

Исходные данные

Коэф. запаса:	safety = 1.3
Степень двухконтурности:	m2 = 6
РТ: Воздух	compressor = "КНД"
Число Маха:	M = 0
Геометрическая высота работы (м):	H _{ww} = 0
Массовый расход (кг/с):	<div>G_{ww} = <div><div>35.65 + 213.93 if compressor = "Вл" = 35.65</div><div>35.65 if compressor = "КНД"</div><div>34.81 if compressor = "КВД"</div></div></div>
Полная температура на входе в К (К):	<div>T*_{K1} = <div><div>418.2 if compressor = "КВД" = 288.2</div><div>288.2 otherwise</div></div></div>
Полное давление на входе в К (Па):	<div>P*_{K1} = <div><div>316.2·10³ if compressor = "КВД" = 101.3·10³</div><div>101325 otherwise</div></div></div>
Степень повышения давления КВД:	<div>π*_K = <div><div>1.6 if compressor = "Вл" = 2.000</div><div><div>3.2</div><div>1.6</div>if compressor = "КНД"</div><div>9 if compressor = "КВД"</div></div></div>

Ожидаемый адиабатический КПД ОК:

$$\eta^*_K = \begin{cases} 0.86 & \text{if compressor = "Вл"} \\ 0.87 & \text{if compressor = "КНД"} \\ 0.88 & \text{if compressor = "КВД"} \end{cases} = 87.00\cdot\%$$

Частота вращения ротора (с⁻¹):

$$\omega = \begin{cases} 1570.8 & \text{if compressor = "КВД"} \\ 555 & \text{otherwise} \end{cases} = 555.0$$

Относ. диаметркорня 1ой ступени [14, с.7]:

$$\overline{d}_1 = \begin{cases} 0.40 & \text{if compressor = "Вл"} \\ 0.75 & \text{if compressor = "КНД"} \\ 0.65 & \text{if compressor = "КВД"} \end{cases} = 0.75$$

$0.3 \leq \overline{d}_1 \leq 0.6 = 0$

Частота вращения ротора (об/мин):

$$n = \frac{60 \cdot \omega}{2 \cdot \pi} = 5300$$

Закон профилирования проточной части (ЗППЧ):

$$\text{ЗППЧ} = \left(\begin{array}{c|c|c} \begin{array}{l} \text{"пер" if compressor = "Вл"} \\ \text{"пер" if compressor = "КНД"} \\ \text{"ср" if compressor = "КВД"} \end{array} & \begin{array}{l} \text{"пер" if compressor = "Вл"} \\ \text{"0.96" if compressor = "КНД"} \\ \text{"ср" if compressor = "КВД"} \end{array} & \begin{array}{l} \text{"пер" if compressor = "Вл"} \\ \text{"0.92" if compressor = "КНД"} \\ \text{"кор" if compressor = "КВД"} \end{array} \end{array} \begin{array}{cccccccccccccccc} \text{"кор"} & \text{"кор"} & \text{"кор"} & \text{"кор"} & \text{"кор"} & \text{"кор"} & \text{"пер"} & \text{"пер"} & \text{"пер"} & \text{"пер"} & \text{"пер"} & \text{"пер"} & \text{"пер"} & \text{"пер"} \end{array} \right)^T$$

Относ. параметры по относительным ступеням:

$$\begin{pmatrix} z_{\sim} \\ R_{L\sim \text{ср}} \\ K_{\sim H} \\ \eta^*_{\sim} \\ \overline{c}_{\sim a1} \\ \overline{H}_{\sim T} \end{pmatrix} = \begin{bmatrix} (1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8)^T \\ (0.5 \ 0.5 \ 0.5 \ 0.5 \ 0.5 \ 0.5 \ 0.5 \ 0.5)^T \\ (0.99 \ 0.98 \ 0.97 \ 0.96 \ 0.95 \ 0.95 \ 0.95 \ 0.95)^T \\ (0.88 \ 0.89 \ 0.905 \ 0.91 \ 0.91 \ 0.905 \ 0.89 \ 0.88)^T \\ (0.435 \ 0.425 \ 0.415 \ 0.405 \ 0.395 \ 0.385 \ 0.375 \ 0.365)^T \\ (0.25 \ 0.29 \ 0.32 \ 0.33 \ 0.35 \ 0.32 \ 0.29 \ 0.27)^T \end{bmatrix}$$

Тип компрессора	Номер ступени и $\overline{L}_{CT,i}$							
	I	II	III	IV	$z_{ср}$	$z - 2$	$z - 1$	z
Дозвуковой	0,18-0,20	0,24-0,25	0,24-0,25	0,29-0,30	0,30-0,32	0,28-0,29	0,27-0,28	0,26-0,27
Трансзвуковой	0,19-0,22	0,27-0,29	0,30-0,32	0,32-0,33	0,33-0,35	0,31-0,32	0,27-0,28	0,26-0,27
С одной св/зв ступенью	0,23-0,25	0,27-0,29	0,30-0,32	0,32-0,33	0,33-0,35	0,31-0,32	0,27-0,28	0,26-0,27
С 2-мя св/зв ступенями	0,23-0,25	0,27-0,29	0,30-0,32	0,32-0,33	0,33-0,35	0,31-0,32	0,27-0,28	0,26-0,27
С 3-мя св/зв ступенями	0,23-0,25	0,27-0,29	0,30-0,32	0,32-0,33	0,33-0,35	0,31-0,32	0,27-0,28	0,25-0,26

[16, с. 60]

[18, с. 24]

Уточнение параметров:

$$R_{L\sim cp} = R_{L\sim cp} + \begin{cases} 0.0 & \text{if compressor = "Вл"} \\ 0.1 & \text{if compressor = "КНД"} \\ 0.2 & \text{if compressor = "КВД"} \end{cases}$$

увеличение несущественно увеличивает π

$$\eta^*_{\sim} = \eta^*_{\sim} + \begin{cases} -0.020 & \text{if compressor = "Вл"} \\ -0.028 & \text{if compressor = "КНД"} \\ -0.017 & \text{if compressor = "КВД"} \end{cases}$$

увеличение несущественно увеличивает π

$$\overline{c}_{\sim a1} = \overline{c}_{\sim a1} - \begin{cases} 0.100 & \text{if compressor = "Вл"} \\ 0.141 & \text{if compressor = "КНД"} \\ 0.203 & \text{if compressor = "КВД"} \end{cases}$$

понижение существенно увеличивает π

$$\overline{H}_{\sim T} = \overline{H}_{\sim T} + \begin{cases} 0.0145 & \text{if compressor = "Вл"} \\ 0.0164 & \text{if compressor = "КНД"} \\ 0.0173 & \text{if compressor = "КВД"} \end{cases}$$

увеличение существенно увеличивает π

$$\text{stack}\left(R_{L\sim cp}^T, K_{\sim H}^T, \eta^{*}_{\sim}{}^T, \overline{c}_{\sim a1}^T, \overline{H}_{\sim T}^T\right) =$$

	1	2	3	4	5	6	7	8
1	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
2	0.990	0.980	0.970	0.960	0.950	0.950	0.950	0.950
3	0.852	0.862	0.877	0.882	0.882	0.877	0.862	0.852
4	0.294	0.284	0.274	0.264	0.254	0.244	0.234	0.224
5	0.266	0.306	0.336	0.346	0.366	0.336	0.306	0.286

$$0.15 \leq \overline{c}_{\sim a1}^T = (1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1)$$

$$\overline{c}_{\sim a1}^T \leq 0.65 = (1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1)$$

$$0.18 \leq \overline{H}_{\sim T}^T = (1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1 \quad 1)$$

$$\overline{H}_{\sim T}^T \leq 0.35 = (1 \quad 1 \quad 1 \quad 1 \quad 0 \quad 1 \quad 1 \quad 1)$$

Коэф. теор. напора "средней" ступени [14, с.11]:

$$\overline{H}_{Tcp} = \frac{\sum_{i=1}^{rows(z_{\sim})} \overline{H}_{\sim T_i}}{rows(z_{\sim})} = 0.3189$$

$$0.25 \leq \overline{H}_{Tcp} \leq 0.32 = 1$$

Кинематическая степень реактивности: $\widetilde{R_{L\sim cp}}(i) = \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, R_{L\sim cp}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, R_{L\sim cp}, i\right)$

Коэф. уменьшения теор. напора: $K_{\sim H}(i) = \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, K_{\sim H}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, K_{\sim H}, i\right)$

Изоэнтропический КПД: $\eta_{\sim}^*(i) = \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \eta_{\sim}^*\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \eta_{\sim}^*, i\right)$

Коэф. расхода: $\overline{c}_{\sim a1}(i) = \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{c}_{\sim a1}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{c}_{\sim a1}, i\right)$

Коэф. напора: $\overline{H}_{\sim T}(i) = \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{H}_{\sim T}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{H}_{\sim T}, i\right)$

$$\begin{pmatrix} R_{L.cp} \\ K_{.H} \\ \eta^*_{.} \\ \bar{c}_{.a1} \\ \bar{H}_{.T} \end{pmatrix} = \begin{pmatrix} R_{L.cp}(Z,i) \\ K_{.H}(Z,i) \\ \eta^*_{.}(Z,i) \\ \bar{c}_{.a1}(Z,i) \\ \bar{H}_{.T}(Z,i) \end{pmatrix} = \begin{cases} R_{L\sim cp}\left(\frac{1}{rows(z_{\sim})}\right) & \text{if } i < 1 \\ R_{L\sim cp}(1) & \text{if } i > Z \\ R_{L\sim cp}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases}$$

$$\begin{cases} K_{\sim H}\left(\frac{1}{rows(z_{\sim})}\right) & \text{if } i < 1 \\ K_{\sim H}(1) & \text{if } i > Z \\ K_{\sim H}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases}$$

$$\begin{cases} \eta^*_{\sim}\left(\frac{1}{rows(z_{\sim})}\right) & \text{if } i < 1 \\ \eta^*_{\sim}(1) & \text{if } i > Z \\ \eta^*_{\sim}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases}$$

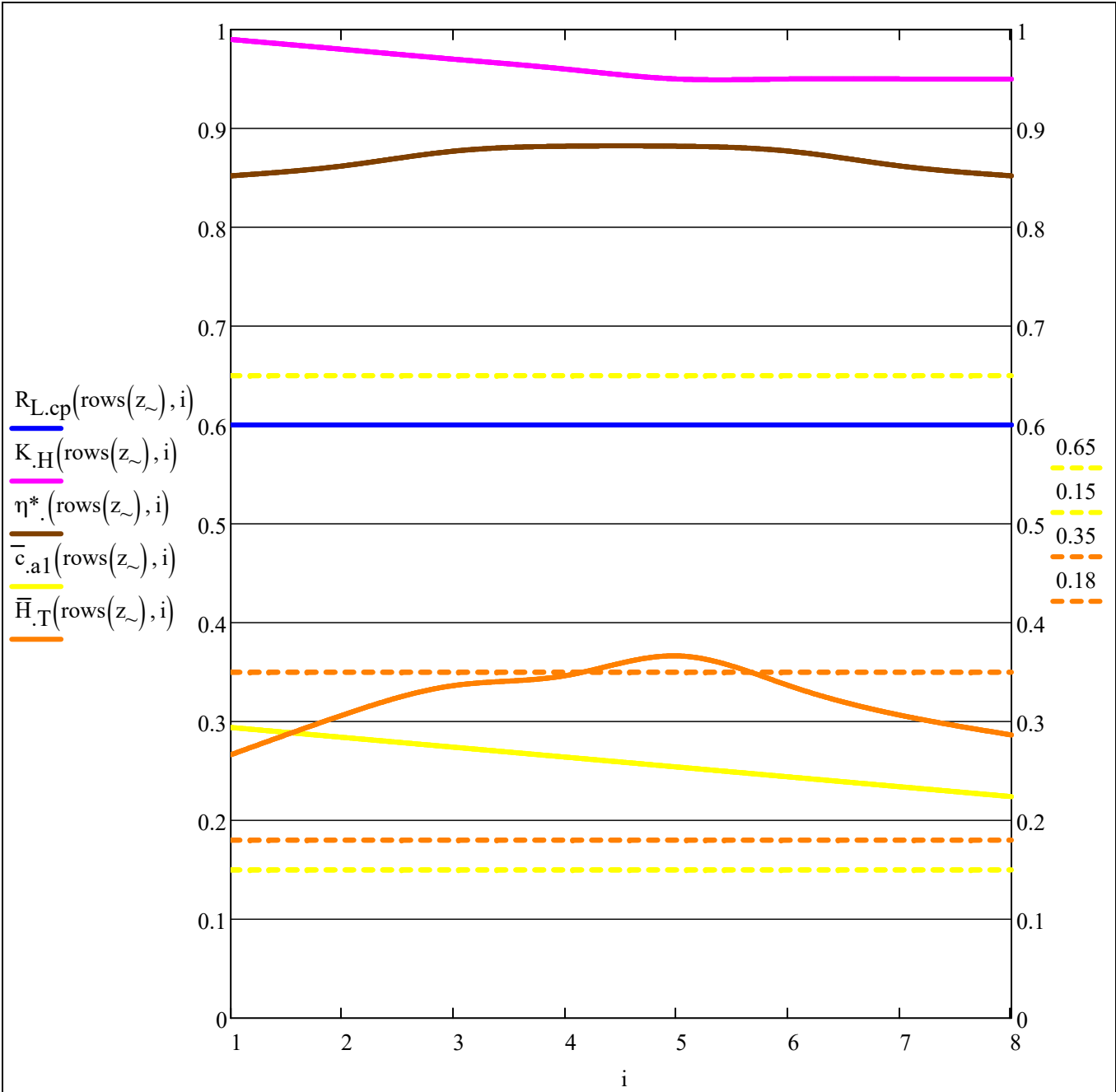
$$\begin{cases} \bar{c}_{\sim a1}\left(\frac{1}{rows(z_{\sim})}\right) & \text{if } i < 1 \\ \bar{c}_{\sim a1}(1) & \text{if } i > Z \\ \bar{c}_{\sim a1}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases}$$

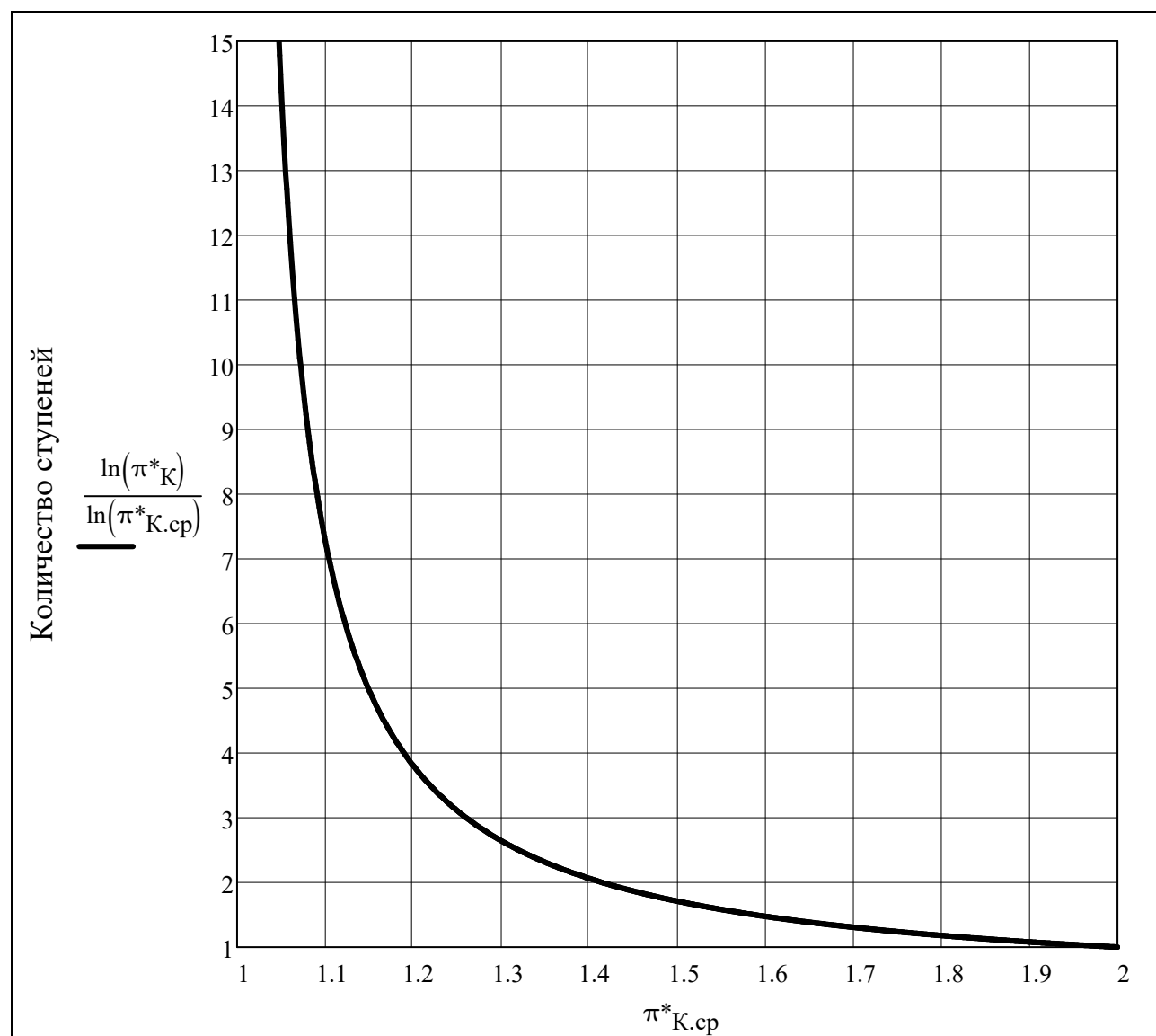
$$\begin{cases} \bar{H}_{\sim T}\left(\frac{1}{rows(z_{\sim})}\right) & \text{if } i < 1 \\ \bar{H}_{\sim T}(1) & \text{if } i > Z \\ \bar{H}_{\sim T}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases}$$

$$\left(R_{L.cp} \ K_{.H} \ \eta^*_{.} \ \bar{c}_{.a1} \ \bar{H}_{.T}\right)^T$$

$$\begin{pmatrix} Z_{temp} \\ i_{temp} \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \end{pmatrix}$$

$$\begin{pmatrix} R_{L.cp}(Z_{temp},i_{temp}) \\ K_{.H}(Z_{temp},i_{temp}) \\ \eta^*_{.}(Z_{temp},i_{temp}) \\ \bar{c}_{.a1}(Z_{temp},i_{temp}) \\ \bar{H}_{.T}(Z_{temp},i_{temp}) \end{pmatrix} = \begin{pmatrix} 0.600 \\ 0.950 \\ 0.852 \\ 0.224 \\ 0.286 \end{pmatrix}$$





Показатель адиабаты перед K []: $k_{K1} = k_{\text{ад}}\left(C_{p_{\text{воздух}}}\left(P^*_{K1}, T^*_{K1}\right), R_B\right) = 1.401$

Полное давление после K [Па]: $P^*_{K3} = \pi^*_K \cdot P^*_{K1} = 203 \cdot 10^3$

iteration₃

T^{*}_{K3}

k_{K3}

=

iteration₃ = 0

k_{K3} = k_{K1}

while 0 < 1

iteration₃ = iteration₃ + 1

trace("iteration.3 = ", num2str(iteration₃))

k_{ср} = mean(k_{K1}, k_{K3})

$T^*_{K3} = T^*_{K1} \cdot \left(1 + \frac{\pi^*_K \frac{k_{ср}-1}{k_{ср}} - 1}{\eta^*_K}\right)$

C_p_{K3} = C_p_{воздух}(P^{*}_{K3}, T^{*}_{K3})

k'_{K3} = k_{ад}(C_p_{K3}, R_B)

if |eps("rel", k_{K3}, k'_{K3})| ≤ epsilon

k_{K3} = k'_{K3}

break

k_{K3} = k'_{K3}

iteration₃

T^{*}_{K3}

k_{K3}

Количество итераций []: iteration₃ = 1

Полная температура после K [K]: T^{*}_{K3} = 360.9

Показатель адиабаты после K []: k_{K3} = 1.398

Полная плотность перед и после K [кг/м³]: $\begin{pmatrix} \rho^*_{K1} \\ \rho^*_{K3} \end{pmatrix} = \frac{1}{R_B} \cdot \begin{pmatrix} \frac{P^*_{K1}}{T^*_{K1}} \\ \frac{P^*_{K3}}{T^*_{K3}} \end{pmatrix} = \begin{pmatrix} 1.224 \\ 1.955 \end{pmatrix}$

Критические скорости перед и после K [м/с]: $\begin{pmatrix} a^*_{с.вх} \\ a^*_{с.вых} \end{pmatrix} = \begin{pmatrix} a_{кр}(k_{K1}, R_B, T^*_{K1}) \\ a_{кр}(k_{K3}, R_B, T^*_{K3}) \end{pmatrix} = \begin{pmatrix} 310.8 \\ 347.6 \end{pmatrix}$

Ср. показатель адиабаты K []: k_{ср} = k_{ад}(C_p_{воздух.ср}(P^{*}_{K1}, P^{*}_{K3}, T^{*}_{K1}, T^{*}_{K3}), R_B) = 1.4

Теоретический напор [Дж/кг]: $H_{TK} = \frac{C_{p_{\text{воздух.ср}}}(P^*_{K1}, P^*_{K3}, T^*_{K1}, T^*_{K3}) \cdot T^*_{K1} \cdot \left(\pi^*_K \frac{k_{ср}-1}{k_{ср}} - 1\right)}{\eta^*_K} = 72.9 \cdot 10^3$

iteration_u

u_{1пер}

Z_{recomend}

c_{вх}

λ_{вх}

ρ_{K1}

=

iteration_u = 0

ρ_{K1} = ρ*_{K1}

while 0 < 1

iteration_u = iteration_u + 1

trace(concat("iteration.u = ", num2str(iteration_u)))

$$u_{1пер} = \sqrt[3]{\frac{\pi \cdot G \cdot n^2}{900 \cdot \bar{c}_{.a1}(1,0) \cdot \rho_{K1} \cdot [1 - (\bar{d}_1)^2]}}$$

$$Z_{recomend} = \max\left(\text{round}\left(\frac{H_{TK}}{\bar{H}_{Tcp} \cdot u_{1пер}^2}\right), 1\right)$$

c_{вх} = $\bar{c}_{.a1}(Z_{recomend}, 0) \cdot u_{1пер}$

$$\lambda_{вх} = \frac{c_{вх}}{a^*_{c.вх}}$$

ρ'_{K1} = ρ*_{K1} · ГДФ("ρ", λ_{вх}, k_{K1})

if |eps("rel", ρ'_{K1}, ρ_{K1})| ≤ epsilon

ρ_{K1} = ρ'_{K1}

break

ρ_{K1} = ρ'_{K1}

iteration_u

u_{1пер}

Z_{recomend}

c_{вх}

λ_{вх}

ρ_{K1}

Количество итераций []: iteration_u = 2

Окружная скорость на перифкрии перед K [м/с]: u_{1пер} = 283.8

Рекомендуемое количество ступеней []: Z_{recomend} = 3

Абс. скорость перед K [м/с]: c_{вх} = 83.4

Приведенная скорость перед K []: λ_{вх} = 0.2685

Плотность перед K [кг/м^3]: ρ_{K1} = 1.188

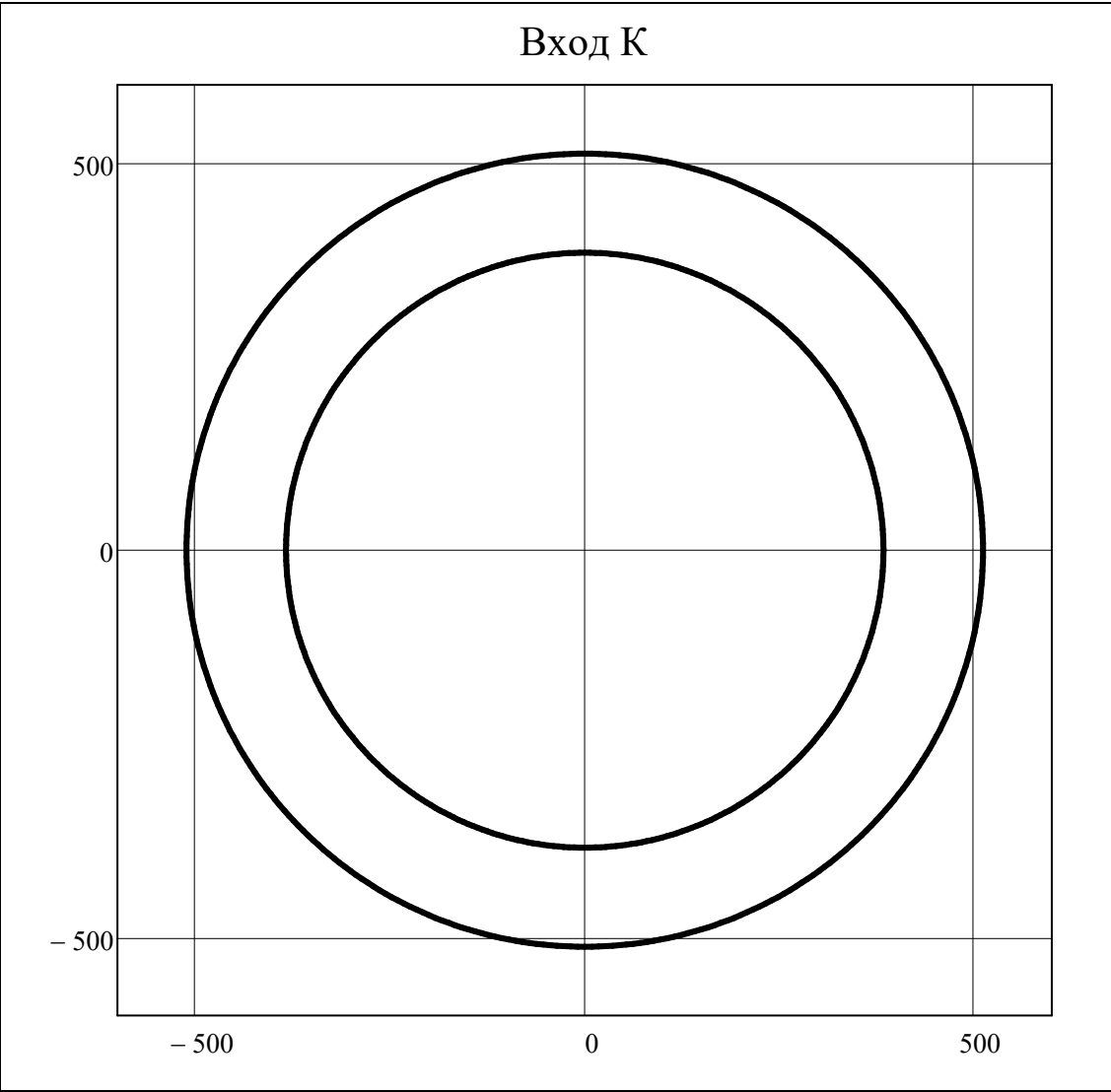
Кольцевая площадь перед K [м²]:
$$F_{вх} = \frac{G \cdot \sqrt{R_B \cdot T^*_{K1}}}{m_q(k_{K1}) \cdot P^*_{K1} \cdot \Gamma Д \Phi("G", \lambda_{вх}, k_{K1})} = 0.3596$$

$$D'_{пер1} = \frac{2 \cdot u_{1пер}}{\omega} = 1022.8 \cdot 10^{-3}$$

Диаметры перед K [м]:
$$D'_{ср1} = \bar{r}_{ср}(\bar{d}_1) \cdot D'_{пер1} = 904 \cdot 10^{-3}$$

$$D'_{кор1} = \bar{d}_1 \cdot D'_{пер1} = 767.1 \cdot 10^{-3}$$

$\varphi = 0, \frac{2 \cdot \pi}{360} \dots 2 \cdot \pi$



Рекомендуемое количество ступеней []: Z_{recomend} = 3

Количество ступеней []:

Z =	1	if compressor = "Вл"	= 3
	3	if compressor = "КНД"	
	9	if compressor = "КВД"	

$$c_{u1BHA_r} = \frac{c_{a1BHA_r}}{\tan(\alpha_{1BHA_r})}$$

$$c_{1BHA_r} = \frac{c_{a1BHA_r}}{\sin(\alpha_{1BHA_r})}$$

$$\lambda_{c1BHA_r} = \frac{c_{1BHA_r}}{a_{kp1BHA_r}}$$

$$\sigma_{BHA} = \begin{cases} \left[1 + \text{mean}(0.03, 0.06) \cdot \Gamma\text{Д}\Phi\left("p", \lambda_{c1BHA_r}, k_{1BHA_r}\right) \cdot \frac{k_{1BHA_r}}{k_{1BHA_r} + 1} \cdot \left(\lambda_{c1BHA_r}\right)^2 \right]^{-1} & \text{if } BHA = 1 \\ 1 & \text{otherwise} \end{cases}$$

$$P^*_{3BHA_r} = P^*_{1BHA_r} \cdot \sigma_{BHA}$$

$$\rho^*_{3BHA_r} = \frac{P^*_{3BHA_r}}{R_B \cdot T^*_{3BHA_r}}$$

$$k_{3BHA_r} = k_{ад}\left(C_{p\text{воздух}}\left(P^*_{3BHA_r}, T^*_{3BHA_r}\right), R_B\right)$$

$$a_{kp3BHA_r} = a_{kp}\left(k_{3BHA_r}, R_B, T^*_{3BHA_r}\right)$$

$$\bar{c}_{a3BHA_r} = \begin{cases} \bar{c}_{a1}(Z, 1) & \text{if } BHA = 1 \\ \bar{c}_{a1BHA_r} & \text{otherwise} \end{cases}$$

$$\bar{c}_{u3BHA_r} = \begin{cases} \bar{r}_{cp}(\bar{d}_{3BHA}) \cdot (1 - R_{L,cp}(Z, 1)) - \frac{\bar{H}_T(Z, 1)}{2 \cdot \bar{r}_{cp}(\bar{d}_{3BHA})} & \text{if } BHA = 1 \\ 0 & \text{otherwise} \end{cases}$$

$$\alpha_{3BHA_r} = \begin{cases} \text{triangle}\left(\bar{c}_{a1BHA_r}, \bar{c}_{u1BHA_r}\right) & \text{if } BHA = 1 \\ \frac{\pi}{2} & \text{otherwise} \end{cases}$$

$$c_{a3BHA_r} = \bar{c}_{a1BHA_r} \cdot u_{1\text{пер}}$$

$$c_{u3BHA_r} = \frac{c_{a3BHA_r}}{\tan(\alpha_{3BHA_r})}$$

$$c_{3BHA_r} = \frac{c_{a3BHA_r}}{\sin(\alpha_{3BHA_r})}$$

$$\lambda_{c3BHA_r} = \frac{c_{3BHA_r}}{a_{kp3BHA_r}}$$

$$\text{submatrix}\left(T^*_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (288.2)$$

$$\text{submatrix}\left(T^*_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (288.2)$$

$$\text{submatrix}\left(P^*_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (101.3) \cdot 10^3$$

$$\text{submatrix}\left(P^*_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (101.3) \cdot 10^3$$

$$\text{submatrix}\left(\rho^*_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.224)$$

$$\text{submatrix}\left(\rho^*_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.224)$$

$$\text{submatrix}\left(k_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.401)$$

$$\text{submatrix}\left(k_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.401)$$

$$\text{submatrix}\left(a_{kp1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (310.8)$$

$$\text{submatrix}\left(a_{kp3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (310.8)$$

$$\text{submatrix}\left(\bar{c}_{a1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.294)$$

$$\text{submatrix}\left(\bar{c}_{a3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.294)$$

$$\text{submatrix}\left(\bar{c}_{u1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.000)$$

$$\text{submatrix}\left(\bar{c}_{u3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.000)$$

$$\text{submatrix}\left(c_{a1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (83.4)$$

$$\text{submatrix}\left(c_{a3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (83.4)$$

$$\text{submatrix}\left(c_{u1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.0)$$

$$\text{submatrix}\left(c_{u3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.0)$$

$$\text{submatrix}\left(c_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (83.4)$$

$$\text{submatrix}\left(c_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (83.4)$$

$$\text{submatrix}\left(\lambda_{c1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.268)$$

$$\text{submatrix}\left(\lambda_{c3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.268)$$

		$\left(\begin{matrix} F_{1BHA} \\ F_{3BHA} \end{matrix} \right) = G \cdot \sqrt{R_B} \cdot \left(\begin{matrix} \frac{\sqrt{T^*_{1BHA_r}}}{m_q(k_{1BHA_r}) \cdot P^*_{1BHA_r} \cdot \Gamma \Delta \Phi("G", \lambda_{c1BHA_r}, k_{1BHA_r}) \cdot \sin(\alpha_{1BHA_r})} \\ \frac{\sqrt{T^*_{3BHA_r}}}{m_q(k_{3BHA_r}) \cdot P^*_{3BHA_r} \cdot \Gamma \Delta \Phi("G", \lambda_{c3BHA_r}, k_{3BHA_r}) \cdot \sin(\alpha_{3BHA_r})} \end{matrix} \right)$
		$\epsilon_{BHA_r} = -1 \cdot (\alpha_{3BHA_r} - \alpha_{1BHA_r})$
	$\left(\begin{matrix} \alpha_{1BHA} & \alpha_{3BHA} \\ \sigma_{BHA} & \sigma_{BHA} \\ \overline{d}_{1BHA} & \overline{d}_{3BHA} \\ T^*_{1BHA} & T^*_{3BHA} \\ P^*_{1BHA} & P^*_{3BHA} \\ \rho^*_{1BHA} & \rho^*_{3BHA} \\ k_{1BHA} & k_{3BHA} \\ a_{kp1BHA} & a_{kp3BHA} \\ \overline{c}_{a1BHA} & \overline{c}_{a3BHA} \\ \overline{c}_{u1BHA} & \overline{c}_{u3BHA} \\ c_{a1BHA} & c_{a3BHA} \\ c_{u1BHA} & c_{u3BHA} \\ c_{1BHA} & c_{3BHA} \\ \lambda_{c1BHA} & \lambda_{c3BHA} \\ F_{1BHA} & F_{3BHA} \\ \epsilon_{BHA} & \epsilon_{BHA} \end{matrix} \right)$	

R_L	π^*	
K_H	η^*	
C_p	k	
\bar{H}_T	H_T	
L^*	\underline{L}	
T^*	\underline{T}	
P^*	P	
ρ^*	ρ	
a^*_c	a_{3B}	
λ_c	λ_c	
\underline{F}	F	$= r = av(N_r)$
D	\underline{R}	$T^*_{st(1,1),r} = T^*_{3BHA_r}$
\bar{d}	h	$P^*_{st(1,1),r} = P^*_{3BHA_r}$
\bar{c}_a	\bar{c}_u	$\rho^*_{st(1,1),r} = \rho^*_{3BHA_r}$
c_a	c_u	$Cp_{st(1,1),r} = Cp_{\text{БорзДyx}}(P^*_{st(1,1),r}, T^*_{st(1,1),r})$
u	w_u	$k_{st(1,1),r} = k_{a\Delta}(Cp_{st(1,1),r}, R_B)$
\underline{c}	w	$a^*_{c_{st(1,1),r}} = a_{kp}(k_{st(1,1),r}, R_B, T^*_{st(1,1),r})$
M_c	M_w	$\bar{c}_{a_{st(1,1),r}} = \bar{c}_{a3BHA_r}$
α	β	$\bar{c}_{u_{st(1,1),r}} = \bar{c}_{u3BHA_r}$
ϵ_{rotor}	ϵ_{stator}	$c_{a_{st(1,1),r}} = c_{a3BHA_r}$
		$u_{st(1,1),Nr} = u_{1пер}$
		$\alpha_{st(1,1),r} = \alpha_{3BHA_r}$
		$c_{st(1,1),r} = \frac{c_{a_{st(1,1),r}}}{\sin(\alpha_{st(1,1),r})}$
		$\lambda_{c_{st(1,1),r}} = \frac{c_{st(1,1),r}}{a^*_{c_{st(1,1),r}}}$
		$F_{st(1,1)} = \frac{G \cdot \sqrt{R_B \cdot T^*_{st(1,1),r}}}{m_q(k_{st(1,1),r}) \cdot \Gamma \Delta \Phi("G", \lambda_{c_{st(1,1),r}}, k_{st(1,1),r}) \cdot \sin(\alpha_{st(1,1),r}) \cdot P^*_{st(1,1),r}}$

$$D_{\text{st}(1,1),N_r} = \frac{2 \cdot u_{\text{st}(1,1),N_r}}{\omega}$$

$$D_{\text{st}(1,1),1} = \sqrt{\left(D_{\text{st}(1,1),N_r}\right)^2 - \frac{4 \cdot F_{\text{st}(1,1)}}{\pi}}$$

$$D_{\text{st}(1,1),r} = \overline{r}_{\text{cp}}\left(\frac{D_{\text{st}(1,1),1}}{D_{\text{st}(1,1),N_r}}\right) \cdot D_{\text{st}(1,1),N_r}$$

$$\overline{d}_{\text{st}(1,1)} = \frac{D_{\text{st}(1,1),1}}{D_{\text{st}(1,1),N_r}}$$

for i ∈ 1..Z

```
trace(concat("ступень i = ", num2str(i)))
```

$$\begin{pmatrix} \overline{H}_{T_i} \\ K_{H_i} \\ \eta^*_{i} \\ R_{L_{i,r}} \end{pmatrix} = \begin{pmatrix} \overline{H}_{.T}(Z,i) \\ K_{.H}(Z,i) \\ \eta^*_{.}(Z,i) \\ R_{L.cp}(Z,i) \end{pmatrix}$$

$$H_{T_{i,r}} = \overline{H}_{T_i} \cdot \left(u_{\text{st}(i,1),N_r}\right)^2$$

$$L_i = K_{H_i} \cdot H_{T_{i,r}}$$

$$L^*_{i} = L_i \cdot \eta^*_{i}$$

$$\text{iteration}_{12} = 0$$

$$k_{\text{st}(i,2),r} = k_{\text{st}(i,1),r}$$

while 0 < 1

```
iteration12 = iteration12 + 1
```

```
trace\big(concat\big(" iteration.12 = ", num2str\big(iteration12\big)\big)\big)
```

$$k_{12} = \text{mean}\big(k_{\text{st}(i,1),r}, k_{\text{st}(i,2),r}\big)$$

$$Cp_{12} = \frac{k_{12}}{k_{12}-1} \cdot R_B$$

$$T^*_{\text{st}(i,2),r} = T^*_{\text{st}(i,1),r} + \frac{L_i}{Cp_{12}}$$

$$\pi^*_{i} = \left(1 + \frac{L^*_{i}}{Cp_{12} \cdot T^*_{\text{st}(i,1),r}}\right)^{\frac{k_{12}}{k_{12}-1}}$$

$$P^*_{\text{st}(i,2),r} = P^*_{\text{st}(i,1),r} \cdot \pi^*_{i}$$

$$Cp_{\text{st}(i,2),r} = Cp_{\text{mean}}\big(P^*_{\text{st}(i,2),r}, T^*_{\text{st}(i,2),r}\big)$$

1 st(i, 2), r = k'2
1 BO3ДУХ\ st(i, 2), r = k'2
st(i, 2), r = k'2

$$k'_2 = k_{a\text{Д}}\left(C_{\text{Pst}(i, 2), r}, R_{\text{Б}}\right)$$

$$\text{if } \left| \text{eps}\left(\text{"rel"}, k_{\text{st}(i, 2), r}, k'_2\right) \right| < \text{epsilon}$$

$$k_{\text{st}(i, 2), r} = k'_2$$

break

$$k_{\text{st}(i, 2), r} = k'_2$$

$$a^*_{c_{\text{st}(i, 2), r}} = a_{\text{КР}}\left(k_{\text{st}(i, 2), r}, R_{\text{Б}}, T^*_{\text{st}(i, 2), r}\right)$$

$$T^*_{\text{st}(i, 3), r} = T^*_{\text{st}(i, 2), r}$$

$$P^*_{\text{st}(i, 3), r} = P^*_{\text{st}(i, 2), r}$$

$$C_{\text{Pst}(i, 3), r} = C_{\text{BO3ДУХ}}\left(P^*_{\text{st}(i, 3), r}, T^*_{\text{st}(i, 3), r}\right)$$

$$k_{\text{st}(i, 3), r} = k_{a\text{Д}}\left(C_{\text{Pst}(i, 3), r}, R_{\text{Б}}\right)$$

$$a^*_{c_{\text{st}(i, 3), r}} = a_{\text{КР}}\left(k_{\text{st}(i, 3), r}, R_{\text{Б}}, T^*_{\text{st}(i, 3), r}\right)$$

$$\overline{c}_{a_{\text{st}(i, 3), r}} = \overline{c}_{.a1}(Z, i + 1)$$

$$\text{iteration}_3 = 0$$

$$\begin{pmatrix} \alpha_{\text{st}(i, 3), r} \\ u_{\text{st}(i, 3), N_{\text{r}}} \end{pmatrix} = \begin{pmatrix} \alpha_{\text{st}(i, 1), r} \\ u_{\text{st}(i, 1), N_{\text{r}}} \end{pmatrix}$$

$$c_{a_{\text{st}(i, 3), r}} = \overline{c}_{a_{\text{st}(i, 3), r}} \cdot u_{\text{st}(i, 3), N_{\text{r}}}$$

$$c_{\text{st}(i, 3), r} = \frac{c_{a_{\text{st}(i, 3), r}}}{\sin\left(\alpha_{\text{st}(i, 3), r}\right)}$$

$$\lambda_{\text{c}_{\text{st}(i, 3), r}} = \frac{c_{\text{st}(i, 3), r}}{a^*_{c_{\text{st}(i, 3), r}}}$$

$$F_{\text{st}(i, 3)} = \frac{F_{\text{st}(i, 1)} \cdot m_{\text{q}}\left(k_{\text{st}(i, 1), r}\right) \cdot \Gamma \text{Д} \Phi\left(\text{"G"}, \lambda_{\text{c}_{\text{st}(i, 1), r}}, k_{\text{st}(i, 1), r}\right) \cdot \sin\left(\alpha_{\text{st}(i, 1), r}\right) \cdot P^*_{\text{st}(i, 1), r} \sqrt{T^*_{\text{st}(i, 3), r}}}{m_{\text{q}}\left(k_{\text{st}(i, 3), r}\right) \cdot \Gamma \text{Д} \Phi\left(\text{"G"}, \lambda_{\text{c}_{\text{st}(i, 3), r}}, k_{\text{st}(i, 3), r}\right) \cdot \sin\left(\alpha_{\text{st}(i, 3), r}\right) \cdot P^*_{\text{st}(i, 3), r} \sqrt{T^*_{\text{st}(i, 1), r}}}$$

while 0 < 1

$$\text{iteration}_3 = \text{iteration}_3 + 1$$

$$\text{trace}\left(\text{concat}\left(\text{" iteration.3 = "}, \text{num2str}\left(\text{iteration}_3\right)\right)\right)$$

$$\text{if } \left(3\Pi\Pi\Pi_i \neq \text{"пер"}\right) \wedge \left(3\Pi\Pi\Pi_i \neq \text{"кор"}\right) \wedge \left(3\Pi\Pi\Pi_i \neq \text{"cp"}\right)$$

$$D_{\text{st}(i, 3), N_{\text{r}}} = D_{\text{st}(i, 1), N_{\text{r}}} \cdot \text{str2num}\left(3\Pi\Pi\Pi_i\right)$$

$$D_{\text{st}(i, 3), 1} = \sqrt{\left(D_{\text{st}(i, 3), N_{\text{r}}}\right)^2 - \frac{4F_{\text{st}(i, 3)}}{\pi}}$$

$$\text{if } 3\Pi\Pi\Pi_i = \text{"пер"}$$

$$\begin{cases} D_{\text{st}(i,3),N_r} = D_{\text{st}(i,1),N_r} \\ D_{\text{st}(i,3),1} = \sqrt{\left(D_{\text{st}(i,3),N_r}\right)^2 - \frac{4F_{\text{st}(i,3)}}{\pi}} \end{cases}$$

if $3\Pi\Pi\Pi_i = \text{"kop"}$

$$\begin{cases} D_{\text{st}(i,3),1} = D_{\text{st}(i,1),1} \\ D_{\text{st}(i,3),N_r} = \sqrt{\left(D_{\text{st}(i,3),1}\right)^2 + \frac{4F_{\text{st}(i,3)}}{\pi}} \end{cases}$$

if $3\Pi\Pi\Pi_i = \text{"cp"}$

$$\begin{cases} D_{\text{st}(i,3),N_r} = \sqrt{\left(D_{\text{st}(i,1),r}\right)^2 + \frac{2F_{\text{st}(i,3)}}{\pi}} \\ D_{\text{st}(i,3),1} = \sqrt{\left(D_{\text{st}(i,1),r}\right)^2 - \frac{2F_{\text{st}(i,3)}}{\pi}} \end{cases}$$

$$\overline{d}_{\text{st}(i,3)} = \frac{D_{\text{st}(i,3),1}}{D_{\text{st}(i,3),N_r}}$$

$$D_{\text{st}(i,3),r} = \overline{r}_{\text{cp}}(\overline{d}_{\text{st}(i,3)}) \cdot D_{\text{st}(i,3),N_r}$$

$$\overline{c}_{u_{\text{st}(i,3),r}} = \overline{r}_{\text{cp}}(\overline{d}_{\text{st}(i,3)}) \cdot \left(1 - R_{\text{L.cp}}(Z,i+1)\right) - \frac{\overline{H}.T(Z,i+1)}{2 \cdot \overline{r}_{\text{cp}}(\overline{d}_{\text{st}(i,3)})}$$

$$\alpha_{\text{st}(i,3),r} = \begin{cases} \text{atan}\left(\frac{\overline{c}_{a_{\text{st}(i,3),r}}}{\overline{c}_{u_{\text{st}(i,3),r}}}\right) & \text{if } \text{atan}\left(\frac{\overline{c}_{a_{\text{st}(i,3),r}}}{\overline{c}_{u_{\text{st}(i,3),r}}}\right) \geq 0 \\ \text{atan}\left(\frac{\overline{c}_{a_{\text{st}(i,3),r}}}{\overline{c}_{u_{\text{st}(i,3),r}}}\right) + 2\pi & \text{otherwise} \end{cases}$$

$$u_{\text{st}(i,3),N_r} = u_{\text{st}(i,1),N_r} \cdot \frac{D_{\text{st}(i,3),N_r}}{D_{\text{st}(i,1),N_r}}$$

$$c_{a_{\text{st}(i,3),r}} = \overline{c}_{a_{\text{st}(i,3),r}} \cdot u_{\text{st}(i,3),N_r}$$

$$c_{\text{st}(i,3),r} = \frac{c_{a_{\text{st}(i,3),r}}}{\sin(\alpha_{\text{st}(i,3),r})}$$

$$\lambda_{c_{\text{st}(i,3),r}} = \frac{c_{\text{st}(i,3),r}}{a^* c_{\text{st}(i,3),r}}$$

$$F'_3 = \frac{G \cdot \sqrt{R_B \cdot T^*_{\text{st}(i,3),r}}}{m_q(k_{\text{st}(i,3),r}) \cdot \Gamma \mathcal{D} \Phi\left("G", \lambda_{c_{\text{st}(i,3),r}}, k_{\text{st}(i,3),r}\right) \cdot \sin(\alpha_{\text{st}(i,3),r}) \cdot P^*_{\text{st}(i,3),r}}$$

break if $\left(\left|\text{eps}(\text{"rel"}, F'_3, F_{\text{st}(i,3)})\right| < \text{epsilon}\right) \wedge \left(\text{iteration}_3 = 0\right)$

