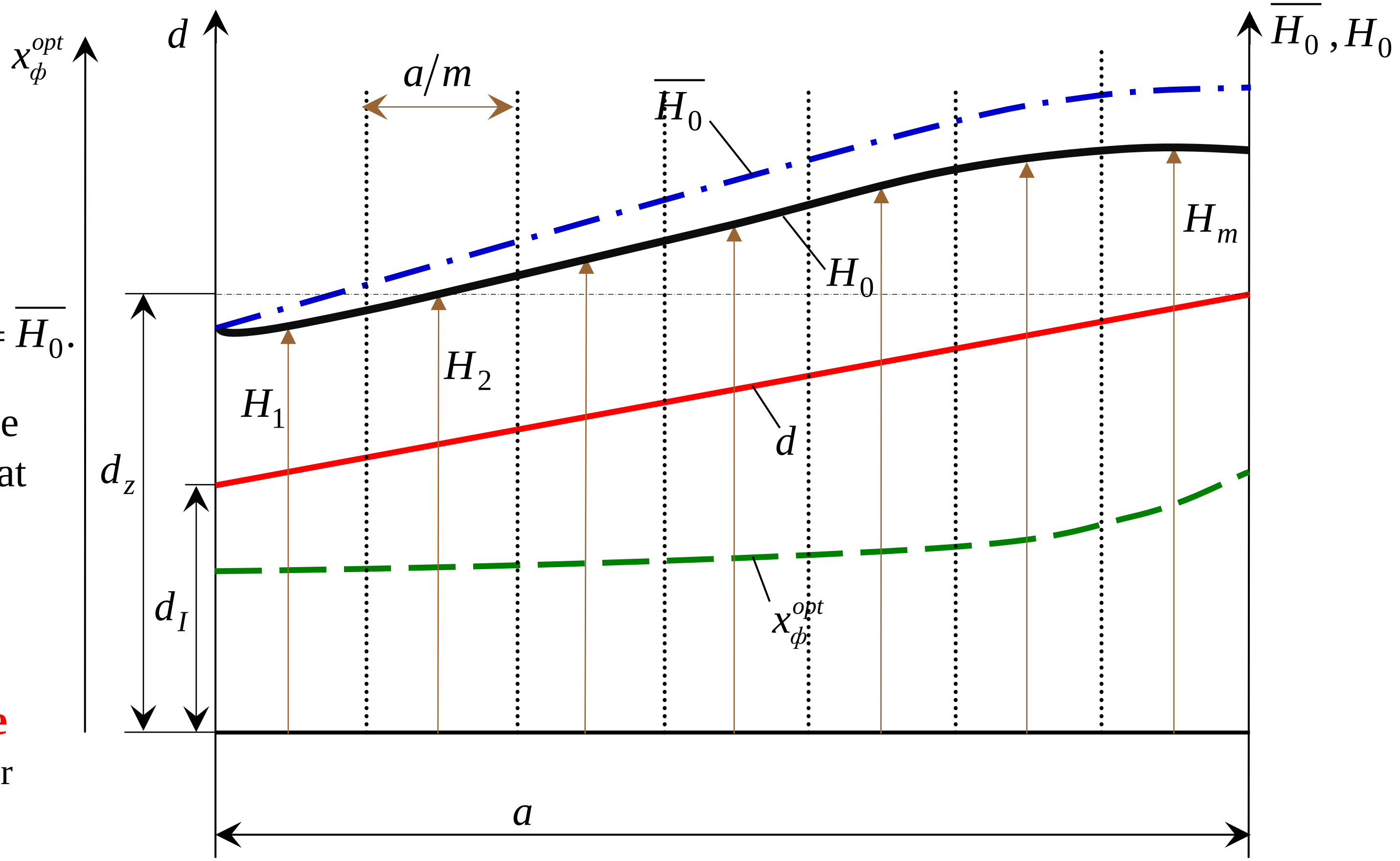
4. $\overline{H_{0j}} = H_{0j} + \frac{c_{0j}^2}{2};$

$$H_0 = (0{,}92 \div 0{,}96)\overline{H_0}$$

For the 1-st stage

$$\chi = 0; \Rightarrow \frac{c_{01}^2}{2} = 0; \Rightarrow H_{01} = \overline{H_0}.$$

Plot the dependence for the change in the available heat drop in static parameters



5. **Determine the average available heat drop** (linear dependence).