$\text{iteration}_3 = -1$ if $\left(\left|\text{eps}(\text{"rel"}, F'_3, F_{\text{st}(i,3)})\right| < \text{epsilon}\right)$

```

Fst(i,3) = F'3
 $\overline{c}_{a_{st(i,2)},r} = \text{mean}(\overline{c}_{a_{st(i,1)},r}, \overline{c}_{a_{st(i,3)},r})$ 
iteration2 = 0
Fst(i,2) = mean(Fst(i,1), Fst(i,3))
while 0 < 1
    iteration2 = iteration2 + 1
    trace(concat(" iteration.2 = ", num2str(iteration2)))
    if (3ΠΠΨi ≠ "nep") ∧ (3ΠΠΨi ≠ "kop") ∧ (3ΠΠΨi ≠ "cp")
         $D_{st(i,2),N_r} = \text{mean}(D_{st(i,1),N_r}, D_{st(i,3),N_r})$ 
         $\overline{d}_{st(i,2)} = \sqrt{2 \cdot \text{mean}(\overline{r}_{cp}(\overline{d}_{st(i,1)}), \overline{r}_{cp}(\overline{d}_{st(i,3)}))^2 - 1}$ 
         $D_{st(i,2),r} = D_{st(i,2),N_r} \cdot \overline{r}_{cp}(\overline{d}_{st(i,2)})$ 
         $D_{st(i,2),1} = \overline{d}_{st(i,2)} \cdot D_{st(i,2),N_r}$ 
    if 3ΠΠΨi = "nep"
         $D_{st(i,2),N_r} = D_{st(i,1),N_r}$ 
         $\overline{d}_{st(i,2)} = \sqrt{2 \cdot \text{mean}(\overline{r}_{cp}(\overline{d}_{st(i,1)}), \overline{r}_{cp}(\overline{d}_{st(i,3)}))^2 - 1}$ 
         $D_{st(i,2),r} = D_{st(i,2),N_r} \cdot \overline{r}_{cp}(\overline{d}_{st(i,2)})$ 
         $D_{st(i,2),1} = \overline{d}_{st(i,2)} \cdot D_{st(i,2),N_r}$ 
    if 3ΠΠΨi = "kop"
         $D_{st(i,2),1} = D_{st(i,1),1}$ 
         $\overline{d}_{st(i,2)} = \sqrt{2 \cdot \text{mean}(\overline{r}_{cp}(\overline{d}_{st(i,1)}), \overline{r}_{cp}(\overline{d}_{st(i,3)}))^2 - 1}$ 
         $D_{st(i,2),N_r} = \frac{D_{st(i,2),1}}{\overline{d}_{st(i,2)}}$ 
         $D_{st(i,2),r} = D_{st(i,2),N_r} \cdot \overline{r}_{cp}(\overline{d}_{st(i,2)})$ 
    if 3ΠΠΨi = "cp"
         $D_{st(i,2),r} = D_{st(i,1),r}$ 
         $\overline{d}_{st(i,2)} = \sqrt{2 \cdot \text{mean}(\overline{r}_{cp}(\overline{d}_{st(i,1)}), \overline{r}_{cp}(\overline{d}_{st(i,3)}))^2 - 1}$ 
         $D_{st(i,2),N_r} = \frac{D_{st(i,2),r}}{\overline{r}_{cp}(\overline{d}_{st(i,2)})}$ 
         $D_{st(i,2),1} = \overline{d}_{st(i,2)} \cdot D_{st(i,2),N_r}$ 

```

$$\overline{c}_{u_{st(i,2),r}} = \frac{1}{\overline{r}_{cp}(\overline{d}_{st(i,2)})} \left(\frac{\nu_{st(i,1),N_r}}{D_{st(i,2),N_r}} \right) \cdot \left(\overline{H}_{T_i} + \overline{c}_{u_{st(i,1),r}} \cdot \frac{D_{st(i,1),r}}{D_{st(i,1),N_r}} \right)$$

$$\alpha_{st(i,2),r} = \text{triangle}(\overline{c}_{a_{st(i,2),r}}, \overline{c}_{u_{st(i,2),r}})$$

$$u_{st(i,2),N_r} = u_{st(i,1),N_r} \cdot \frac{D_{st(i,2),N_r}}{D_{st(i,1),N_r}}$$

$$c_{a_{st(i,2),r}} = \overline{c}_{a_{st(i,2),r}} \cdot u_{st(i,2),N_r}$$

$$c_{st(i,2),r} = \frac{c_{a_{st(i,2),r}}}{\sin(\alpha_{st(i,2),r})}$$

$$\lambda_{c_{st(i,2),r}} = \frac{c_{st(i,2),r}}{a^*_{c_{st(i,2),r}}}$$

$$F'_2 = \frac{G \cdot \sqrt{R_B \cdot T^*_{st(i,2),r}}}{m_q(k_{st(i,2),r}) \cdot \Gamma \mathcal{D} \Phi \left("G", \lambda_{c_{st(i,2),r}}, k_{st(i,2),r} \right) \cdot \sin(\alpha_{st(i,2),r}) \cdot P^*_{st(i,2),r}}$$

$$\text{break if } \left(\left| \text{eps}("rel", F'_2, F_{st(i,2)}) \right| < \text{epsilon} \right) \wedge \left(\text{iteration}_2 = 0 \right)$$

$$\text{iteration}_2 = -1 \quad \text{if } \left(\left| \text{eps}("rel", F'_2, F_{st(i,2)}) \right| < \text{epsilon} \right)$$

$$F_{st(i,2)} = F'_2$$

for a ∈ 1 .. 3

$$\rho^*_{st(i,a),r} = \frac{P^*_{st(i,a),r}}{R_B \cdot T^*_{st(i,a),r}}$$

$$T_{st(i,a),r} = T^*_{st(i,a),r} \cdot \Gamma \mathcal{D} \Phi \left("T", \lambda_{c_{st(i,a),r}}, k_{st(i,a),r} \right)$$

$$P_{st(i,a),r} = P^*_{st(i,a),r} \cdot \Gamma \mathcal{D} \Phi \left("P", \lambda_{c_{st(i,a),r}}, k_{st(i,a),r} \right)$$

$$\rho_{st(i,a),r} = \rho^*_{st(i,a),r} \cdot \Gamma \mathcal{D} \Phi \left(" \rho ", \lambda_{c_{st(i,a),r}}, k_{st(i,a),r} \right)$$

$$a_{3B_{st(i,a),r}} = \sqrt{k_{st(i,a),r} \cdot R_B \cdot T_{st(i,a),r}}$$

$$\beta_{st(i,a),r} = \text{triangle}(\overline{c}_{a_{st(i,a),r}}, \overline{r}_{cp}(\overline{d}_{st(i,a)}) - \overline{c}_{u_{st(i,a),r}})$$

$$w_{st(i,a),r} = \frac{c_{a_{st(i,a),r}}}{\sin(\beta_{st(i,a),r})}$$

$$w_{u_{st(i,a),r}} = w_{st(i,a),r} \cdot \cos(\beta_{st(i,a),r})$$

$$c_{u_{st(i,a),r}} = c_{st(i,a),r} \cdot \cos(\alpha_{st(i,a),r})$$

$$M_{w_{st(i,a),r}} = \frac{w_{st(i,a),r}}{a_{3B_{st(i,a),r}}}$$

$$u_{st(i,a),r} = c_{st(i,a),r}$$

$$M_{c_{st(i,a),r}} = \overline{a_{3B_{st(i,a),r}}}$$

$$h_{st(i,a)} = 0.5 \cdot \left(D_{st(i,a),N_r} - D_{st(i,a),1} \right)$$

for radius $\in 1..N_r$

$$u_{st(i,a),radius} = \omega \cdot \frac{D_{st(i,a),radius}}{2}$$

$$\begin{pmatrix} \epsilon_{rotor_{i,av(N_r)}} \\ \epsilon_{stator_{i,av(N_r)}} \end{pmatrix} = \begin{pmatrix} \beta_{st(i,2),av(N_r)} - \beta_{st(i,1),av(N_r)} \\ \alpha_{st(i,3),av(N_r)} - \alpha_{st(i,2),av(N_r)} \end{pmatrix}$$

for i $\in 1..Z$

for a $\in 1..3$

for r $\in 1..N_r$

$$R_{st(i,a),r} = 0.5 \cdot D_{st(i,a),r}$$

$$\begin{pmatrix} R_L & K_H & C_p & \bar{H}_T & L^* & T^* & P^* & \rho^* & a^*_c & \lambda_c & F & D & \bar{d} & \bar{c}_a & c_a & u & c & M_c & \alpha & \epsilon_{rotor} \\ \pi^* & \eta^* & k & H_T & L & T & P & \rho & a_{3B} & \lambda_c & F & R & h & \bar{c}_u & c_u & w_u & w & M_w & \beta & \epsilon_{stator} \end{pmatrix}^T$$

$$CA = \begin{cases} 1 & \text{if compressor = "КВД"} \\ 0 & \text{otherwise} \end{cases} = 0$$

Расчет CA:

$$\begin{pmatrix} \alpha_{1CA} & \alpha_{3CA} \\ \sigma_{CA} & \sigma_{CA} \\ \overline{d}_{1CA} & \overline{d}_{3CA} \\ T^*_{1CA} & T^*_{3CA} \\ P^*_{1CA} & P^*_{3CA} \\ \rho^*_{1CA} & \rho^*_{3CA} \\ k_{1CA} & k_{3CA} \\ a_{kp1CA} & a_{kp3CA} \\ \overline{c}_{a1CA} & \overline{c}_{a3CA} \\ \overline{c}_{u1CA} & \overline{c}_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ c_{u1CA} & c_{u3CA} \\ c_{1CA} & c_{3CA} \\ \lambda_{1CA} & \lambda_{3CA} \\ F_{1CA} & F_{3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{pmatrix} = \begin{cases} \text{for } r \in \text{av}\left(N_r\right) \\ \left| \begin{array}{l} \alpha_{1CA_r} = \alpha_{st(Z,3),r} \\ \alpha_{3CA_r} = \begin{cases} 90\cdot^{\circ} & \text{if } CA = 1 \\ \alpha_{1CA_r} & \text{otherwise} \end{cases} \\ \overline{d}_{1CA} = \overline{d}_{st(Z,3)} \\ \overline{d}_{3CA} = \overline{d}_{1CA} \\ T^*_{1CA_r} = T^*_{st(Z,3),r} \\ T^*_{3CA_r} = T^*_{1CA_r} \\ P^*_{1CA_r} = P^*_{st(Z,3),r} \\ \text{iterarion}_{CA} = 0 \\ \sigma_{CA} = 1 \\ \text{while } 0 < 1 \\ \left| \begin{array}{l} \text{iterarion}_{CA} = \text{iterarion}_{CA} + 1 \\ \text{trace}\left(\text{concat}\left(\text{"iterarion.CA = "}, \text{num2str}\left(\text{iterarion}_{CA}\right)\right)\right) \\ P^*_{3CA_r} = P^*_{1CA_r} \cdot \sigma_{CA} \\ \left(\rho^*_{1CA_r}\right) \cdot \left(\frac{P^*_{1CA_r}}{T^*_{1CA_r}}\right) \end{array} \right. \end{array} \right. \end{cases}$$

$$\sigma_{CA} = 1.0000$$

$$\text{submatrix}\left(\varepsilon_{CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.00) \cdot \text{deg}$$

$$\text{submatrix}\left(\alpha_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (51.49) \cdot \text{deg}$$

$$\text{submatrix}\left(\alpha_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (51.49) \cdot \text{deg}$$

$$\begin{pmatrix} \overline{d}_{1CA} \\ \overline{d}_{3CA} \end{pmatrix} = \begin{pmatrix} 0.6953 \\ 0.6953 \end{pmatrix} \qquad \begin{pmatrix} F_{1CA} \\ F_{3CA} \end{pmatrix} = \begin{pmatrix} 0.3310 \\ 0.3310 \end{pmatrix}$$

$$\left(\rho^*_{3CA_r}\right) = \frac{1}{R_B} \cdot \left(\frac{P^*_{3CA_r}}{T^*_{3CA_r}}\right)$$

$$\begin{pmatrix} k_{1CA_r} \\ k_{3CA_r} \end{pmatrix} = \begin{pmatrix} k_{aд}\left(Cp_{\text{воздух}}\left(P^*_{1CA_r}, T^*_{1CA_r}\right), R_B\right) \\ k_{aд}\left(Cp_{\text{воздух}}\left(P^*_{3CA_r}, T^*_{3CA_r}\right), R_B\right) \end{pmatrix}$$

$$\begin{pmatrix} a_{kp1CA_r} \\ a_{kp3CA_r} \end{pmatrix} = \begin{pmatrix} a_{kp}\left(k_{1CA_r}, R_B, T^*_{1CA_r}\right) \\ a_{kp}\left(k_{3CA_r}, R_B, T^*_{3CA_r}\right) \end{pmatrix}$$

$$\overline{c}_{a1CA_r} = \overline{c}_{a_{st(Z,3)},r}$$

$$\overline{c}_{a3CA_r} = \overline{c}_{.a1}(Z, Z + 1)$$

$$\overline{c}_{u1CA_r} = \overline{c}_{u_{st(Z,3)},r}$$

$$\overline{c}_{u3CA_r} = \begin{cases} 0 & \text{if } CA = 1 \\ \overline{c}_{u1CA_r} & \text{otherwise} \end{cases}$$

$$c_{a1CA_r} = \overline{c}_{a3CA_r} \cdot u_{st(Z,3),N_r}$$

$$c_{a3CA_r} = c_{a1CA_r} - \begin{cases} 10 & \text{if } CA = 1 \\ 0 & \text{otherwise} \end{cases}$$

$$\begin{pmatrix} c_{u1CA_r} \\ c_{u3CA_r} \end{pmatrix} = \begin{pmatrix} \frac{c_{a1CA_r}}{\tan(\alpha_{1CA_r})} \\ \frac{c_{a3CA_r}}{\tan(\alpha_{3CA_r})} \end{pmatrix}$$

$$\begin{pmatrix} c_{1CA_r} \\ c_{3CA_r} \end{pmatrix} = \begin{pmatrix} \frac{c_{a1CA_r}}{\sin(\alpha_{1CA_r})} \\ \frac{c_{a3CA_r}}{\sin(\alpha_{3CA_r})} \end{pmatrix}$$

$$\begin{pmatrix} \lambda_{1CA_r} \\ \lambda_{3CA_r} \end{pmatrix} = \begin{pmatrix} \frac{c_{1CA_r}}{a_{kp1CA_r}} \\ \frac{c_{3CA_r}}{a_{kp3CA_r}} \end{pmatrix}$$

$$\sigma'_{CA} = \begin{cases} 1 - \text{mean}(0.25, 0.5) \cdot \Gamma\text{Д}\Phi\left("p", \lambda_{3CA_r}, k_{3CA_r}\right) \cdot \frac{k_{3CA_r}}{k_{3CA_r} + 1} \cdot \left(\lambda_{3CA_r}\right)^2 & \text{if } CA = 1 \end{cases}$$

$$\text{submatrix}\left(T^*_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (361.5)$$

$$\text{submatrix}\left(T^*_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (361.5)$$

$$\text{submatrix}\left(P^*_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (202.7) \cdot 10^3$$

$$\text{submatrix}\left(P^*_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (202.7) \cdot 10^3$$

$$\text{submatrix}\left(\rho^*_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.952)$$

$$\text{submatrix}\left(\rho^*_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.952)$$

$$\text{submatrix}\left(k_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.398)$$

$$\text{submatrix}\left(k_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.398)$$

$$\text{submatrix}\left(a_{kp1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (347.9)$$

$$\text{submatrix}\left(a_{kp3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (347.9)$$

$$\text{submatrix}\left(\overline{c}_{a1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.224)$$

$$\text{submatrix}\left(\overline{c}_{a3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.224)$$

$$\text{submatrix}\left(\overline{c}_{u1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.178)$$

$$\text{submatrix}\left(\overline{c}_{u3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.178)$$

$$\text{submatrix}\left(c_{a1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (56.1)$$

$$\text{submatrix}\left(c_{a3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (56.1)$$

$$\text{submatrix}\left(c_{u1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (44.7)$$

$$\text{submatrix}\left(c_{u3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (44.7)$$

$$\text{submatrix}\left(c_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (71.8)$$

$$\text{submatrix}\left(c_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (71.8)$$

$$\text{submatrix}\left(\lambda_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.206)$$

$$\text{submatrix}\left(\lambda_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.206)$$

$$\begin{array}{l} \quad \quad \quad | \quad 1 \quad \text{otherwise} \\ \text{break if } \left(\left| \text{eps}(\text{"rel"}, \sigma'_{CA}, \sigma_{CA}) \right| < \text{epsilon} \right) \wedge \left(\text{iterarion}_{CA} = 0 \right) \\ \text{iterarion}_{CA} = -1 \quad \text{if } \left(\left| \text{eps}(\text{"rel"}, \sigma'_{CA}, \sigma_{CA}) \right| < \text{epsilon} \right) \\ \sigma_{CA} = \sigma'_{CA} \end{array}$$

$$\begin{pmatrix} F_{1CA} \\ F_{3CA} \end{pmatrix} = \begin{pmatrix} F_{st}(Z, 3) \\ G \cdot \sqrt{R_B \cdot T^*_{3CA_r}} \\ \frac{m_q(k_{3CA_r}) \cdot P^*_{3CA_r} \cdot \Gamma_D \Phi("G", \lambda_{3CA_r}, k_{3CA_r}) \cdot \sin(\alpha_{3CA_r})}{m_q(k_{3CA_r}) \cdot P^*_{3CA_r} \cdot \Gamma_D \Phi("G", \lambda_{3CA_r}, k_{3CA_r}) \cdot \sin(\alpha_{3CA_r})} \end{pmatrix}$$

$$\left| \varepsilon_{CA_r} = \alpha_3 CA_r - \alpha_1 CA_r \right|$$

$$\left(\begin{array}{cc} \alpha_{1CA} & \alpha_{3CA} \\ \sigma_{CA} & \sigma_{CA} \\ \bar{d}_{1CA} & \bar{d}_{3CA} \\ T^*_{1CA} & T^*_{3CA} \\ P^*_{1CA} & P^*_{3CA} \\ \rho^*_{1CA} & \rho^*_{3CA} \\ k_{1CA} & k_{3CA} \\ a_{kp1CA} & a_{kp3CA} \\ \bar{c}_{a1CA} & \bar{c}_{a3CA} \\ \bar{c}_{u1CA} & \bar{c}_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ c_{u1CA} & c_{u3CA} \\ c_{1CA} & c_{3CA} \\ \lambda_{1CA} & \lambda_{3CA} \\ F_{1CA} & F_{3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{array} \right)$$

Относ. погрешность расчета по массовому расходу (кг/с):

$\overline{\Delta G} =$

for i ∈ 1..Z

for a ∈ 1..3

$\overline{\Delta G}_{st(i,a)} = \left| \text{eps}\left(\text{"rel"}, G, \rho_{st(i,a),av(N_r)} \cdot c_{a_{st(i,a),av(N_r)}} \cdot F_{st(i,a)} \right) \right|$

$\overline{\Delta G}$

$\overline{\Delta G}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.00	0.00	0.01	0.00	0.00	0.00	0.00												

.%

$\overline{\Delta G}^T < 1\% =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1	1	1	1	1												

Количество ступеней ОК:

$Z = 3$

Дискретизация сечений:

$ii = 1..2Z + 1$

Дискретизация ступеней:

$i = 1..Z$

$\pi^{*T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.300	1.297	1.187												

[16, с 114] $\pi^{*T} \leq 1.9 =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1												

Полученная степень повышения полного давления []:

$$\prod_{i = 1}^Z \pi^{*}_i = 2.000$$

Степень повышения давления в ЛА:

$$\pi^{*}_{\text{ЛА}} = \frac{P^{*}_{3CA_{av(N_r)}}}{P^{*}_{1BHA_{av(N_r)}} = 2.000$$

$$\pi^{*}_{\text{ЛА}} \geq \pi^{*}_{\text{К}} = 1$$

$H_T^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	26.51	29.08	21.26												
2	26.51	29.08	21.26												
3	26.51	29.08	21.26												

 $\cdot 10^3$

Действительная работа К (Дж/кг):
$$L_K = \sum_{i=1}^Z L_i = 73.6 \cdot 10^3$$

Адиабатная работа К [Дж/кг]:
$$L_K^* = \sum_{i=1}^Z L_{i}^* = 64.1 \cdot 10^3$$

Адиабатная КПД К [%]:

$$\eta_K^* = \frac{L_K^*}{L_K} = 87.02\%$$

Мощность К (Вт):
$$N_K = G \cdot L_K = 2.62 \cdot 10^6$$

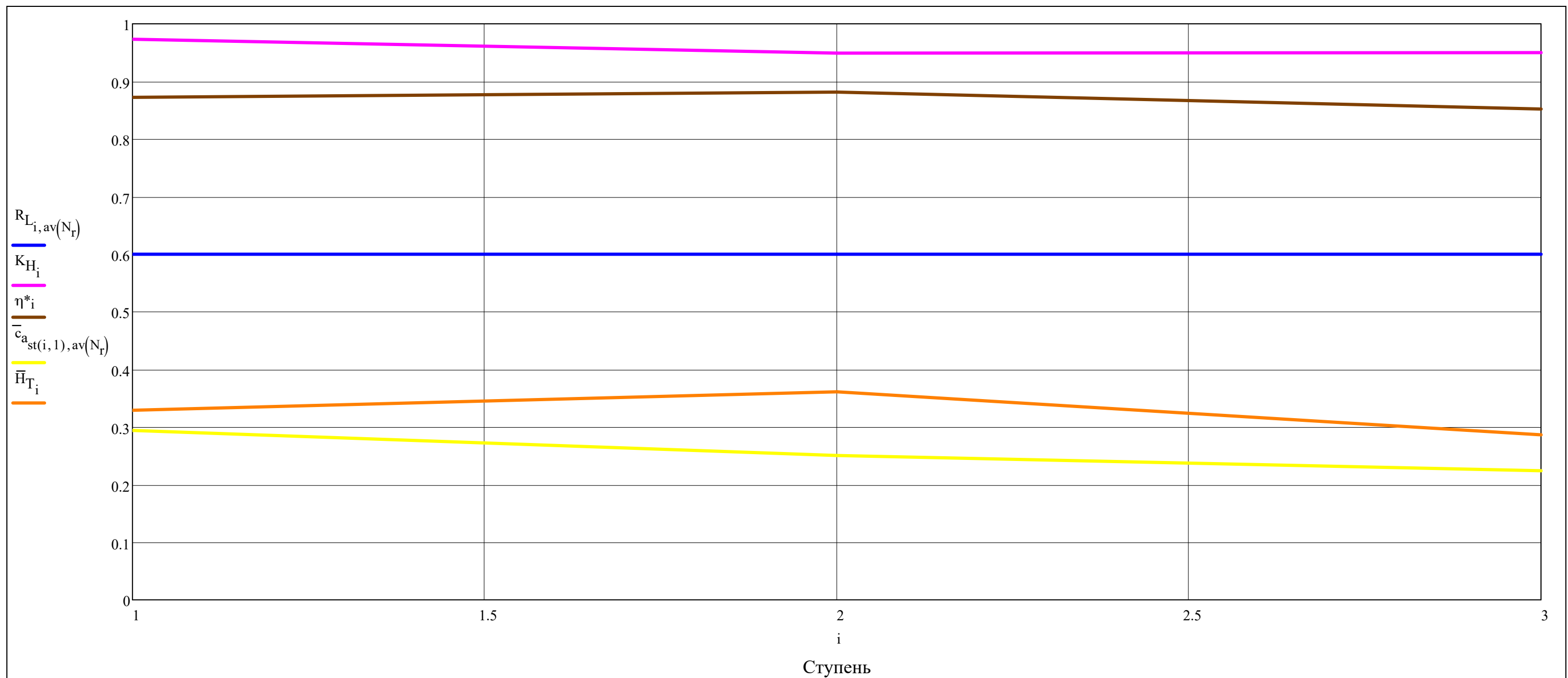
[illegible]

$$K_H^T = \begin{array}{c|ccccccccccccccccc} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 \\ \hline 1 & 0.973 & 0.949 & 0.95 & & & & & & & & & & & & \end{array}$$

[illegible]

[illegible]

$$\bar{H}_T^T = \begin{array}{c|cccccccccccccccc} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 \\ \hline 1 & 0.33 & 0.36 & 0.29 & & & & & & & & & & & & \end{array}$$



$$\text{submatrix}\Big(\text{Cp},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 \\ \hline 1 & 1002.6 & 1004.1 & 1004.1 & 1006.4 & 1006.4 & 1008.5 & 1008.5 & & & & & & & & & & & & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{k},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 1.401 & 1.401 & 1.401 & 1.399 & 1.399 & 1.398 & 1.398 & & & & & & & & & & & & & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{T}^*,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 288.2 & 313.9 & 313.9 & 341.4 & 341.4 & 361.5 & 361.5 & & & & & & & & & & & & & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{T},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 284.7 & 305.4 & 310.5 & 326.2 & 338.3 & 349 & 359 & & & & & & & & & & & & & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{P}^*,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 \\ \hline 1 & 101.3 & 131.7 & 131.7 & 170.8 & 170.8 & 202.7 & 202.7 & & & & & & & & & & & \\ \hline \end{array} \cdot 10^3$$

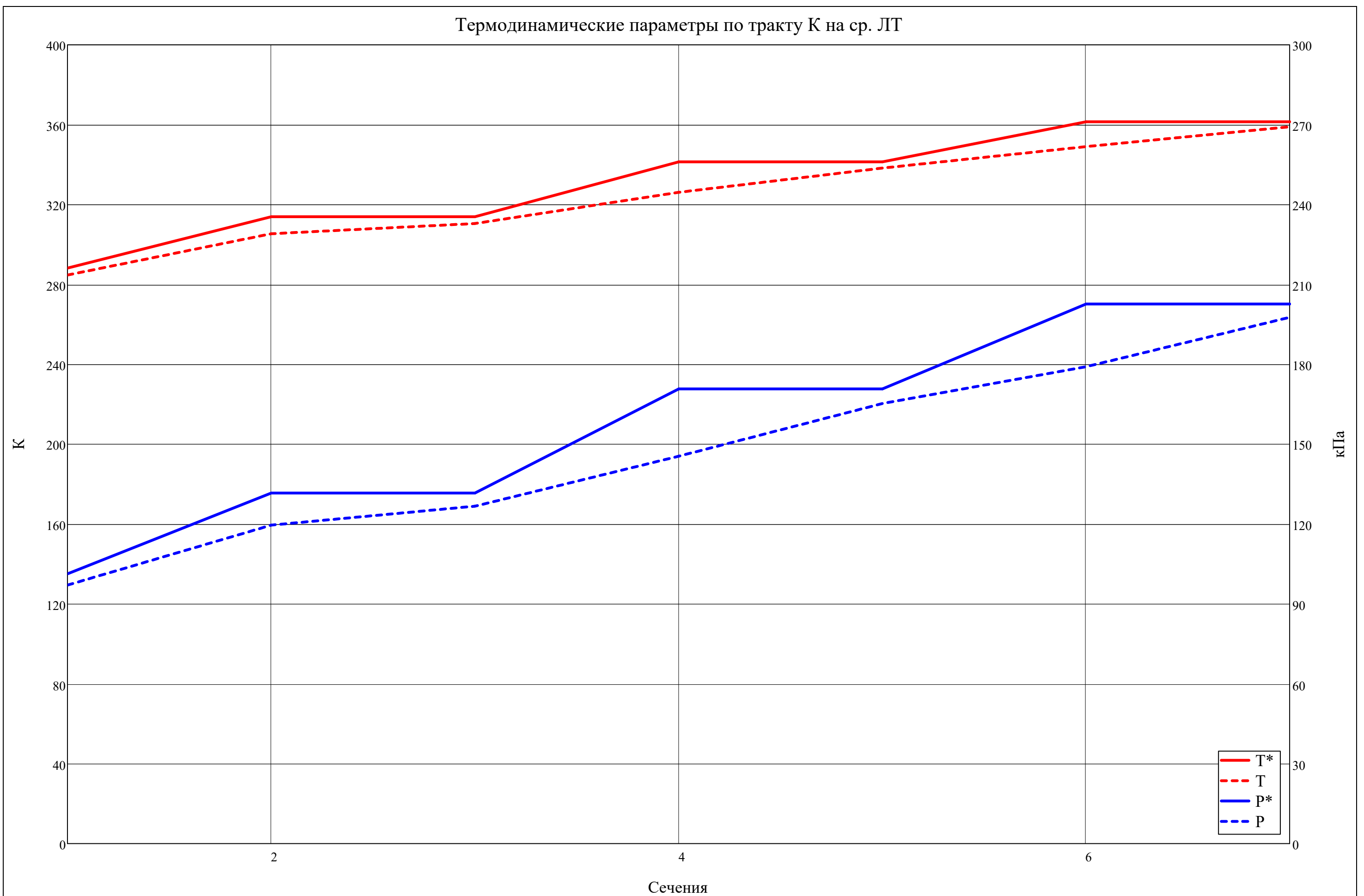
$$\text{submatrix}\Big(\text{P},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 \\ \hline 1 & 97.1 & 119.6 & 126.7 & 145.5 & 165.3 & 179.1 & 197.7 & & & & & & & & & & & \\ \hline \end{array} \cdot 10^3$$

$$\text{submatrix}\Big(\rho^*,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 \\ \hline 1 & 1.224 & 1.461 & 1.461 & 1.742 & 1.742 & 1.952 & 1.952 & & & & & & & & & & & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\rho,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 \\ \hline 1 & 1.188 & 1.364 & 1.421 & 1.553 & 1.702 & 1.787 & 1.918 & & & & & & & & & & & & \\ \hline \end{array}$$

$$\textcolor{green}{k_{cp}} = k_{\text{ад}}\Big(\text{Cp}_{\text{воздух.ср}}\Big(\text{P}^*_{\text{st}(1,1),\text{av}\Big(\text{N}_{\text{r}}\Big)},\text{P}^*_{\text{st}(Z,3),\text{av}\Big(\text{N}_{\text{r}}\Big)},\text{T}^*_{\text{st}(1,1),\text{av}\Big(\text{N}_{\text{r}}\Big)},\text{T}^*_{\text{st}(Z,3),\text{av}\Big(\text{N}_{\text{r}}\Big)}\Big),\text{R}_{\text{B}}\Big) = 1.400$$

Термодинамические параметры по тракту К на ср. ЛТ



$F^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.3596	0.3382	0.3526	0.3476	0.3433	0.3404	0.331														

$\overline{d}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.7498	0.7527	0.7555	0.7474	0.7393	0.7175	0.6953																

$\overline{d}_{st(Z,3)} = 0.6953$

$\overline{d}_{st(Z,3)} \leq 0.9 = 1$

$D^T =$

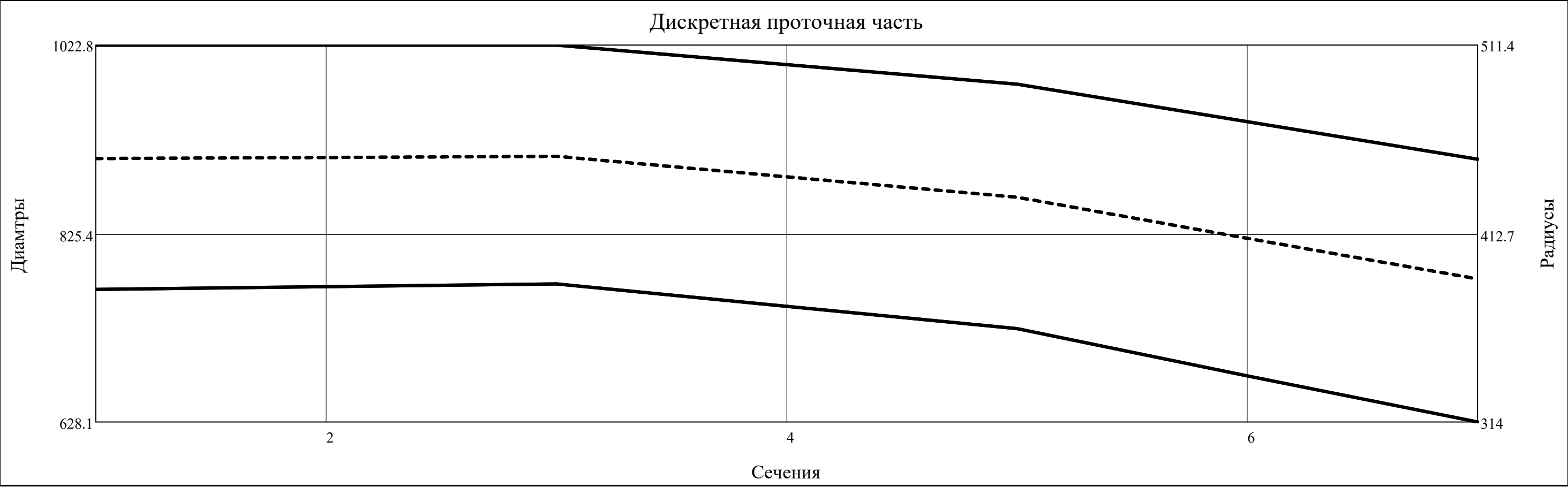
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	766.9	769.8	772.7	749.2	725.9	676.3	628.1														
2	903.9	905.2	906.4	884.8	863.4	820.3	777.9														
3	1022.8	1022.8	1022.8	1002.3	981.8	942.6	903.3														

$\cdot 10^{-3}$

$R^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	383.4	384.9	386.3	374.6	363.0	338.2	314.0																		
2	452.0	452.6	453.2	442.4	431.7	410.2	389.0																		
3	511.4	511.4	511.4	501.1	490.9	471.3	451.6																		

$\cdot 10^{-3}$



$h^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	127.9	126.5	125.0	126.6	128.0	133.1	137.6																		

$\cdot 10^{-3}$

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

$$c_{a_{st(Z,3),av}(N_r)} = 56.15 \quad c_{a_{st(Z,3),av}(N_r)} \leq 130 = 1 \quad \text{Для КС}$$

[illegible]

[illegible]

[illegible]

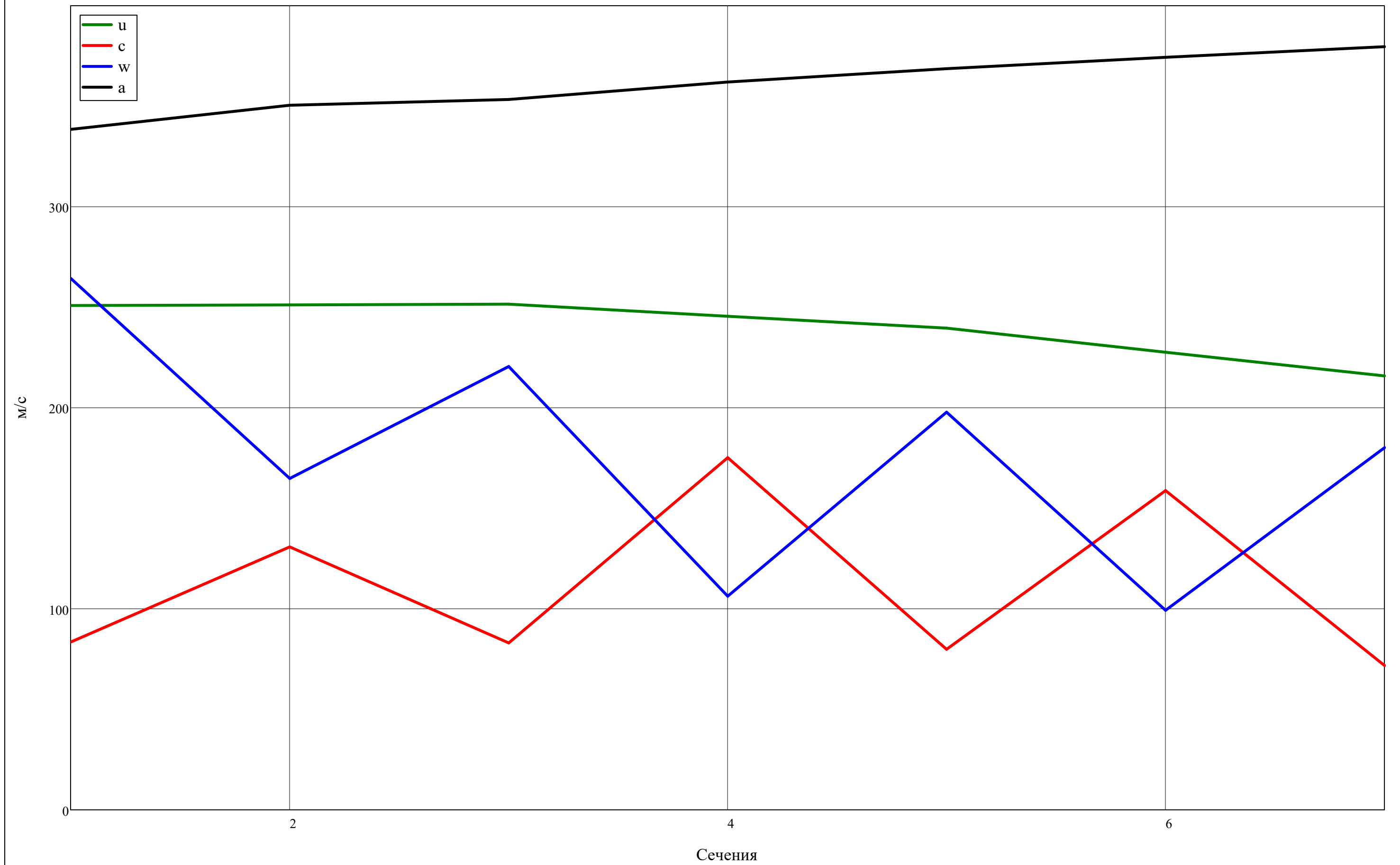
$$\Delta c_{a,i,av(N_r)} = \left(c_{a,st(i,2),av(N_r)} - c_{a,st(i,1),av(N_r)} \right)$$

$$\text{submatrix}(\Delta c_a, l, Z, \text{av}(N_r), \text{av}(N_r))^T =$$

	1	2	3	4	5	6	7	8	9	10	11	12
1	-6.15	-5.13	-2.44									

[illegible]

Скорости по тракту К на ср. ЛТ



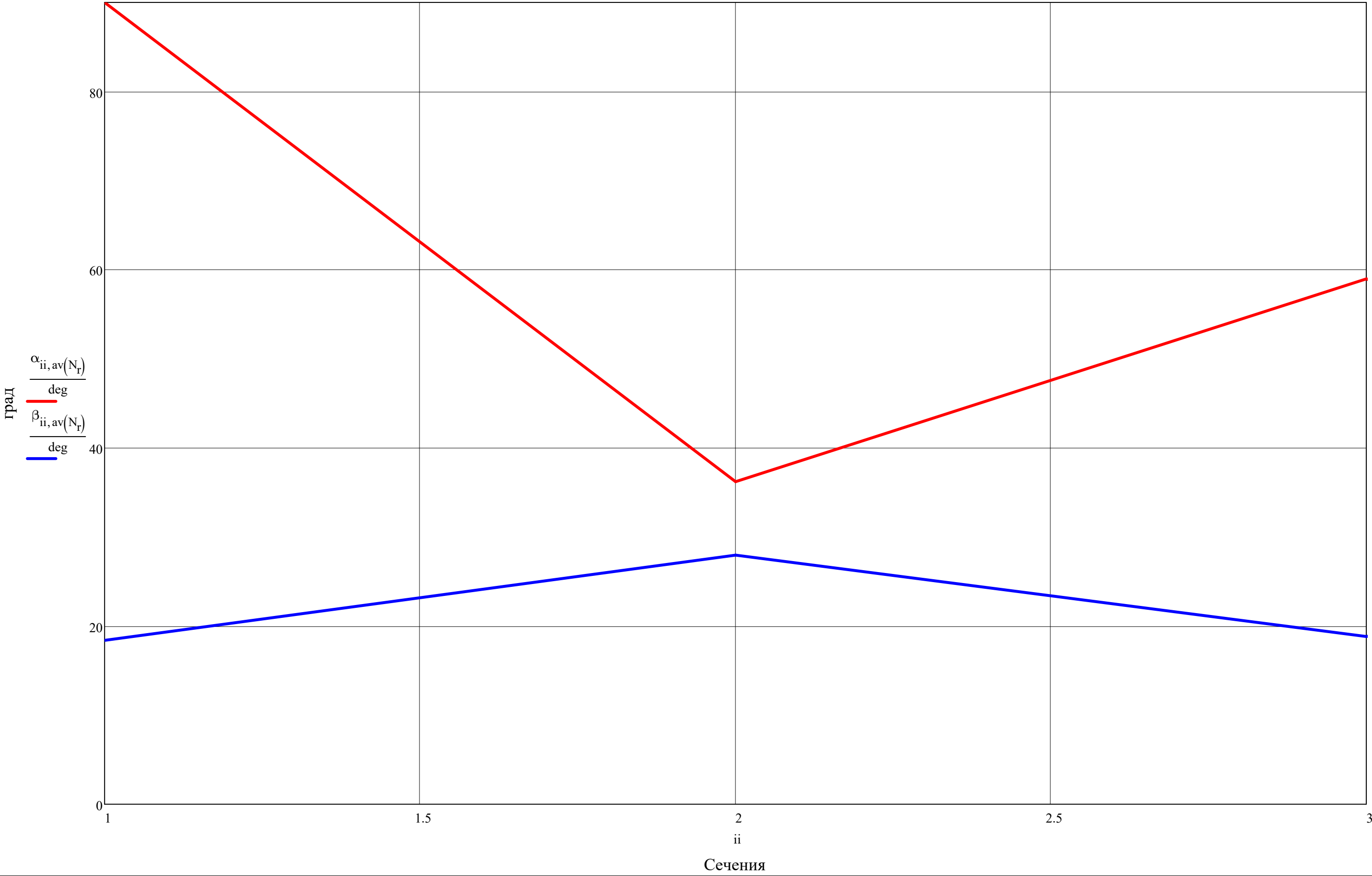
[illegible]

[illegible]

[illegible]

[illegible]

Углы по тракту К на ср. ЛТ



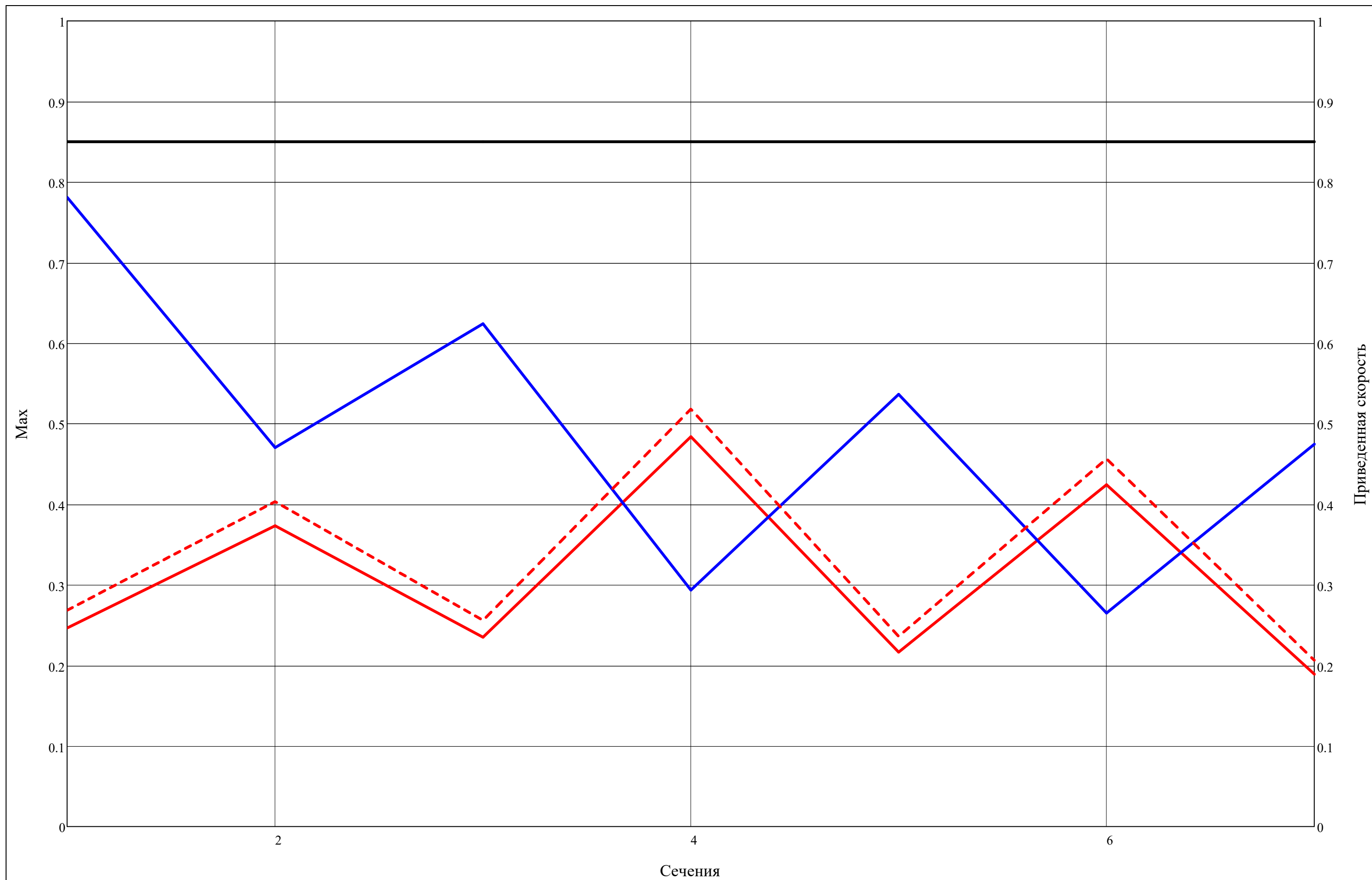
[illegible]

[16, c. 87] $\text{submatrix}(\lambda_{\mathbf{c}}, 1, 2Z + 1, \text{av}(\mathbf{N}_{\mathbf{r}}), \text{av}(\mathbf{N}_{\mathbf{r}}))^{\mathbf{T}} \leq 0.85 =$

	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1

[illegible]

[illegible]



$$\begin{pmatrix} T^*_{1BHA} & T^*_{3BHA} \\ P^*_{1BHA} & P^*_{3BHA} \\ \rho^*_{1BHA} & \rho^*_{3BHA} \\ C_{p1BHA} & C_{p3BHA} \\ k_{1BHA} & k_{3BHA} \\ a^*_{c1BHA} & a^*_{c3BHA} \\ c_{u1BHA} & c_{u3BHA} \\ c_{a1BHA} & c_{a3BHA} \\ \alpha_{1BHA} & \alpha_{3BHA} \\ c_{1BHA} & c_{3BHA} \\ \lambda_{c1BHA} & \lambda_{c3BHA} \\ \epsilon_{BHA} & \epsilon_{BHA} \end{pmatrix} = \begin{cases} \text{for } i \in 1 \\ \text{for } r \in 1..N_r \\ \begin{pmatrix} T^*_{1BHA_r} \\ T^*_{3BHA_r} \end{pmatrix} = \begin{pmatrix} T^*_{1BHA_{av}(N_r)} \\ T^*_{3BHA_{av}(N_r)} \end{pmatrix} \\ \begin{pmatrix} P^*_{1BHA_r} \\ P^*_{3BHA_r} \end{pmatrix} = \begin{pmatrix} P^*_{1BHA_{av}(N_r)} \\ P^*_{3BHA_{av}(N_r)} \end{pmatrix} \\ \begin{pmatrix} \rho^*_{1BHA_r} \\ \rho^*_{3BHA_r} \end{pmatrix} = \begin{pmatrix} \rho^*_{1BHA_{av}(N_r)} \\ \rho^*_{3BHA_{av}(N_r)} \end{pmatrix} \\ \begin{pmatrix} C_{p1BHA_r} \\ C_{p3BHA_r} \end{pmatrix} = \begin{pmatrix} C_{p_{\text{воздух}}}(P^*_{1BHA_r}, T^*_{1BHA_r}) \\ C_{p_{\text{воздух}}}(P^*_{3BHA_r}, T^*_{3BHA_r}) \end{pmatrix} \\ \begin{pmatrix} k_{1BHA_r} \\ k_{3BHA_r} \end{pmatrix} = \begin{pmatrix} k_{ад}(C_{p1BHA_r}, R_B) \\ k_{ад}(C_{p3BHA_r}, R_B) \end{pmatrix} \\ \begin{pmatrix} a^*_{c1BHA_r} \\ a^*_{c3BHA_r} \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{2 \cdot k_{1BHA_r}}{k_{1BHA_r} + 1} \cdot R_B \cdot T^*_{1BHA_r}} \\ \sqrt{\frac{2 \cdot k_{3BHA_r}}{k_{3BHA_r} + 1} \cdot R_B \cdot T^*_{3BHA_r}} \end{pmatrix} \\ A = \left(1 - R_{L_{1, av}(N_r)}\right) \cdot \omega \cdot \left(R_{st(i, 1), av}(N_r)\right)^{m_i+1} \\ B = \frac{H_{T_{i, av}(N_r)}}{2 \cdot \omega} \\ \begin{pmatrix} c_{u1BHA_r} \\ c_{u3BHA_r} \end{pmatrix} = \begin{pmatrix} c_{u1BHA_{av}(N_r)} \\ c_{u3BHA_{av}(N_r)} \end{pmatrix} \end{cases}$$

$$\begin{aligned}
\begin{pmatrix} c_{1BHA_r} \\ c_{u3BHA_r} \end{pmatrix} &= \begin{bmatrix} \frac{A}{\left(R_{st(i,1),r}\right)^{m_i}} - \frac{B}{\left(R_{st(i,1),r}\right)} \text{ if } BHA = 1 \\ c_{u1BHA_{av}(N_r)} \text{ otherwise} \end{bmatrix} \\
\begin{pmatrix} c_{a1BHA_r} \\ c_{a3BHA_r} \end{pmatrix} &= \begin{bmatrix} c_{a1BHA_{av}(N_r)} \\ \begin{bmatrix} \text{if } BHA = 1 \\ \sqrt{\left(c_{a3BHA_{av}(N_r)}\right)^2 - 2 \cdot A^2 \cdot \left[\left(R_{st(i,1),r}\right)^2 - \left(R_{st(i,1),av(N_r)}\right)^2\right] + 4 \cdot A \cdot B \cdot \ln\left(\frac{R_{st(i,1),r}}{R_{st(i,1),av(N_r)}}\right)} \text{ if } m_i = -1 \\ \sqrt{\left(c_{a3BHA_{av}(N_r)}\right)^2 - 2 \cdot A^2 \cdot \ln\left(\frac{R_{st(i,1),r}}{R_{st(i,1),av(N_r)}}\right) - 2 \cdot A \cdot B \cdot \left(\frac{1}{R_{st(i,1),r}} - \frac{1}{R_{st(i,1),av(N_r)}}\right)} \text{ if } m_i = 0 \\ \sqrt{\left(c_{a3BHA_{av}(N_r)}\right)^2 + \frac{A \cdot (m_i - 1) \cdot \left[-A \cdot (m_i + 1) \cdot \left[\frac{1}{\left(R_{st(i,1),r}\right)^{2 \cdot m_i}} - \frac{1}{\left(R_{st(i,1),av(N_r)}\right)^{2 \cdot m_i}}\right] \dots}{+ 2 \cdot B \cdot m_i \cdot \left[\frac{1}{\left(R_{st(i,1),r}\right)^{m_i+1}} - \frac{1}{\left(R_{st(i,1),av(N_r)}\right)^{m_i+1}}\right]} } \text{ otherwise} \end{bmatrix} \\ c_{a1BHA_{av}(N_r)} \text{ otherwise} \end{bmatrix} \\
\begin{pmatrix} \alpha_{1BHA_r} \\ \alpha_{3BHA_r} \end{pmatrix} &= \begin{pmatrix} \text{triangle}(c_{a1BHA_r}, c_{u1BHA_r}) \\ \text{triangle}(c_{a3BHA_r}, c_{u3BHA_r}) \end{pmatrix} \\
\begin{pmatrix} c_{1BHA_r} \\ c_{3BHA_r} \end{pmatrix} &= \begin{pmatrix} \frac{c_{a1BHA_r}}{\sin(\alpha_{1BHA_r})} \\ \frac{c_{a3BHA_r}}{\sin(\alpha_{3BHA_r})} \end{pmatrix} \\
\begin{pmatrix} \lambda_{c1BHA_r} \\ \lambda_{c3BHA_r} \end{pmatrix} &= \begin{pmatrix} \frac{c_{1BHA_r}}{a^*_{c1BHA_r}} \\ \frac{c_{3BHA_r}}{a^*_{c3BHA_r}} \end{pmatrix} \\
\epsilon_{BHA_r} &= -1 \cdot (\alpha_{3BHA_r} - \alpha_{1BHA_r}) \\
\begin{pmatrix} T^*_{1BHA} & P^*_{1BHA} & \rho^*_{1BHA} & C_{P1BHA} & k_{1BHA} & a^*_{c1BHA} & c_{u1BHA} & c_{a1BHA} & \alpha_{1BHA} & c_{1BHA} & \lambda_{c1BHA} & \epsilon_{BHA} \\ T^*_{3BHA} & P^*_{3BHA} & \rho^*_{3BHA} & C_{P3BHA} & k_{3BHA} & a^*_{c3BHA} & c_{u3BHA} & c_{a3BHA} & \alpha_{3BHA} & c_{3BHA} & \lambda_{c3BHA} & \epsilon_{BHA} \end{pmatrix}^T
\end{aligned}$$

T^*	T	=	for $i \in 1..Z$	for $a \in 1..3$	for $r \in 1..N_r$	$T_{st(i,a),r}^* = T_{st(i,a),av(N_r)}^*$
P^*	P					$P_{st(i,a),r}^* = P_{st(i,a),av(N_r)}^*$
ρ^*	ρ					$\rho_{st(i,a),r}^* = \rho_{st(i,a),av(N_r)}^*$
C_p	k					$C_{p_{st(i,a),r}} = C_{p_{BO3DYX}}(P_{st(i,a),r}^*, T_{st(i,a),r}^*)$
a_c^*	a_{3B}					$k_{st(i,a),r} = k_{a\Delta}(C_{p_{st(i,a),r}}, R_B)$
c_u	c_a					$a_{c_{st(i,a),r}}^* = \sqrt{\frac{2 \cdot k_{st(i,a),r}}{k_{st(i,a),r} + 1}} \cdot R_B \cdot T_{st(i,a),r}^*$
α	β					if $\Delta H_{Tmax} = 0$
c	w					$A_{st(i,a)} = \left(1 - R_{L_{i,av(N_r)}}\right) \cdot \omega \cdot \left(R_{st(i,a),av(N_r)}\right)^{m_i+1}$
λ_c	w_u					$B_{st(i,a)} = \frac{H_{T_{i,av(N_r)}}}{2 \cdot \omega}$
M_w	M_c					$c_{u_{st(i,a),r}} = \begin{cases} c_{u_{st(i,a-1),r}} \cdot \frac{R_{st(i,a),r}}{R_{st(i,a-1),r}} + \frac{H_{T_{i,av(N_r)}}}{\omega \cdot R_{st(i,a),r}} & \text{if } a = 2 \\ \text{otherwise} \\ \begin{cases} 0 & \text{if } (a = 1) \wedge (i = 1) \wedge (BHA = 0) \\ \frac{A_{st(i,a)}}{\left(R_{st(i,a),r}\right)^{m_i}} - \frac{B_{st(i,a)}}{\left(R_{st(i,a),r}\right)} & \text{otherwise} \end{cases} \end{cases}$
R_L	R_L	$c_{a_{st(i,a),r}} = \begin{cases} c_{a3BHA_r} & \text{if } (a = 1) \wedge (i = 1) \wedge (BHA = 1) \\ \sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 - 2 \cdot \left(A_{st(i,a)}\right)^2 \cdot \left[\left(R_{st(i,a),r}\right)^2 - \left(R_{st(i,a),av(N_r)}\right)^2\right] + 4 \cdot A_{st(i,a)} \cdot B_{st(i,a)} \cdot \ln\left(\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right)} \cdot \begin{cases} -1 & \text{if } a = 2 \\ 1 & \text{otherwise} \end{cases} & \text{if } m_i = -1 \\ \sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 - 2 \cdot \left(A_{st(i,a)}\right)^2 \cdot \ln\left[\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right] - 2 \cdot A_{st(i,a)} \cdot B_{st(i,a)} \cdot \left(\frac{1}{R_{st(i,a),r}} - \frac{1}{R_{st(i,a),av(N_r)}}\right)} \cdot \begin{cases} -1 & \text{if } a = 2 \\ 1 & \text{otherwise} \end{cases} & \text{if } m_i = 0 \end{cases}$				
ϵ_{rotor}	ϵ_{stator}					

$$\sqrt{\left(\frac{c_{st(i,a),av(N_r)}}{A_{st(i,a)} \cdot (m_i - 1) \cdot \left[\frac{1}{(R_{st(i,a),r})^{2 \cdot m_i}} - \frac{1}{(R_{st(i,a),av(N_r)})^{2 \cdot m_i}} \right] \cdots} \right)^2 + \frac{1}{m_i \cdot (m_i + 1)}} \quad \text{otherwise}$$

if $\Delta H_{Tmax} \neq 0$

$$A_{st(i,a)} = \frac{1}{(R_{st(i,a),av(N_r)})^2 - (R_{st(i,a),l})^2} \left[\omega \cdot (R_{st(i,a),av(N_r)})^2 \cdot (1 - R_{L_{i,av(N_r)}}) - \omega \cdot (R_{st(i,a),l})^2 \cdot (1 - R_{L_{i,l}}) + \frac{H_{T_{i,l}} - H_{T_{i,av(N_r)}}}{2 \cdot \omega} \right]$$

$$B_{st(i,a)} = \frac{(R_{st(i,a),l}) \cdot (R_{st(i,a),av(N_r)})}{(R_{st(i,a),av(N_r)})^2 - (R_{st(i,a),l})^2} \left[\omega \cdot R_{st(i,a),l} \cdot R_{st(i,a),av(N_r)} \cdot (1 - R_{L_{i,l}}) - \omega \cdot R_{st(i,a),av(N_r)} \cdot R_{st(i,a),l} \cdot (1 - R_{L_{i,av(N_r)}}) \cdots \right]$$

$$+ - \frac{1}{2 \cdot \omega} \cdot \left(\frac{H_{T_{i,l}} \cdot R_{st(i,a),av(N_r)}}{R_{st(i,a),l}} - \frac{H_{T_{i,av(N_r)}} \cdot R_{st(i,a),l}}{R_{st(i,a),av(N_r)}} \right)$$

$$c_{u_{st(i,a),r}} = \begin{cases} A_{st(i,a)} \cdot R_{st(i,a),r} + \frac{B_{st(i,a)}}{R_{st(i,a),r}} + \frac{H_{T_{i,r}}}{\omega \cdot R_{st(i,a),r}} & \text{if } a = 2 \\ \text{otherwise} \\ \begin{cases} 0 & \text{if } (a = 1) \wedge (i = 1) \wedge (BHA = 0) \\ A_{st(i,a)} \cdot R_{st(i,a),r} + \frac{B_{st(i,a)}}{R_{st(i,a),r}} & \text{otherwise} \end{cases} \end{cases}$$

$$k_{HT} = \frac{H_{T_{i,av(N_r)}} - H_{T_{i,l}}}{R_{st(i,a),av(N_r)} - R_{st(i,a),l}}$$

$$b_{HT} = H_{T_{i,av(N_r)}} - k_{HT} \cdot R_{st(i,a),av(N_r)}$$

$$c_{a_{st(i,a),r}} = \begin{cases} c_{a3BHA_r} & \text{if } (a = 1) \wedge (i = 1) \wedge (BHA = 1) \\ \sqrt{\left(\frac{c_{a_{st(i,a),av(N_r)}}}{\left(\frac{c_{a_{st(i,a),av(N_r)}}}{A_{st(i,a)} \cdot (m_i - 1) \cdot \left[\frac{1}{(R_{st(i,a),r})^{2 \cdot m_i}} - \frac{1}{(R_{st(i,a),av(N_r)})^{2 \cdot m_i}} \right] \cdots} \right)^2 + \frac{1}{m_i \cdot (m_i + 1)}} \right)^2 - 2 \cdot (A_{st(i,a)})^2 \cdot \left[(R_{st(i,a),r})^2 - (R_{st(i,a),av(N_r)})^2 \right] \cdots} & \text{if } a = 2 \\ + - \left(6 \cdot \frac{A_{st(i,a)}}{\omega} - 2 \right) \cdot k_{HT} \cdot (R_{st(i,a),r} - R_{st(i,a),av(N_r)}) \cdots \\ + - 2 \cdot \frac{k_{HT}}{\omega} \cdot \left(B_{st(i,a)} + \frac{b_{HT}}{\omega} \right) \cdot \frac{R_{st(i,a),r} - R_{st(i,a),av(N_r)}}{R_{st(i,a),r} \cdot R_{st(i,a),av(N_r)}} - 2 \cdot \left[2 \cdot A_{st(i,a)} \cdot \left(B_{st(i,a)} + \frac{b_{HT}}{\omega} \right) + \frac{k_{HT}^2}{\omega^2} \right] \cdot \ln \left(\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}} \right) \\ \sqrt{\left(\frac{c_{a_{st(i,a),av(N_r)}}}{A_{st(i,a)} \cdot (m_i - 1) \cdot \left[\frac{1}{(R_{st(i,a),r})^{2 \cdot m_i}} - \frac{1}{(R_{st(i,a),av(N_r)})^{2 \cdot m_i}} \right] \cdots} \right)^2 - 2 \cdot (A_{st(i,a)})^2 \cdot \left[(R_{st(i,a),r})^2 - (R_{st(i,a),av(N_r)})^2 \right] - 4 \cdot A_{st(i,a)} \cdot B_{st(i,a)} \cdot \ln \left(\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}} \right)} & \text{otherwise} \end{cases}$$

$$\alpha_{\text{st}(i,a),r} = \text{triangle}\left(c_{a_{\text{st}(i,a),r}}, u_{\text{st}(i,a),r}\right)$$

$$c_{\text{st}(i,a),r} = \frac{c_{a_{\text{st}(i,a),r}}}{\sin\left(\alpha_{\text{st}(i,a),r}\right)}$$

$$\lambda_{c_{\text{st}(i,a),r}} = \frac{c_{\text{st}(i,a),r}}{a^*_{c_{\text{st}(i,a),r}}}$$

$$\begin{pmatrix} T_{\text{st}(i,a),r} \\ P_{\text{st}(i,a),r} \\ \rho_{\text{st}(i,a),r} \end{pmatrix} = \begin{pmatrix} T^*_{\text{st}(i,a),r} \cdot \Gamma \mathcal{D} \Phi\left("T", \lambda_{c_{\text{st}(i,a),r}}, k_{\text{st}(i,a),r}\right) \\ P^*_{\text{st}(i,a),r} \cdot \Gamma \mathcal{D} \Phi\left("P", \lambda_{c_{\text{st}(i,a),r}}, k_{\text{st}(i,a),r}\right) \\ \rho^*_{\text{st}(i,a),r} \cdot \Gamma \mathcal{D} \Phi\left(" \rho", \lambda_{c_{\text{st}(i,a),r}}, k_{\text{st}(i,a),r}\right) \end{pmatrix}$$

$$a_{3B_{\text{st}(i,a),r}} = \sqrt{k_{\text{st}(i,a),r} \cdot R_B \cdot T_{\text{st}(i,a),r}}$$

$$\beta_{\text{st}(i,a),r} = \text{triangle}\left(c_{a_{\text{st}(i,a),r}}, u_{\text{st}(i,a),r} - c_{u_{\text{st}(i,a),r}}\right)$$

$$w_{\text{st}(i,a),r} = \frac{c_{a_{\text{st}(i,a),r}}}{\sin\left(\beta_{\text{st}(i,a),r}\right)}$$

$$w_{u_{\text{st}(i,a),r}} = w_{\text{st}(i,a),r} \cdot \cos\left(\beta_{\text{st}(i,a),r}\right)$$

$$\begin{pmatrix} M_{w_{\text{st}(i,a),r}} \\ M_{c_{\text{st}(i,a),r}} \end{pmatrix} = \frac{1}{a_{3B_{\text{st}(i,a),r}}} \cdot \begin{pmatrix} w_{\text{st}(i,a),r} \\ c_{\text{st}(i,a),r} \end{pmatrix}$$

for $r \in 1..N_r$

$$\left| \begin{aligned} R_{L_{i,r}} &= 1 - \frac{c_{u_{\text{st}(i,1),r}} + c_{u_{\text{st}(i,2),r}}}{u_{\text{st}(i,1),r} + u_{\text{st}(i,2),r}} \\ \begin{pmatrix} \varepsilon_{\text{rotor}_{i,r}} \\ \varepsilon_{\text{stator}_{i,r}} \end{pmatrix} &= \begin{pmatrix} \beta_{\text{st}(i,2),r} - \beta_{\text{st}(i,1),r} \\ \alpha_{\text{st}(i,3),r} - \alpha_{\text{st}(i,2),r} \end{pmatrix} \end{aligned} \right|$$

$$\begin{pmatrix} T^* & P^* & \rho^* & C_p & a^*_c & c_u & \alpha & c & \lambda_c & M_w & R_L & \varepsilon_{\text{rotor}} \\ T & P & \rho & k & a_{3B} & c_a & \beta & w & w_u & M_c & R_L & \varepsilon_{\text{stator}} \end{pmatrix}^T$$

$$\begin{pmatrix} T^*_{1CA} & T^*_{3CA} \\ P^*_{1CA} & P^*_{3CA} \\ \rho^*_{1CA} & \rho^*_{3CA} \\ C_{p1CA} & C_{p3CA} \\ k_{1CA} & k_{3CA} \\ a^*_{c1CA} & a^*_{c3CA} \\ c_{u1CA} & c_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ \alpha_{1CA} & \alpha_{3CA} \\ c_{1CA} & c_{3CA} \\ \lambda_{c1CA} & \lambda_{c3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{pmatrix} =$$

$$\begin{array}{l} \text{for } i \in Z \\ \text{for } r \in 1..N_r \end{array}$$

$$\begin{pmatrix} T^*_{1CA_r} \\ T^*_{3CA_r} \end{pmatrix} = \begin{pmatrix} T^*_{st(i,3),r} \\ T^*_{3CA_{av}(N_r)} \end{pmatrix}$$

$$\begin{pmatrix} P^*_{1CA_r} \\ P^*_{3CA_r} \end{pmatrix} = \begin{pmatrix} P^*_{st(i,3),r} \\ P^*_{3CA_{av}(N_r)} \end{pmatrix}$$

$$\begin{pmatrix} \rho^*_{1CA_r} \\ \rho^*_{3CA_r} \end{pmatrix} = \begin{pmatrix} \rho^*_{st(i,3),r} \\ \rho^*_{3CA_{av}(N_r)} \end{pmatrix}$$

$$\begin{pmatrix} C_{p1CA_r} \\ C_{p3CA_r} \end{pmatrix} = \begin{pmatrix} C_{p_{\text{БорзДух}}}\left(P^*_{1CA_r},T^*_{1CA_r}\right) \\ C_{p_{\text{БорзДух}}}\left(P^*_{3CA_r},T^*_{3CA_r}\right) \end{pmatrix}$$

$$\begin{pmatrix} k_{1CA_r} \\ k_{3CA_r} \end{pmatrix} = \begin{pmatrix} k_{a\text{д}}\left(C_{p1CA_r},R_B\right) \\ k_{a\text{д}}\left(C_{p3CA_r},R_B\right) \end{pmatrix}$$

$$\begin{pmatrix} a^*_{c1CA_r} \\ a^*_{c3CA_r} \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{2 \cdot k_{1CA_r}}{k_{1CA_r} + 1} \cdot R_B \cdot T^*_{1CA_r}} \\ \sqrt{\frac{2 \cdot k_{3CA_r}}{k_{3CA_r} + 1} \cdot R_B \cdot T^*_{3CA_r}} \end{pmatrix}$$

$$A = \left(1 - R_{L_{i,av}(N_r)}\right) \cdot \omega \cdot \left(R_{st(i,3),av(N_r)}\right)^{m_i+1}$$

$$B = \frac{H_{T_{i,av}(N_r)}}{2 \cdot \omega}$$

$$\begin{pmatrix} c_{u1CA_r} \\ c_{u3CA_r} \end{pmatrix} = \begin{pmatrix} c_{u_{st(i,3),r}} \\ c_{u3CA_{av}(N_r)} \text{ if } CA = 1 \end{pmatrix}$$

$T^*_{1BHA} = \begin{pmatrix} 288.2 \\ 288.2 \\ 288.2 \end{pmatrix}$	$T^*_{3BHA} = \begin{pmatrix} 288.2 \\ 288.2 \\ 288.2 \end{pmatrix}$	$a^*_{c1BHA} = \begin{pmatrix} 310.78 \\ 310.78 \\ 310.78 \end{pmatrix}$	$a^*_{c3BHA} = \begin{pmatrix} 310.78 \\ 310.78 \\ 310.78 \end{pmatrix}$	$\alpha_{1BHA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ^\circ$	$\alpha_{3BHA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ^\circ$
$P^*_{1BHA} = \begin{pmatrix} 101.3 \\ 101.3 \\ 101.3 \end{pmatrix} \cdot 10^3$	$P^*_{3BHA} = \begin{pmatrix} 101.3 \\ 101.3 \\ 101.3 \end{pmatrix} \cdot 10^3$	$c_{1BHA} = \begin{pmatrix} 83.4 \\ 83.4 \\ 83.4 \end{pmatrix}$	$c_{3BHA} = \begin{pmatrix} 83.4 \\ 83.4 \\ 83.4 \end{pmatrix}$	$\epsilon_{BHA} = \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \cdot ^\circ$	
$\rho^*_{1BHA} = \begin{pmatrix} 1.224 \\ 1.224 \\ 1.224 \end{pmatrix}$	$\rho^*_{3BHA} = \begin{pmatrix} 1.224 \\ 1.224 \\ 1.224 \end{pmatrix}$	$c_{u1BHA} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix}$	$c_{u3BHA} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix}$		
$Cp_{1BHA} = \begin{pmatrix} 1002.6 \\ 1002.6 \\ 1002.6 \end{pmatrix}$	$Cp_{3BHA} = \begin{pmatrix} 1002.6 \\ 1002.6 \\ 1002.6 \end{pmatrix}$	$c_{a1BHA} = \begin{pmatrix} 83.4 \\ 83.4 \\ 83.4 \end{pmatrix}$	$c_{a3BHA} = \begin{pmatrix} 83.4 \\ 83.4 \\ 83.4 \end{pmatrix}$	$\lambda_{c1BHA} = \begin{pmatrix} 0.268 \\ 0.268 \\ 0.268 \end{pmatrix}$	$\lambda_{c3BHA} = \begin{pmatrix} 0.268 \\ 0.268 \\ 0.268 \end{pmatrix}$
$k_{1BHA} = \begin{pmatrix} 1.401 \\ 1.401 \\ 1.401 \end{pmatrix}$	$k_{3BHA} = \begin{pmatrix} 1.401 \\ 1.401 \\ 1.401 \end{pmatrix}$				

[illegible]

[illegible]

[illegible]

[illegible]

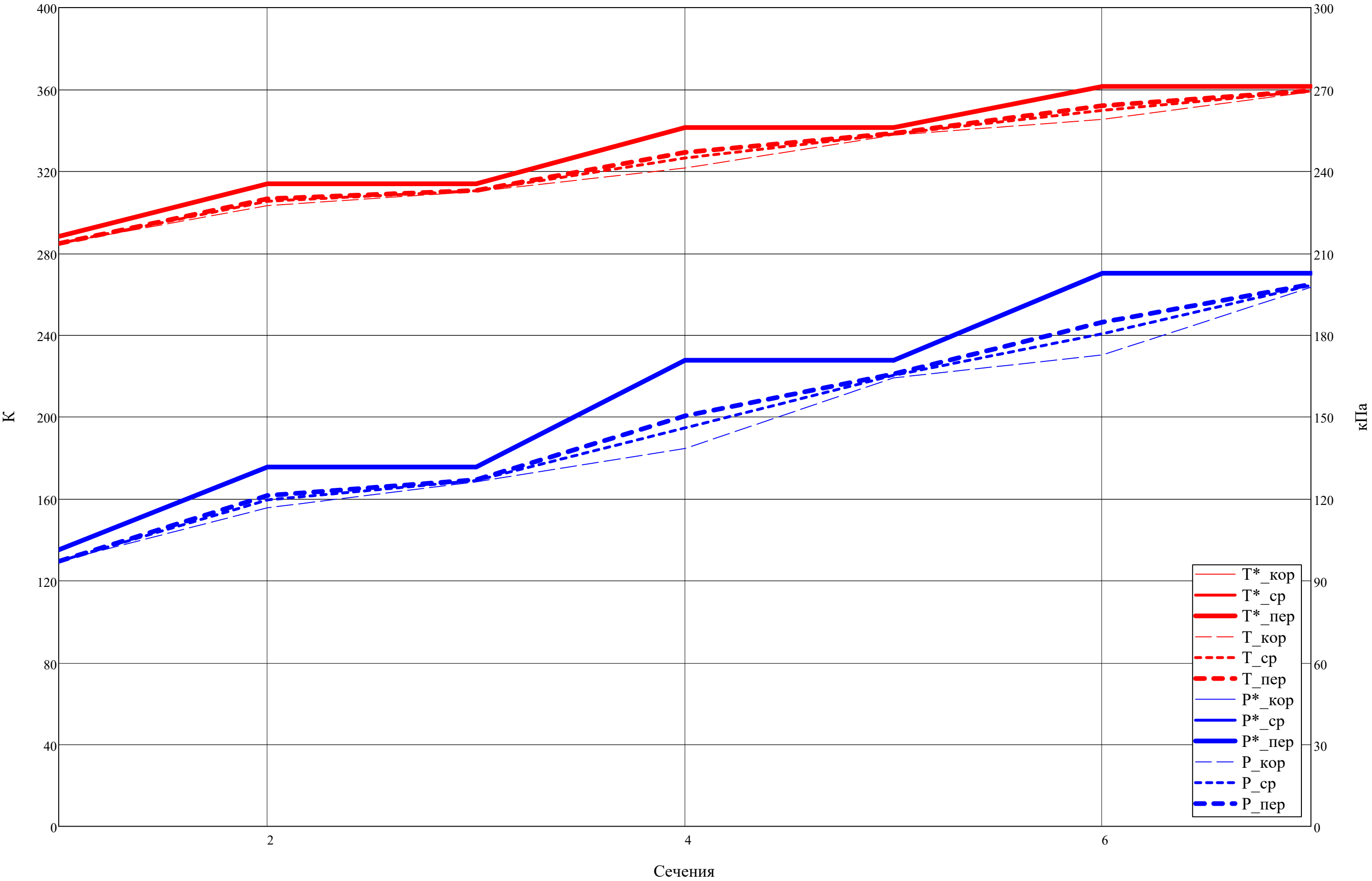
[illegible]

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Термодинамические параметры по тракту К



$$\Delta c_a = \begin{cases} \text{for } i \in 1..Z \\ \text{for } a \in 2..3 \\ \text{for } r \in 1..N_r \end{cases}$$

$$\Delta c_a$$

$$\Delta \mathbf{c}_a^T =$$

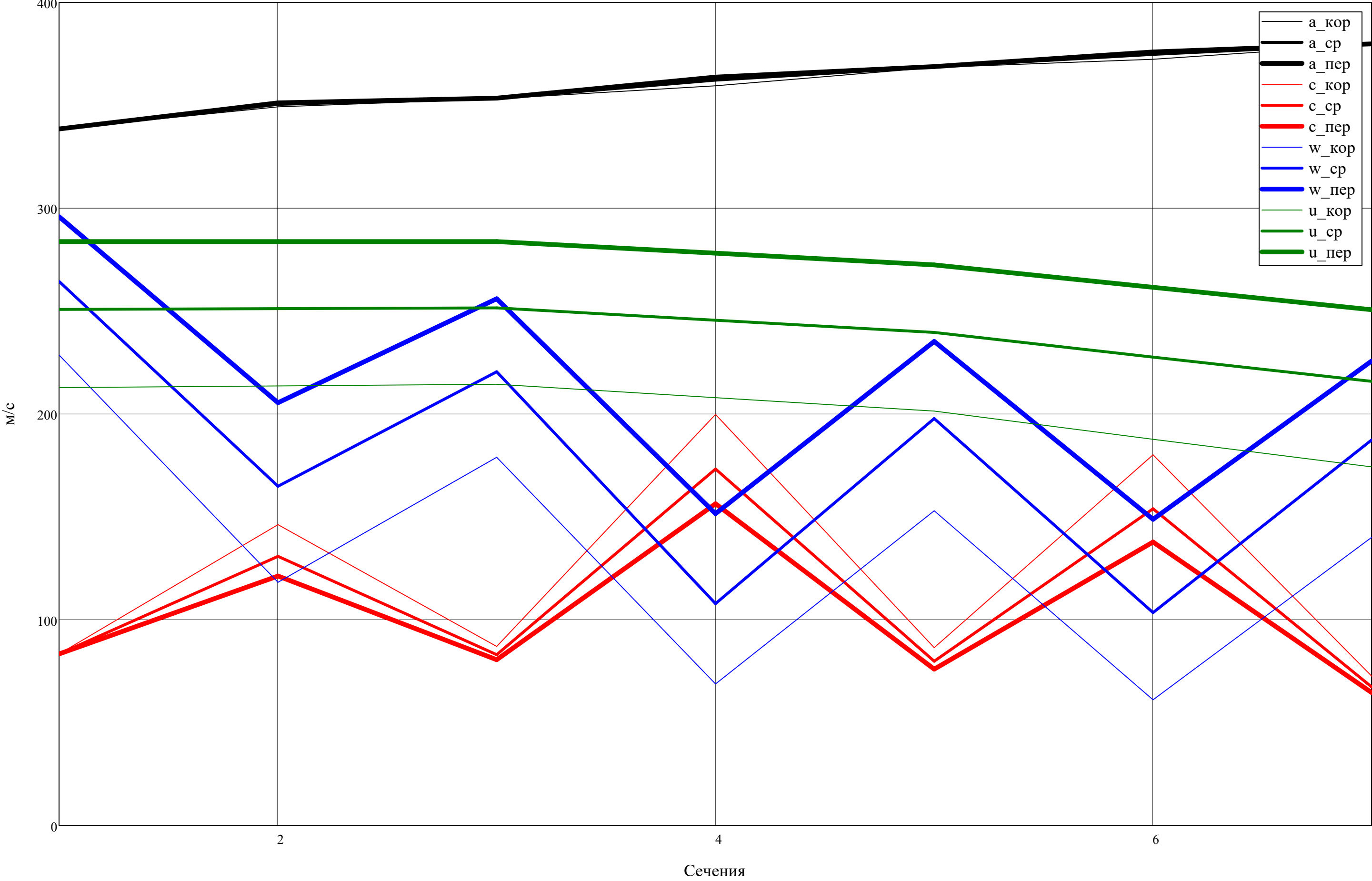
[16, c. 81]

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$$\mathbf{R}_L^T =$$

$$\mathbf{R}_L^T \geq 0 =$$

Скорости по тракту К



$\alpha^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	90.00	31.91	54.79	19.29	44.91	18.98	50.69																		
2	90.00	36.21	58.97	22.39	49.86	22.38	56.54																		
3	90.00	39.60	61.94	24.97	53.44	25.16	60.35																		

 .°

$\beta^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	21.41	40.81	23.42	73.68	23.52	73.49	23.63														
2	18.40	27.96	18.82	37.73	17.97	34.47	17.44														
3	16.38	22.10	16.14	25.82	15.04	23.18	14.40														

 .°

$\beta^T \leq 91.^\circ =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	1	1	1	1	1	1														
2	1	1	1	1	1	1	1														
3	1	1	1	1	1	1	1														

$\beta.2 > 91 \Rightarrow$ поменять 3-н профилирования

$\epsilon_{\text{rotor}}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	19.40	50.26	49.97												
2	9.56	18.91	16.50												
3	5.71	9.69	8.14												

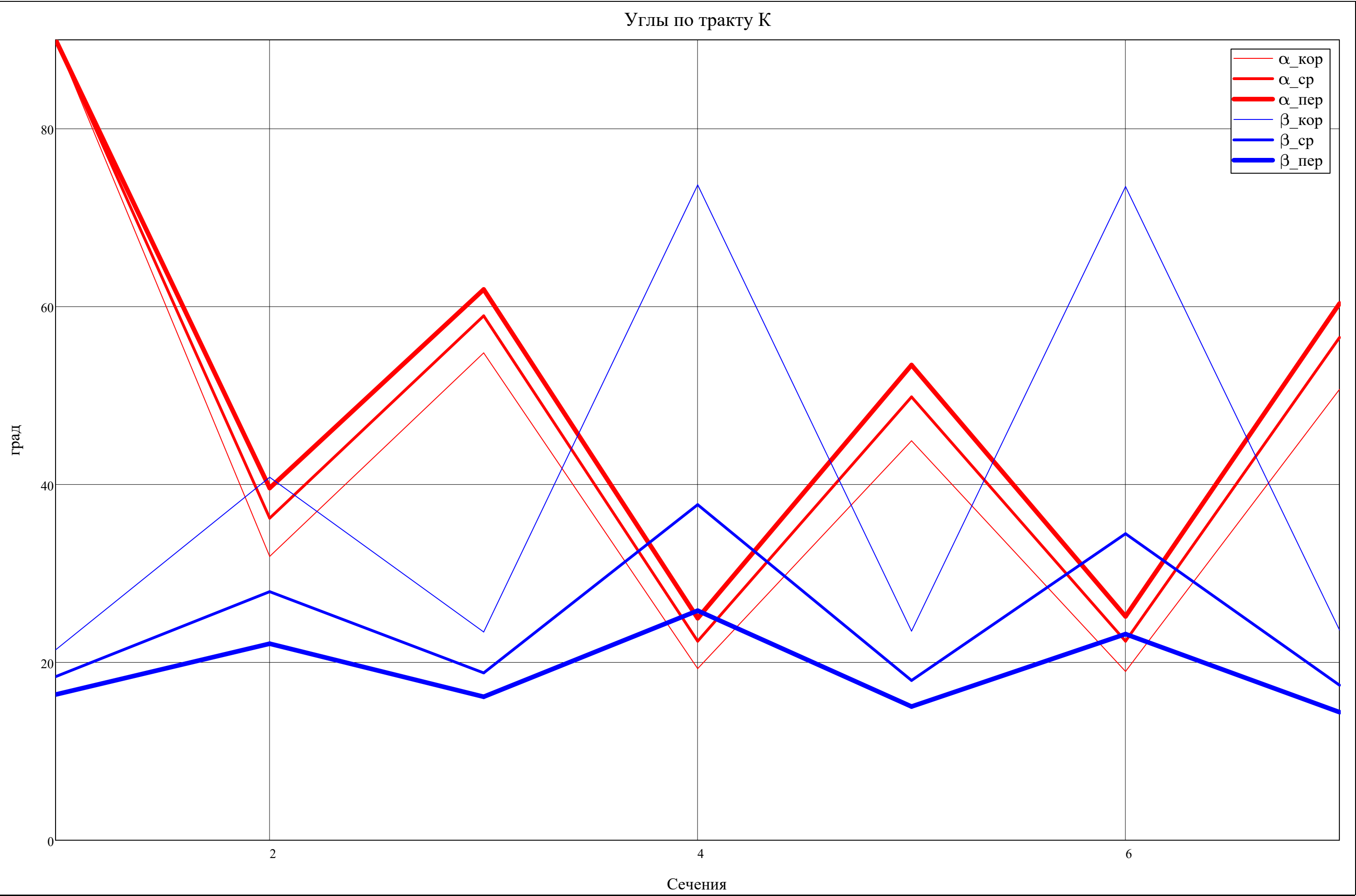
 .°

$\epsilon_{\text{stator}}^T =$

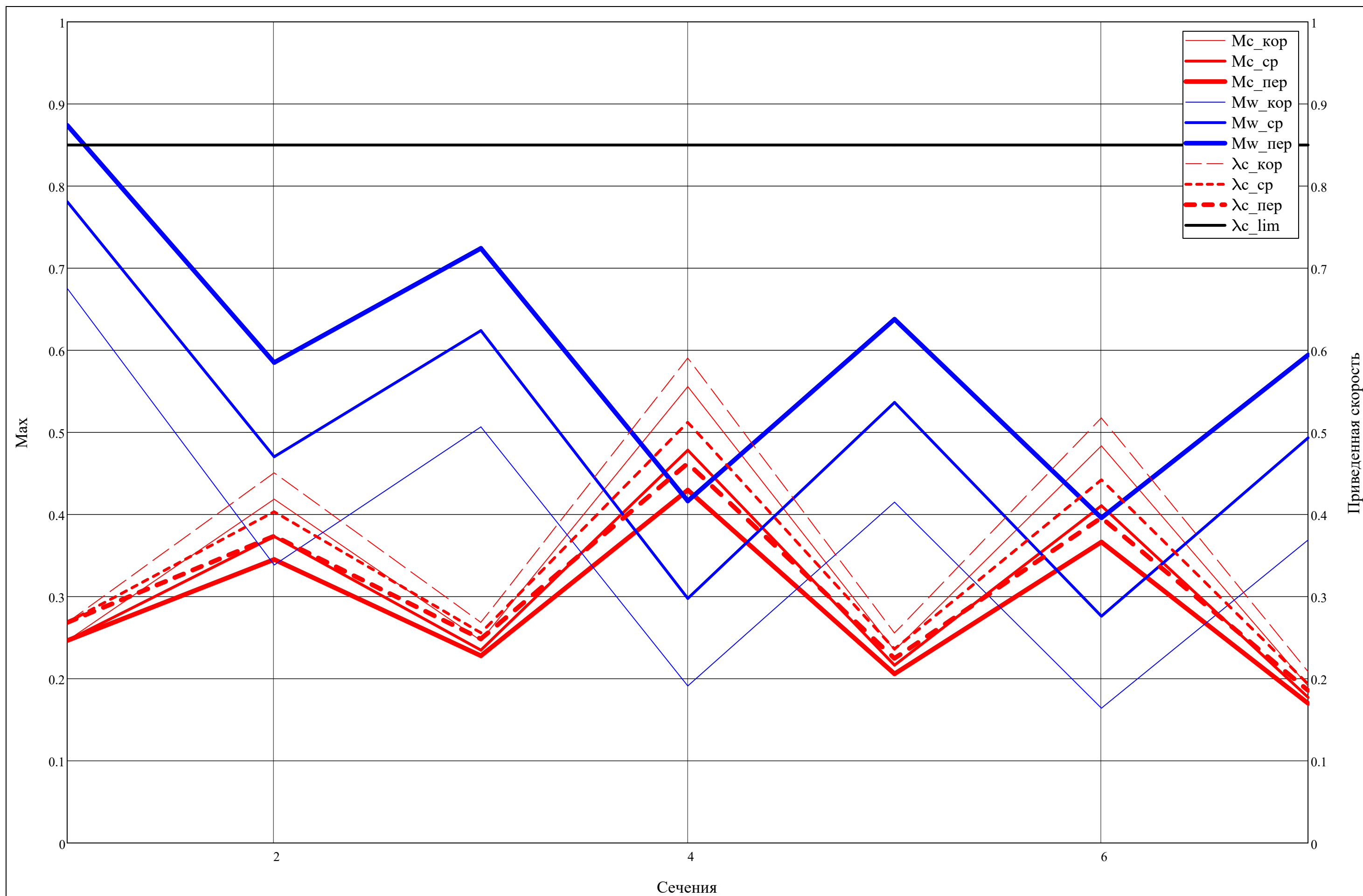
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	19.79	36.30	31.71												
2	19.83	37.67	34.16												
3	19.57	38.17	35.19												