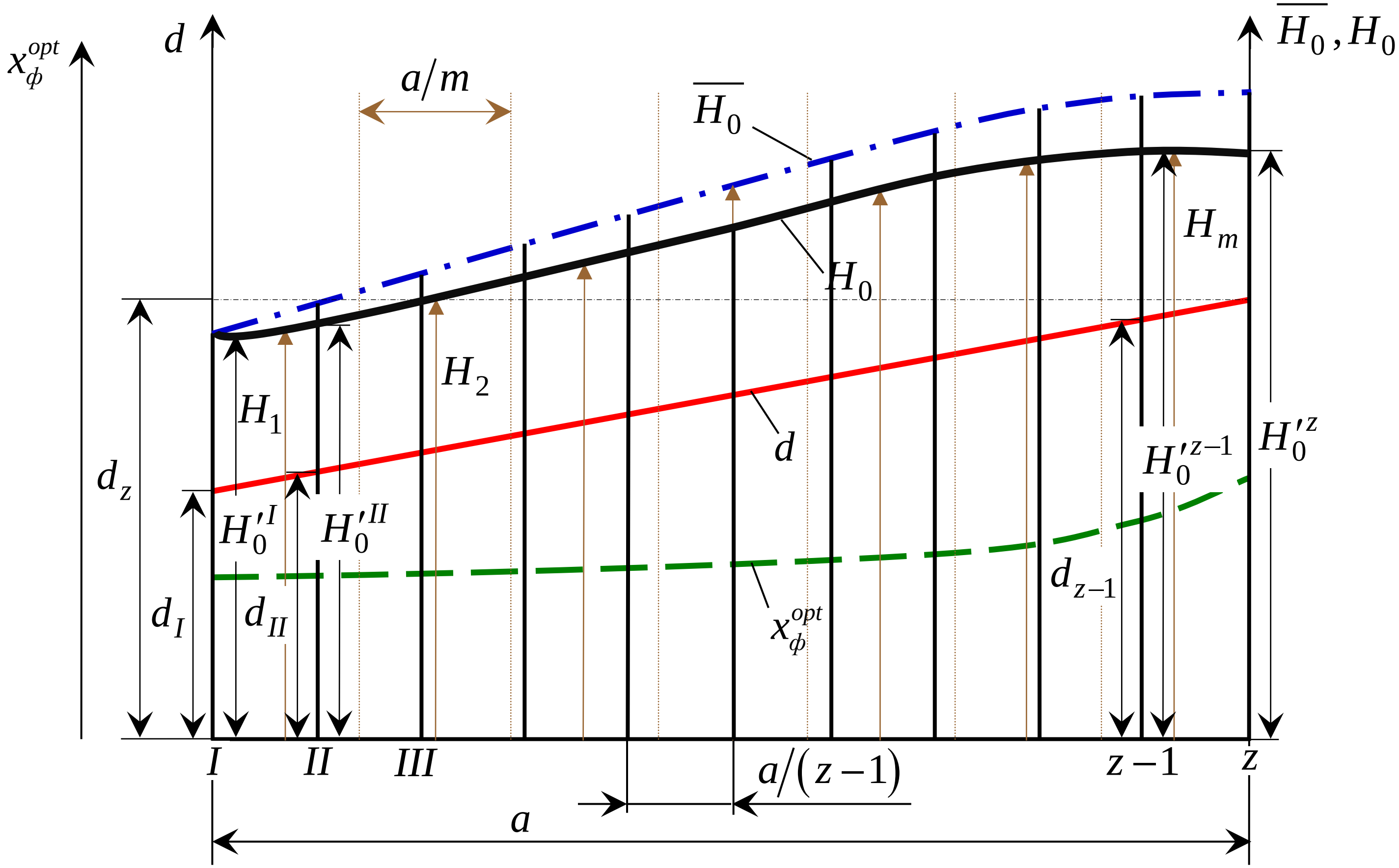
Divide the interval ***a*** into arbitrary number **m** of segments ***m***=(6÷8).

$$H_0^{cp} = \frac{\sum_{j=1}^{m} H_j}{m}$$

6. Determine the number of stages:

$$z = \frac{H_0^T (1 + q_t)}{H_0^{cp}}$$

z – round up to the nearest whole by arithmetic rounding rules



7. Determin the diameter and available heat drop of each of the ***z*** stages

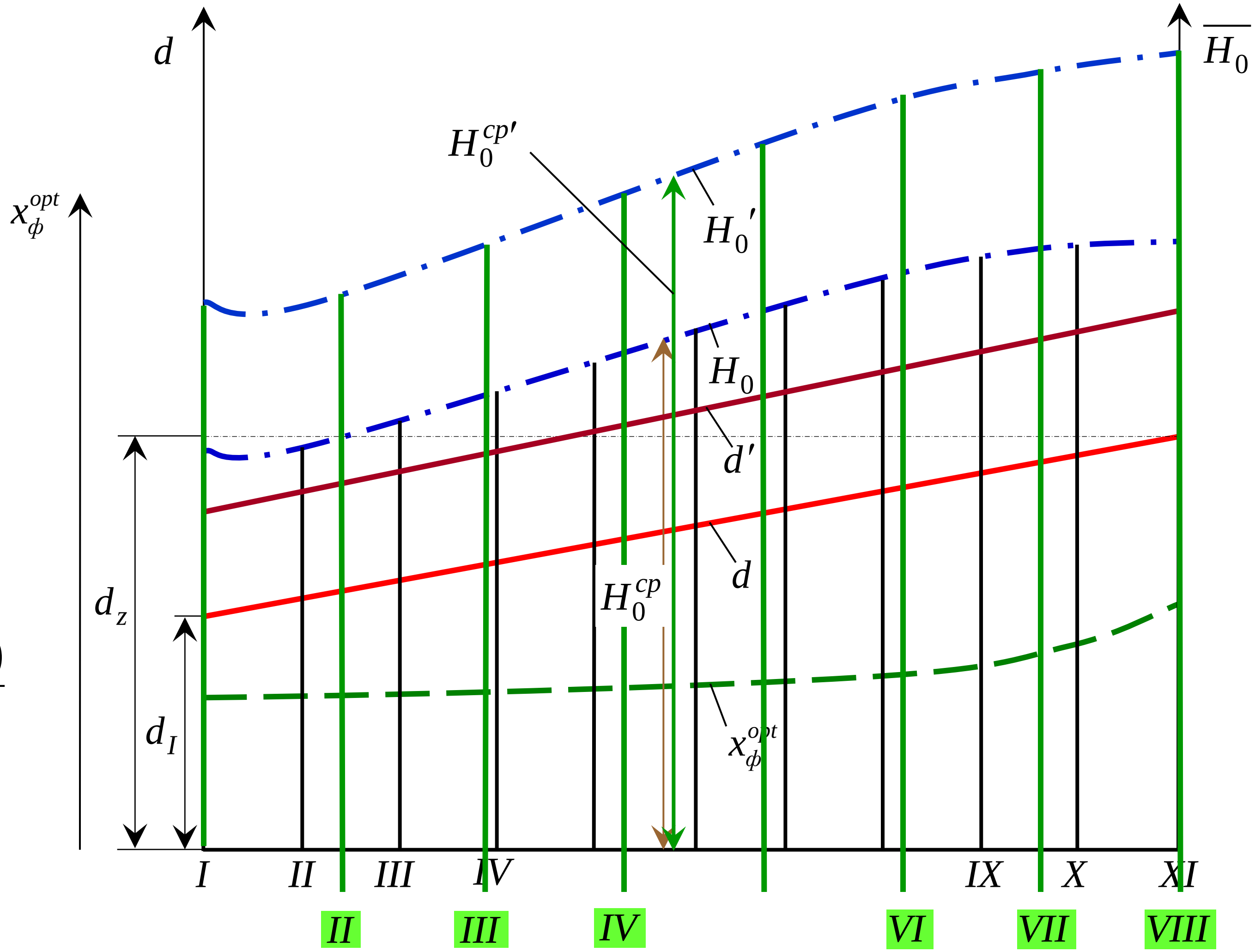
Divide segment ***a*** into (***z-1***) segments