 .°

Углы по тракту К



[illegible][illegible][illegible][illegible]



$T^*_{1CA} = \begin{pmatrix} 361.5 \\ 361.5 \\ 361.5 \end{pmatrix}$	$T^*_{3CA} = \begin{pmatrix} 361.5 \\ 361.5 \\ 361.5 \end{pmatrix}$	$a^*_{c1CA} = \begin{pmatrix} 347.9 \\ 347.9 \\ 347.9 \end{pmatrix}$	$a^*_{c3CA} = \begin{pmatrix} 347.9 \\ 347.9 \\ 347.9 \end{pmatrix}$	$\alpha_{1CA} = \begin{pmatrix} 50.69 \\ 56.54 \\ 60.35 \end{pmatrix} \cdot ^\circ$	$\alpha_{3CA} = \begin{pmatrix} 50.69 \\ 56.54 \\ 60.35 \end{pmatrix} \cdot ^\circ$
$P^*_{1CA} = \begin{pmatrix} 202.7 \\ 202.7 \\ 202.7 \end{pmatrix} \cdot 10^3$	$P^*_{3CA} = \begin{pmatrix} 202.7 \\ 202.7 \\ 202.7 \end{pmatrix} \cdot 10^3$	$c_{1CA} = \begin{pmatrix} 72.6 \\ 67.3 \\ 64.6 \end{pmatrix}$	$c_{3CA} = \begin{pmatrix} 72.6 \\ 67.3 \\ 64.6 \end{pmatrix}$	$\varepsilon_{CA} = \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \cdot ^\circ$	
$\rho^*_{1CA} = \begin{pmatrix} 1.952 \\ 1.952 \\ 1.952 \end{pmatrix}$	$\rho^*_{3CA} = \begin{pmatrix} 1.952 \\ 1.952 \\ 1.952 \end{pmatrix}$	$c_{u1CA} = \begin{pmatrix} 46.0 \\ 37.1 \\ 32.0 \end{pmatrix}$	$c_{u3CA} = \begin{pmatrix} 46.0 \\ 37.1 \\ 32.0 \end{pmatrix}$		
$Cp_{1CA} = \begin{pmatrix} 1008.5 \\ 1008.5 \\ 1008.5 \end{pmatrix}$	$Cp_{3CA} = \begin{pmatrix} 1008.5 \\ 1008.5 \\ 1008.5 \end{pmatrix}$	$c_{a1CA} = \begin{pmatrix} 56.1 \\ 56.1 \\ 56.1 \end{pmatrix}$	$c_{a3CA} = \begin{pmatrix} 56.1 \\ 56.1 \\ 56.1 \end{pmatrix}$	$\lambda_{c1CA} = \begin{pmatrix} 0.209 \\ 0.193 \\ 0.186 \end{pmatrix}$	$\lambda_{c3CA} = \begin{pmatrix} 0.209 \\ 0.193 \\ 0.186 \end{pmatrix}$
$k_{1CA} = \begin{pmatrix} 1.398 \\ 1.398 \\ 1.398 \end{pmatrix}$	$k_{3CA} = \begin{pmatrix} 1.398 \\ 1.398 \\ 1.398 \end{pmatrix}$				

Рассматриваемая ступень:

j =

j = 1

j =

"Такой ступени не существует!" if (j < 1) ∨ (j > Z)

j otherwise

= 1

☒ Построение треугольников скоростей в 3х сечениях

Δ_c(v,i,j,r) =

tan(α_{st(i,j),r})·v if (tan(α_{st(i,j),r}) ≥ 0 ∧ −|c_{st(i,j),r}·cos(α_{st(i,j),r})| ≤ v ≤ 0)

tan(α_{st(i,j),r})·v if (tan(α_{st(i,j),r}) < 0 ∧ 0 ≤ v ≤ |c_{st(i,j),r}·cos(α_{st(i,j),r})|)

Δ_w(v,i,j,r) =

−tan(β_{st(i,j),r})·v if (−tan(β_{st(i,j),r}) ≥ 0) ∧ (−|w_{st(i,j),r}·cos(β_{st(i,j),r})| ≤ v ≤ 0) ∧ (j ≠ 3)

−tan(β_{st(i,j),r})·v if (−tan(β_{st(i,j),r}) < 0) ∧ (0 ≤ v ≤ |w_{st(i,j),r}·cos(β_{st(i,j),r})|) ∧ (j ≠ 3)

Δ_u(v,i,j,r) =

−c_{a_{st(i,j),r}} if (−c_{st(i,j),r}·cos(α_{st(i,j),r}) ≤ v ≤ w_{st(i,j),r}·cos(β_{st(i,j),r})) ∧ (j ≠ 3)

NaN otherwise

v_{lim} =

ceil

(

max(c,w,u)

)

·10² = 300

Дискретизация скорости:

v =

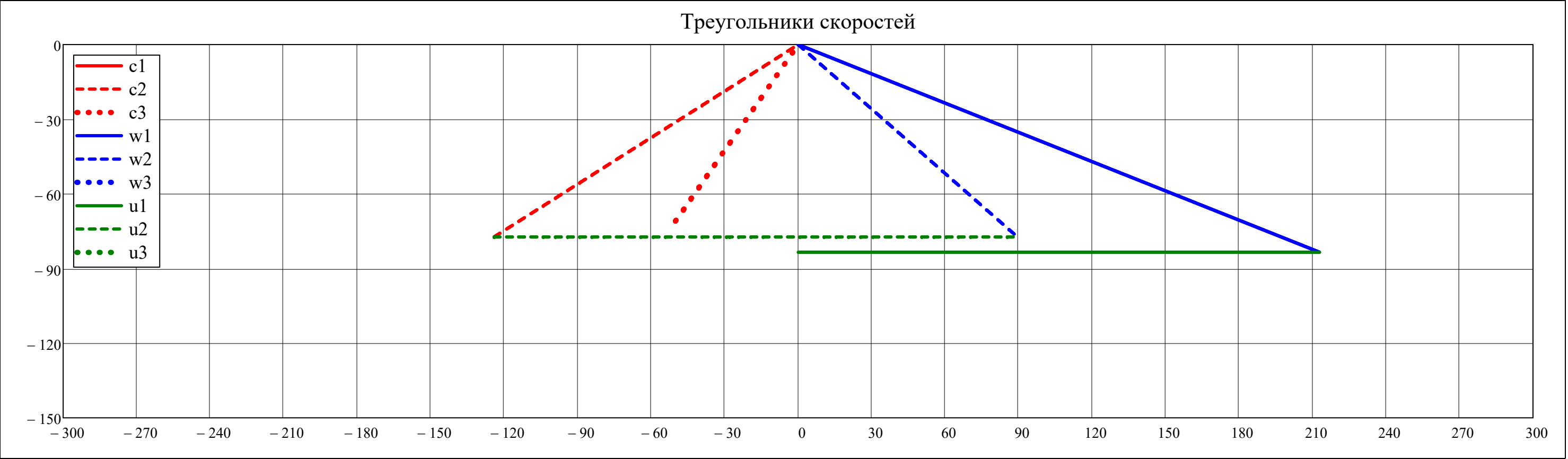
−v_{lim}, −v_{lim} +

v_{lim}

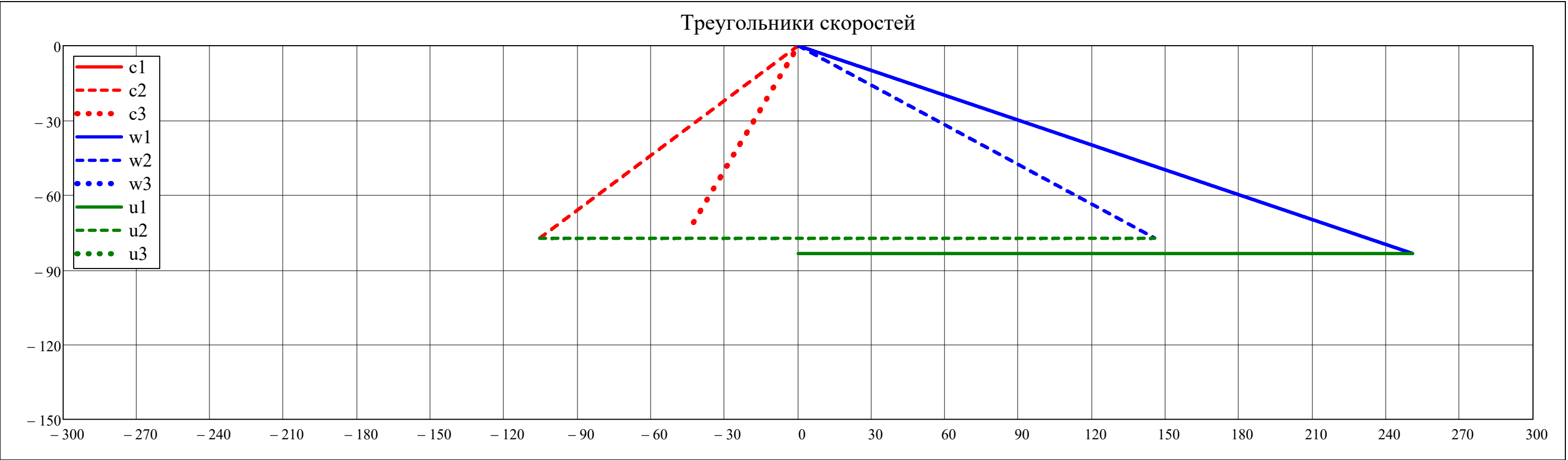
3000

·· v_{lim}

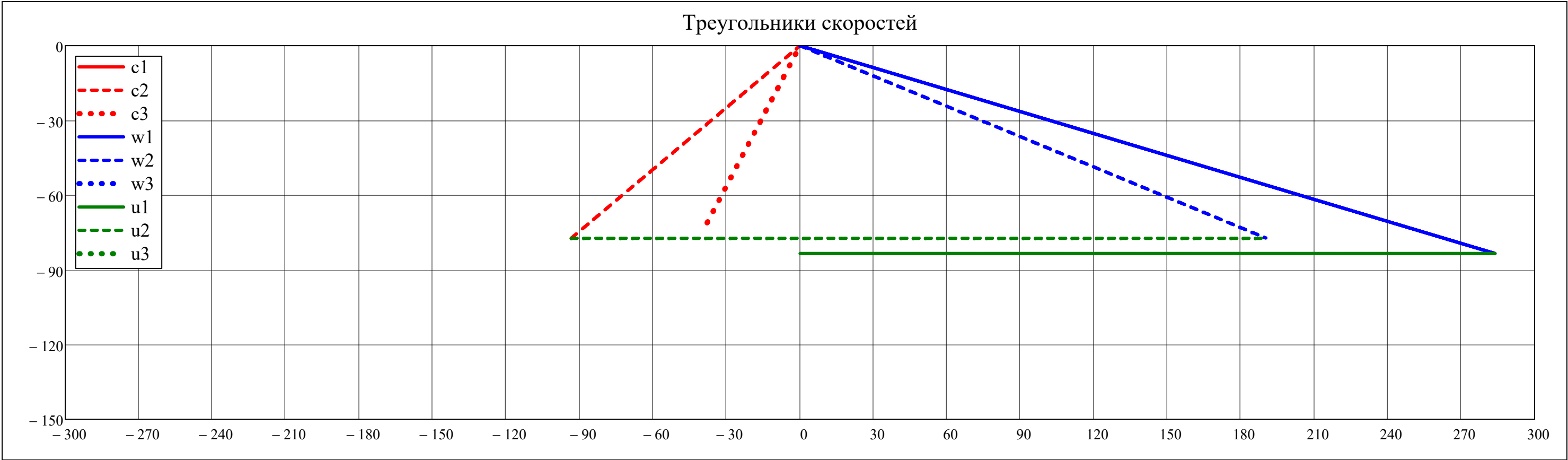
r = 1



$\bar{r}_w = \text{av}(N_r)$



$r_w = N_r$



Построение треугольников скоростей в 3х сечениях


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$$\begin{pmatrix} F_I & F_{II} \\ D2 & R2 \end{pmatrix} = \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } a \in 1..3 \\ \quad \left| \begin{array}{l} \rho_{\cdot}(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T, \text{submatrix}\left(\rho, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T, \text{submatrix}\left(\rho, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T, z\right) \\ c_a(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T, \text{submatrix}\left(c_a, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T, \text{submatrix}\left(c_a, \text{st}(i, a), \text{st}(i, a), 1, N_r\right)^T, z\right) \\ R2 = \sqrt{\frac{\left(R_{\text{st}(i, a), N_r}\right)^2 + m2 \cdot \left(R_{\text{st}(i, a), 1}\right)^2}{1 + m2}} \\ R2_{\text{st}(i, a)} = \text{root}\left[\frac{\rho_{\cdot}(R2) \cdot c_a(R2) \cdot \pi \cdot \left[\left(R_{\text{st}(i, a), N_r}\right)^2 - (R2)^2\right]}{\rho_{\cdot}(R2) \cdot c_a(R2) \cdot \pi \cdot \left[\left(R2\right)^2 - \left(R_{\text{st}(i, a), 1}\right)^2\right]} - m2, R2\right] \\ D2_{\text{st}(i, a)} = 2 \cdot R2_{\text{st}(i, a)} \\ \begin{pmatrix} F_{II_{\text{st}(i, a)}} \\ F_{I_{\text{st}(i, a)}} \end{pmatrix} = \pi \cdot \begin{bmatrix} \left(R_{\text{st}(i, a), N_r}\right)^2 - \left(R2_{\text{st}(i, a)}\right)^2 \\ \left(R2_{\text{st}(i, a)}\right)^2 - \left(R_{\text{st}(i, a), 1}\right)^2 \end{bmatrix} \end{array} \right. \\ \begin{pmatrix} F_I & F_{II} \\ D2 & R2 \end{pmatrix} \end{array}$$


```

Кольцевые площади (м²):

[illegible]

Радиус и диаметр двухконтурности (м):

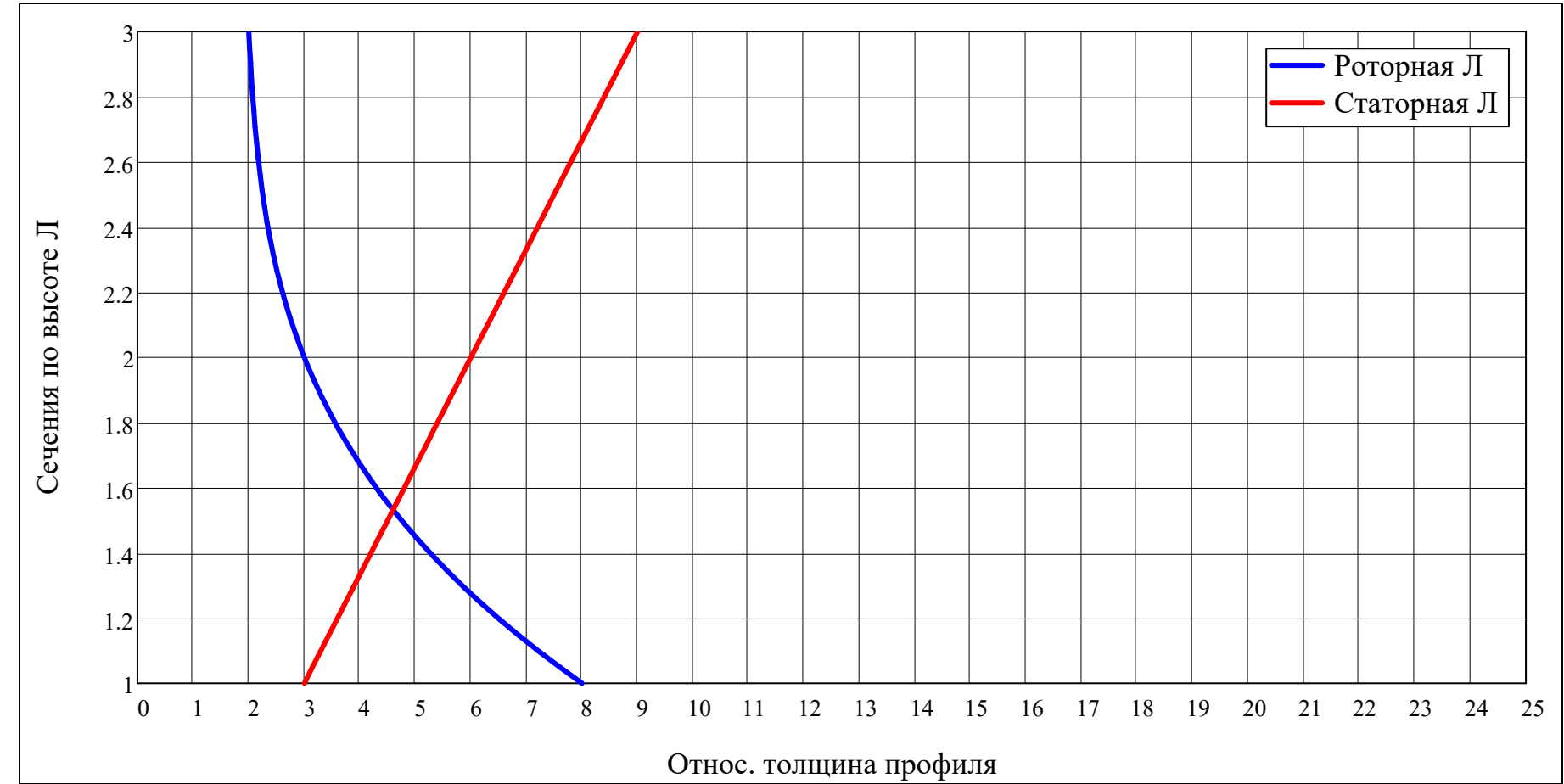
[illegible]

Относ. толщины ЛРК и СА:

$$\overline{c}_{\text{rotor.}}(r) = \text{interp} \left[\text{cspline} \left[\begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 12 + \begin{cases} 4 & \text{if compressor} = \text{"Вл"} \\ -4 & \text{if compressor} = \text{"КНД"} \\ -0.8 & \text{otherwise} \end{cases} \\ 3 + \begin{cases} 1.65 & \text{if compressor} = \text{"Вл"} \\ 0 & \text{if compressor} = \text{"КНД"} \\ 0.62 & \text{otherwise} \end{cases} \\ 2 \end{pmatrix} \% , \begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 12 + \begin{cases} 4 & \text{if compressor} = \text{"Вл"} \\ -4 & \text{if compressor} = \text{"КНД"} \\ -0.8 & \text{otherwise} \end{cases} \\ 3 + \begin{cases} 1.65 & \text{if compressor} = \text{"Вл"} \\ 0 & \text{if compressor} = \text{"КНД"} \\ 0.62 & \text{otherwise} \end{cases} \\ 2 \end{pmatrix} \% , r \right]$$

$$\overline{c}_{\text{stator.}}(r) = \text{interp} \left[\text{cspline} \left[\begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 3 \\ 6 \\ 9 \end{pmatrix} \% , \begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 3 \\ 6 \\ 9 \end{pmatrix} \% , r \right]$$

$$\underline{r} = \text{ORIGIN}, \text{ORIGIN} + \frac{N_r - \text{ORIGIN}}{N_{\text{dis}}} .. N_r$$



$$\overline{c}_{\text{BHA}} = \left| \begin{array}{l} \text{for } r \in 1..N_r \\ \overline{c}_{\text{BHA}_r} = \overline{c}_{\text{stator.}(r)} \\ \overline{c}_{\text{BHA}} \end{array} \right.$$

$$\overline{c}_{\text{BHA}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.00 \\ \hline 2 & 6.00 \\ \hline 3 & 9.00 \\ \hline \end{array} \cdot\%$$

$$\left(\begin{array}{c} \overline{c}_{\text{stator}} \\ \overline{c}_{\text{rotor}} \end{array} \right) = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \text{for } r \in 1..N_r \\ \left(\begin{array}{c} \overline{c}_{\text{stator}_{i,r}} \\ \overline{c}_{\text{rotor}_{i,r}} \end{array} \right) = \left(\begin{array}{c} \overline{c}_{\text{stator.}(r)} \\ \overline{c}_{\text{rotor.}(r)} \end{array} \right) \\ \left(\begin{array}{c} \overline{c}_{\text{stator}} \\ \overline{c}_{\text{rotor}} \end{array} \right) \end{array} \right.$$

$$\overline{c}_{\text{stator}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 3.00 & 3.00 & 3.00 \\ \hline 2 & 6.00 & 6.00 & 6.00 \\ \hline 3 & 9.00 & 9.00 & 9.00 \\ \hline \end{array} \cdot\%$$

$$\overline{c}_{\text{rotor}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 8.00 & 8.00 & 8.00 \\ \hline 2 & 3.00 & 3.00 & 3.00 \\ \hline 3 & 2.00 & 2.00 & 2.00 \\ \hline \end{array} \cdot\%$$

$$\overline{c}_{\text{CA}} = \left| \begin{array}{l} \text{for } r \in 1..N_r \\ \overline{c}_{\text{CA}_r} = \overline{c}_{\text{stator.}(r)} \\ \overline{c}_{\text{CA}} \end{array} \right.$$

$$\overline{c}_{\text{CA}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.00 \\ \hline 2 & 6.00 \\ \hline 3 & 9.00 \\ \hline \end{array} \cdot\%$$

$$\begin{pmatrix} \overline{r_inlet_{BHA}} \\ \overline{r_outlet_{BHA}} \end{pmatrix} = \begin{cases} \text{for } r \in 1..N_r & \text{if } BHA = 1 \\ \begin{pmatrix} \overline{r_inlet_{BHA_r}} \\ \overline{r_outlet_{BHA_r}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c_{stator.}(r)} \\ \begin{pmatrix} \overline{r_inlet_{BHA}} \\ \overline{r_outlet_{BHA}} \end{pmatrix} \end{cases}$$

$$\begin{pmatrix} \overline{r_inlet_{CA}} \\ \overline{r_outlet_{CA}} \end{pmatrix} = \begin{cases} \text{for } r \in 1..N_r & \text{if } CA = 1 \\ \begin{pmatrix} \overline{r_inlet_{CA_r}} \\ \overline{r_outlet_{CA_r}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c_{stator.}(r)} \\ \begin{pmatrix} \overline{r_inlet_{CA}} \\ \overline{r_outlet_{CA}} \end{pmatrix} \end{cases}$$

$$\overline{r_inlet_{BHA}} = 0.000 \cdot \%$$

$$\overline{r_inlet_{stator}}^T =$$

	1	2	3
1	0.300	0.300	0.300
2	0.600	0.600	0.600
3	0.900	0.900	0.900

·%

$$\overline{r_outlet_{stator}}^T =$$

	1	2	3
1	0.150	0.150	0.150
2	0.300	0.300	0.300
3	0.450	0.450	0.450

·%

$$\overline{r_outlet_{BHA}} = 0.000 \cdot \%$$

$$\begin{pmatrix} \overline{r_inlet_{rotor}} & \overline{r_inlet_{stator}} \\ \overline{r_outlet_{rotor}} & \overline{r_outlet_{stator}} \end{pmatrix} = \begin{cases} \text{for } i \in 1..Z \\ \text{for } r \in 1..N_r \\ \begin{pmatrix} \overline{r_inlet_{stator_{i,r}}} \\ \overline{r_outlet_{stator_{i,r}}} \end{pmatrix} = \begin{pmatrix} 0.10 \\ 0.05 \end{pmatrix} \cdot \overline{c_{stator.}(r)} \\ \begin{pmatrix} \overline{r_inlet_{rotor_{i,r}}} \\ \overline{r_outlet_{rotor_{i,r}}} \end{pmatrix} = \begin{pmatrix} 0.10 \\ 0.05 \end{pmatrix} \cdot \overline{c_{rotor.}(r)} \\ \begin{pmatrix} \overline{r_inlet_{rotor}} & \overline{r_inlet_{stator}} \\ \overline{r_outlet_{rotor}} & \overline{r_outlet_{stator}} \end{pmatrix} \end{cases}$$

$$\overline{r_inlet_{CA}} = 0.000 \cdot \%$$

$$\overline{r_inlet_{rotor}}^T =$$

	1	2	3
1	0.800	0.800	0.800
2	0.300	0.300	0.300
3	0.200	0.200	0.200

·%

$$\overline{r_outlet_{rotor}}^T =$$

	1	2	3
1	0.400	0.400	0.400
2	0.150	0.150	0.150
3	0.100	0.100	0.100

·%

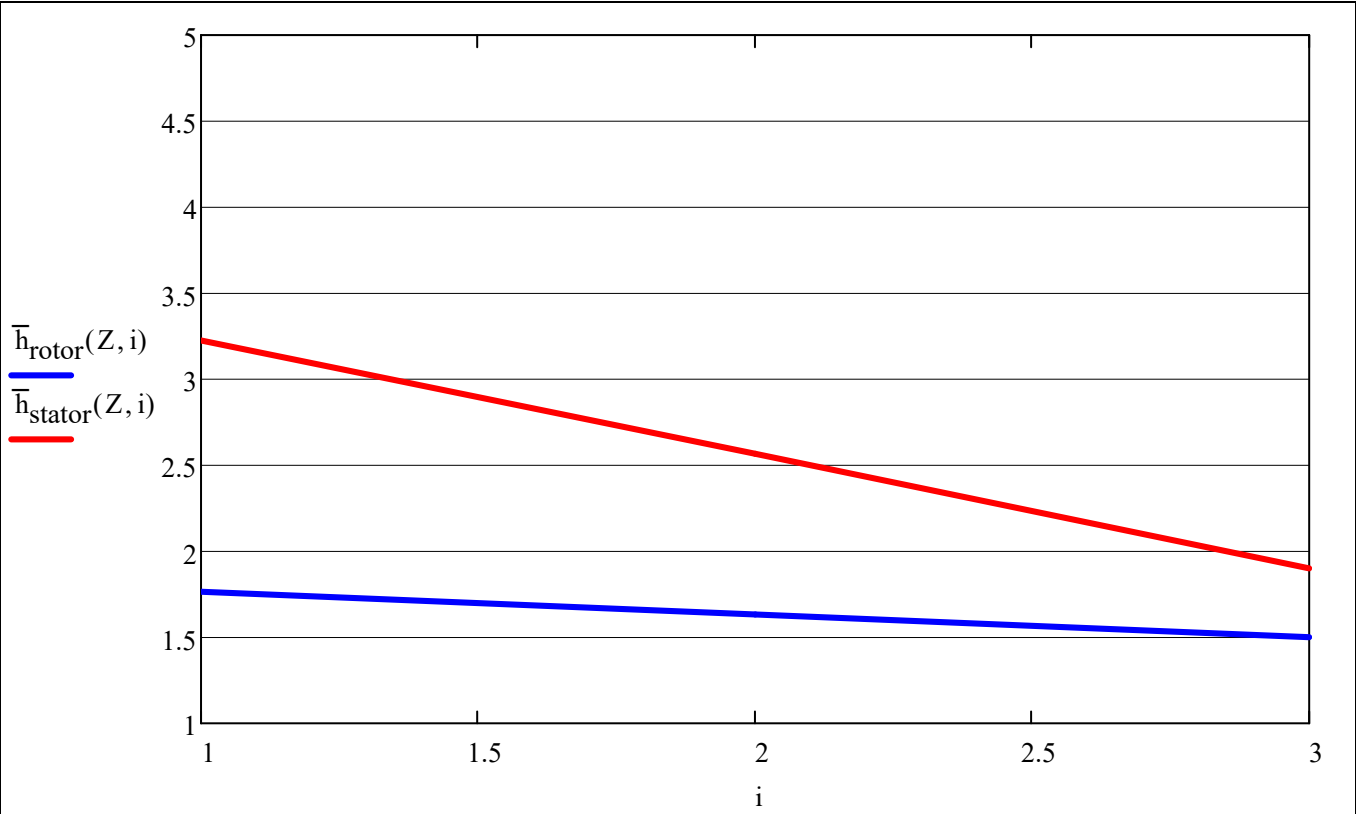
$$\overline{r_outlet_{CA}} = 0.000 \cdot \%$$

Относ. удлинение ЛРК и НА: [16, с. 244]

$$\bar{h}_{\sim\text{rotor}} = (2 \ 1.9 \ 1.85 \ 1.8 \ 1.75 \ 1.7 \ 1.65 \ 1.6)^T + \begin{cases} 1.1 & \text{if compressor = "Вл"} \\ -0.1 & \text{if compressor = "КНД"} \\ -0.55 & \text{if compressor = "КВД"} \end{cases}$$

$$\bar{h}_{\sim\text{stator}} = (4 \ 3.5 \ 3.25 \ 3 \ 2.75 \ 2.5 \ 2.25 \ 2)^T + \begin{cases} 1.1 & \text{if compressor = "Вл"} \\ -0.1 & \text{if compressor = "КНД"} \\ -0.7 & \text{if compressor = "КВД"} \end{cases}$$

$$\bar{h}_{\text{rotor}}(Z,i) = \begin{cases} \bar{h}_{\sim\text{rotor}}\left(\frac{1}{\text{rows}(z_{\sim})}\right) & \text{if } i < 1 \\ \bar{h}_{\sim\text{rotor}}(1) & \text{if } i > Z \\ \bar{h}_{\sim\text{rotor}}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases} \quad \bar{h}_{\text{stator}}(Z,i) = \begin{cases} \bar{h}_{\sim\text{stator}}\left(\frac{1}{\text{rows}(z_{\sim})}\right) & \text{if } i < 1 \\ \bar{h}_{\sim\text{stator}}(1) & \text{if } i > Z \\ \bar{h}_{\sim\text{stator}}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases}$$



$$\bar{h}_{\sim\text{rotor}}(i) = \text{interp}\left(\text{cspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \bar{h}_{\sim\text{rotor}}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \bar{h}_{\sim\text{rotor}}, i\right)$$

$$\bar{h}_{\sim\text{stator}}(i) = \text{interp}\left(\text{cspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \bar{h}_{\sim\text{stator}}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \bar{h}_{\sim\text{stator}}, i\right)$$

Для компрессора газогенератора

$\frac{h_{PK}}{S_{PK}} = 2,5 \dots 4,5$ – для первой дозвуковой ступени;

$\frac{h_{PK}}{S_{PK}} = 2,0 \dots 3,5$ – для первой околосвуковой ступени;

$\frac{h_{PK}}{S_{PK}} = 1,7 \dots 3,0$ – для первой сверхзвуковой ступени;

$\frac{h_{PK}}{S_{PK}} = 1,0 \dots 2,5$ – для последней ступени.

Парусность:

$$\begin{pmatrix} \text{sail}_{\text{rotor}} \\ \text{sail}_{\text{stator}} \end{pmatrix} = \begin{pmatrix} 1.3 \\ 1.2 \end{pmatrix}$$

Расчет длин хорд по высоте Л