$$\left(1+q_t\right)H_0^T - \sum_{j=1}^{z} H_0'^j = \Delta$$

$$H_0^j = H_0'^j + \frac{\Delta}{z}$$

Stage number	I	II	...	$z-1$	z	
Average diameter	d_I	d_{II}	...	d_{z-1}	d_z	
Pre-heat drop	$H_0'^I$	$H_0'^{II}$	...	$H_0'^{z-1}$	$H_0'^z$	$\sum_{j=1}^{z} H_0'^j$
Final heat drop	H_0^I	H_0^{II}	...	H_0^{z-1}	H_0^z	$\left(1+q_t\right)H_0^T$

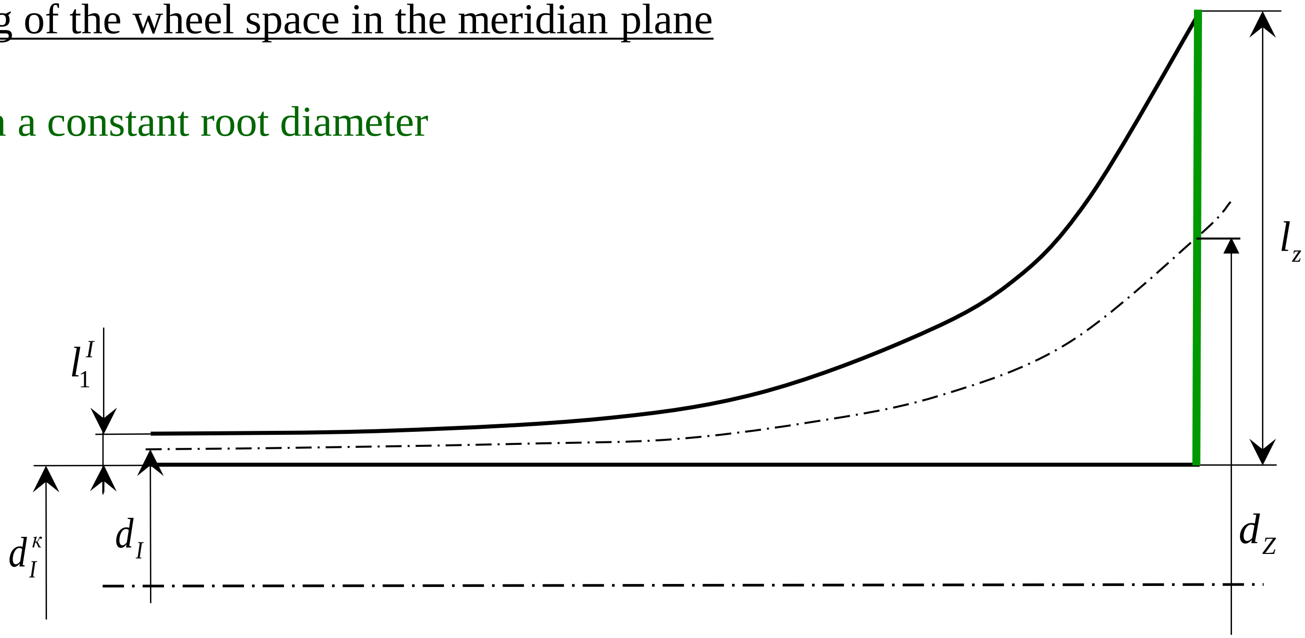
$$z = \frac{H_0^T\left(1+q_t\right)}{H_0^{cp}}$$