```
chordBHA = for i ∈ 1 if BHA = 1
| chordBHAav(Nr) =  $\frac{h_{\text{st}(i, 1)}}{\bar{h}_{\text{stator}}(Z, 0)}$ 
| sail =  $\frac{R_{\text{st}(1, 1), N_r} - R_{\text{st}(1, 1), 1}}{R_{\text{st}(1, 1), \text{av}(N_r)} - R_{\text{st}(1, 1), 1}}$ 
| for r ∈ 1 .. Nr
| |  $b_{\text{BHA}_{\text{кор}}} = \frac{\text{chord}_{\text{BHA}_{\text{av}}(N_r)} \cdot \text{sail}}{\text{sail}_{\text{stator}} - 1 + \text{sail}}$ 
| |  $b_{\text{BHA}_{\text{пер}}} = b_{\text{BHA}_{\text{кор}}} \cdot \text{sail}_{\text{stator}}$ 
| |  $b_{\text{BHA.}}(z) = \text{interp} \left[ \text{cspline} \left[ \begin{pmatrix} R_{\text{st}(i, 1), 1} \\ R_{\text{st}(i, 1), \text{av}(N_r)} \\ R_{\text{st}(i, 1), N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{BHA}_{\text{кор}}} \\ \text{chord}_{\text{BHA}_{\text{av}}(N_r)} \\ b_{\text{BHA}_{\text{пер}}} \end{pmatrix} \right], \begin{pmatrix} R_{\text{st}(i, 1), 1} \\ R_{\text{st}(i, 1), \text{av}(N_r)} \\ R_{\text{st}(i, 1), N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{BHA}_{\text{кор}}} \\ \text{chord}_{\text{BHA}_{\text{av}}(N_r)} \\ b_{\text{BHA}_{\text{пер}}} \end{pmatrix}, z \right]$ 
| | chordBHAr = bBHA.(Rst(i, 1), r)
chordBHA
```

$(\text{chord}_{\text{rotor}} \quad \text{chord}_{\text{stator}}) =$	<div>for $i \in 1 \dots Z$</div> <div> $\begin{pmatrix} \text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \\ \text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \end{pmatrix} = \begin{pmatrix} \frac{\text{mean}(h_{\text{st}}(i, 1), h_{\text{st}}(i, 2))}{\bar{h}_{\text{rotor}}(Z, i)} \\ \frac{\text{mean}(h_{\text{st}}(i, 2), h_{\text{st}}(i, 3))}{\bar{h}_{\text{stator}}(Z, i)} \end{pmatrix}$ </div> <div> $\text{sail} = \frac{R_{\text{st}(i, 2), N_r} - R_{\text{st}(i, 2), 1}}{R_{\text{st}(i, 2), \text{av}}(N_r) - R_{\text{st}(i, 2), 1}}$ </div> <div>for $r \in 1 \dots N_r$</div> <div> $b_{\text{PKkop}} = \frac{\text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \cdot \text{sail}}{\text{sail}_{\text{rotor}} - 1 + \text{sail}}$ </div> <div> $b_{\text{HAKop}} = \frac{\text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \cdot \text{sail}}{\text{sail}_{\text{stator}} - 1 + \text{sail}}$ </div> <div> $\begin{pmatrix} b_{\text{PKпер}} \\ b_{\text{HAпер}} \end{pmatrix} = \begin{pmatrix} b_{\text{PKkop}} \cdot \text{sail}_{\text{rotor}} \\ b_{\text{HAKop}} \cdot \text{sail}_{\text{stator}} \end{pmatrix}$ </div> <div> $\text{chord}_{\text{rotor.}}(z) = \text{interp} \left[\text{cspline} \left[\begin{pmatrix} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{PKkop}} \\ \text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \\ b_{\text{PKпер}} \end{pmatrix} \right], \begin{pmatrix} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{PKkop}} \\ \text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \\ b_{\text{PKпер}} \end{pmatrix}, z \right]$ </div> <div> $\text{chord}_{\text{stator.}}(z) = \text{interp} \left[\text{cspline} \left[\begin{pmatrix} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{HAKop}} \\ \text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \\ b_{\text{HAпер}} \end{pmatrix} \right], \begin{pmatrix} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{HAKop}} \\ \text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \\ b_{\text{HAпер}} \end{pmatrix}, z \right]$ </div> <div> $\text{chord}_{\text{rotor}_{i, r}} = \text{chord}_{\text{rotor.}}(R_{\text{st}(i, 2), r})$ </div> <div> $\text{chord}_{\text{stator}_{i, r}} = \text{chord}_{\text{stator.}}(R_{\text{st}(i, 2), r})$ </div> <div>$(\text{chord}_{\text{rotor}} \quad \text{chord}_{\text{stator}})$</div>
--	---

chord_{CA} =

for i ∈ Z

chord_{CA_{av}(N_r)} = $\frac{h_{st(i,3)}}{\overline{h}_{stator}(Z,Z+1)}$

sail = $\frac{R_{st(1,1),N_r} - R_{st(1,1),1}}{R_{st(1,1),av(N_r)} - R_{st(1,1),1}}$

for r ∈ 1 .. N_r

b_{CA_{коп}} = $\frac{chord_{CA_{av}(N_r)} \cdot sail}{sail_{stator} - 1 + sail}$

b_{CA_{пер}} = b_{CA_{коп}} · sail_{stator}

b_{CA.}(z) = interp $\left[cspline \left[\begin{pmatrix} R_{st(i,1),1} \\ R_{st(i,1),av(N_r)} \\ R_{st(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{CA_{коп}} \\ chord_{CA_{av}(N_r)} \\ b_{CA_{пер}} \end{pmatrix} \right], \begin{pmatrix} R_{st(i,1),1} \\ R_{st(i,1),av(N_r)} \\ R_{st(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{CA_{коп}} \\ chord_{CA_{av}(N_r)} \\ b_{CA_{пер}} \end{pmatrix}, z \right]$

chord_{CA_r} = b_{CA.}(R_{st(i,1),r})

chord_{CA}

if CA = 1

Ср. линия профиля:
0.5 - дуга окружности
0.45 - парабола

$\overline{x_f} = 0.5$

Определение количества Л РК и НА

$$\left(\begin{array}{l} \varepsilon_{BHA(b/t)=1} \\ Z_{BHA} \\ r_{inlet_{BHA}} \\ r_{outlet_{BHA}} \\ t_{BHA} \\ i_{BHA} \\ m_{BHA} \\ \theta_{BHA} \\ \delta_{BHA} \\ \chi_{BHA} \\ v_{BHA} \\ R_{CЛ.BHA} \\ K_{BHA} \\ D_{BHA} \end{array} \right)$$

= if BHA = 1

for $r \in av(N_r)$

$$\varepsilon_{BHA(b/t)=1_r} = \varepsilon_{(b/t)=1}(\alpha_{3BHA_r})$$

$$b/t_{BHA_r} = b/t=1 \left(\frac{\varepsilon_{BHA_r}}{\varepsilon_{BHA(b/t)=1_r}} \right)$$

$$t_{BHA_r} = \frac{chord_{BHA_r}}{b/t_{BHA_r}}$$

$$Z_{BHA} = \left| \begin{array}{l} \text{round}\left(\frac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right) \text{ if } \text{mod}\left(\text{round}\left(\frac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right), 2\right) = 0 \\ \text{round}\left(\frac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right) + 1 \text{ otherwise} \end{array} \right|$$

for $r \in 1..N_r$

$$\left(r_{inlet_{BHA_r}} \ r_{outlet_{BHA_r}} \right) = chord_{BHA_r} \cdot \left(\overline{r}_{inlet_{BHA_r}} \ \overline{r}_{outlet_{BHA_r}} \right)$$

$$t_{BHA_r} = \frac{D_{st(1,1),r}}{Z_{BHA}}$$

$$i_{BHA_r} = 2.5 \cdot \left(\frac{chord_{BHA_r}}{t_{BHA_r}} - 2 \right) \cdot ^\circ$$

$$m_{BHA} = 0.23 \cdot (2 \cdot \overline{x_f})^2 + 0.18 - \frac{0.002}{1 + \overline{x_f}} \cdot (\alpha_{3BHA_r})$$

$$\theta_{\text{BHA}_r} = \frac{\epsilon_{\text{BHA}_r} - i_{\text{BHA}_r}}{1 - m_{\text{BHA}_r} \cdot \sqrt{\frac{t_{\text{BHA}_r}}{\text{chord}_{\text{BHA}_r}}}}$$

$$\delta_{\text{BHA}_r} = m_{\text{BHA}_r} \cdot \theta_{\text{BHA}_r} \cdot \sqrt{\frac{t_{\text{BHA}_r}}{\text{chord}_{\text{BHA}_r}}}$$

$$\chi_{\text{BHA}_r} = \theta_{\text{BHA}_r} \cdot \frac{1 + 2 \cdot (1 - 2 \cdot \bar{x}_f)}{2}$$

$$v_{\text{BHA}_r} = \chi_{\text{BHA}_r} + \alpha_{1\text{BHA}_r} + i_{\text{BHA}_r}$$

$$R_{CJL.BHA_r} = \frac{\text{chord}_{BHA_r}}{2 \cdot \sin\left(0.5 \cdot \theta_{BHA_r}\right)}$$

$$K_{\text{BHA}_r} = \frac{c_{a3\text{BHA}_r}}{c_{a1\text{BHA}_r}}$$

$$D_{BHA_r} = \left(1 - K_{BHA_r} \cdot \frac{\sin(\alpha_{1BHA_r})}{\sin(\alpha_{3BHA_r})} \right) + \left(\frac{1}{\tan(\alpha_{1BHA_r})} - K_{BHA_r} \cdot \frac{1}{\tan(\alpha_{3BHA_r})} \right) \cdot \frac{\sin(\alpha_{1BHA_r})}{2 \cdot \frac{\text{chord}_{BHA_r}}{t_{BHA_r}}}$$

$$\left(\varepsilon_{\text{BHA}(\text{b/t})=1} \quad Z_{\text{BHA}} \quad r_{\text{inlet}}^{\text{BHA}} \quad r_{\text{outlet}}^{\text{BHA}} \quad t_{\text{BHA}} \quad i_{\text{BHA}} \quad m_{\text{BHA}} \quad \theta_{\text{BHA}} \quad \delta_{\text{BHA}} \quad \chi_{\text{BHA}} \quad v_{\text{BHA}} \quad R_{\text{CJ.BHA}} \quad K_{\text{BHA}} \quad D_{\text{BHA}} \right)^T$$

$$\left(\begin{array}{cc} \varepsilon_{\text{PK}(b/t)=1} & \varepsilon_{\text{HA}(b/t)=1} \\ Z_{\text{rotor}} & Z_{\text{stator}} \\ r_{\text{inlet}_{\text{rotor}}} & r_{\text{inlet}_{\text{stator}}} \\ r_{\text{outlet}_{\text{rotor}}} & r_{\text{outlet}_{\text{stator}}} \\ t_{\text{rotor}} & t_{\text{stator}} \\ i_{\text{rotor}} & i_{\text{stator}} \\ m_{\text{rotor}} & m_{\text{stator}} \\ \theta_{\text{rotor}} & \theta_{\text{stator}} \\ \delta_{\text{rotor}} & \delta_{\text{stator}} \\ \chi_{\text{rotor}} & \chi_{\text{stator}} \\ v_{\text{rotor}} & v_{\text{stator}} \\ R_{\text{CJL.rotor}} & R_{\text{CJL.stator}} \\ K_{\text{rotor}} & K_{\text{stator}} \\ D_{\text{rotor}} & D_{\text{stator}} \\ \zeta_{\text{rotor}} & \zeta_{\text{stator}} \\ \text{quality}_{\text{rotor}} & \text{quality}_{\text{stator}} \\ \eta_{\text{stage}} & \eta_{\text{stage}} \end{array} \right)$$

=

for $i \in 1..Z$

for $r \in \text{av}(N_r)$

$$\left(\begin{array}{c} \varepsilon_{\text{PK}(b/t)=1_{i,r}} \\ \varepsilon_{\text{HA}(b/t)=1_{i,r}} \end{array} \right) = \left(\begin{array}{c} \varepsilon_{(b/t)=1}(\beta_{\text{st}(i,2),r}) \\ \varepsilon_{(b/t)=1}(\alpha_{\text{st}(i,3),r}) \end{array} \right)$$

$$\left(\begin{array}{c} b/t_{\text{PK}_{i,r}} \\ b/t_{\text{HA}_{i,r}} \end{array} \right) = \left(\begin{array}{c} b/t=1 \left(\frac{\varepsilon_{\text{rotor}_{i,r}}}{\varepsilon_{\text{PK}(b/t)=1_{i,r}}} \right) \\ b/t=1 \left(\frac{\varepsilon_{\text{stator}_{i,r}}}{\varepsilon_{\text{HA}(b/t)=1_{i,r}}} \right) \end{array} \right)$$

$$\left(\begin{array}{c} t_{\text{rotor}_{i,r}} \\ t_{\text{stator}_{i,r}} \end{array} \right) = \left(\begin{array}{c} \frac{\text{chord}_{\text{rotor}_{i,r}}}{b/t_{\text{PK}_{i,r}}} \\ \frac{\text{chord}_{\text{stator}_{i,r}}}{b/t_{\text{HA}_{i,r}}} \end{array} \right)$$

$$Z_{\text{stator}_i} = \left| \begin{array}{l} \text{round} \left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,2),r}, D_{\text{st}(i,3),r})}{t_{\text{stator}_{i,r}}} \right) \text{ if } \text{mod} \left(\text{round} \left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,2),r}, D_{\text{st}(i,3),r})}{t_{\text{stator}_{i,r}}} \right), 2 \right) = 0 \\ \text{round} \left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,2),r}, D_{\text{st}(i,3),r})}{t_{\text{stator}_{i,r}}} \right) + 1 \text{ otherwise} \end{array} \right|$$

$$Z_{\text{rotor}_i} = \left| \begin{array}{l} Z_{\text{rotor}_i} = \text{round} \left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,1),r}, D_{\text{st}(i,2),r})}{t_{\text{rotor}_{i,r}}} \right) \end{array} \right|$$

while $\text{gcd}(Z_{\text{rotor}_i}, Z_{\text{stator}_i}) \neq 1$

$$Z_{\text{rotor}_i} = Z_{\text{rotor}_i} + 1$$

for $r \in 1 \dots N_r$

$$\begin{pmatrix} r_{\text{inlet_stator}_{i,r}} & r_{\text{outlet_stator}_{i,r}} \\ r_{\text{inlet_rotor}_{i,r}} & r_{\text{outlet_rotor}_{i,r}} \end{pmatrix} = \begin{pmatrix} \overline{r}_{\text{inlet_stator}_{i,r}} \cdot \text{chord}_{\text{stator}_{i,r}} & \overline{r}_{\text{outlet_stator}_{i,r}} \cdot \text{chord}_{\text{stator}_{i,r}} \\ \overline{r}_{\text{inlet_rotor}_{i,r}} \cdot \text{chord}_{\text{rotor}_{i,r}} & \overline{r}_{\text{outlet_rotor}_{i,r}} \cdot \text{chord}_{\text{rotor}_{i,r}} \end{pmatrix}$$

$$\begin{pmatrix} t_{\text{rotor}_{i,r}} \\ t_{\text{stator}_{i,r}} \end{pmatrix} = \pi \cdot \begin{pmatrix} \frac{\text{mean}(D_{\text{st}(i,1),r}, D_{\text{st}(i,2),r})}{Z_{\text{rotor}_i}} \\ \frac{\text{mean}(D_{\text{st}(i,2),r}, D_{\text{st}(i,3),r})}{Z_{\text{stator}_i}} \end{pmatrix}$$

$$\begin{pmatrix} i_{\text{rotor}_{i,r}} \\ i_{\text{stator}_{i,r}} \end{pmatrix} = 2.5 \cdot \begin{pmatrix} \frac{\text{chord}_{\text{rotor}_{i,r}}}{t_{\text{rotor}_{i,r}}} - 1 \\ \frac{\text{chord}_{\text{stator}_{i,r}}}{t_{\text{stator}_{i,r}}} - 2 \end{pmatrix} \cdot \circ$$

$$\begin{pmatrix} m_{\text{rotor}_{i,r}} \\ m_{\text{stator}_{i,r}} \end{pmatrix} = 0.23 \cdot (2 \cdot \overline{x}_f)^2 + 0.18 - \frac{0.002}{\text{deg}} \cdot \begin{pmatrix} \beta_{\text{st}(i,2),r} \\ \alpha_{\text{st}(i,3),r} \end{pmatrix}$$

$$\begin{pmatrix} \theta_{\text{rotor}_{i,r}} \\ \theta_{\text{stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \frac{\epsilon_{\text{rotor}_{i,r}} - i_{\text{rotor}_{i,r}}}{1 - m_{\text{rotor}_{i,r}} \cdot \sqrt{\frac{t_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}}}} \\ \frac{\epsilon_{\text{stator}_{i,r}} - i_{\text{stator}_{i,r}}}{1 - m_{\text{stator}_{i,r}} \cdot \sqrt{\frac{t_{\text{stator}_{i,r}}}{\text{chord}_{\text{stator}_{i,r}}}}} \end{pmatrix}$$

$$\begin{pmatrix} \delta_{\text{rotor}_{i,r}} \\ \delta_{\text{stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} m_{\text{rotor}_{i,r}} \cdot \theta_{\text{rotor}_{i,r}} \cdot \sqrt{\frac{t_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}}} \\ m_{\text{stator}_{i,r}} \cdot \theta_{\text{stator}_{i,r}} \cdot \sqrt{\frac{t_{\text{stator}_{i,r}}}{\text{chord}_{\text{stator}_{i,r}}}} \end{pmatrix}$$

$$\begin{pmatrix} \chi_{\text{rotor}_{i,r}} \\ \chi_{\text{stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \theta_{\text{rotor}_{i,r}} \\ \theta_{\text{stator}_{i,r}} \end{pmatrix} \cdot \frac{1 + 2 \cdot (1 - 2 \cdot \overline{x}_f)}{2}$$

$$\begin{pmatrix} v_{\text{rotor}_{i,r}} \\ v_{\text{stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \chi_{\text{rotor}_{i,r}} + \beta_{\text{st}(i,1),r} + i_{\text{rotor}_{i,r}} \\ \chi_{\text{stator}_{i,r}} + \alpha_{\text{st}(i,2),r} + i_{\text{stator}_{i,r}} \end{pmatrix}$$

$$\left(\text{chord}_{\text{rotor}_{i,r}} \right)$$

$$\begin{pmatrix} R_{\text{CЛ.rotor}_{i,r}} \\ R_{\text{CЛ.stator}_{i,r}} \end{pmatrix} = \frac{1}{2} \cdot \begin{pmatrix} \frac{1}{\sin(0.5 \cdot \theta_{\text{rotor}_{i,r}})} \\ \frac{\text{chord}_{\text{stator}_{i,r}}}{\sin(0.5 \cdot \theta_{\text{stator}_{i,r}})} \end{pmatrix}$$

$$\begin{pmatrix} K_{\text{rotor}_{i,r}} \\ K_{\text{stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \frac{c_{a_{\text{st}(i,2),r}}}{c_{a_{\text{st}(i,1),r}}} \\ \frac{c_{a_{\text{st}(i,3),r}}}{c_{a_{\text{st}(i,2),r}}} \end{pmatrix}$$

$$\begin{pmatrix} D_{\text{rotor}_{i,r}} \\ D_{\text{stator}_{i,r}} \end{pmatrix} = \begin{bmatrix} \left(1 - K_{\text{rotor}_{i,r}} \cdot \frac{\sin(\beta_{\text{st}(i,1),r})}{\sin(|\beta_{\text{st}(i,2),r}|)} \right) + \left(\frac{1}{\tan(\beta_{\text{st}(i,1),r})} - K_{\text{rotor}_{i,r}} \cdot \frac{1}{\tan(\beta_{\text{st}(i,2),r})} \right) \cdot \frac{\sin(\beta_{\text{st}(i,1),r})}{2 \cdot \frac{\text{chord}_{\text{rotor}_{i,r}}}{t_{\text{rotor}_{i,r}}}} \\ \left(1 - K_{\text{stator}_{i,r}} \cdot \frac{\sin(\alpha_{\text{st}(i,2),r})}{\sin(\alpha_{\text{st}(i,3),r})} \right) + \left(\frac{1}{\tan(\alpha_{\text{st}(i,2),r})} - K_{\text{stator}_{i,r}} \cdot \frac{1}{\tan(\alpha_{\text{st}(i,3),r})} \right) \cdot \frac{\sin(\alpha_{\text{st}(i,2),r})}{2 \cdot \frac{\text{chord}_{\text{stator}_{i,r}}}{t_{\text{stator}_{i,r}}}} \end{bmatrix}$$

$$\begin{pmatrix} \zeta_{\text{rotor}_{i,r}} \\ \zeta_{\text{stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \frac{\zeta \cdot \sin(\beta_3) / (2b/t) \left(D_{\text{rotor}_{i,r}} \right) \cdot 2 \cdot \frac{\text{chord}_{\text{rotor}_{i,r}}}{t_{\text{rotor}_{i,r}}}}{\sin(\beta_{\text{st}(i,2),r})} \\ \frac{\zeta \cdot \sin(\beta_3) / (2b/t) \left(D_{\text{stator}_{i,r}} \right) \cdot 2 \cdot \frac{\text{chord}_{\text{stator}_{i,r}}}{t_{\text{stator}_{i,r}}}}{\sin(\alpha_{\text{st}(i,3),r})} \end{pmatrix}$$

$$\begin{pmatrix} \beta_{\text{cp}_{i,r}} \\ \alpha_{\text{cp}_{i,r}} \end{pmatrix} = \begin{pmatrix} \text{atan} \left(\frac{c_{a_{\text{st}(i,1),r}}}{\text{mean}(w_{u_{\text{st}(i,1),r}}, w_{u_{\text{st}(i,2),r}})} \right) \\ \text{atan} \left(\frac{c_{a_{\text{st}(i,2),r}}}{\text{mean}(c_{u_{\text{st}(i,2),r}}, c_{u_{\text{st}(i,3),r}})} \right) \end{pmatrix}$$

$$\begin{pmatrix} \text{quality}_{\text{rotor}_{i,r}} \\ \text{quality}_{\text{stator}_{i,r}} \end{pmatrix} = \begin{bmatrix} \frac{2}{\zeta_{\text{rotor}_{i,r}}} \cdot \left(\frac{1}{\tan(\beta_{\text{st}(i,1),r})} - \frac{1}{\tan(\beta_{\text{st}(i,2),r})} \right) \cdot \left(\frac{\sin(\beta_{\text{st}(i,1),r})}{\sin(\beta_{\text{cp}_{i,r}})} \right)^2 - \frac{1}{\tan(\beta_{\text{cp}_{i,r}})} \\ \frac{2}{\zeta_{\text{stator}_{i,r}}} \cdot \left(\frac{1}{\tan(\alpha_{\text{st}(i,2),r})} - \frac{1}{\tan(\alpha_{\text{st}(i,3),r})} \right) \cdot \left(\frac{\sin(\alpha_{\text{st}(i,2),r})}{\sin(\alpha_{\text{cp}_{i,r}})} \right)^2 - \frac{1}{\tan(\alpha_{\text{cp}_{i,r}})} \end{bmatrix}$$

$$\begin{bmatrix} \left(\frac{c_{a_{\text{st}(i,1),r}}}{u_{\text{st}(i,1),r}} \right)^2 + (R_{L_{i,r}})^2 & \left(\frac{c_{a_{\text{st}(i,2),r}}}{u_{\text{st}(i,2),r}} \right)^2 + (1 - R_{L_{i,r}})^2 \end{bmatrix}$$

$$\eta_{\text{stage}_{i,r}} = 1 - \left[\frac{\frac{c_{a_{\text{st}(i,1),r}}}{\text{quality}_{\text{rotor}_{i,r}} \cdot u_{\text{st}(i,1),r}} + R_{L_{i,r}}}{\frac{c_{a_{\text{st}(i,2),r}}}{\text{quality}_{\text{stator}_{i,r}} \cdot u_{\text{st}(i,2),r}} + (1 - R_{L_{i,r}})} \right]$$

$$\left(\begin{array}{c} \varepsilon_{\text{PK}(b/t)=1} \\ \varepsilon_{\text{HA}(b/t)=1} \end{array} \begin{array}{c} Z_{\text{rotor}} \\ Z_{\text{stator}} \end{array} \begin{array}{c} r_{\text{inlet}_{\text{rotor}}} \\ r_{\text{inlet}_{\text{stator}}} \end{array} \begin{array}{c} r_{\text{outlet}_{\text{rotor}}} \\ r_{\text{outlet}_{\text{stator}}} \end{array} \begin{array}{c} t_{\text{rotor}} \\ t_{\text{stator}} \end{array} \begin{array}{c} i_{\text{rotor}} \\ i_{\text{stator}} \end{array} \begin{array}{c} m_{\text{rotor}} \\ m_{\text{stator}} \end{array} \begin{array}{c} \theta_{\text{rotor}} \\ \theta_{\text{stator}} \end{array} \begin{array}{c} \delta_{\text{rotor}} \\ \delta_{\text{stator}} \end{array} \begin{array}{c} \chi_{\text{rotor}} \\ \chi_{\text{stator}} \end{array} \begin{array}{c} v_{\text{rotor}} \\ v_{\text{stator}} \end{array} \begin{array}{c} R_{\text{CJL.rotor}} \\ R_{\text{CJL.stator}} \end{array} \begin{array}{c} K_{\text{rotor}} \\ K_{\text{stator}} \end{array} \begin{array}{c} D_{\text{rotor}} \\ D_{\text{stator}} \end{array} \begin{array}{c} \zeta_{\text{rotor}} \\ \zeta_{\text{stator}} \end{array} \begin{array}{c} \text{quality}_{\text{rotor}} \\ \text{quality}_{\text{stator}} \end{array} \begin{array}{c} \eta_{\text{stage}} \\ \eta_{\text{stage}} \end{array} \right)^T$$

$$\begin{pmatrix} \varepsilon_{CA(b/t)=1} \\ Z_{CA} \\ r_{inlet_{CA}} \\ r_{outlet_{CA}} \\ t_{CA} \\ i_{CA} \\ m_{CA} \\ \theta_{CA} \\ \delta_{CA} \\ \chi_{CA} \\ v_{CA} \\ R_{CJL,CA} \\ K_{CA} \\ D_{CA} \end{pmatrix} = \begin{cases} \text{if } CA = 1 \\ \quad \text{for } r \in av(N_r) \\ \quad \left| \begin{array}{l} \varepsilon_{CA(b/t)=1_r} = \varepsilon_{(b/t)=1}(\alpha_{3CA_r}) \\ b/t_{CA_r} = b/t=1 \left(\frac{\varepsilon_{CA_r}}{\varepsilon_{CA(b/t)=1_r}} \right) \\ t_{CA_r} = \frac{chord_{CA_r}}{b/t_{CA_r}} \\ Z_{CA} = \begin{cases} \text{round}\left(\frac{\pi \cdot D_{st}(Z, 3)_r}{t_{CA_r}}\right) & \text{if } \text{mod}\left(\text{round}\left(\frac{\pi \cdot D_{st}(Z, 3)_r}{t_{CA_r}}\right), 2\right) = 0 \\ \text{round}\left(\frac{\pi \cdot D_{st}(Z, 3)_r}{t_{CA_r}}\right) + 1 & \text{otherwise} \end{cases} \end{array} \right. \\ \quad \text{for } r \in 1..N_r \\ \quad \left| \begin{array}{l} (r_{inlet_{CA_r}} \ r_{outlet_{CA_r}}) = chord_{CA_r} \cdot (\bar{r}_{inlet_{CA_r}} \ \bar{r}_{outlet_{CA_r}}) \\ t_{CA_r} = \frac{D_{st}(Z, 3)_r}{Z_{CA}} \\ i_{CA_r} = 2.5 \cdot \left(\frac{chord_{CA_r}}{t_{CA_r}} - 2 \right) \cdot ^\circ \\ m_{CA_r} = 0.23 \cdot (2 \cdot \bar{x}_f)^2 + 0.18 - \frac{0.002}{deg} \cdot (\alpha_{3CA_r}) \\ \theta_{CA_r} = \frac{\varepsilon_{CA_r} - i_{CA_r}}{1 - m_{CA_r} \cdot \sqrt{\frac{t_{CA_r}}{chord_{CA_r}}}} \end{array} \right. \end{cases}
\end{pmatrix}$$

$$\delta_{CA_r} = m_{CA_r} \cdot \theta_{CA_r} \cdot \sqrt{\frac{r_{CA_r}}{\text{chord}_{CA_r}}}$$

$$\chi_{\text{CA}_r} = \theta_{\text{CA}_r} \cdot \frac{1 + 2 \cdot (1 - 2 \cdot \bar{x}_f)}{2}$$

$$v_{\text{CA}_r} = \chi_{\text{CA}_r} + \alpha_{1\text{CA}_r} + i_{\text{CA}_r}$$

$$R_{CJL,CA_r} = \frac{\text{chord}_{CA_r}}{2 \cdot \sin\left(0.5 \cdot \theta_{CA_r}\right)}$$

$$K_{CA_r} = \frac{c_{a3CA_r}}{c_{a1CA_r}}$$