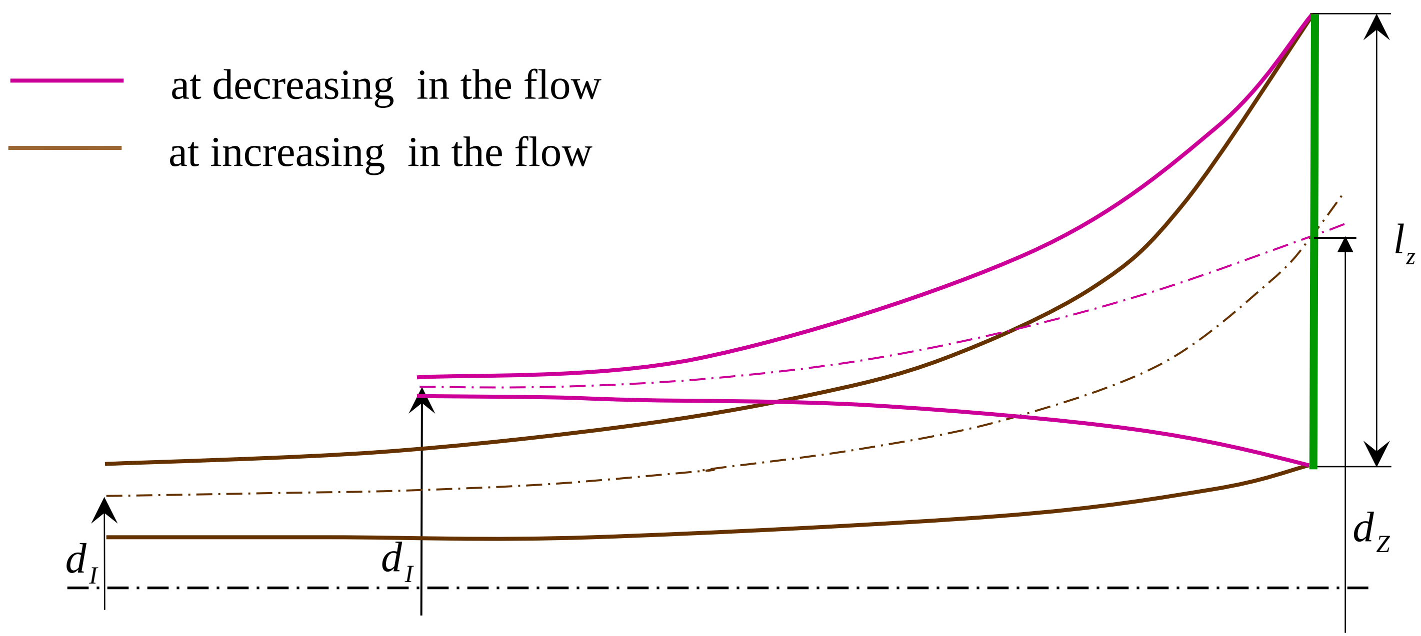
1. $d \uparrow \Rightarrow z \downarrow$
2. $d_j \uparrow \Rightarrow \overline{H}_0^{\,j} \uparrow$
3. $\left(d, \overline{H}_0\right) \uparrow \Rightarrow \left(l_1, l_2\right) \downarrow$

Opening of the wheel space in the meridian plane

A. With a constant root diameter



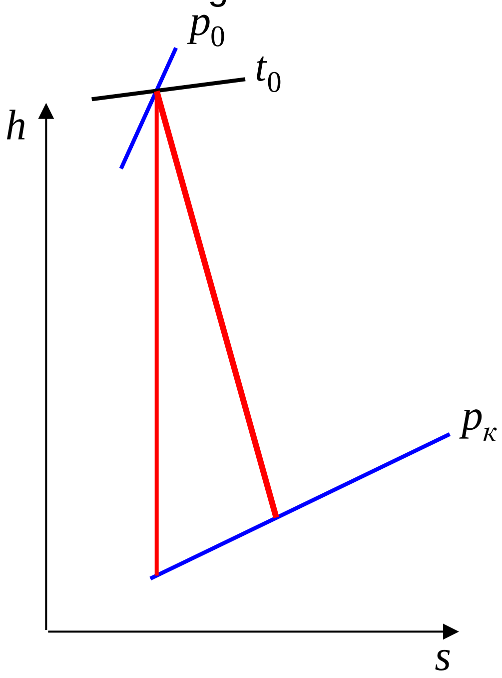
B. With varying root diameter



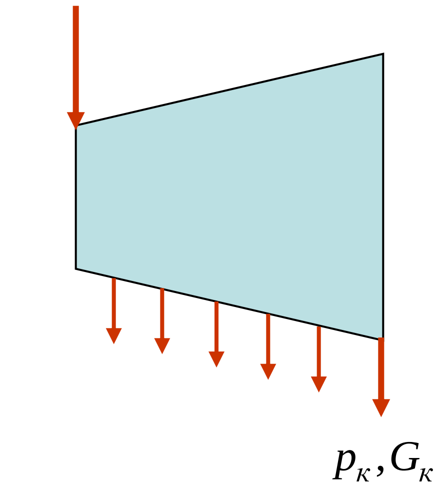
Maximum turbine power

A. The concept **(!)** of maximum power

Maximum turbine power is the power which can be designed for a **single-flow** turbine for given **initial and final parameters** under the terms of **the blade strength** in the final stage



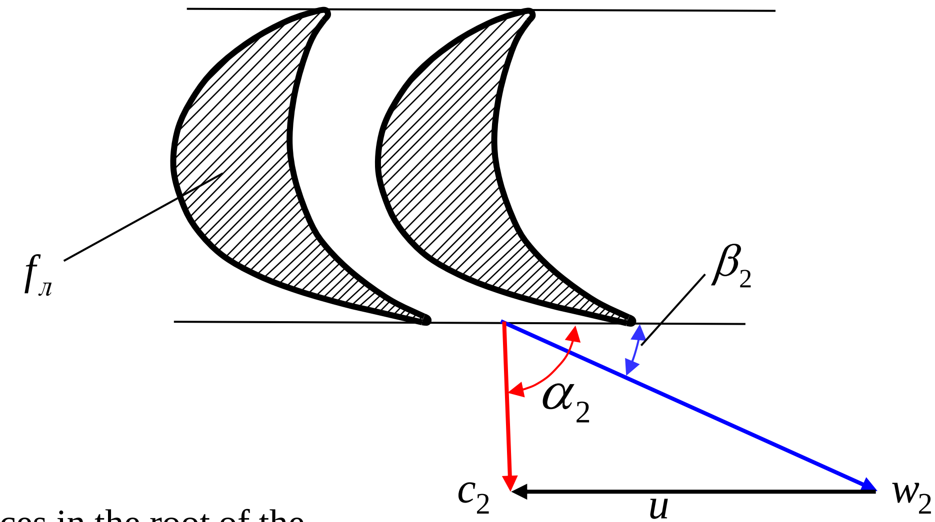
B. Determination of maximum power



$$N_i = mG_к H_0 \eta_{oi}, (*)$$

m - coefficient taking into account power generation by steam flowing to regenerative extractions

Express steam flow $G_к$ by the continuity equation written for the cross section after rotor blades of the final stage:



$$G_к = F_2 c_2 / \upsilon_2 = \frac{\pi d_2 l_2 \sin\alpha_2 c_2}{\upsilon_2}$$

$$\sin\alpha_2 \approx 1$$

$$\pi d_2 l_2 = \Omega$$

$$G_к = \frac{\Omega c_2}{\upsilon_2}. (**)$$

Determine the tensile stress from centrifugal forces in the root of the blade with constant section:

$$\sigma_p = \frac{C_л}{f_л} \quad = 2\rho_м l_2 d \pi^2 n^2 \quad = 2\rho_м \Omega \pi^2 n^2$$

$$C_л = m_л a_ц = \rho_м f_л l_2 \frac{u^2}{r} \; = \rho_м f_л l_2 \frac{2\pi^2 n^2 d^2}{d}$$