$$D_{CA_r} = \left(1 - K_{CA_r} \cdot \frac{\sin(\alpha_{1CA_r})}{\sin(\alpha_{3CA_r})} \right) + \left(\frac{1}{\tan(\alpha_{1CA_r})} - K_{CA_r} \cdot \frac{1}{\tan(\alpha_{3CA_r})} \right) \cdot \frac{\sin(\alpha_{1CA_r})}{2 \cdot \frac{\text{chord}_{CA_r}}{t_{CA_r}}}$$

$$\left(\varepsilon_{CA(b/t)=1} \quad Z_{CA} \quad r_{inlet_CA} \quad r_{outlet_CA} \quad t_{CA} \quad i_{CA} \quad m_{CA} \quad \theta_{CA} \quad \delta_{CA} \quad \chi_{CA} \quad v_{CA} \quad R_{CJ,CA} \quad K_{CA} \quad D_{CA} \right)^T$$

$\text{chord}_{\text{BHA}} = 0.00 \cdot 10^{-3}$

$\text{chord}_{\text{rotor}}^{\text{T}}$

=

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	62.10	66.35	74.88												
2	72.07	77.02	87.03												
3	80.73	86.26	97.34												

$\cdot 10^{-3}$

Длина хорды Л (м):

$\text{chord}_{\text{stator}}^{\text{T}}$

=

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	35.22	44.78	64.29												
2	38.99	49.58	71.24												
3	42.27	53.74	77.15												

$\cdot 10^{-3}$

$\text{chord}_{\text{CA}} = 0.00 \cdot 10^{-3}$

Радисы входных и выходных кромок профилей Л (мм):

$\text{r_inlet}_{\text{BHA}} = 0.00 \cdot 10^{-3}$

$\text{r_outlet}_{\text{BHA}} = 0.00 \cdot 10^{-3}$

$\text{r_inlet}_{\text{rotor}}^{\text{T}}$

=

	1	2	3
1	0.50	0.53	0.60
2	0.22	0.23	0.26
3	0.16	0.17	0.19

$\cdot 10^{-3}$

$\text{r_inlet}_{\text{stator}}^{\text{T}}$

=

	1	2	3
1	0.11	0.13	0.19
2	0.23	0.30	0.43
3	0.38	0.48	0.69

$\cdot 10^{-3}$

$\text{r_outlet}_{\text{rotor}}^{\text{T}}$

=

	1	2	3
1	0.25	0.27	0.30
2	0.11	0.12	0.13
3	0.08	0.09	0.10

$\cdot 10^{-3}$

$\text{r_outlet}_{\text{stator}}^{\text{T}}$

=

	1	2	3
1	0.05	0.07	0.10
2	0.12	0.15	0.21
3	0.19	0.24	0.35

$\cdot 10^{-3}$

$\text{r_inlet}_{\text{CA}} = 0.00 \cdot 10^{-3}$

$\text{r_outlet}_{\text{CA}} = 0.00 \cdot 10^{-3}$

$\epsilon_{\text{BHA}(\text{b/t})=1_{\text{av}(\text{N}_r)}} = \text{■} \cdot ^\circ$

Угол поворота потока:

$\text{submatrix}\left(\epsilon_{\text{PK}(\text{b/t})=1}, 1, Z, \text{av}\left(\text{N}_r\right), \text{av}\left(\text{N}_r\right)\right)^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	7.51	10.23	9.22												

 $\cdot ^\circ$

$\text{submatrix}\left(\epsilon_{\text{HA}(\text{b/t})=1}, 1, Z, \text{av}\left(\text{N}_r\right), \text{av}\left(\text{N}_r\right)\right)^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	19.44	14.94	18.16												

 $\cdot ^\circ$

$\epsilon_{\text{CA}(\text{b/t})=1_{\text{av}(\text{N}_r)}} = \text{■} \cdot ^\circ$

$\frac{\text{chord}_{\text{BHA}}}{\text{■}_{\text{BHA}}} = \text{■}$

Густота решетки:

$\left(\frac{\text{chord}_{\text{rotor}}}{\text{t}_{\text{rotor}}}\right)^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-296.234	-398.209	-987.065												
2	729.114	978.250	2415.163												
3	4.441	6.615	19.774												

$\left(\frac{\text{chord}_{\text{stator}}}{\text{t}_{\text{stator}}}\right)^T =$

	1	2	3
1	42.848	56.310	96.221
2	-570.660	-751.566	-1297.432
3	22.076	29.244	51.852

$\frac{\text{chord}_{\text{CA}}}{\text{■}_{\text{CA}}} = \text{■}$

$Z_{\text{BHA}} = 0$

Количество Л:

$Z_{\text{rotor}}^T =$

	1	2	3
1	61	149	113

$Z_{\text{stator}}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	76	812	152												

$Z_{\text{CA}} = 0$

Значения округляются до целого в большую сторону так, чтобы при разъемном корпусе количество Л НА было четным, а количества Л РК и НА были взаимно простыми

$t_{BHA} = 0.00 \cdot 10^{-3}$

$t_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	39.57	16.04	19.49												
2	46.58	18.88	23.41												
3	52.67	21.35	26.75												

$\cdot 10^{-3}$

Шаг решетки (м):

$t_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	31.88	2.85	13.48												
2	37.44	3.38	16.52												
3	42.28	3.84	19.08												

$\cdot 10^{-3}$

$t_{CA} = 0.00 \cdot 10^{-3}$

$i_{BHA} = 0.000 \cdot ^\circ$

$i_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.423	7.839	7.103												
2	1.368	7.697	6.796												
3	1.332	7.601	6.597												

$\cdot ^\circ$

Угол атаки:

$i_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-2.238	34.232	6.923												
2	-2.396	31.650	5.784												
3	-2.501	30.000	5.111												

$\cdot ^\circ$

$i_{CA} = 0.000 \cdot ^\circ$

$m_{BHA} = 0.0000$

$m_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.3284	0.2626	0.2630												
2	0.3541	0.3345	0.3411												
3	0.3658	0.3584	0.3636												

Коэф. формы ср. линии профиля по Ховеллу:

$m_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.3004	0.3202	0.3086												
2	0.2921	0.3103	0.2969												
3	0.2861	0.3031	0.2893												

$m_{CA} = 0.0000$

$\theta_{BHA} = 0.00^{\circ}$

$\theta_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	24.37	48.71	49.51												
2	11.45	13.44	11.79												
3	6.22	2.54	1.91												

 $^{\circ}$

Угол изгиба ср. линии профиля:

$\theta_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	30.84	2.25	28.87												
2	31.14	6.56	33.11												
3	30.92	8.89	35.13												

 $^{\circ}$

$\theta_{CA} = 0.00^{\circ}$

$\delta_{\text{BHA}} = 0.000 \cdot ^\circ$

$\delta_{\text{rotor}}^{\text{T}} =$

	1	2	3
1	6.388	6.291	6.644
2	3.260	2.226	2.085
3	1.837	0.453	0.365

 $\cdot ^\circ$

Угол отставания:

$\delta_{\text{stator}}^{\text{T}} =$

	1	2	3
1	8.813	0.182	4.079
2	8.913	0.531	4.733
3	8.848	0.720	5.054

 $\cdot ^\circ$

$\delta_{\text{CA}} = 0.000 \cdot ^\circ$

$v_{\text{BHA}} = 0.00 \cdot ^\circ$

$v_{\text{rotor}}^{\text{T}} =$

	1	2	3
1	35.02	55.62	55.38
2	25.49	33.24	30.66
3	20.82	25.01	22.59

 $\cdot ^\circ$

Угол установки Л:

$v_{\text{stator}}^{\text{T}} =$

	1	2	3
1	45.09	54.65	40.34
2	49.39	57.32	44.72
3	52.56	59.42	47.84

 $\cdot ^\circ$

$v_{\text{CA}} = 0.00 \cdot ^\circ$

$R_{\text{СЛ.ВНА}} = 0.00 \cdot 10^{-3}$

Радиус дуги ср. линии (м):

$R_{\text{СЛ.rotor}}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	147.12	80.44	89.40												
2	361.24	329.11	423.80												
3	744.39	1946.18	2916.47												

$\cdot 10^{-3}$

$R_{\text{СЛ.stator}}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	66.24	1140.87	128.96												
2	72.63	433.59	125.02												
3	79.28	346.65	127.80												

$\cdot 10^{-3}$

$R_{\text{СЛ.СА}} = 0.00 \cdot 10^{-3}$

$K_{\text{ВНА}} = 0.0000$

Фактор диффузорности решетки:

$K_{\text{rotor}}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.9263	0.9279	0.9600												
2	0.9263	0.9279	0.9600												
3	0.9263	0.9279	0.9600												

$K_{\text{stator}}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.9204	0.9246	0.9583												
2	0.9204	0.9246	0.9583												
3	0.9204	0.9246	0.9583												

$K_{\text{СА}} = 0.0000$

$D_{BHA} = 0.0000$

$D_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.6545	0.7136	0.7050												
2	0.5050	0.5794	0.5465												
3	0.4084	0.4609	0.4201												

Диффузорность решетки:

$D_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.6333	0.5876	0.6695												
2	0.5958	0.5607	0.6419												
3	0.5640	0.5361	0.6144												

$D_{CA} = 0.0000$

$D_{BHA} \leq 0.6 = 1$

$D_{rotor}^T \leq 0.6 =$

	1	2	3
1	0	0	0
2	1	1	1
3	1	1	1

[18, с. 71]

$D_{stator}^T \leq 0.6 =$

	1	2	3
1	0	1	0
2	1	1	0
3	1	1	0

$D_{CA} \leq 0.6 = 1$

Коэф. потерь полного давления:

Качество профилей решеток РК и НА:

$$\text{quality}_{\text{stator}}^T =$$

КПД элементарной ступени:

•%



Вывод параметров решеток

EXCEL_{AIRFOIL.subsonic} =
...\\A40.xlsx

X/B_{subsonic} = submatrix(EXCEL_{AIRFOIL.subsonic}, 2, rows(EXCEL_{AIRFOIL.subsonic}), ORIGIN + 0, ORIGIN + 0)
Y/B_{subsonic} = submatrix(EXCEL_{AIRFOIL.subsonic}, 2, rows(EXCEL_{AIRFOIL.subsonic}), ORIGIN + 1, ORIGIN + 1)

Предел использования дозвукового профиля: M_{lim} = 0.95

EXCEL_{AIRFOIL.supersonic} =
...\\Емин сверхзвуковой профиль.xlsx

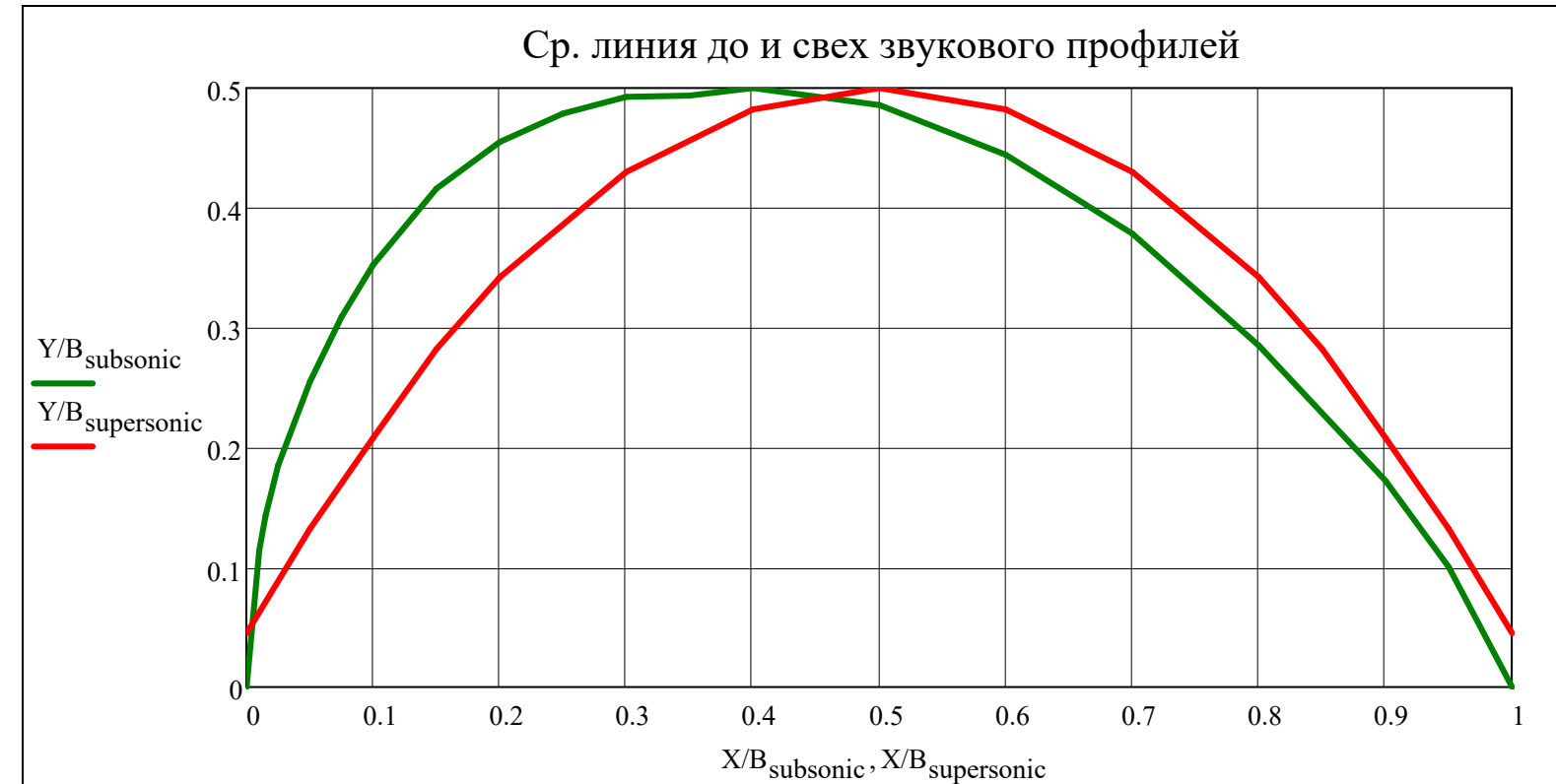
X/B_{supersonic} = submatrix(EXCEL_{AIRFOIL.supersonic}, 2, rows(EXCEL_{AIRFOIL.supersonic}), ORIGIN + 0, ORIGIN + 0)
Y/B_{supersonic} = submatrix(EXCEL_{AIRFOIL.supersonic}, 2, rows(EXCEL_{AIRFOIL.supersonic}), ORIGIN + 1, ORIGIN + 1)

augment(X/B_{subsonic}, Y/B_{subsonic})^T =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.000	0.010	0.015	0.025	0.050	0.075	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.500	0.600	0.700	0.800	0.900	0.950	1.000
2	0.000	0.114	0.143	0.185	0.255	0.309	0.352	0.416	0.455	0.479	0.493	0.494	0.500	0.486	0.444	0.378	0.285	0.172	0.100	0.000

augment(X/B_{supersonic}, Y/B_{supersonic})^T =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.000	0.050	0.100	0.150	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.850	0.900	0.950	1.000
2	0.045	0.132	0.208	0.282	0.342	0.430	0.482	0.500	0.482	0.430	0.342	0.282	0.208	0.132	0.045



$$\text{AIRFOIL}_{\text{subsonic}}(x, \text{line}, \overline{c}, \theta) =$$

if $0 \leq x \leq 1$

$$\text{interp}\left(\text{cspline}\left(X/B_{\text{subsonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{subsonic}}, \theta\right) + Y/B_{\text{subsonic}} \cdot \overline{c}\right), X/B_{\text{subsonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{subsonic}}, \theta\right) + Y/B_{\text{subsonic}} \cdot \overline{c}, x\right)$$

$$\text{interp}\left(\text{cspline}\left(X/B_{\text{subsonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{subsonic}}, \theta\right)\right), X/B_{\text{subsonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{subsonic}}, \theta\right), x\right)$$

$$\text{interp}\left(\text{cspline}\left(X/B_{\text{subsonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{subsonic}}, \theta\right) - Y/B_{\text{subsonic}} \cdot \overline{c}\right), X/B_{\text{subsonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{subsonic}}, \theta\right) - Y/B_{\text{subsonic}} \cdot \overline{c}, x\right)$$

NaN otherwise

$$\text{AIRFOIL}_{\text{supersonic}}(x, \text{line}, \overline{c}, \theta) =$$

if $0 \leq x \leq 1$

$$\text{interp}\left(\text{cspline}\left(X/B_{\text{supersonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}}, \theta\right) + Y/B_{\text{supersonic}} \cdot \overline{c}\right), X/B_{\text{supersonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}}, \theta\right) + Y/B_{\text{supersonic}} \cdot \overline{c}, x\right)$$

$$\text{interp}\left(\text{cspline}\left(X/B_{\text{supersonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}}, \theta\right)\right), X/B_{\text{supersonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}}, \theta\right), x\right)$$

$$\text{interp}\left(\text{cspline}\left(X/B_{\text{supersonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}}, \theta\right) - Y/B_{\text{supersonic}} \cdot \overline{c}\right), X/B_{\text{supersonic}}, y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}}, \theta\right) - Y/B_{\text{supersonic}} \cdot \overline{c}, x\right)$$

NaN otherwise

$x = 0, 0.005..1$

$\dot{w} = 1$



$l_{upper_stator}^T =$

	1	2	3
1	35.57	45.89	65.57
2	39.65	51.37	73.50
3	43.33	56.32	80.52

 $\cdot 10^{-3}$

$l_{lower_stator}^T =$

	1	2	3
1	35.31	45.28	64.80
2	39.07	50.00	71.71
3	42.43	54.12	77.61

 $\cdot 10^{-3}$

$area_{stator}^T =$

	1	2	3
1	27.22	44.00	90.69
2	66.72	107.87	222.74
3	117.60	190.07	391.78

 $\cdot 10^{-6}$

$Sx_{stator}^T =$

	1	2	3
1	31.7	120.5	310.6
2	86.2	339.8	911.9
3	162.5	657.7	1790.7

 $\cdot 10^{-9}$

$Sy_{stator}^T =$

	1	2	3
1	433.1	889.8	2633.2
2	1175.0	2415.3	7167.0
3	2244.9	4612.6	13650.7

 $\cdot 10^{-9}$

$x0_{stator}^T =$

	1	2	3
1	15.91	20.22	29.04
2	17.61	22.39	32.18
3	19.09	24.27	34.84

 $\cdot 10^{-3}$

$y0_{stator}^T =$

	1	2	3
1	1.16	2.74	3.42
2	1.29	3.15	4.09
3	1.38	3.46	4.57

 $\cdot 10^{-3}$

$l_{upper_rotor}^T =$

	1	2	3
1	63.46	70.54	79.57
2	72.37	77.73	87.70
3	80.87	86.51	97.57

 $\cdot 10^{-3}$

$l_{lower_rotor}^T =$

	1	2	3
1	62.29	67.36	76.00
2	72.11	77.18	87.15
3	80.75	86.30	97.37

 $\cdot 10^{-3}$

$area_{rotor}^T =$

	1	2	3	4	5	6	7	8	9
1	225.65	257.58	328.05						
2	113.97	130.15	166.18						
3	95.34	108.83	138.60						

 $\cdot 10^{-6}$

$Sx_{rotor}^T =$

	1	2	3
1	454.0	1464.2	2091.6
2	130.7	316.4	398.0
3	73.2	151.4	182.9

 $\cdot 10^{-9}$

$Sy_{rotor}^T =$

	1	2	3
1	6328.8	7718.7	11093.6
2	3709.6	4527.2	6531.4
3	3476.1	4239.5	6093.1

 $\cdot 10^{-9}$

$x0_{rotor}^T =$

	1	2	3
1	28.05	29.97	33.82
2	32.55	34.78	39.30
3	36.46	38.96	43.96

 $\cdot 10^{-3}$

$y0_{rotor}^T =$

	1	2	3
1	2.01	5.68	6.38
2	1.15	2.43	2.39
3	0.77	1.39	1.32

 $\cdot 10^{-3}$

$$J_{x_{\text{stator}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 42 & 367 & 1188 \\ \hline 2 & 145 & 1233 & 4347 \\ \hline 3 & 350 & 2767 & 10133 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y_{\text{stator}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 8814 & 23022 & 97817 \\ \hline 2 & 26473 & 69192 & 295031 \\ \hline 3 & 54829 & 143219 & 608525 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy_{\text{stator}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 524 & 2533 & 9375 \\ \hline 2 & 1578 & 7908 & 30503 \\ \hline 3 & 3225 & 16590 & 64856 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{x0_{\text{stator}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 5.51 & 37.05 & 124.93 \\ \hline 2 & 33.25 & 162.37 & 613.04 \\ \hline 3 & 125.74 & 491.68 & 1947.68 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y0_{\text{stator}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 1925 & 5027 & 21360 \\ \hline 2 & 5781 & 15109 & 64424 \\ \hline 3 & 11974 & 31278 & 132897 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy0_{\text{stator}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 20.05 & 96.26 & 357.11 \\ \hline 2 & 60.38 & 300.31 & 1160.56 \\ \hline 3 & 123.40 & 628.77 & 2462.20 \\ \hline \end{array} \cdot 10^{-12}$$

$$\alpha_{\text{major}_{\text{stator}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 0.60 & 1.10 & 0.96 \\ \hline 2 & 0.60 & 1.15 & 1.04 \\ \hline 3 & 0.60 & 1.17 & 1.08 \\ \hline \end{array} \cdot ^\circ$$

$$J_{x_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 1343 & 9558 & 15325 \\ \hline 2 & 197 & 888 & 1117 \\ \hline 3 & 77 & 251 & 297 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 227101 & 295924 & 479972 & & & & & & \\ \hline 2 & 154477 & 201466 & 328422 & & & & & & \\ \hline 3 & 162150 & 211290 & 342699 & & & & & & \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 13241 & 45588 & 73495 & & & & & & \\ \hline 2 & 4425 & 11445 & 16265 & & & & & & \\ \hline 3 & 2774 & 6135 & 8363 & & & & & & \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{x0_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 429.29 & 1235.81 & 1989.52 & & & & & & \\ \hline 2 & 47.35 & 118.62 & 163.61 & & & & & & \\ \hline 3 & 20.72 & 40.70 & 56.02 & & & & & & \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y0_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 49597 & 64627 & 104822 & & & & & & \\ \hline 2 & 33732 & 43993 & 71715 & & & & & & \\ \hline 3 & 35408 & 46138 & 74833 & & & & & & \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy0_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 506.75 & 1713.59 & 2763.18 & & & & & & \\ \hline 2 & 169.70 & 438.07 & 622.93 & & & & & & \\ \hline 3 & 106.43 & 235.26 & 320.79 & & & & & & \\ \hline \end{array} \cdot 10^{-1}$$

$$\alpha_{\text{major}_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 0.59 & 1.55 & 1.54 \\ \hline 2 & 0.29 & 0.57 & 0.50 \\ \hline 3 & 0.17 & 0.29 & 0.25 \\ \hline \end{array} \cdot ^\circ$$

$$J_{u_{\text{stator}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 5.30 & 35.19 & 118.93 \\ 32.61 & 156.34 & 591.94 \\ 124.46 & 478.84 & 1901.40 \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$J_{v_{\text{stator}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 1925 & 5029 & 21366 \\ 5781 & 15115 & 64445 \\ 11975 & 31291 & 132943 \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$J_{uv_{\text{stator}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} -0.00 & -0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & -0.00 & -0.00 \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$J_{p_{\text{stator}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 1930 & 5064 & 21485 \\ 5814 & 15271 & 65037 \\ 12100 & 31770 & 134844 \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$W_{p_{\text{stator}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 99.7 & 205.0 & 606.5 \\ 271.4 & 558.0 & 1655.6 \\ 521.1 & 1070.8 & 3168.9 \end{bmatrix} \end{matrix} \cdot 10^{-9}$$

$$\text{stiffness}_{\text{stator}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 7.39 & 19.31 & 82.06 \\ 88.84 & 232.19 & 990.06 \\ 413.97 & 1081.34 & 4594.52 \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$J_{u_{\text{rotor}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 424.07 & 1189.52 & 1915.33 & & & & & & \\ 46.49 & 114.24 & 158.18 & & & & & & \\ 20.40 & 39.50 & 54.65 & & & & & & \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$J_{v_{\text{rotor}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 49602 & 64674 & 104896 & & & & & & \\ 33733 & 43997 & 71721 & & & & & & \\ 35408 & 46139 & 74834 & & & & & & \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$J_{uv_{\text{rotor}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} -0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$J_{p_{\text{rotor}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 50026 & 65863 & 106811 & & & & & & \\ 33779 & 44111 & 71879 & & & & & & \\ 35428 & 46179 & 74889 & & & & & & \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

$$W_{p_{\text{rotor}}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 1466.4 & 1788.5 & 2570.5 & & & & & & \\ 854.3 & 1042.7 & 1504.3 & & & & & & \\ 800.1 & 975.9 & 1402.5 & & & & & & \end{bmatrix} \end{matrix} \cdot 10^{-9}$$

$$\text{stiffness}_{\text{rotor}}^T = \begin{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 1354.80 & 1765.38 & 2863.34 & & & & & & \\ 129.60 & 169.02 & 275.53 & & & & & & \\ 60.46 & 78.78 & 127.78 & & & & & & \end{bmatrix} \end{matrix} \cdot 10^{-12}$$

CP _x _{stator} ^T =		1	2	3	4	5	6	7	8	9	·10 ⁻³	CP _x _{rotor} ^T =		1	2	3	4	5	6	7	8	9	·10 ⁻³
	1	12.328	15.673	22.502									1	21.736	23.223	26.207							
	2	13.648	17.353	24.936									2	25.225	26.956	30.459							
	3	14.794	18.807	27.002									3	28.256	30.189	34.069							
CP _y _{stator} ^T =		1	2	3	4	5	6	7	8	9	·10 ⁻³	CP _y _{rotor} ^T =		1	2	3	4	5	6	7	8	9	·10 ⁻³
	1	0.0000	0.0000	0.0000									1	0.0000	0.0000	0.0000							
	2	0.0000	0.0000	0.0000									2	0.0000	0.0000	0.0000							
	3	0.0000	0.0000	0.0000									3	0.0000	0.0000	0.0000							

Абс. координаты профиля:

Airfoil(type,x,line,i,r) =	<div><div>if type = "BHA"</div><div><div>AIRFOIL_{subsonic}$\left(x, \text{line}, \overline{c}_{\text{BHA}_r}, \varepsilon_{\text{BHA}_r}\right)$ if $M_{c_{\text{st}(1,1),r}} < M_{\text{lim}}$</div><div>AIRFOIL_{supersonic}$\left(x, \text{line}, \overline{c}_{\text{BHA}_r}, \varepsilon_{\text{BHA}_r}\right)$ otherwise</div></div><div><div>if type = "rotor"</div><div><div>AIRFOIL_{subsonic}$\left(x, \text{line}, \overline{c}_{\text{rotor}_{i,r}}, \varepsilon_{\text{rotor}_{i,r}}\right)$ if $M_{w_{\text{st}(i,1),r}} < M_{\text{lim}}$</div><div>AIRFOIL_{supersonic}$\left(x, \text{line}, \overline{c}_{\text{rotor}_{i,r}}, \varepsilon_{\text{rotor}_{i,r}}\right)$ otherwise</div></div><div><div>if type = "stator"</div><div><div>AIRFOIL_{subsonic}$\left(x, \text{line}, \overline{c}_{\text{stator}_{i,r}}, \varepsilon_{\text{stator}_{i,r}}\right)$ if $M_{c_{\text{st}(i,2),r}} < M_{\text{lim}}$</div><div>AIRFOIL_{supersonic}$\left(x, \text{line}, \overline{c}_{\text{stator}_{i,r}}, \varepsilon_{\text{stator}_{i,r}}\right)$ otherwise</div></div><div><div>if type = "CA"</div><div><div>AIRFOIL_{subsonic}$\left(x, \text{line}, \overline{c}_{\text{CA}_r}, \varepsilon_{\text{CA}_r}\right)$ if $M_{c_{\text{st}(Z,3),r}} < M_{\text{lim}}$</div><div>AIRFOIL_{supersonic}$\left(x, \text{line}, \overline{c}_{\text{CA}_r}, \varepsilon_{\text{CA}_r}\right)$ otherwise</div></div></div></div></div></div>