For blades with varying section ($f_к > f_n$):

$$\sigma_p = \frac{2\rho_м \Omega \pi^2 n^2}{k_{разгр}}; (***)$$

$$\frac{1}{k_{разгр}} = 0,35 + 0,65 \frac{f_n}{f_к}; \qquad \left(\frac{f_n}{f_к}\right)_{\min} = 0,1 \div 0,4 \Rightarrow k_{разгр}^{\max} = 2,3 \div 2,4.$$

From (***): $\Omega = \dfrac{[\sigma]k_{разгр}}{2\pi\rho_{мат}n^2}$ → in (**) $G_к = \dfrac{[\sigma]k_{разгр}c_2}{2\pi\rho_{мат}n^2\upsilon_2}$

in (*) we obtain:

$$N_i^{пред} = \frac{m}{2\pi}k_{разгр}H_0\eta_{oi}\,\frac{[\sigma]c_2}{\rho_{мат}\omega^2\upsilon_2}$$

B. Techniques to increase the **maximum** power of the turbine

$$N_i^{пред} = \frac{m}{2\pi} k_{разгр} H_0 \eta_{oi} \frac{[\sigma] c_2}{\rho_{мат} n^2 \upsilon_2}$$

1. Reducing the rotation rate twice as less, i.e. transition to a four-pole generator

$$\frac{\left[N_i^{пред}\right]_{n=25c^{-1}}}{\left[N_i^{пред}\right]_{n=50c^{-1}}} = 4$$

This leads to increase in the radial size of the turbine and decrease axial sizeы

2. Increase in losses with the exhaust velocity. (!! This leads to decreased efficient performance of the turbine)

Increase in the loss with the exhaust velocity by half results in:

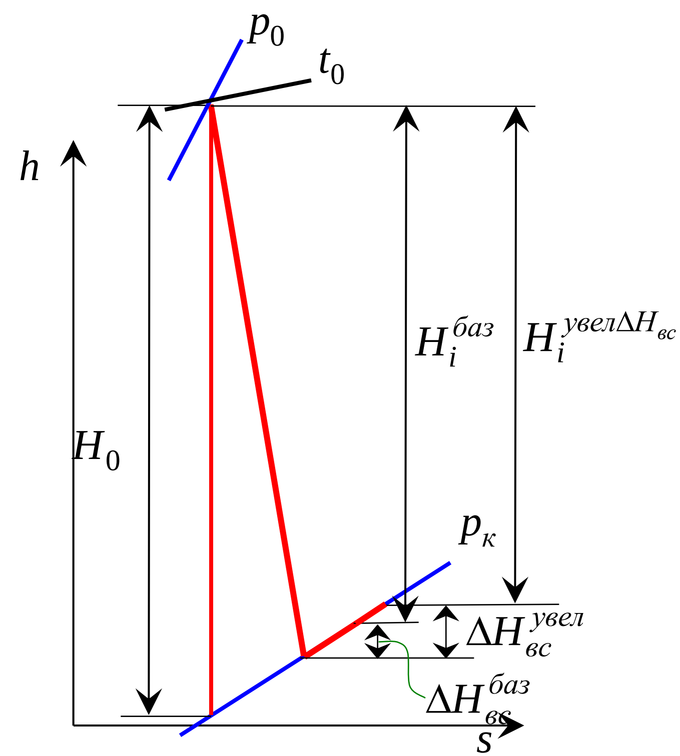
А. $$\frac{\left[N_i^{пред}\right]_{\Delta H_{вс}=1,5\Delta H_{вс}^{баз}}}{\left[N_i^{пред}\right]_{\Delta H_{вс}^{баз}}} = 1,22$$

Б. - for turbines of high parameters

$$\frac{\eta_{oi}^{баз} - \eta_{oi}^{увел\Delta H_{вс}}}{\eta_{oi}^{баз}} = \frac{\Delta\eta_{oi}}{\eta_{oi}^{баз}} = 0,7\%$$