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Рассматриваемая ступень:

$$j_w = \begin{cases} j = 1 & = 1 \\ j = & \text{"Такой ступени не существует!" if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{cases}$$

Построение профилей Л РК и НА

AXLE0(type,x,i,r) =

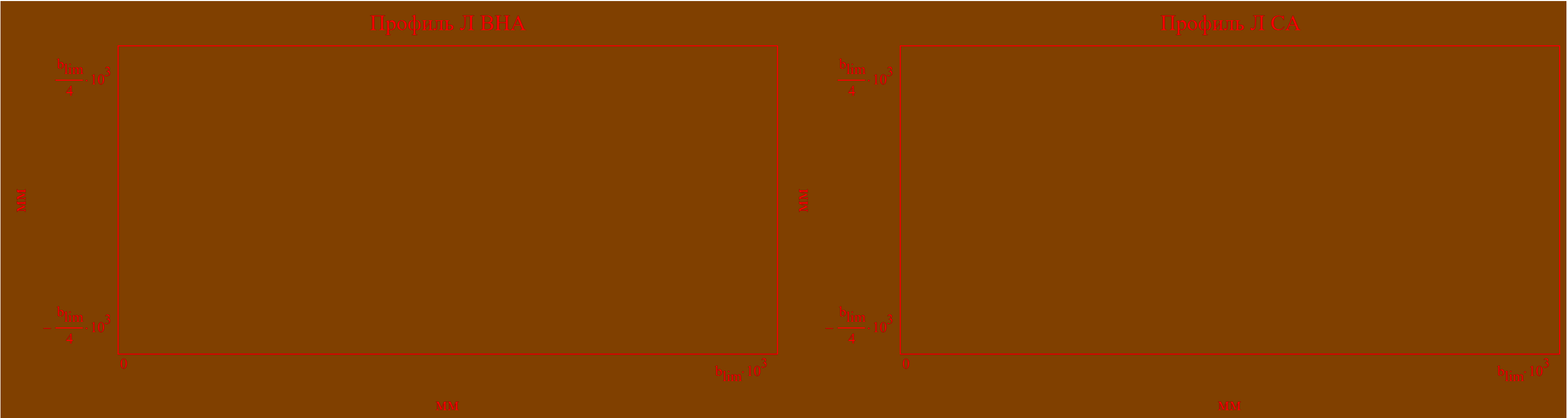
$$\begin{cases} \frac{y0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}} + \tan\left(\alpha_{\text{major}_{\text{rotor}_{i,r}}}\right) \cdot \left(x - \frac{x0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}}\right) & \text{if type = "rotor"} \\ \frac{y0_{\text{stator}_{i,r}}}{\text{chord}_{\text{stator}_{i,r}}} + \tan\left(\alpha_{\text{major}_{\text{stator}_{i,r}}}\right) \cdot \left(x - \frac{x0_{\text{stator}_{i,r}}}{\text{chord}_{\text{stator}_{i,r}}}\right) & \text{if type = "stator"} \\ \text{NaN} & \text{otherwise} \end{cases}$$

AXLE90(type,x,i,r) =

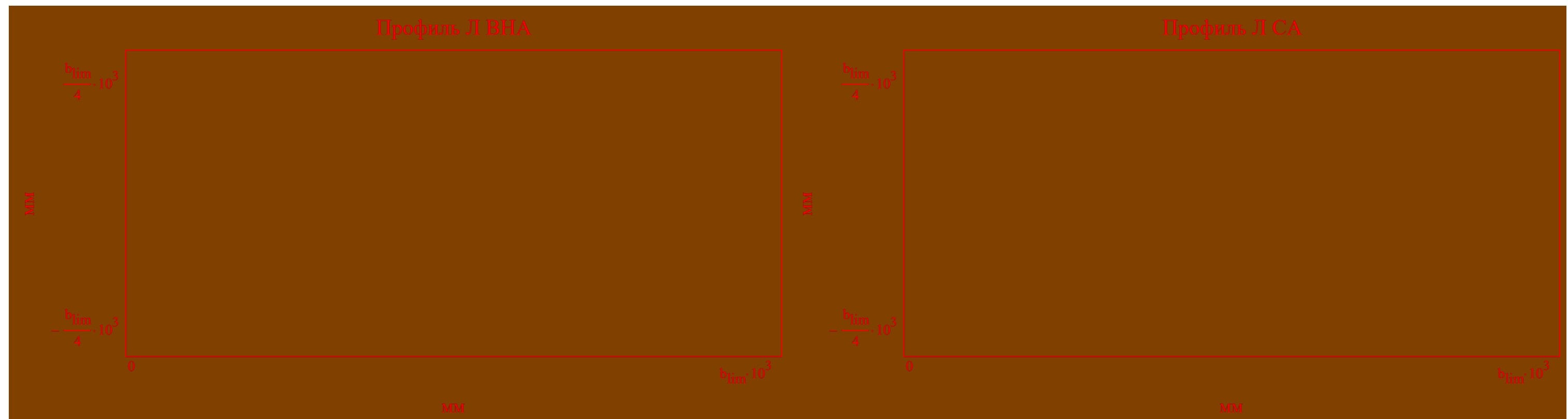
$$\begin{cases} \frac{y0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}} + \tan\left(\alpha_{\text{major}_{\text{rotor}_{i,r}}} + \frac{\pi}{2}\right) \cdot \left(x - \frac{x0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}}\right) & \text{if (type = "rotor") } \wedge \left|\alpha_{\text{major}_{\text{rotor}_{i,r}}}\right| \geq 1.^{\circ} \\ \frac{y0_{\text{stator}_{i,r}}}{\text{chord}_{\text{stator}_{i,r}}} + \tan\left(\alpha_{\text{major}_{\text{stator}_{i,r}}} + \frac{\pi}{2}\right) \cdot \left(x - \frac{x0_{\text{stator}_{i,r}}}{\text{chord}_{\text{stator}_{i,r}}}\right) & \text{if (type = "stator") } \wedge \left|\alpha_{\text{major}_{\text{stator}_{i,r}}}\right| \geq 1.^{\circ} \\ \text{NaN} & \text{otherwise} \end{cases}$$

$$b_{\text{lim}} = \frac{\text{ceil}\left(\max\left(\text{chord}_{\text{rotor}_{j,N_r}}, \text{chord}_{\text{stator}_{j,N_r}}\right) \cdot 10^2\right)}{10^2} = 90 \cdot 10^{-3}$$

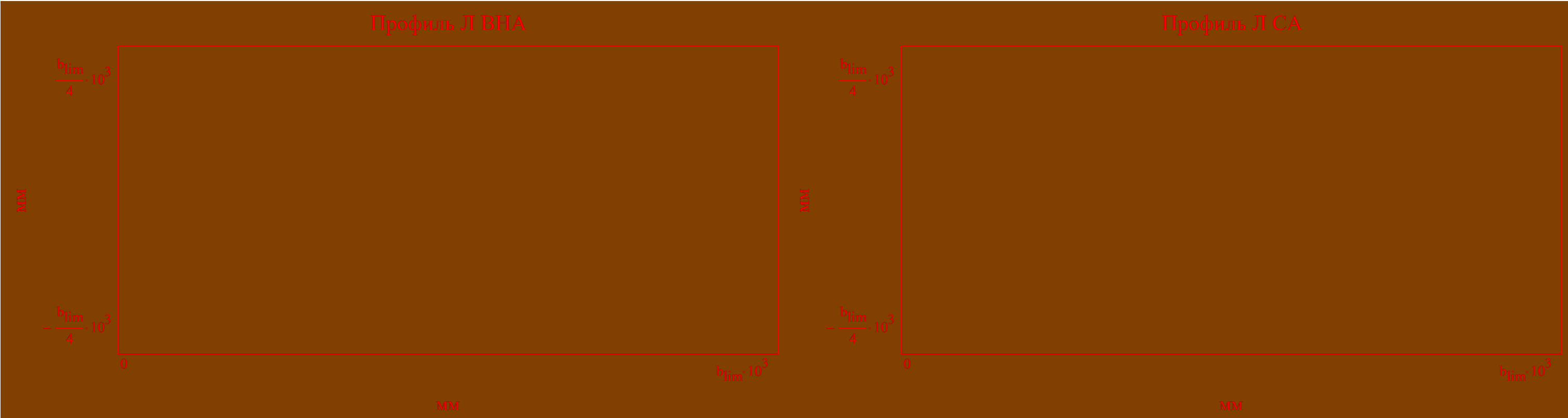
$r = 1$



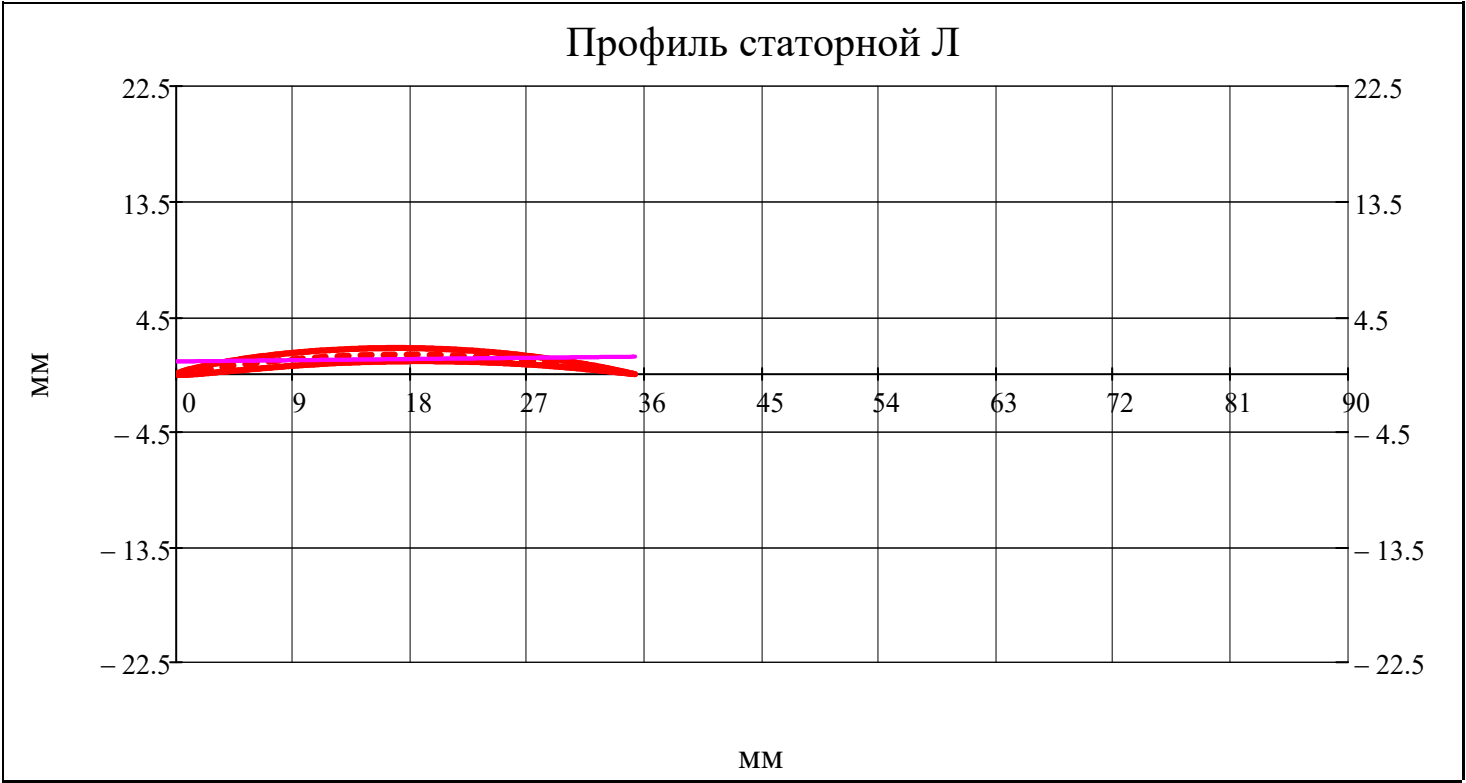
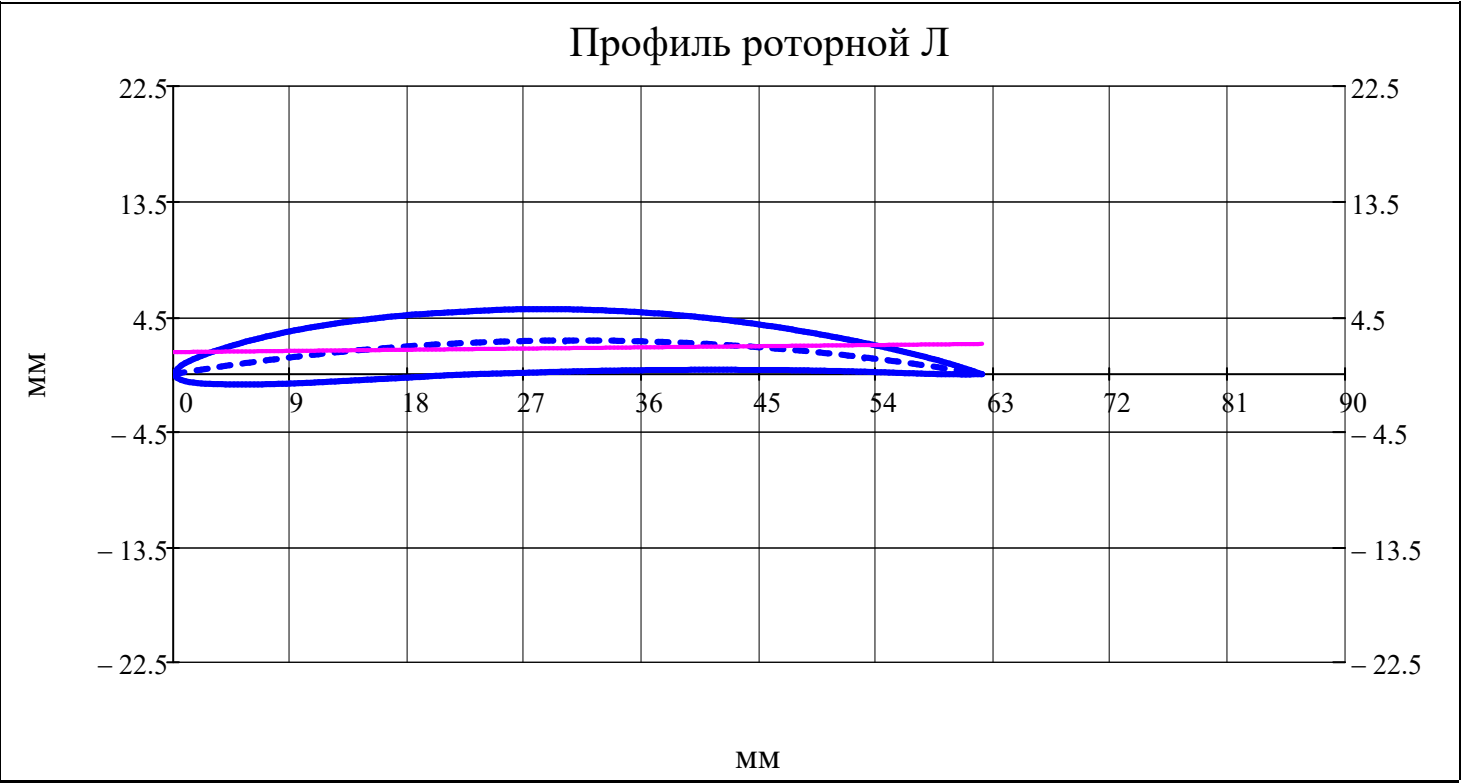
$$\underline{r} = \text{av}(\mathbf{N}_r)$$



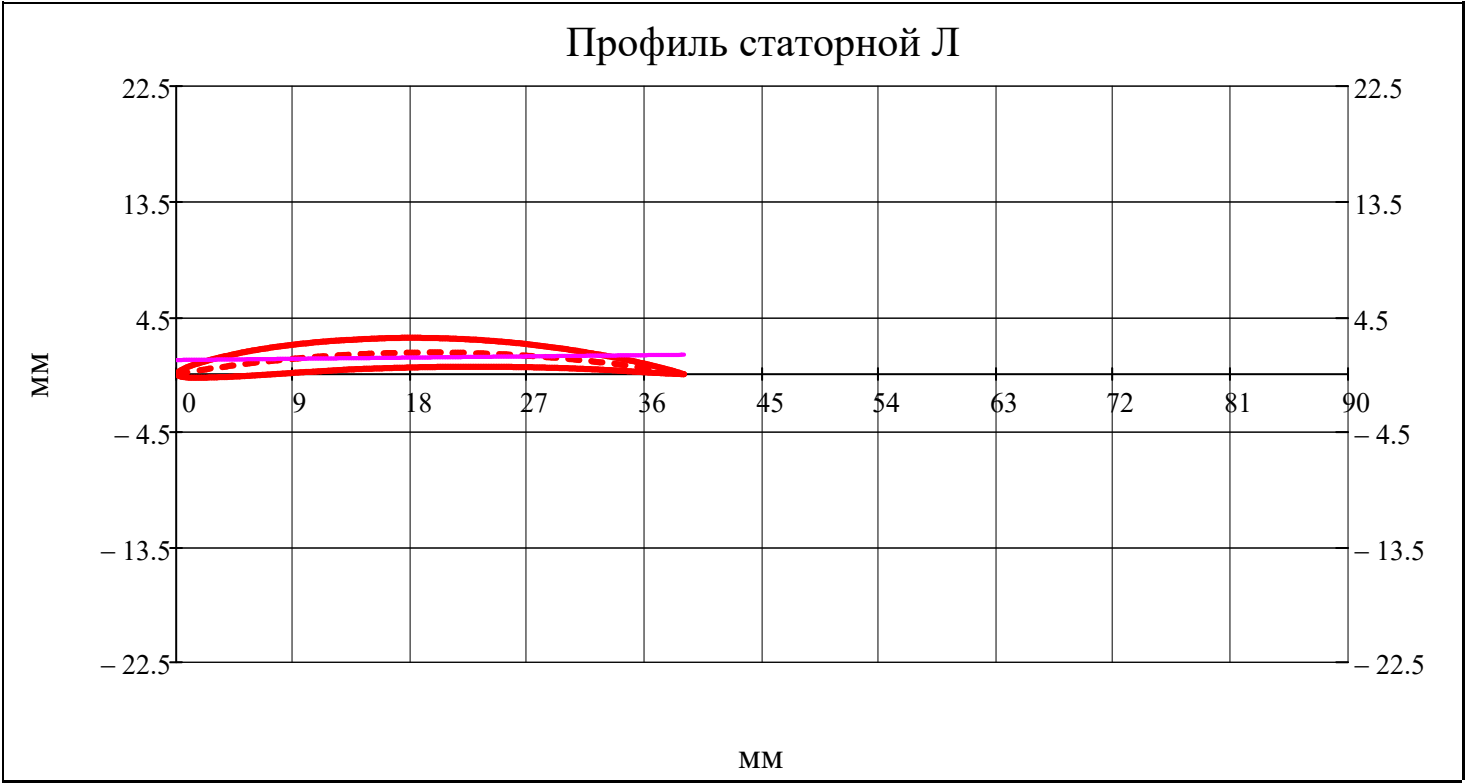
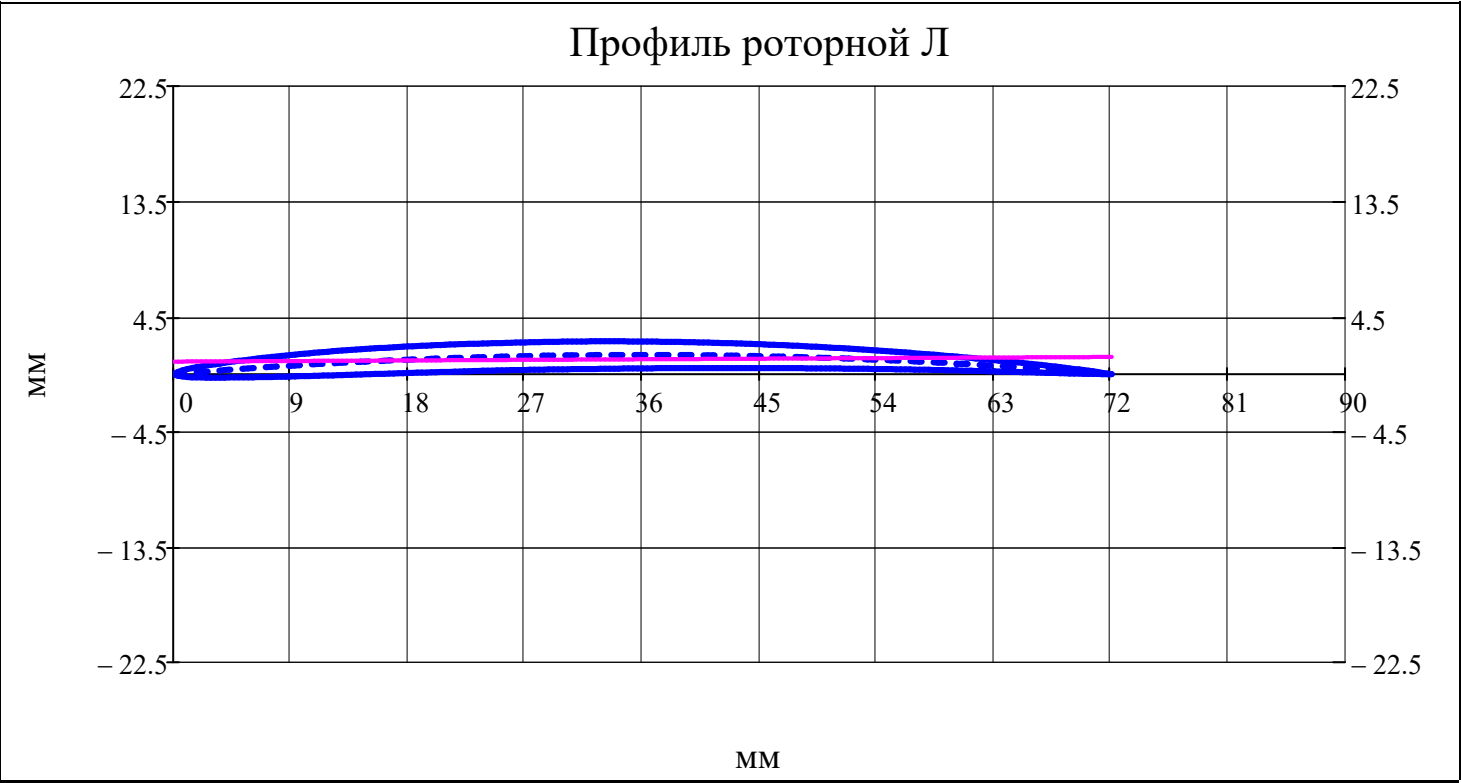
$r_w = N_r$



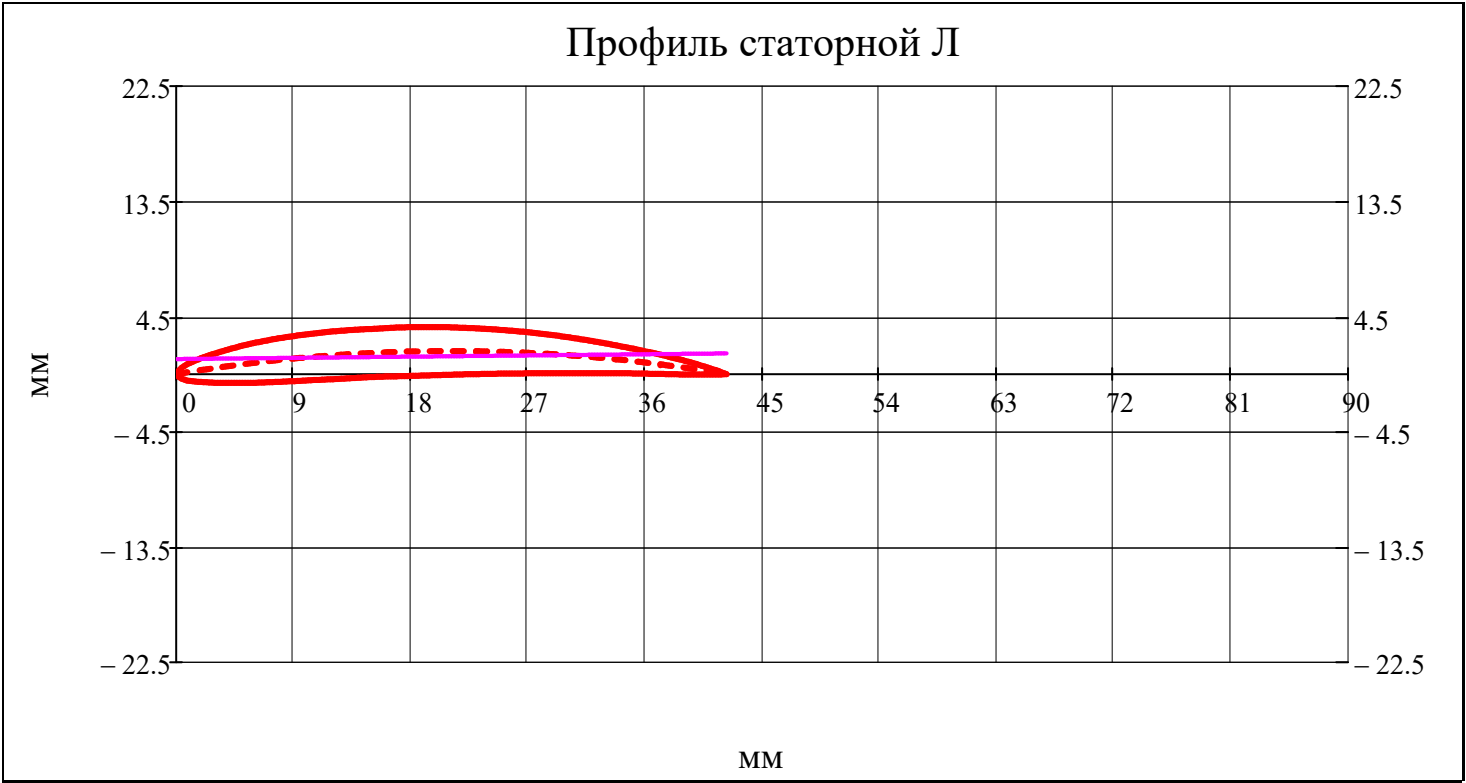
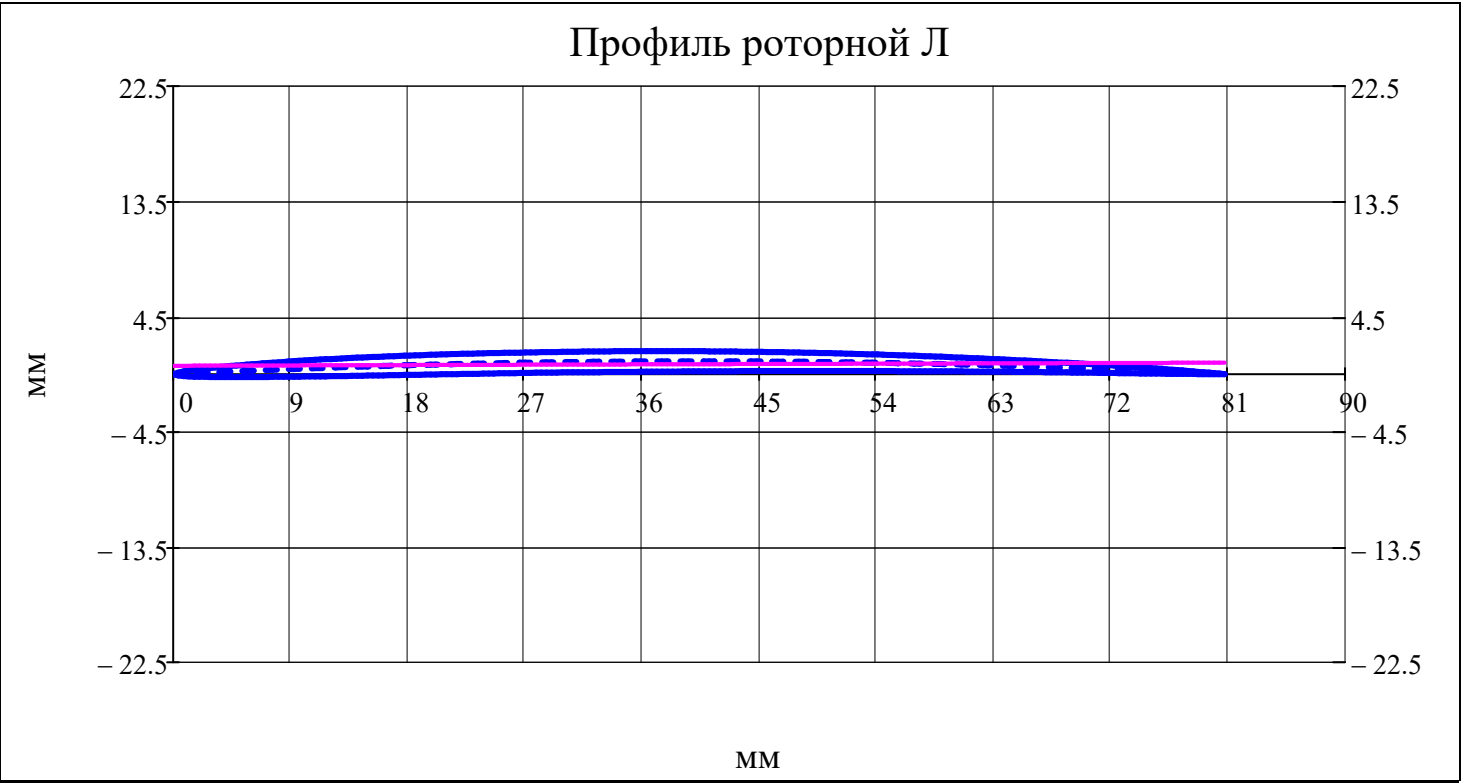
$r_w = 1$



$r_w = av(N_r)$



$r_w = N_r$



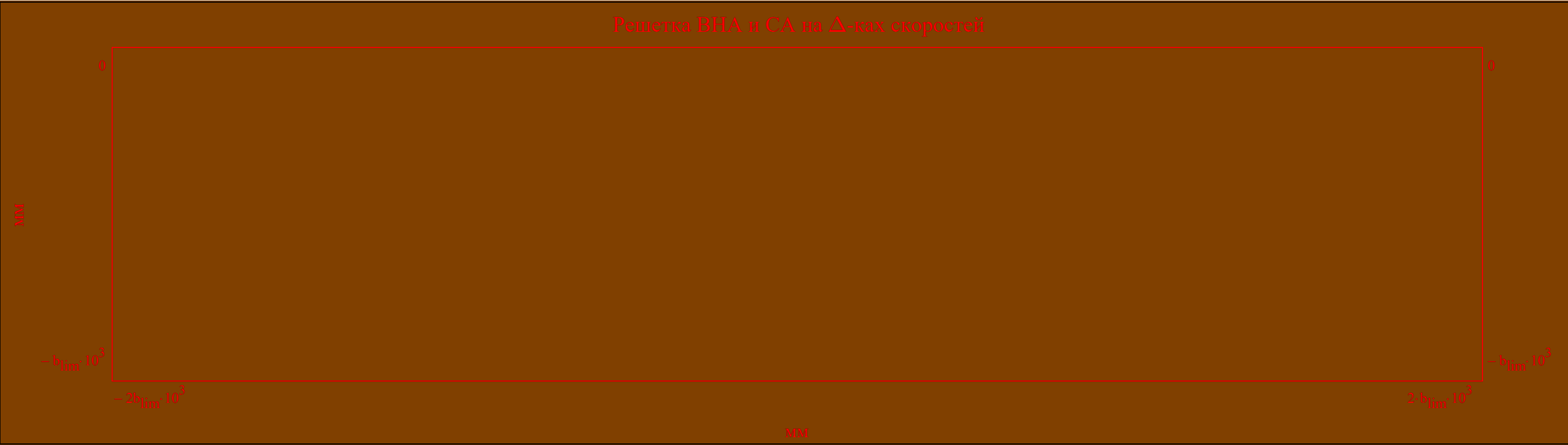
Рассматриваемая ступень:

$$j_w = \begin{cases} j = 1 & \\ j = & \text{"Такой ступени не существует!" if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{cases} = 1$$

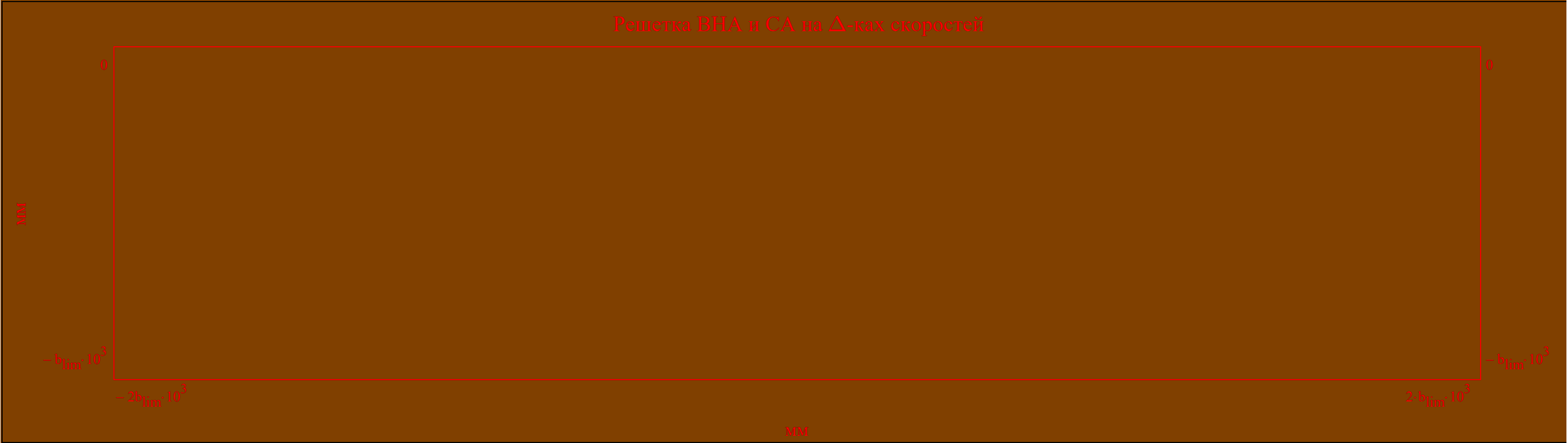
$$b_{lim} = \frac{ceil\left(\max\left(chord_{rotor_{j,N_r}}, chord_{stator_{j,N_r}}\right) \cdot 10^2\right)}{10^2} = 90 \cdot 10^{-3}$$

Построение плоских решеток профилей Л РК и НА (+ ВНА и СА) на треугольниках скоростей

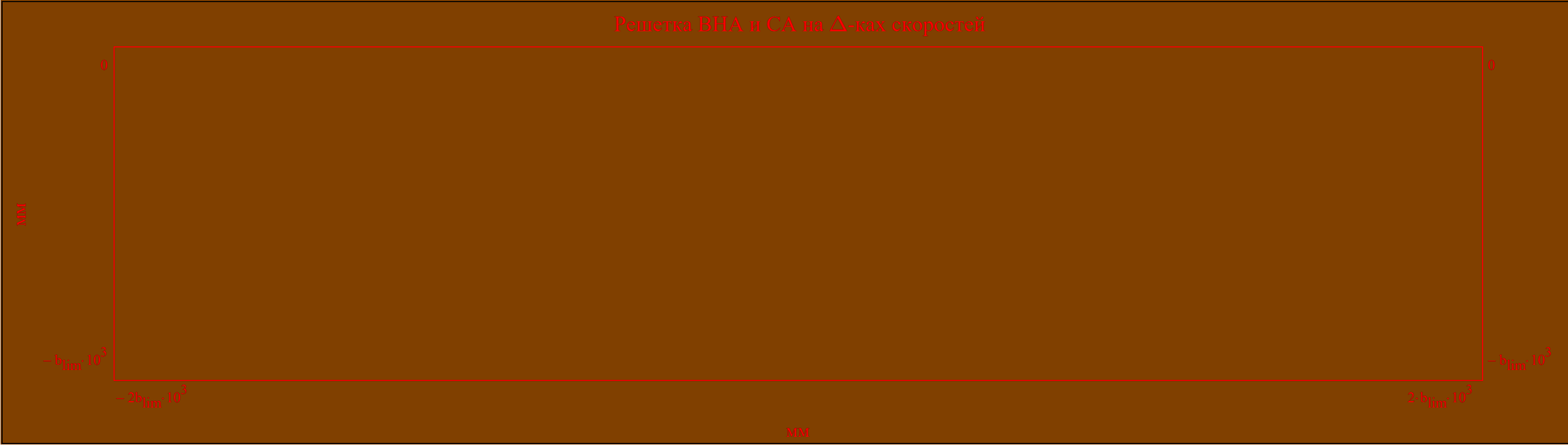
$$r_w = 1$$



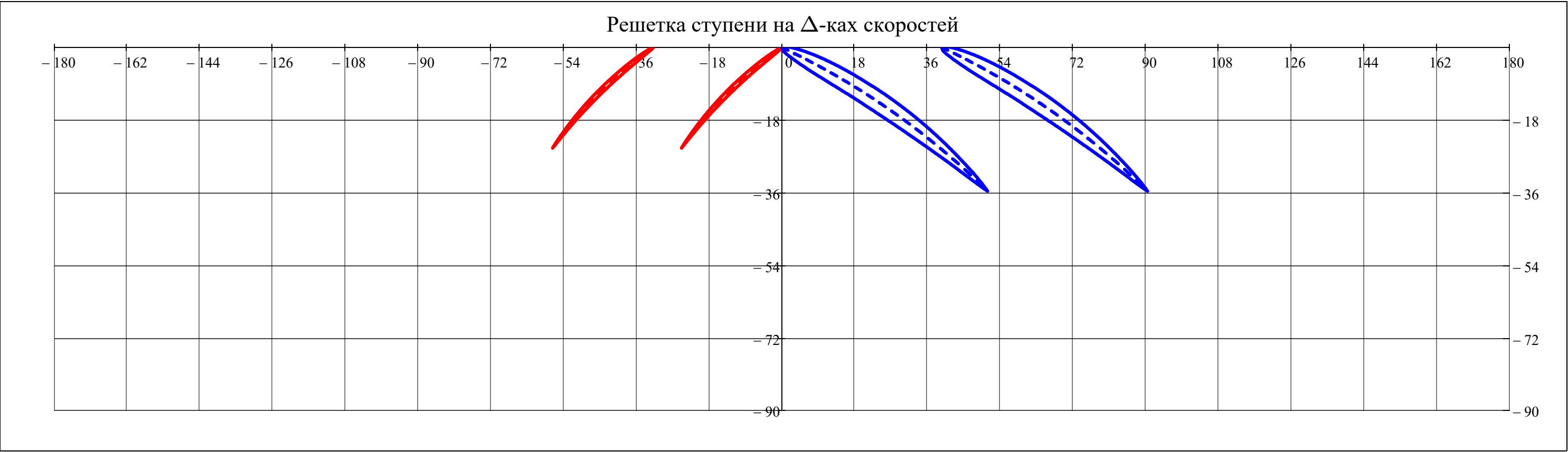
$$\tilde{r}_w = \text{av}\left(N_r\right)$$



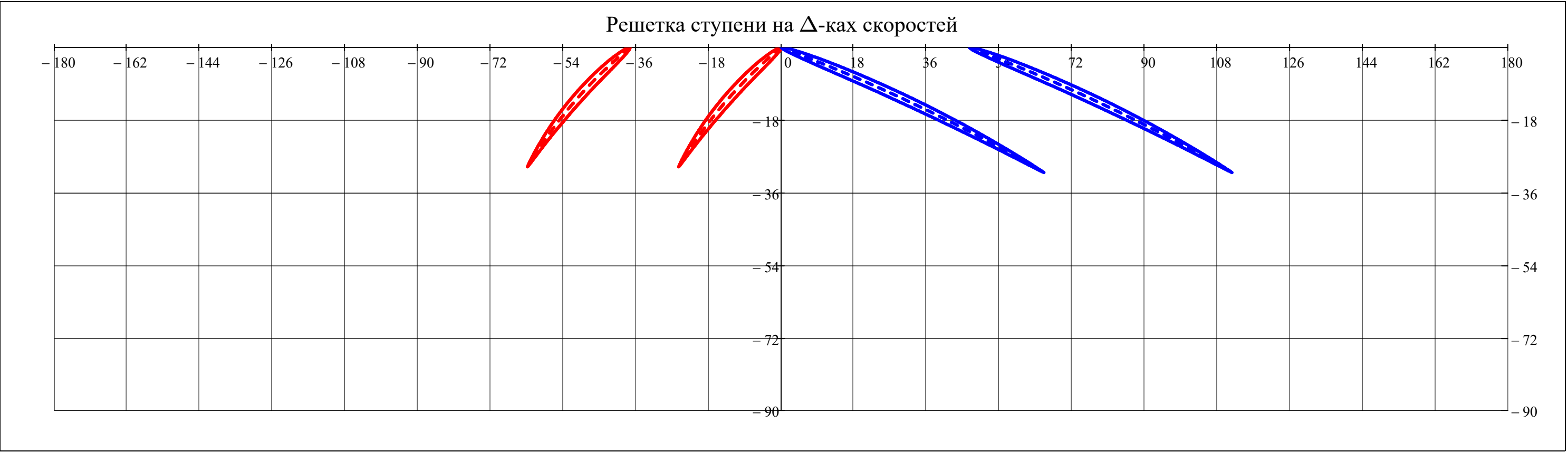
$\tilde{r}_w = N_r$



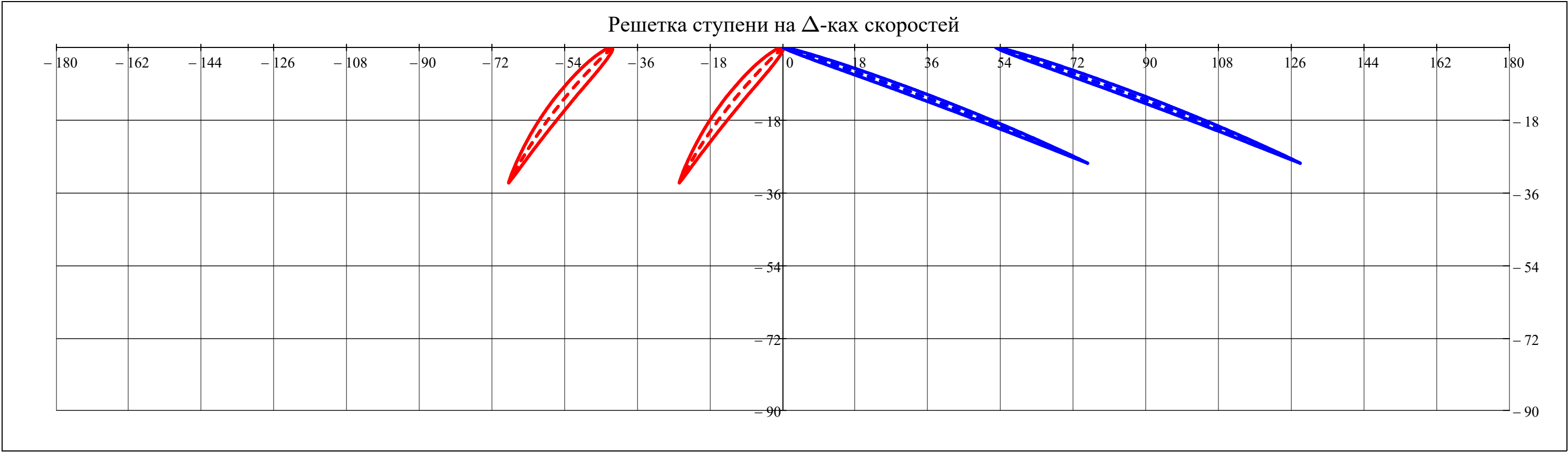
$r_w = 1$



$r_w = \text{av}(N_r)$



$r_w = N_r$



Радиальный зазор (м)
[с.64 казаджан]:

0.0015 ≤ Δr ≤ 0.0035 = 1

$\Delta_{r_i} = \bar{\Delta}_r \cdot D_{st(i, 2), N_r}$

$\Delta_r^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 2.56 & 2.51 & 2.36 \\ \hline \end{array} \cdot 10^{-3}$

Относительный осевой зазор () [16, с. 245]:

0.1 ≤ Δa ≤ 0.2 = 1

Осевой зазор (м): $\Delta a_i = \bar{\Delta}a \cdot \text{chord}_{\text{rotor}_{i, av}(N_r)}$

$\Delta a^T = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 12.25 & 13.09 & 14.79 \\ \hline \end{array} \cdot 10^{-3}$

Односторонний осевой зазор (м):

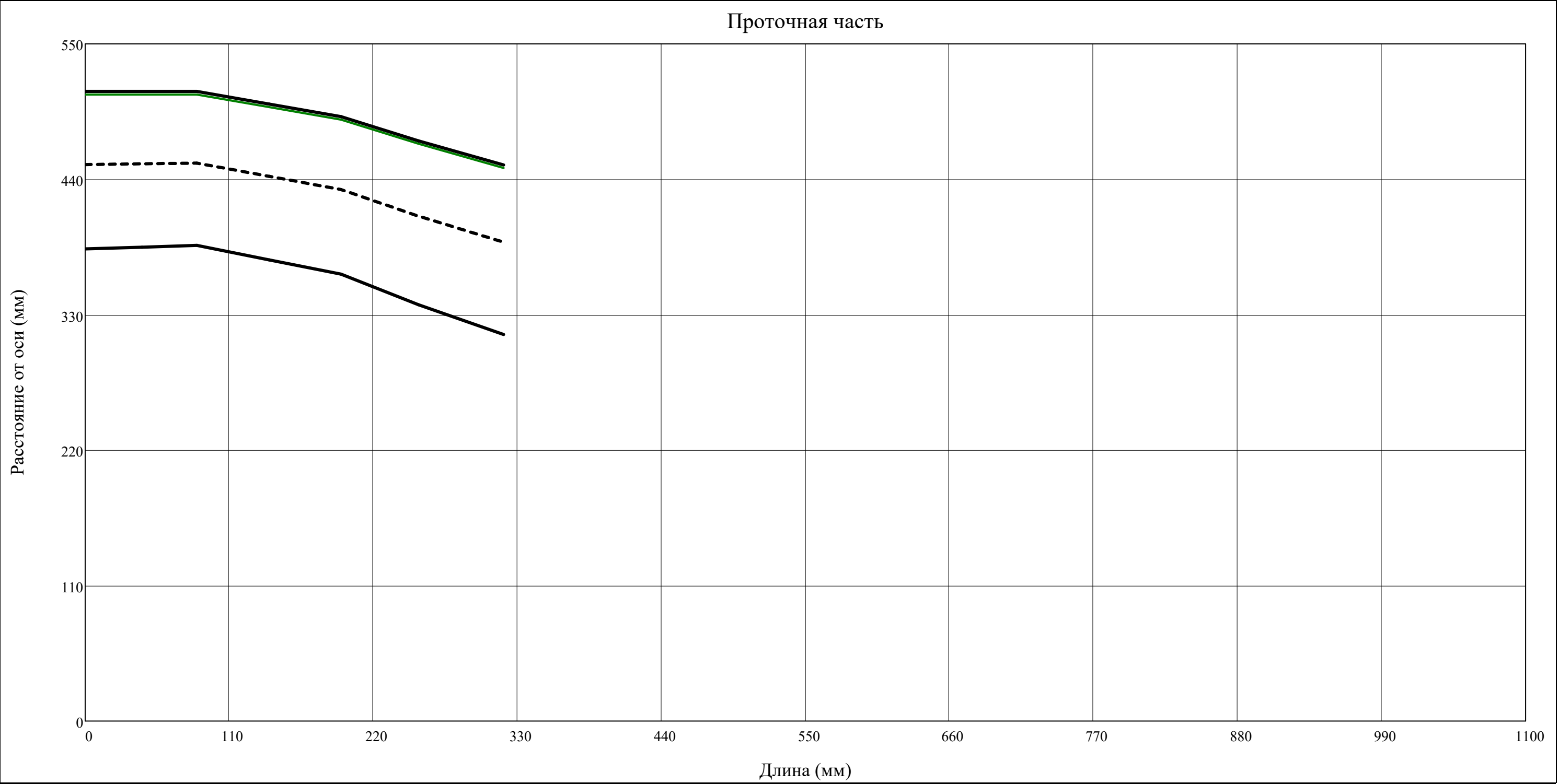
$\frac{\Delta a^T}{2} = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 6.13 & 6.55 & 7.40 \\ \hline \end{array} \cdot 10^{-3}$

Длина ОК (м):

$$\text{Length} = \left[\begin{array}{l} \Delta a_1 + \left| \begin{array}{l} \text{chord}_{\text{BHA}_{av}(N_r)} \cdot \sin\left(v_{\text{BHA}_{av}(N_r)}\right) \text{ if BHA} = 1 \quad \dots \\ 0 \text{ otherwise} \end{array} \right. \\ + \sum_{i=1}^Z \left(\text{chord}_{\text{rotor}_{i, av}(N_r)} \cdot \sin\left(v_{\text{rotor}_{i, av}(N_r)}\right) \right) + 2 \cdot \sum_{i=1}^Z \Delta a_i + \sum_{i=1}^Z \left(\text{chord}_{\text{stator}_{i, av}(N_r)} \cdot \sin\left(v_{\text{stator}_{i, av}(N_r)}\right) \right) \dots \\ + \left| \begin{array}{l} \text{chord}_{\text{CA}_{av}(N_r)} \cdot \sin\left(v_{\text{CA}_{av}(N_r)}\right) \text{ if CA} = 1 \quad + \Delta a_Z \\ 0 \text{ otherwise} \end{array} \right. \end{array} \right] = 346.4 \cdot 10^{-3}$$

$$\begin{pmatrix} x_{\text{ПЧ}} \\ y_{\text{ПЧпер}} \\ y_{\text{ПЧср}} \\ y_{\text{ПЧкор}} \\ y_{\text{Лпер}} \end{pmatrix} = \begin{cases} c = 1 \\ x_{\text{ПЧ}_c} = \begin{cases} \text{chord}_{\text{BHA}_{\text{av}}(N_r)} \cdot \sin\left(v_{\text{BHA}_{\text{av}}(N_r)}\right) & \text{if } \text{BHA} = 1 \\ 0 & \text{otherwise} \end{cases} \\ y_{\text{ПЧпер}_c} = R_{\text{st}(c, 1), N_r} \\ y_{\text{Лпер}_c} = y_{\text{ПЧпер}_c} - \Delta r_c \\ y_{\text{ПЧср}_c} = R_{\text{st}(c, 1), \text{av}(N_r)} \\ y_{\text{ПЧкор}_c} = R_{\text{st}(c, 1), \text{ORIGIN}} \\ \text{for } i \in 1..Z \\ \begin{cases} c = c + 1 \\ x_{\text{ПЧ}_c} = x_{\text{ПЧ}_{c-1}} + 0.5 \cdot \Delta a_i + \text{chord}_{\text{rotor}_i, \text{av}(N_r)} \cdot \sin\left(v_{\text{rotor}_i, \text{av}(N_r)}\right) + 0.5 \cdot \Delta a_i \\ \begin{pmatrix} y_{\text{ПЧпер}_c} \\ y_{\text{ПЧср}_c} \\ y_{\text{ПЧкор}_c} \end{pmatrix} = \begin{pmatrix} R_{\text{st}(i, 2), N_r} \\ R_{\text{st}(i, 2), \text{av}(N_r)} \\ R_{\text{st}(i, 2), \text{ORIGIN}} \end{pmatrix} \\ y_{\text{Лпер}_c} = y_{\text{ПЧпер}_c} - \Delta r_i \\ c = c + 1 \\ x_{\text{ПЧ}_c} = x_{\text{ПЧ}_{c-1}} + 0.5 \cdot \Delta a_i + \text{chord}_{\text{stator}_i, \text{av}(N_r)} \cdot \sin\left(v_{\text{stator}_i, \text{av}(N_r)}\right) + 0.5 \cdot \Delta a_i \\ \begin{pmatrix} y_{\text{ПЧпер}_c} \\ y_{\text{ПЧср}_c} \\ y_{\text{ПЧкор}_c} \end{pmatrix} = \begin{pmatrix} R_{\text{st}(i, 3), N_r} \\ R_{\text{st}(i, 3), \text{av}(N_r)} \\ R_{\text{st}(i, 3), \text{ORIGIN}} \end{pmatrix} \\ y_{\text{Лпер}_c} = y_{\text{ПЧпер}_c} - \Delta r_i \end{cases} \end{cases} \\ \left(x_{\text{ПЧ}} \ y_{\text{ПЧпер}} \ y_{\text{ПЧср}} \ y_{\text{ПЧкор}} \ y_{\text{Лпер}} \right)^T
 \end{cases}$$

$$\begin{aligned} y_{\text{ПЧпер}}(l) &= \text{interp}\left(\text{cspline}(x_{\text{ПЧ}}, y_{\text{ПЧпер}}), x_{\text{ПЧ}}, y_{\text{ПЧпер}}, l\right) \\ y_{\text{ПЧср}}(l) &= \text{interp}\left(\text{cspline}(x_{\text{ПЧ}}, y_{\text{ПЧср}}), x_{\text{ПЧ}}, y_{\text{ПЧср}}, l\right) \\ y_{\text{ПЧкор}}(l) &= \text{interp}\left(\text{cspline}(x_{\text{ПЧ}}, y_{\text{ПЧкор}}), x_{\text{ПЧ}}, y_{\text{ПЧкор}}, l\right) \\ y_{\text{Лпер}}(l) &= \text{interp}\left(\text{cspline}(x_{\text{ПЧ}}, y_{\text{Лпер}}), x_{\text{ПЧ}}, y_{\text{Лпер}}, l\right) \end{aligned}$$



Рассматриваемая ступень:

$$j_w = \begin{cases} j = 1 & = 1 \\ j = & \text{"Такой ступени не существует!" if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{cases}$$

⌵ Поперечная часть ступени

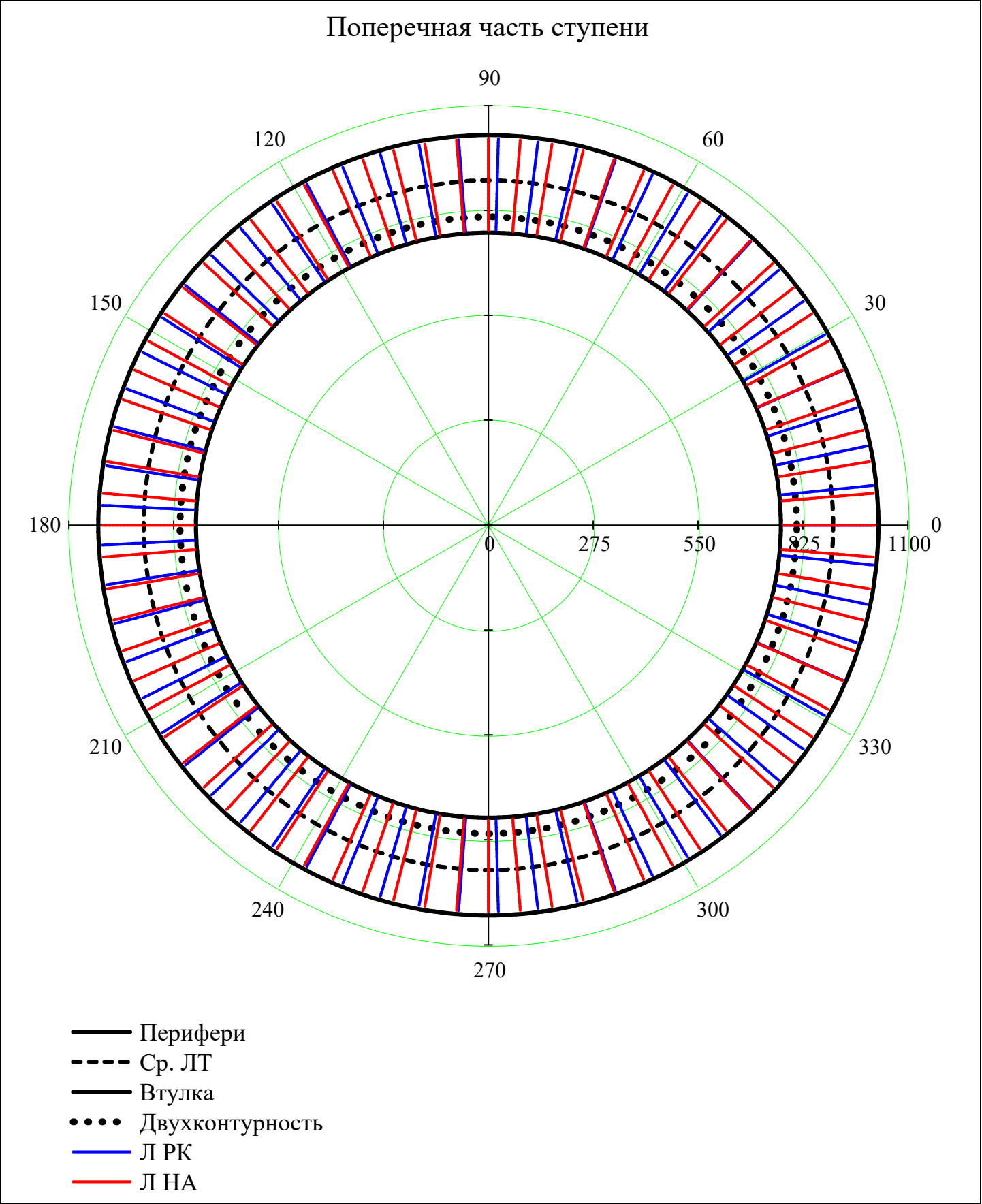
$$r_w = \min(D), \min(D) + \frac{\max(D) - \min(D)}{N_{\text{dis}}} \dots \max(D)$$

$$i_{\text{rotor}} = 1 \dots Z_{\text{rotor}_j}$$

$$i_{\text{stator}} = 1 \dots Z_{\text{stator}_j}$$

$$L_{\text{PK}}(r,j) = \begin{cases} \frac{2 \cdot \pi}{Z_{\text{rotor}_j}} & \text{if } D_{\text{st}(j,1)}, 1 < r < D_{\text{st}(j,1)}, N_r \\ \text{NaN} & \text{otherwise} \end{cases}$$

$$L_{\text{HA}}(r,j) = \begin{cases} \frac{2 \cdot \pi}{Z_{\text{stator}_j}} & \text{if } D_{\text{st}(j,2)}, 1 < r < D_{\text{st}(j,2)}, N_r \\ \text{NaN} & \text{otherwise} \end{cases}$$



Запас по температуре (K):

$\Delta T_{\text{safety}} = 50$

Выбранный материал Л:

$\text{material_blade}_i =$

"ЖС-6К" if $1123 \leq T_{\text{st}(i,2),\text{av}(N_r)}^* + \Delta T_{\text{safety}}$

"BT41" if $873 \leq T_{\text{st}(i,2),\text{av}(N_r)}^* + \Delta T_{\text{safety}} < 1123$

"BT25" if $753 \leq T_{\text{st}(i,2),\text{av}(N_r)}^* + \Delta T_{\text{safety}} < 873$

"BT9" otherwise

$\text{material_blade}_i =$

"BT23" if compressor = "Бл"

"BT6" if compressor = "КНД"

material_blade_i otherwise

Плотность материала Л (кг/м^3):

$\rho_{\text{blade}_i} =$

8393 if material_blade_i = "ЖС-6К"

7900 if material_blade_i = "BT41"

4500 if material_blade_i = "BT25"

4570 if material_blade_i = "BT23"

4510 if material_blade_i = "BT9"

4430 if material_blade_i = "BT6"

NaN otherwise

Предел длительной прочности Л РК (Па):

$\sigma_{\text{blade_long}_i} = 10^6 \cdot$

125 if material_blade_i = "ЖС-6К"

123 if material_blade_i = "BT41"

150 if material_blade_i = "BT25"

230 if material_blade_i = "BT23"

200 if material_blade_i = "BT9"

210 if material_blade_i = "BT6"

NaN otherwise

Коэф. формы:

$k_n = 6.8$

Модуль Юнга I рода материала Л (Па):

$E_{\text{blade}} = 210 \cdot 10^9$

Коэф. Пуассона материала Л():

$\mu_{\text{steel}} = 0.3$

material_blade^T =

	1	2	3	4	5	6	7	8	9
1	"BT6"	"BT6"	"BT6"						

ρ_{blade}^T =

	1	2	3
1	4430	4430	4430

σ_{blade_long}^T =

	1	2	3
1	210.0	210.0	210.0

·10⁶

$$\begin{pmatrix} \nu_{0\text{изГ.stator}} & \nu_{0\text{изГ.rotor}} \\ \nu_{0\text{угЛ.stator}} & \nu_{0\text{угЛ.rotor}} \\ \nu_{0\text{угЛ.stator_bondage}} & \nu_{0\text{угЛ.rotor_bondage}} \end{pmatrix}$$

=

for i ∈ 1..Z

for r ∈ av(N_r)

for mode ∈ 1..6

$$\nu_{0\text{изГ.stator}_{i,\text{mode}}} = \nu_{0\text{изГИБ}}\left(\text{mode}, \text{mean}\left(h_{\text{st}}(i, 2), h_{\text{st}}(i, 3)\right), E_{\text{blade}}, \rho_{\text{blade}_i}, \text{area}_{\text{stator}_{i,r}}, J_{\text{u}_{\text{stator}_{i,r}}}\right)$$

$$\nu_{0\text{изГ.rotor}_{i,\text{mode}}} = \nu_{0\text{изГИБ}}\left(\text{mode}, \text{mean}\left(h_{\text{st}}(i, 1), h_{\text{st}}(i, 2)\right), E_{\text{blade}}, \rho_{\text{blade}_i}, \text{area}_{\text{rotor}_{i,r}}, J_{\text{u}_{\text{rotor}_{i,r}}}\right)$$

$$\nu_{0\text{угЛ.stator}_{i,\text{mode}}} = \nu_{0\text{угЛ}}\left(\text{mode}, 0, \text{mean}\left(h_{\text{st}}(i, 2), h_{\text{st}}(i, 3)\right), \text{Jung}(2, \mu_{\text{steel}}, E_{\text{blade}}), \rho_{\text{blade}_i}, \text{stiffness}_{\text{stator}_{i,r}}, J_{\text{p}_{\text{stator}_{i,r}}}\right)$$

$$\nu_{0\text{угЛ.rotor}_{i,\text{mode}}} = \nu_{0\text{угЛ}}\left(\text{mode}, 0, \text{mean}\left(h_{\text{st}}(i, 1), h_{\text{st}}(i, 2)\right), \text{Jung}(2, \mu_{\text{steel}}, E_{\text{blade}}), \rho_{\text{blade}_i}, \text{stiffness}_{\text{rotor}_{i,r}}, J_{\text{p}_{\text{rotor}_{i,r}}}\right)$$

$$\nu_{0\text{угЛ.stator_bondage}_{i,\text{mode}}} = \nu_{0\text{угЛ}}\left(\text{mode}, 1, \text{mean}\left(h_{\text{st}}(i, 2), h_{\text{st}}(i, 3)\right), \text{Jung}(2, \mu_{\text{steel}}, E_{\text{blade}}), \rho_{\text{blade}_i}, \text{stiffness}_{\text{stator}_{i,r}}, J_{\text{p}_{\text{stator}_{i,r}}}\right)$$

$$\nu_{0\text{угЛ.rotor_bondage}_{i,\text{mode}}} = \nu_{0\text{угЛ}}\left(\text{mode}, 1, \text{mean}\left(h_{\text{st}}(i, 1), h_{\text{st}}(i, 2)\right), \text{Jung}(2, \mu_{\text{steel}}, E_{\text{blade}}), \rho_{\text{blade}_i}, \text{stiffness}_{\text{rotor}_{i,r}}, J_{\text{p}_{\text{rotor}_{i,r}}}\right)$$

$$\begin{pmatrix} \nu_{0\text{изГ.stator}} & \nu_{0\text{изГ.rotor}} \\ \nu_{0\text{угЛ.stator}} & \nu_{0\text{угЛ.rotor}} \\ \nu_{0\text{угЛ.stator_bondage}} & \nu_{0\text{угЛ.rotor_bondage}} \end{pmatrix}$$

Частота собственных изгибных колебаний (Гц) [9, с.240]:

$\nu_{0\text{изг.rotor}}$ =

	1	2	3	4	5	6
1	152	953	2669	5233	8648	12915
2	228	1429	4003	7849	12970	19370
3	221	1382	3871	7591	12544	18734

$\nu_{0\text{изг.stator}}$ =

	1	2	3	4	5	6
1	170	1067	2989	5861	9685	14465
2	286	1795	5026	9855	16285	24321
3	343	2148	6015	11796	19492	29110

Частота собственных угловых колебаний (Гц) [9, с.243] без и с бандажом:

$\nu_{0\text{угл.rotor}}$ =

	1	2	3	4	5	6
1	520	1559	2599	3638	4678	5718
2	525	1576	2626	3677	4727	5778
3	506	1519	2531	3544	4557	5569

$\nu_{0\text{угл.stator}}$ =

	1	2	3	4	5	6
1	1049	3148	5246	7345	9443	11542
2	1034	3103	5171	7240	9308	11377
3	973	2919	4865	6811	8757	10703

$\nu_{0\text{угл.rotor_bondage}}$ =

	1	2	3	4	5	6
1	1040	2079	3119	4158	5198	6237
2	1051	2101	3152	4202	5253	6303
3	1013	2025	3038	4050	5063	6075

$\nu_{0\text{угл.stator_bondage}}$ =

	1	2	3	4	5	6
1	2099	4197	6296	8394	10493	12591
2	2069	4137	6206	8274	10343	12411
3	1946	3892	5838	7784	9730	11676



Расчетный узел: type = "compressor"

Объем бандажной полки (м³): V_бп = 0

Радиус положения ЦМ бандажной полки (м): R_бп = 0

Расчет Л на прочность

R0_rotor	area0_rotor	
N0_rotor	σ0_z_rotor	
area_rotor.	area_stator.	
N_rotor	σ_z_rotor	
P1	ρ1	
P2	ρ2	
P3	ρ3	
ca1	cu1	
ca2	cu2	
ca3	cu3	
qx_rotor	qx_stator	
qy_rotor	qy_stator	
Mx_rotor	Mx_stator	
My_rotor	My_stator	
shift_x_rotor	shift_y_rotor	
x0_rotor.	x0_stator.	=
y0_rotor.	y0_stator.	
α_major_rotor.	α_major_stator.	
Ju_rotor.	Ju_stator.	$\chi_{\text{rotor}}(i,z) = \frac{\text{area}_{\text{rotor}_i, N_r}}{\text{area}_{\text{rotor}_i, 1}}$
Jv_rotor.	Jv_stator.	
CPx_rotor.	CPx_stator.	
CPy_rotor.	CPy_stator.	$R0_{\text{rotor}}(i,z) = \frac{1}{\sqrt{1 - \ln(\chi_{\text{rotor}}(i,z))}} \cdot \begin{cases} \sqrt{\text{mean}(R_{\text{st}}(i,1),1,R_{\text{st}}(i,2),1)^2 - \text{mean}(R_{\text{st}}(i,1),N_r,R_{\text{st}}(i,2),N_r)^2 \cdot \ln(\chi_{\text{rotor}}(i,z))} & \text{if type = "compressor"} \\ \sqrt{\text{mean}(R_{\text{st}}(i,2),1,R_{\text{st}}(i,3),1)^2 - \text{mean}(R_{\text{st}}(i,2),N_r,R_{\text{st}}(i,3),N_r)^2 \cdot \ln(\chi_{\text{rotor}}(i,z))} & \text{if type = "turbine"} \end{cases}$
CPx_rotor.axis	CPx_stator.axis	
CPy_rotor.axis	CPy_stator.axis	
		$\sigma0_{\text{rotor.max}}(i,z) = \frac{\rho_{\text{blade}_i} \cdot \omega^2}{2} \cdot \begin{cases} \left[\text{mean}(R_{\text{st}}(i,1),N_r,R_{\text{st}}(i,2),N_r)^2 - (R0_{\text{rotor}}(i,z))^2 \right] & \text{if type = "compressor"} \\ \left[\text{mean}(R_{\text{st}}(i,2),N_r,R_{\text{st}}(i,3),N_r)^2 - (R0_{\text{rotor}}(i,z))^2 \right] & \text{if type = "turbine"} \end{cases}$
		$\left(\rho_{\text{blade}_i} \cdot \omega^2 \quad R0_{\text{rotor}}(i,z) \right)$

$\tau_{rotor,axis}$	$\tau_{stator,axis}$	
$Wp_{rotor.}$	$Wp_{stator.}$	
$M\tau_{rotor}$	$M\tau_{stator}$	
τ_{rotor}	τ_{stator}	
$\varphi_{uv_{rotor}}$	$\varphi_{uv_{stator}}$	
Mu_{rotor}	Mu_{stator}	
Mv_{rotor}	Mv_{stator}	
$\varphi_{neutral_{rotor}}$	$\varphi_{neutral_{stator}}$	
		$area0_{rotor}(i,z) = area_{rotor,i,N_r} \cdot \begin{cases} \left(\frac{\sigma0_{rotor,max}(i,z)}{z} \right)^{\int_z z dz} & \text{if } z \leq R0_{rotor}(i,z) \\ 1 & \text{otherwise} \end{cases}$
		$N0_{rotor}(i,z) = \rho_{blade_i} \cdot \omega^2 \cdot \begin{cases} \left(\int_z^{mean(R_{st(i,1),N_r}, R_{st(i,2),N_r})} area0_{rotor}(i,z) \cdot z dz + V_{\delta_{\Pi}} \cdot R_{\delta_{\Pi}} \right) & \text{if type = "compressor"} \\ \left(\int_z^{mean(R_{st(i,2),N_r}, R_{st(i,3),N_r})} area0_{rotor}(i,z) \cdot z dz + V_{\delta_{\Pi}} \cdot R_{\delta_{\Pi}} \right) & \text{if type = "turbine"} \end{cases}$
		$\sigma0_{z_{rotor}}(i,z) = \frac{N0_{rotor}(i,z)}{area0_{rotor}(i,z)}$
		$area_{rotor.}(i,z) = \text{interp}\left(\text{pspline}\left(\text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(area_{rotor}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(area_{rotor}, i, i, 1, N_r\right)^T, z\right)$
		$area_{stator.}(i,z) = \text{interp}\left(\text{pspline}\left(\text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(area_{stator}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(area_{stator}, i, i, 1, N_r\right)^T, z\right)$
		$N_{rotor}(i,z) = \rho_{blade_i} \cdot \omega^2 \cdot \begin{cases} \left(\int_z^{mean(R_{st(i,1),N_r}, R_{st(i,2),N_r})} area_{rotor.}(i,z) \cdot z dz + V_{\delta_{\Pi}} \cdot R_{\delta_{\Pi}} \right) & \text{if type = "compressor"} \\ \left(\int_z^{mean(R_{st(i,2),N_r}, R_{st(i,3),N_r})} area_{rotor.}(i,z) \cdot z dz + V_{\delta_{\Pi}} \cdot R_{\delta_{\Pi}} \right) & \text{if type = "turbine"} \end{cases}$
		$\sigma_{z_{rotor}}(i,z) = \frac{N_{rotor}(i,z)}{area_{rotor.}(i,z)}$
		$\rho_1(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(\rho, st(i,1), st(i,1), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(\rho, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$
		$\rho_2(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(\rho, st(i,2), st(i,2), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(\rho, st(i,2), st(i,2), 1, N_r\right)^T, z\right)$
		$\rho_3(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^T, \text{submatrix}\left(\rho, st(i,3), st(i,3), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^T, \text{submatrix}\left(\rho, st(i,3), st(i,3), 1, N_r\right)^T, z\right)$
		$P_1(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(P, st(i,1), st(i,1), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(P, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$
		$P_2(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(P, st(i,2), st(i,2), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(P, st(i,2), st(i,2), 1, N_r\right)^T, z\right)$
		$P_3(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^T, \text{submatrix}\left(P, st(i,3), st(i,3), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^T, \text{submatrix}\left(P, st(i,3), st(i,3), 1, N_r\right)^T, z\right)$
		$c_{a1}(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(c_a, st(i,1), st(i,1), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(c_a, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$
		$c_{a2}(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(c_a, st(i,2), st(i,2), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \text{submatrix}\left(c_a, st(i,2), st(i,2), 1, N_r\right)^T, z\right)$
		$c_{a3}(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^T, \text{submatrix}\left(c_a, st(i,3), st(i,3), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^T, \text{submatrix}\left(c_a, st(i,3), st(i,3), 1, N_r\right)^T, z\right)$
		$c_{u1}(i,z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(c_u, st(i,1), st(i,1), 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^T, \text{submatrix}\left(c_u, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$

$$\begin{aligned}
c_{u2}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^1,\text{submatrix}\left(c_u,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^1\right),\text{submatrix}\left(R,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^1,\text{submatrix}\left(c_u,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^1,z\right) \\
c_{u3}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T,\text{submatrix}\left(c_u,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T\right),\text{submatrix}\left(R,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T,\text{submatrix}\left(c_u,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T,z\right) \\