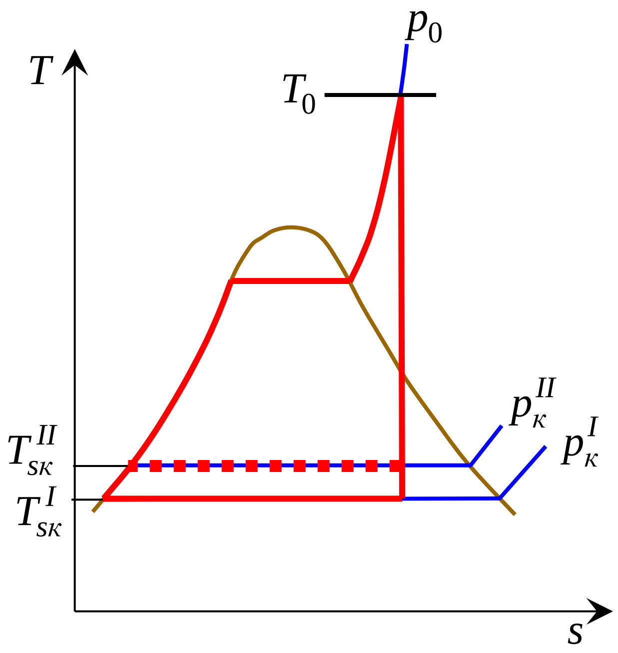
- for saturated steam turbines

$$\frac{\Delta\eta_{oi}}{\eta_{oi}^{баз}} = 1,3\%$$



3. Increase in the final pressure and, consequently, increase in the specific volume of steam after the final blade. (!!! This leads to decreased economic efficiency of the unit).

Transition from $p_к = 3{,}5 кПа$ to $p_к = 5 кПа$ Results in:



A.

$$\frac{\left[N_i^{пред}\right]_{p_к=5кПа}}{\left[N_i^{пред}\right]_{p_к=3,5кПа}} = 1{,}13$$

B. - for turbines of high parameters

$$\frac{\eta_э^{p_к=3,5} - \eta_э^{p_к=5}}{\eta_э^{p_к=3,5}} = \frac{\Delta\eta_э}{\eta_э^{p_к=3,5}} = 0{,}5\%$$

- for saturated steam turbines

$$\frac{\Delta\eta_э}{\eta_э^{p_к=3,5}} = 0{,}9\%$$

4. The use of materials with lower density

Steel - $\rho_м = 7{,}78 \cdot 10^3 кг/м^3.$

Titanium alloy - $\rho_м = 4{,}5 \cdot 10^3 кг/м^3.$

5. The use of materials with high allowable stress

Steel - $[\sigma] = 450 МПа.$

Titanium alloy - $[\sigma] = 360 МПа.$

The choice of material depends on $\frac{\rho_м}{[\sigma]}$,

The smaller the ratio, the better

Steel - $\frac{\rho_м}{[\sigma]} = 17{,}3 \cdot 10^3 кг/\left(м^3 \cdot МПа\right).$

Titanium alloy - $\frac{\rho_м}{[\sigma]} = 12{,}6 \cdot 10^3 кг/\left(м^3 \cdot МПа\right).$

Maximum power of the turbines $\left(\omega = 50c^{-1}, p_к = 4кПа\right)$

Parameters	Value				
$p_0, МПа$	8.83	12.75	23.5	29.4	5.9
$t_0, {}^0C$	535	565	580	650	С.н.п.
$t_{пп}, {}^0C$		565	565	565/565	260
$\left(N_i^{пред}\right)_{\Delta H_{вс}=23кДж/кг}$	76.0	92	104.0	118	52.4
$\left(N_i^{пред}\right)_{\Delta H_{вс}=36,5кДж/кг}$	96.0	116	131.0	148.6	66.0

D. Techniques for generation of the power exceeding the **maximum** power

1. Design of multi-flow turbines

$p_0 = 8{,}8 МПа; t_0 = 535^0 C; \Delta h_{вс} = 23 кДж/кг$ $N_i^{пр} = 76 МВт.$

$N_э = 100 МВт$

К-100-90