w_{u1}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R,\text{st}(i,1),\text{st}(i,1),1,N_r\right)^T,\text{submatrix}\left(w_u,\text{st}(i,1),\text{st}(i,1),1,N_r\right)^T\right),\text{submatrix}\left(R,\text{st}(i,1),\text{st}(i,1),1,N_r\right)^T,\text{submatrix}\left(w_u,\text{st}(i,1),\text{st}(i,1),1,N_r\right)^T,z\right) \\
w_{u2}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^T,\text{submatrix}\left(w_u,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^T\right),\text{submatrix}\left(R,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^T,\text{submatrix}\left(w_u,\text{st}(i,2),\text{st}(i,2),1,N_r\right)^T,z\right) \\
w_{u3}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T,\text{submatrix}\left(w_u,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T\right),\text{submatrix}\left(R,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T,\text{submatrix}\left(w_u,\text{st}(i,3),\text{st}(i,3),1,N_r\right)^T,z\right) \\
q_{x_{\text{rotor}}}(i,z) &= -\frac{2\pi z}{Z_{\text{rotor}_i}} \cdot \begin{cases} \left[\left(P_2(i,z) - P_1(i,z) \right) + \rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(c_{a2}(i,z) - c_{a1}(i,z) \right) \right] & \text{if type = "compressor"} \\ \left[\left(P_3(i,z) - P_2(i,z) \right) + \rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(c_{a3}(i,z) - c_{a2}(i,z) \right) \right] & \text{if type = "turbine"} \end{cases} \\
q_{x_{\text{stator}}}(i,z) &= -\frac{2\pi z}{Z_{\text{stator}_i}} \cdot \begin{cases} \left[\left(P_3(i,z) - P_2(i,z) \right) + \rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(c_{a3}(i,z) - c_{a2}(i,z) \right) \right] & \text{if type = "compressor"} \\ \left[\left(P_2(i,z) - P_1(i,z) \right) + \rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(c_{a2}(i,z) - c_{a1}(i,z) \right) \right] & \text{if type = "turbine"} \end{cases} \\
q_{y_{\text{rotor}}}(i,z) &= \frac{2\pi z}{Z_{\text{rotor}_i}} \cdot \begin{cases} \left[\rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(w_{u2}(i,z) - w_{u1}(i,z) \right) \right] & \text{if type = "compressor"} \\ \left[\rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(w_{u3}(i,z) - w_{u2}(i,z) \right) \right] & \text{if type = "turbine"} \end{cases} \\
q_{y_{\text{stator}}}(i,z) &= -\frac{2\pi z}{Z_{\text{stator}_i}} \cdot \begin{cases} \left[\rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(c_{u3}(i,z) - c_{u2}(i,z) \right) \right] & \text{if type = "compressor"} \\ \left[\rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(c_{u2}(i,z) - c_{u1}(i,z) \right) \right] & \text{if type = "turbine"} \end{cases} \\
M_{x_{\text{rotor}}}(i,z) &= -\int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,1),N_r},R_{\text{st}(i,2),N_r}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,2),N_r},R_{\text{st}(i,3),N_r}\right) & \text{if type="turbine"} \end{cases} q_{y_{\text{rotor}}}(i,z1) \cdot (z1 - z) dz1 \\
M_{x_{\text{stator}}}(i,z) &= \int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,2),1},R_{\text{st}(i,3),1}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,1),1},R_{\text{st}(i,2),1}\right) & \text{if type="turbine"} \end{cases} q_{y_{\text{stator}}}(i,z1) \cdot (z1 - z) dz1 \\
M_{y_{\text{rotor}}}(i,z) &= \int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,1),N_r},R_{\text{st}(i,2),N_r}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,2),N_r},R_{\text{st}(i,3),N_r}\right) & \text{if type="turbine"} \end{cases} q_{x_{\text{rotor}}}(i,z1) \cdot (z1 - z) dz1 \\
M_{y_{\text{stator}}}(i,z) &= -\int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,2),1},R_{\text{st}(i,3),1}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,1),1},R_{\text{st}(i,2),1}\right) & \text{if type="turbine"} \end{cases} q_{x_{\text{stator}}}(i,z1) \cdot (z1 - z) dz1 \\
\int_z^z & \begin{cases} \text{mean}\left(R_{\text{st}(i,1),N_r},R_{\text{st}(i,2),N_r}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,2),N_r},R_{\text{st}(i,3),N_r}\right) & \text{if type="turbine"} \end{cases} q_{x_{\text{rotor}}}(i,z) dz
\end{aligned}$$

[illegible]

$$\begin{aligned}
W_{p_{\text{rotor.}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{rotor.}}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{rotor.}}}, i, i, 1, N_r\right)^T, z\right) \\
W_{p_{\text{stator.}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{stator.}}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{stator.}}}, i, i, 1, N_r\right)^T, z\right) \\
M\tau_{\text{rotor}}(i,z) &= \int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,1), N_r}, R_{\text{st}(i,2), N_r}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,2), N_r}, R_{\text{st}(i,3), N_r}\right) & \text{if type="turbine"} \end{cases} \left(q_{x_{\text{rotor}}}(i,z1) \cdot CP_{y_{\text{rotor.axis}}}(i,z1) - q_{y_{\text{rotor}}}(i,z1) \cdot CP_{x_{\text{rotor.axis}}}(i,z1)\right) dz1 \\
M\tau_{\text{stator}}(i,z) &= \int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,2), 1}, R_{\text{st}(i,3), 1}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,1), 1}, R_{\text{st}(i,2), 1}\right) & \text{if type="turbine"} \end{cases} \left(q_{x_{\text{stator}}}(i,z1) \cdot CP_{y_{\text{stator.axis}}}(i,z1) - q_{y_{\text{stator}}}(i,z1) \cdot CP_{x_{\text{stator.axis}}}(i,z1)\right) dz1 \\
\tau_{\text{rotor}}(i,z) &= \frac{M\tau_{\text{rotor}}(i,z)}{W_{p_{\text{rotor.}}}(i,z)} \\
\tau_{\text{stator}}(i,z) &= \frac{M\tau_{\text{stator}}(i,z)}{W_{p_{\text{stator.}}}(i,z)} \\
\varphi_{uv_{\text{rotor}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{rotor}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{rotor}}, i, i, 1, N_r\right)^T, z\right) \\
\varphi_{uv_{\text{stator}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{stator}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{stator}}, i, i, 1, N_r\right)^T, z\right) \\
Mu_{\text{rotor}}(i,z) &= \text{axis}_x\left(Mx_{\text{rotor}}(i,z), My_{\text{rotor}}(i,z), 0, 0, \varphi_{uv_{\text{rotor}}}(i,z), 1\right) \\
Mu_{\text{stator}}(i,z) &= \text{axis}_x\left(Mx_{\text{stator}}(i,z), My_{\text{stator}}(i,z), 0, 0, \varphi_{uv_{\text{stator}}}(i,z), 1\right) \\
Mv_{\text{rotor}}(i,z) &= \text{axis}_y\left(Mx_{\text{rotor}}(i,z), My_{\text{rotor}}(i,z), 0, 0, \varphi_{uv_{\text{rotor}}}(i,z), 1\right) \\
Mv_{\text{stator}}(i,z) &= \text{axis}_y\left(Mx_{\text{stator}}(i,z), My_{\text{stator}}(i,z), 0, 0, \varphi_{uv_{\text{stator}}}(i,z), 1\right) \\
\varphi_{\text{neutral}_{\text{rotor}}}(i,z) &= \begin{cases} \text{atan}\left(\frac{Mv_{\text{rotor}}(i,z) \cdot Ju_{\text{rotor.}}(i,z)}{Mu_{\text{rotor}}(i,z) \cdot Jv_{\text{rotor.}}(i,z)}\right) & \text{if } Mu_{\text{rotor}}(i,z) \cdot Jv_{\text{rotor.}}(i,z) \neq 0 \\ \frac{\pi}{2} & \text{otherwise} \end{cases} \\
\varphi_{\text{neutral}_{\text{stator}}}(i,z) &= \begin{cases} \text{atan}\left(\frac{Mv_{\text{stator}}(i,z) \cdot Ju_{\text{stator.}}(i,z)}{Mu_{\text{stator}}(i,z) \cdot Jv_{\text{stator.}}(i,z)}\right) & \text{if } Mu_{\text{stator}}(i,z) \cdot Jv_{\text{stator.}}(i,z) \neq 0 \\ \frac{\pi}{2} & \text{otherwise} \end{cases} \\
\left(\begin{array}{cc} R0_{\text{rotor}} & \text{area}0_{\text{rotor}} \\ N0_{\text{rotor}} & \sigma0_z_{\text{rotor}} \\ \text{area}_{\text{rotor.}} & \text{area}_{\text{stator.}} \\ N_{\text{rotor}} & \sigma_Z_{\text{rotor}} \end{array} \right)
\end{aligned}$$

P_1	ρ_1
P_2	ρ_2
P_3	ρ_3
c_{a1}	c_{u1}
c_{a2}	c_{u2}
c_{a3}	c_{u3}
$q_{x_{rotor}}$	$q_{x_{stator}}$
$q_{y_{rotor}}$	$q_{y_{stator}}$
$M_{x_{rotor}}$	$M_{x_{stator}}$
$M_{y_{rotor}}$	$M_{y_{stator}}$
$shift_x_{rotor}$	$shift_y_{rotor}$
$x0_{rotor.}$	$x0_{stator.}$
$y0_{rotor.}$	$y0_{stator.}$
$\alpha_major_{rotor.}$	$\alpha_major_{stator.}$
$J_{u_{rotor.}}$	$J_{u_{stator.}}$
$J_{v_{rotor.}}$	$J_{v_{stator.}}$
$CP_{x_{rotor.}}$	$CP_{x_{stator.}}$
$CP_{y_{rotor.}}$	$CP_{y_{stator.}}$
$CP_{x_{rotor.axis}}$	$CP_{x_{stator.axis}}$
$CP_{y_{rotor.axis}}$	$CP_{y_{stator.axis}}$
$W_{p_{rotor.}}$	$W_{p_{stator.}}$
$M\tau_{rotor}$	$M\tau_{stator}$
τ_{rotor}	τ_{stator}
$\varphi_{uv_{rotor}}$	$\varphi_{uv_{stator}}$
M_u_{rotor}	M_u_{stator}
M_v_{rotor}	M_v_{stator}
$\varphi_neutral_{rotor}$	$\varphi_neutral_{stator}$

$$\text{neutral_line}(\text{type},\text{x},\text{i},\text{r}) = \left\{ \begin{array}{l} \frac{y0_{\text{rotor}_{\text{i},\text{r}}}}{\text{chord}_{\text{rotor}_{\text{i},\text{r}}}} + \tan\left(\left(\alpha_{\text{major}_{\text{rotor}_{\text{i},\text{r}}}} + \varphi_{\text{neutral}_{\text{rotor}}}\left(\text{i},\text{Rst}(\text{i},2),\text{r}\right)\right)\right) \cdot \left(\text{x} - \frac{x0_{\text{rotor}_{\text{i},\text{r}}}}{\text{chord}_{\text{rotor}_{\text{i},\text{r}}}}\right) \text{ if type = "rotor"} \\ \\ \frac{y0_{\text{stator}_{\text{i},\text{r}}}}{\text{chord}_{\text{stator}_{\text{i},\text{r}}}} + \tan\left(\left(\alpha_{\text{major}_{\text{stator}_{\text{i},\text{r}}}} + \varphi_{\text{neutral}_{\text{stator}}}\left(\text{i},\text{Rst}(\text{i},2),\text{r}\right)\right)\right) \cdot \left(\text{x} - \frac{x0_{\text{stator}_{\text{i},\text{r}}}}{\text{chord}_{\text{stator}_{\text{i},\text{r}}}}\right) \text{ if type = "stator"} \end{array} \right.$$

$$\text{epure}(\text{type},\text{x},\text{i},\text{r}) = \left\{ \begin{array}{l} \frac{y0_{\text{rotor}_{\text{i},\text{r}}}}{\text{chord}_{\text{rotor}_{\text{i},\text{r}}}} + \frac{-1}{\tan\left(\alpha_{\text{major}_{\text{rotor}_{\text{i},\text{r}}}} + \varphi_{\text{neutral}_{\text{rotor}}}\left(\text{i},\text{Rst}(\text{i},2),\text{r}\right) - \frac{\pi}{4}\right)} \cdot \left(\text{x} - \frac{x0_{\text{rotor}_{\text{i},\text{r}}}}{\text{chord}_{\text{rotor}_{\text{i},\text{r}}}}\right) \text{ if type = "rotor"} \\ \\ \frac{y0_{\text{stator}_{\text{i},\text{r}}}}{\text{chord}_{\text{stator}_{\text{i},\text{r}}}} + \frac{-1}{\tan\left(\alpha_{\text{major}_{\text{stator}_{\text{i},\text{r}}}} + \varphi_{\text{neutral}_{\text{stator}}}\left(\text{i},\text{Rst}(\text{i},2),\text{r}\right) - \frac{\pi}{4}\right)} \cdot \left(\text{x} - \frac{x0_{\text{stator}_{\text{i},\text{r}}}}{\text{chord}_{\text{stator}_{\text{i},\text{r}}}}\right) \text{ if type = "stator"} \end{array} \right.$$

Наиболее удаленные точки от НЛ (мм):

$u_{\text{u}_{\text{rotor}}}^T =$

	1	2	3	4	5	6	7	8	9
1	-1.888	-10.435	-8.761						
2	-0.829	-0.813	-0.818						
3	-0.658	-0.124	-0.126						

$u_{\text{l}_{\text{rotor}}}^T =$

	1	2	3	4	5	6	7	8	9
1	33.995	32.065	32.633						
2	39.513	39.485	39.495						
3	-0.901	44.262	44.265						

$\cdot 10^{-3}$

$u_{\text{u}_{\text{stator}}}^T =$

	1	2	3	4	5	6	7	8	9
1	-0.048	-0.031	0.314						
2	-0.436	-0.014	-0.026						
3	-0.464	-0.412	-0.430						

$\cdot 10^{-3}$

$u_{\text{l}_{\text{stator}}}^T =$

	1	2	3	4	5	6	7	8	9
1	19.302	19.261	19.278						
2	21.367	21.311	21.331						
3	-14.041	23.088	23.114						

$\cdot 10^{-3} v_{\text{u}_{\text{rotor}}}^T =$

	1	2	3
1	3.091	5.012	4.562
2	1.420	1.754	1.667
3	36.463	1.193	1.131

$\cdot 10^{-3}$

$v_{\text{l}_{\text{rotor}}}^T =$

	1	2	3	4	5	6	7	8	9
1	-2.853	-12.645	-11.080						
2	-1.407	-2.843	-2.453						
3	-44.269	-1.572	-1.317						

$\cdot 10^{-3}$

$v_{\text{u}_{\text{stator}}}^T =$

	1	2	3	4	5	6	7	8	9
1	0.872	1.159	1.080						
2	1.549	1.891	1.824						
3	2.307	2.694	2.631						

$\cdot 10^{-3}$

$\cdot 10^{-3} v_{\text{l}_{\text{stator}}}^T =$

	1	2	3	4	5	6	7	8	9
1	-1.370	-2.599	-2.226						
2	-1.531	-3.031	-2.686						
3	-1.896	-3.403	-3.046						

$\cdot 10^{-3}$

$$\begin{pmatrix} \sigma_{\text{p_rotor}} & \sigma_{\text{n_rotor}} \\ \sigma_{\text{p_stator}} & \sigma_{\text{n_stator}} \end{pmatrix} = \begin{array}{l} \text{for } i \in 1..Z \\ \text{for } r \in 1..N_r \\ \begin{pmatrix} \sigma_{\text{p_rotor}_{i,r}} & \sigma_{\text{n_rotor}_{i,r}} \\ \sigma_{\text{p_stator}_{i,r}} & \sigma_{\text{n_stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \frac{\text{Mu}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{rotor}_{i,r}}} \cdot \text{v_u}_{\text{rotor}_{i,r}} - \frac{\text{Mv}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{rotor}_{i,r}}} \cdot \text{u_u}_{\text{rotor}_{i,r}} & \frac{\text{Mu}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{rotor}_{i,r}}} \cdot \text{v_l}_{\text{rotor}_{i,r}} - \frac{\text{Mv}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{rotor}_{i,r}}} \cdot \text{u_l}_{\text{rotor}_{i,r}} \\ \frac{\text{Mu}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{stator}_{i,r}}} \cdot \text{v_u}_{\text{stator}_{i,r}} - \frac{\text{Mv}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{stator}_{i,r}}} \cdot \text{u_u}_{\text{stator}_{i,r}} & \frac{\text{Mu}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{stator}_{i,r}}} \cdot \text{v_l}_{\text{stator}_{i,r}} - \frac{\text{Mv}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{stator}_{i,r}}} \cdot \text{u_l}_{\text{stator}_{i,r}} \end{pmatrix} \end{array} \\ \begin{pmatrix} \sigma_{\text{p_rotor}} & \sigma_{\text{n_rotor}} \\ \sigma_{\text{p_stator}} & \sigma_{\text{n_stator}} \end{pmatrix} \end{pmatrix}$$

$$\begin{pmatrix} \sigma_{\text{p_rotor.}} & \sigma_{\text{p_stator.}} \\ \sigma_{\text{n_rotor.}} & \sigma_{\text{n_stator.}} \end{pmatrix} = \begin{array}{l} \text{for } i \in 1..Z \\ \begin{array}{l} \sigma_{\text{p_rotor.}}(i, z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{p_rotor}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{p_rotor}}, i, i, 1, N_r\right)^T, z\right) \\ \sigma_{\text{p_stator.}}(i, z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{p_stator}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{p_stator}}, i, i, 1, N_r\right)^T, z\right) \\ \sigma_{\text{n_rotor.}}(i, z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{n_rotor}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{n_rotor}}, i, i, 1, N_r\right)^T, z\right) \\ \sigma_{\text{n_stator.}}(i, z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{n_stator}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(\text{R}, \text{st}(i, 1), \text{st}(i, 1), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{n_stator}}, i, i, 1, N_r\right)^T, z\right) \end{array} \end{array} \\ \begin{pmatrix} \sigma_{\text{p_rotor.}} & \sigma_{\text{p_stator.}} \\ \sigma_{\text{n_rotor.}} & \sigma_{\text{n_stator.}} \end{pmatrix} \end{pmatrix}$$

$\sigma_{\text{p_rotor}}^T =$

	1	2	3	4	5	6	7	8	9
1	-35.55	-2.18	-1.74						
2	-44.51	-7.98	-7.67						
3	0.00	-0.14	-0.39						

 $\cdot 10^6$

$\sigma_{\text{p_rotor}}^T \leq 70 \cdot 10^6 =$

	1	2	3
1	1	1	1
2	1	1	1
3	1	1	1

$\sigma_{\text{n_rotor}}^T =$

	1	2	3	4	5	6	7	8	9
1	38.12	5.84	4.72						
2	45.98	13.70	11.84						
3	0.00	0.19	0.46						

 $\cdot 10^6$

$\sigma_{\text{n_rotor}}^T \leq 70 \cdot 10^6 =$

	1	2	3
1	1	1	1
2	1	1	1
3	1	1	1

$\sigma_{\text{p_stator}}^T =$

	1	2	3	4	5	6	7	8	9
1	0.02	0.04	0.25						
2	38.44	2.31	4.02						
3	51.60	3.35	5.20						

 $\cdot 10^6$

$\sigma_{\text{p_stator}}^T \leq 70 \cdot 10^6 =$

	1	2	3
1	1	1	1
2	1	1	1
3	1	1	1

$\sigma_{\text{n_stator}}^T =$

	1	2	3	4	5	6	7	8	9
1	-0.03	-0.09	-0.53						
2	-38.36	-3.85	-6.05						
3	-41.88	-4.48	-6.22						

 $\cdot 10^6$

$\sigma_{\text{n_stator}}^T \leq 70 \cdot 10^6 =$

	1	2	3
1	1	1	1
2	1	1	1
3	1	1	1

$$\begin{pmatrix} \sigma_{\text{rotor}} \\ \sigma_{\text{stator}} \end{pmatrix} = \begin{cases} \text{for } i \in 1..Z \\ \text{for } r \in 1..N_r \\ \left| \begin{aligned} \sigma_{\text{rotor}_{i,r}} &= \sqrt{\left(\sigma_{-Z_{\text{rotor}}(i, R_{\text{st}}(i, 2), r)} + \max\left(\sigma_{-p_{\text{rotor}_{i,r}}}, \sigma_{-n_{\text{rotor}_{i,r}}}\right)\right)^2 + \tau_{\text{rotor}}(i, R_{\text{st}}(i, 2), r)^2} \\ \sigma_{\text{stator}_{i,r}} &= \sqrt{\left(0 + \max\left(\sigma_{-p_{\text{stator}_{i,r}}}, \sigma_{-n_{\text{stator}_{i,r}}}\right)\right)^2 + \tau_{\text{stator}}(i, R_{\text{st}}(i, 2), r)^2} \end{aligned} \right. \\ \begin{pmatrix} \sigma_{\text{rotor}} \\ \sigma_{\text{stator}} \end{pmatrix} \end{cases}$$

$$\begin{pmatrix} \sigma_{\text{rotor.}} \\ \sigma_{\text{stator.}} \end{pmatrix} = \begin{cases} \text{for } i \in 1..Z \\ \left| \begin{aligned} \sigma_{\text{rotor.}}(i, z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i, 2), \text{st}(i, 2), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{rotor}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i, 2), \text{st}(i, 2), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{rotor}}, i, i, 1, N_r\right)^T, z\right) \\ \sigma_{\text{stator.}}(i, z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i, 2), \text{st}(i, 2), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{stator}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i, 2), \text{st}(i, 2), 1, N_r\right)^T, \text{submatrix}\left(\sigma_{\text{stator}}, i, i, 1, N_r\right)^T, z\right) \end{aligned} \right. \\ \begin{pmatrix} \sigma_{\text{rotor.}} \\ \sigma_{\text{stator.}} \end{pmatrix} \end{cases}$$

$\sigma_{\text{rotor}}^T =$

	1	2	3	4	5	6	7	8	9
1	82.45	50.69	49.65						
2	79.36	49.31	49.03						
3	0.00	3.74	6.95						

$\cdot 10^6$

$\sigma_{\text{stator}}^T =$

	1	2	3	4	5	6	7	8	9
1	0.02	0.04	0.26						
2	38.44	2.31	4.02						
3	51.60	3.35	5.20						

$\cdot 10^6$

Рассматриваемая ступень:

$$j_w = \left\{ \begin{array}{l} j = \left\{ \begin{array}{l} 1 \text{ if type = "compressor"} \\ Z \text{ if type = "turbine"} \end{array} \right. = 1 \\ j = \left\{ \begin{array}{l} \text{"Такой ступени не существует!" if } (j < 1) \vee (j > Z) \\ j \text{ otherwise} \end{array} \right. \end{array} \right.$$

$$b_{lim} = \frac{ceil\left(\max\left(chord_{rotor_{j,N_r}}, chord_{stator_{j,N_r}}\right) \cdot 10^2\right)}{10^2} = 90 \cdot 10^{-3}$$

Расстояния от оси ЛМ до рассматриваемой ступени (м):

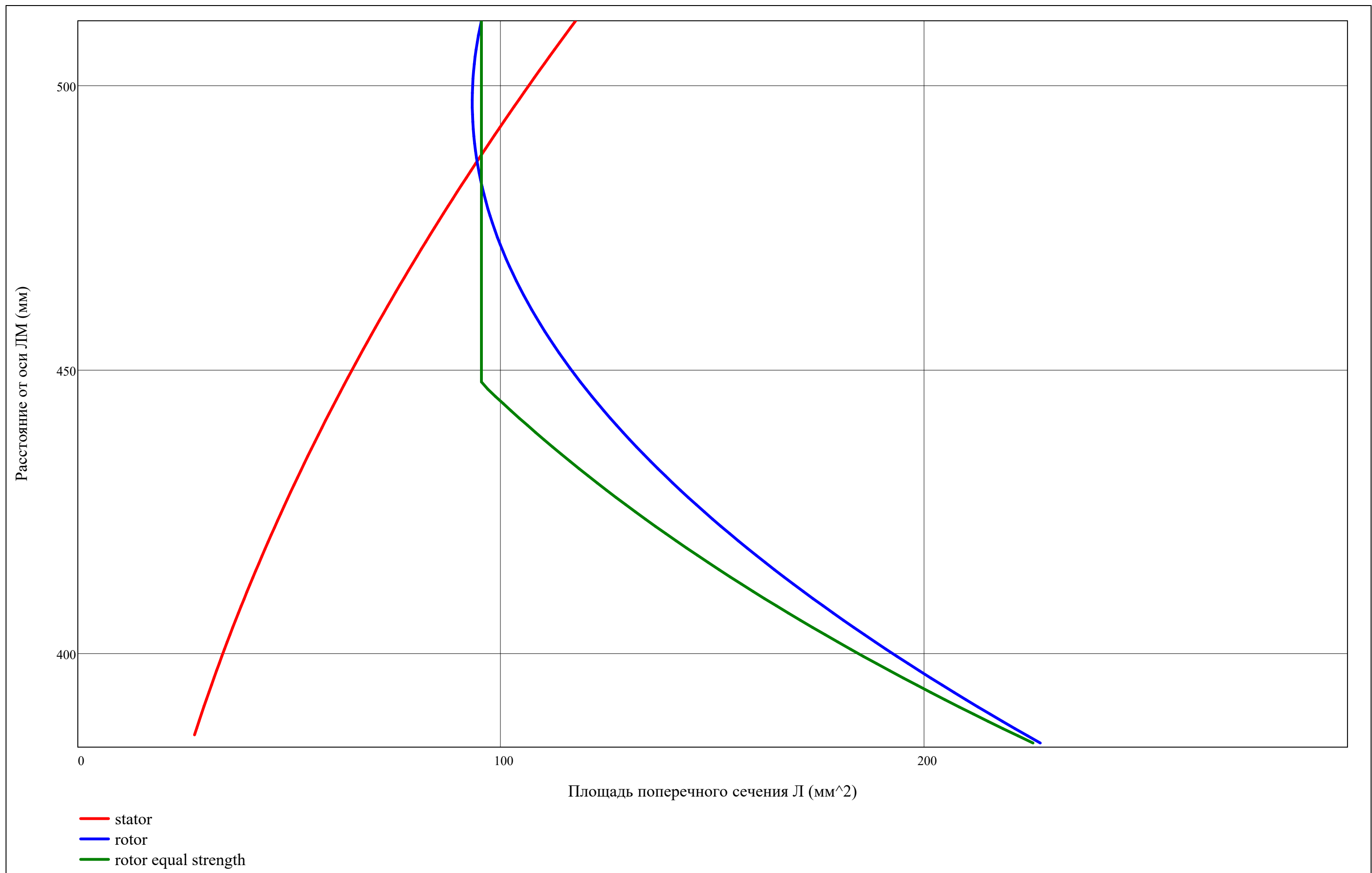
$$R_j = submatrix\left(R, 2 \cdot j - 1, 2 \cdot j + 1, 1, N_r\right) = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 383.4 & 452.0 & 511.4 \\ 2 & 384.9 & 452.6 & 511.4 \\ 3 & 386.3 & 453.2 & 511.4 \\ \hline \end{array} \cdot 10^{-3}$$

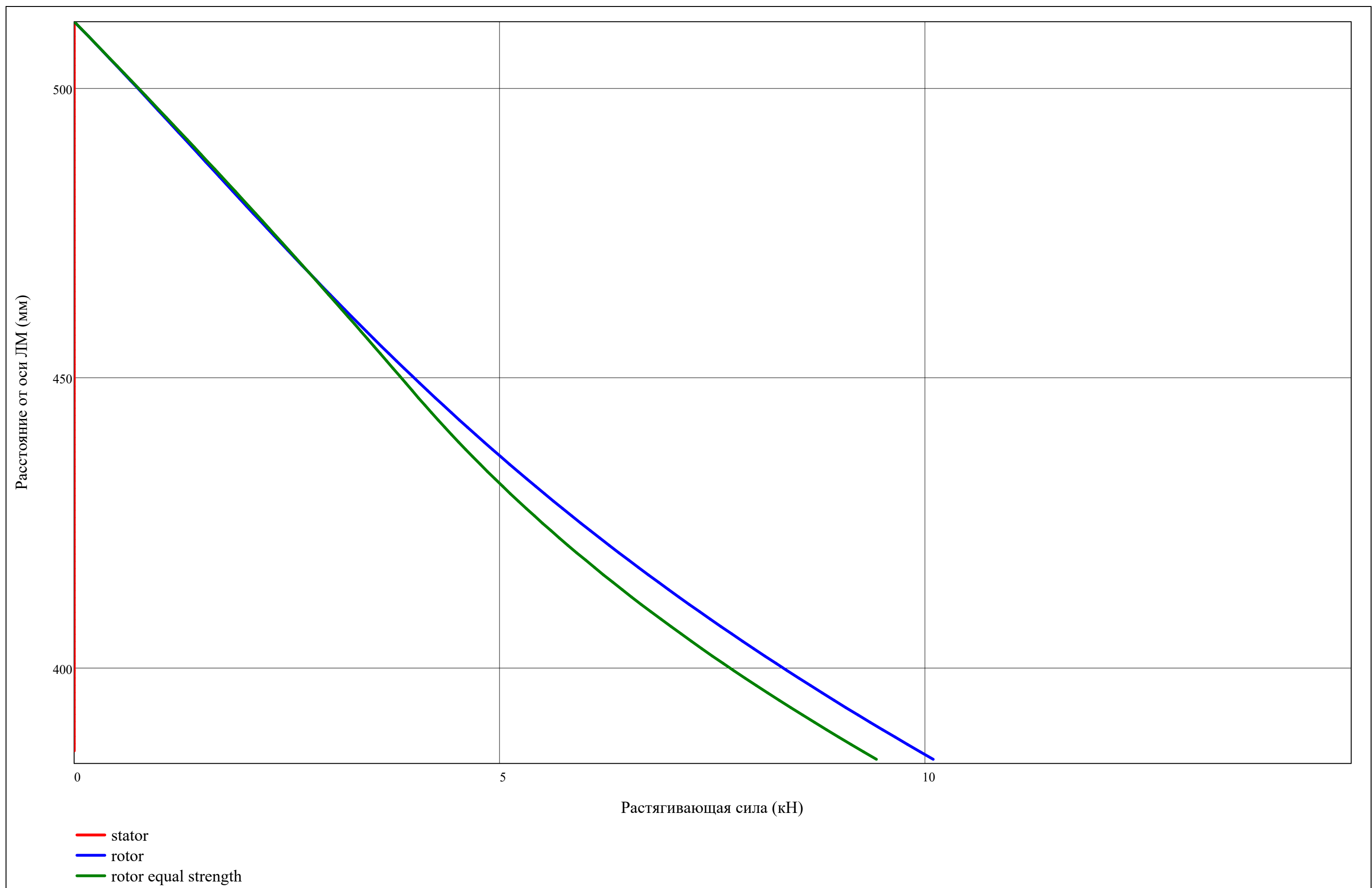
Дискретизация по высоте Л:

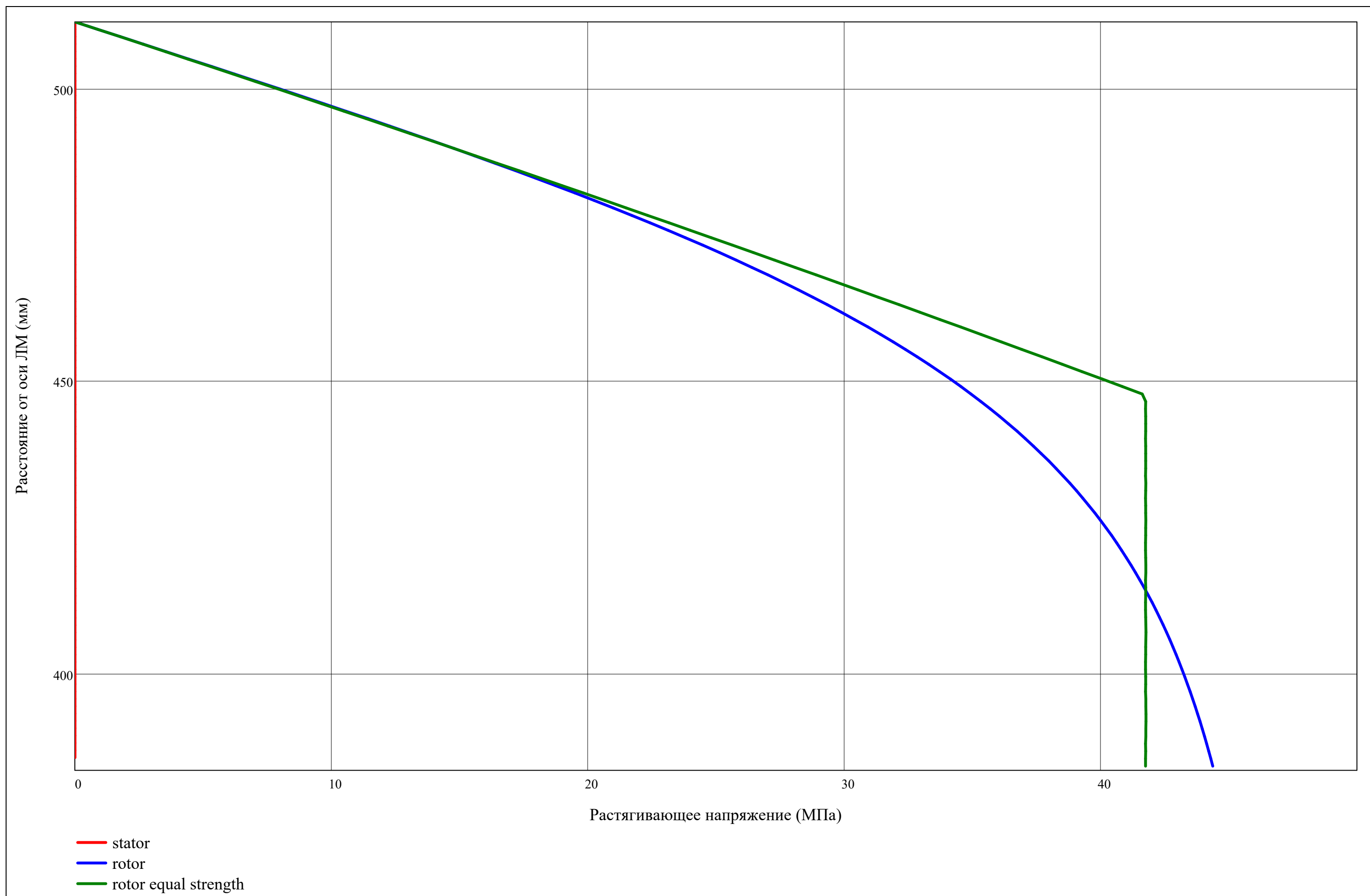
$$z = \min(R_j), \min(R_j) + \frac{\max(R_j) - \min(R_j)}{100} .. \max(R_j)$$

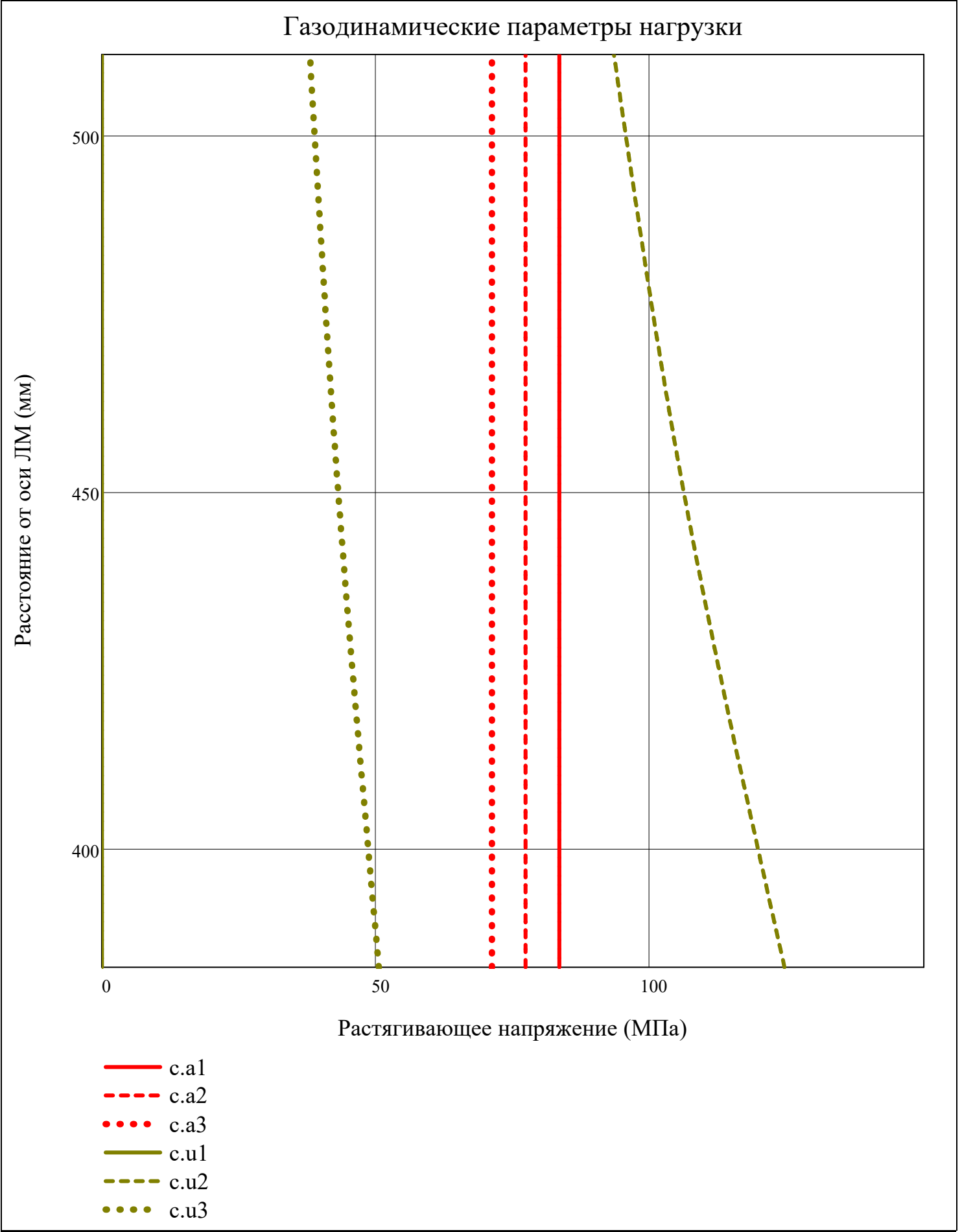
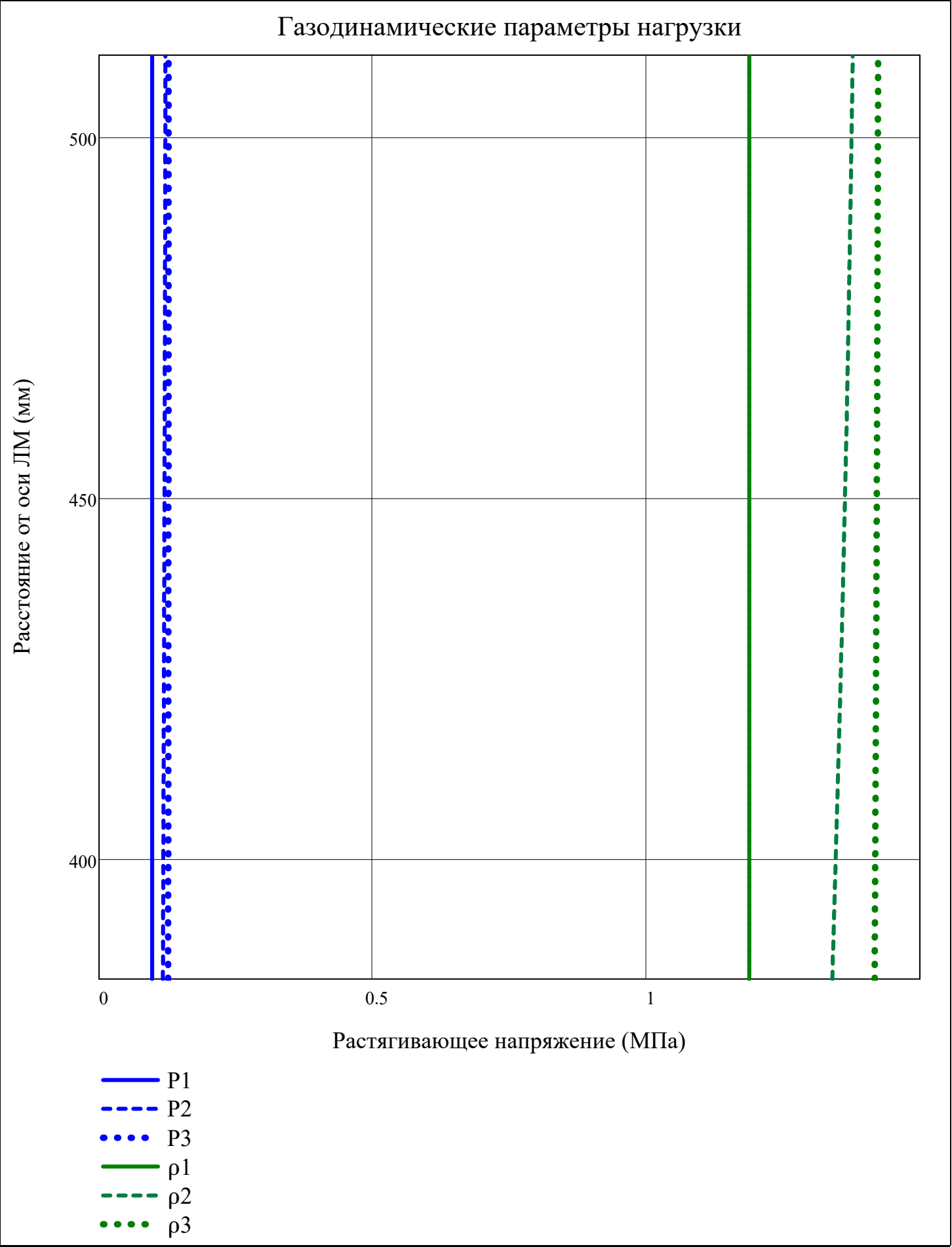
$$z_{rotor} = \left\{ \begin{array}{l} \text{mean}\left(R_{j1,1}, R_{j2,1}\right), \text{mean}\left(R_{j1,1}, R_{j2,1}\right) + \frac{\text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) - \text{mean}\left(R_{j1,1}, R_{j2,1}\right)}{100} .. \text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) \text{ if type = "compressor"} \\ \text{mean}\left(R_{j2,1}, R_{j3,1}\right), \text{mean}\left(R_{j2,1}, R_{j3,1}\right) + \frac{\text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) - \text{mean}\left(R_{j2,1}, R_{j3,1}\right)}{100} .. \text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) \text{ if type = "turbine"} \end{array} \right.$$

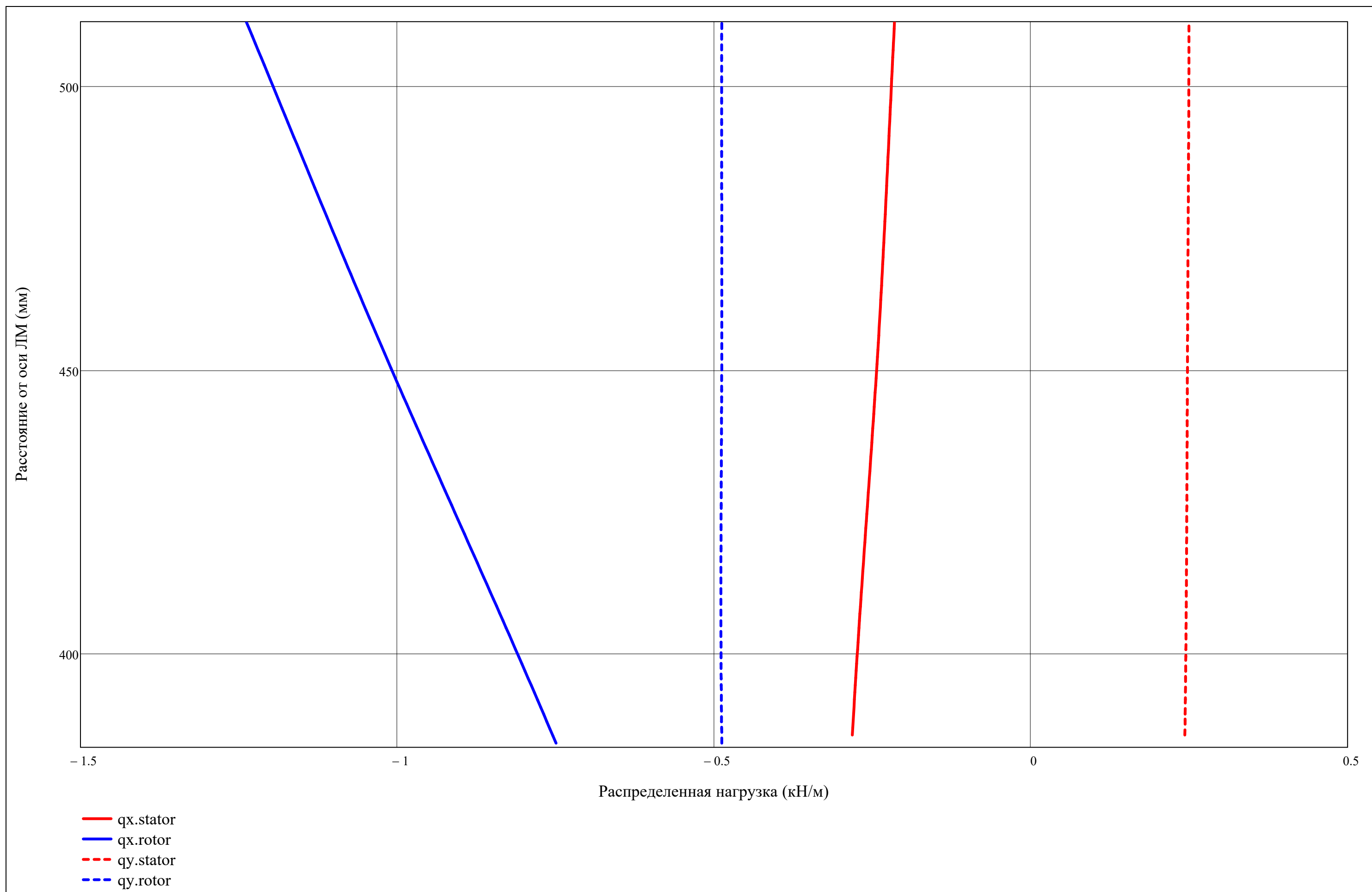
$$z_{stator} = \left\{ \begin{array}{l} \text{mean}\left(R_{j2,1}, R_{j3,1}\right), \text{mean}\left(R_{j2,1}, R_{j3,1}\right) + \frac{\text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) - \text{mean}\left(R_{j2,1}, R_{j3,1}\right)}{100} .. \text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) \text{ if type = "compressor"} \\ \text{mean}\left(R_{j1,1}, R_{j2,1}\right), \text{mean}\left(R_{j1,1}, R_{j2,1}\right) + \frac{\text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) - \text{mean}\left(R_{j1,1}, R_{j2,1}\right)}{100} .. \text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) \text{ if type = "turbine"} \end{array} \right.$$

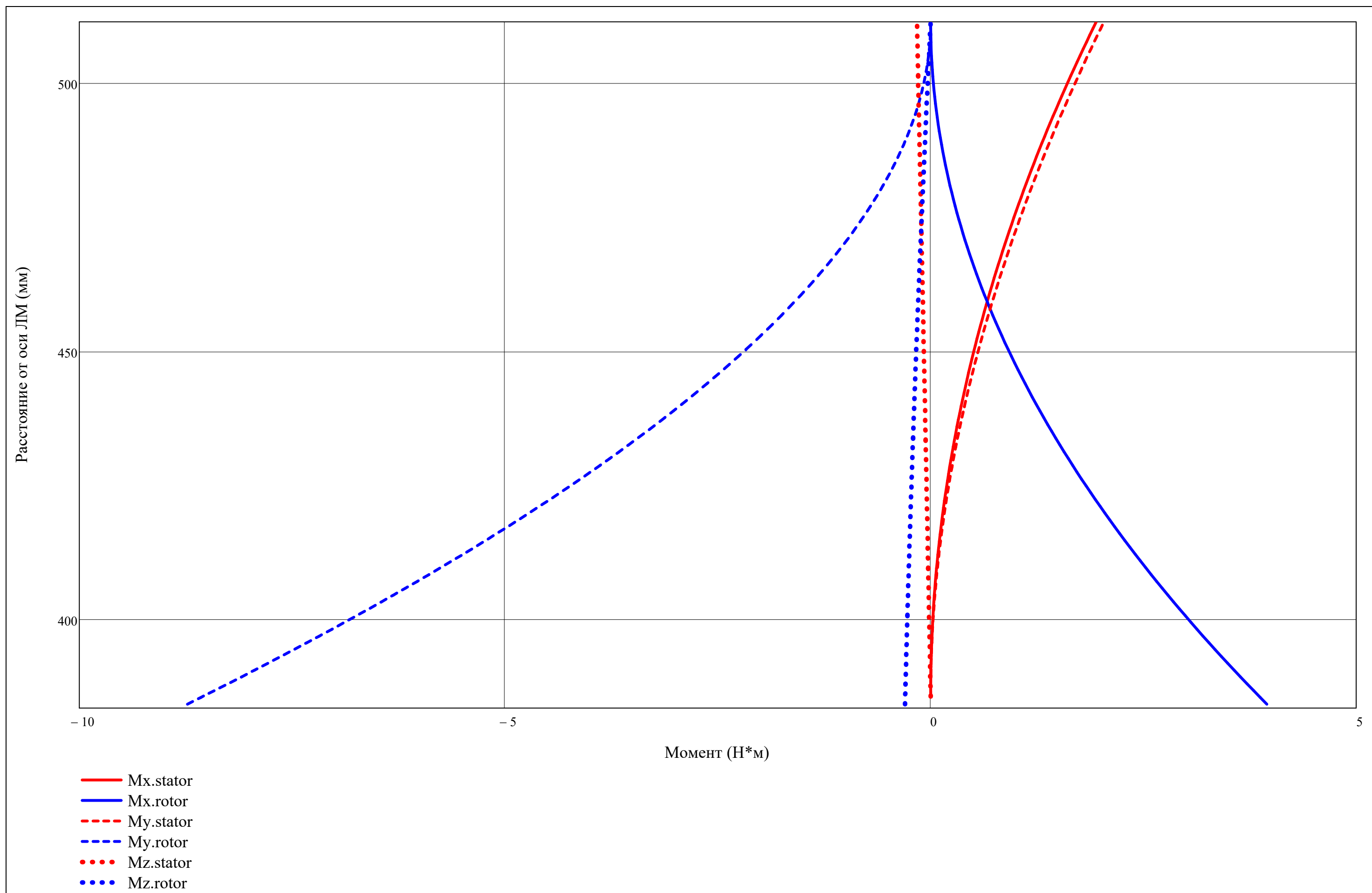


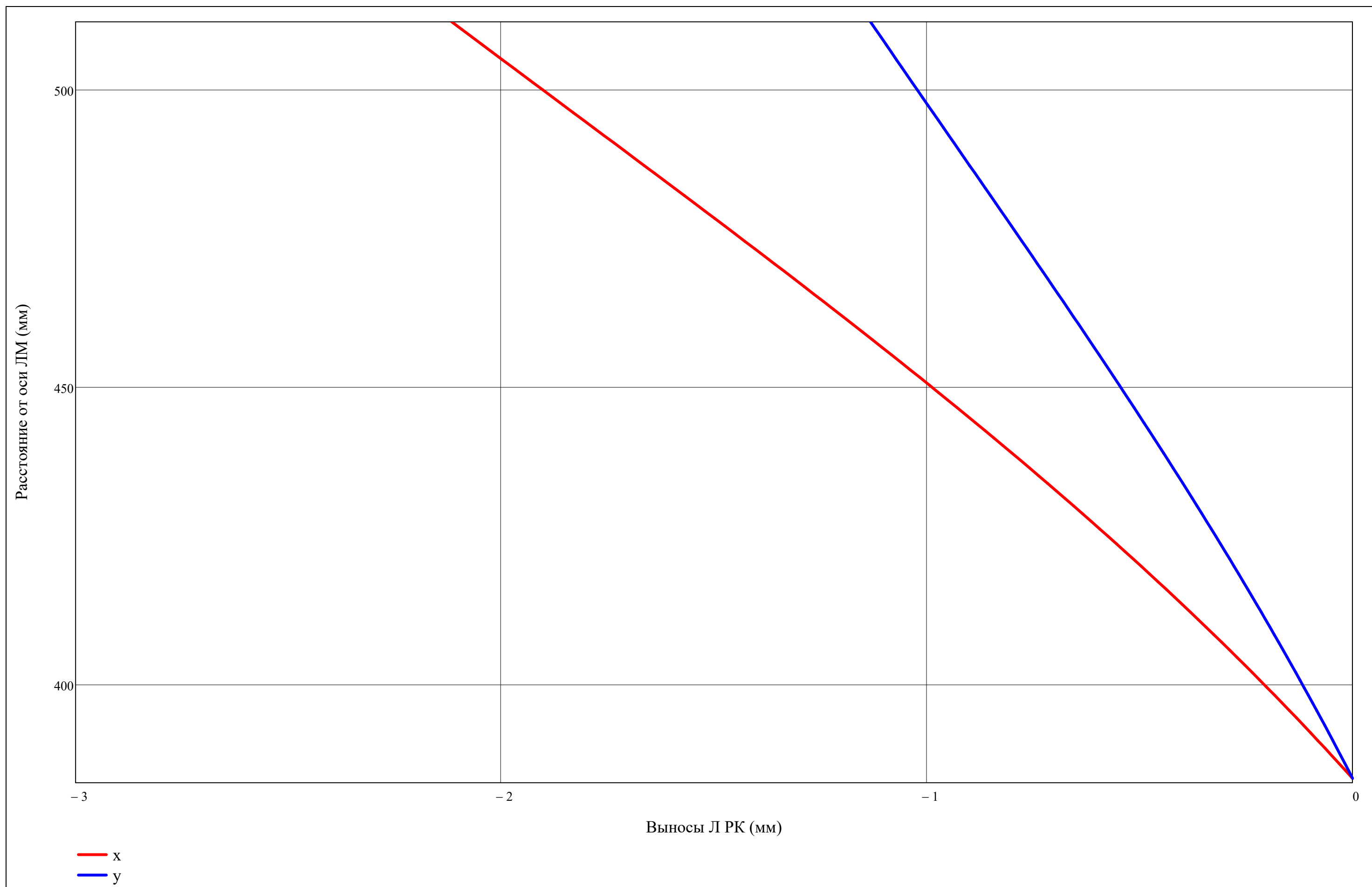


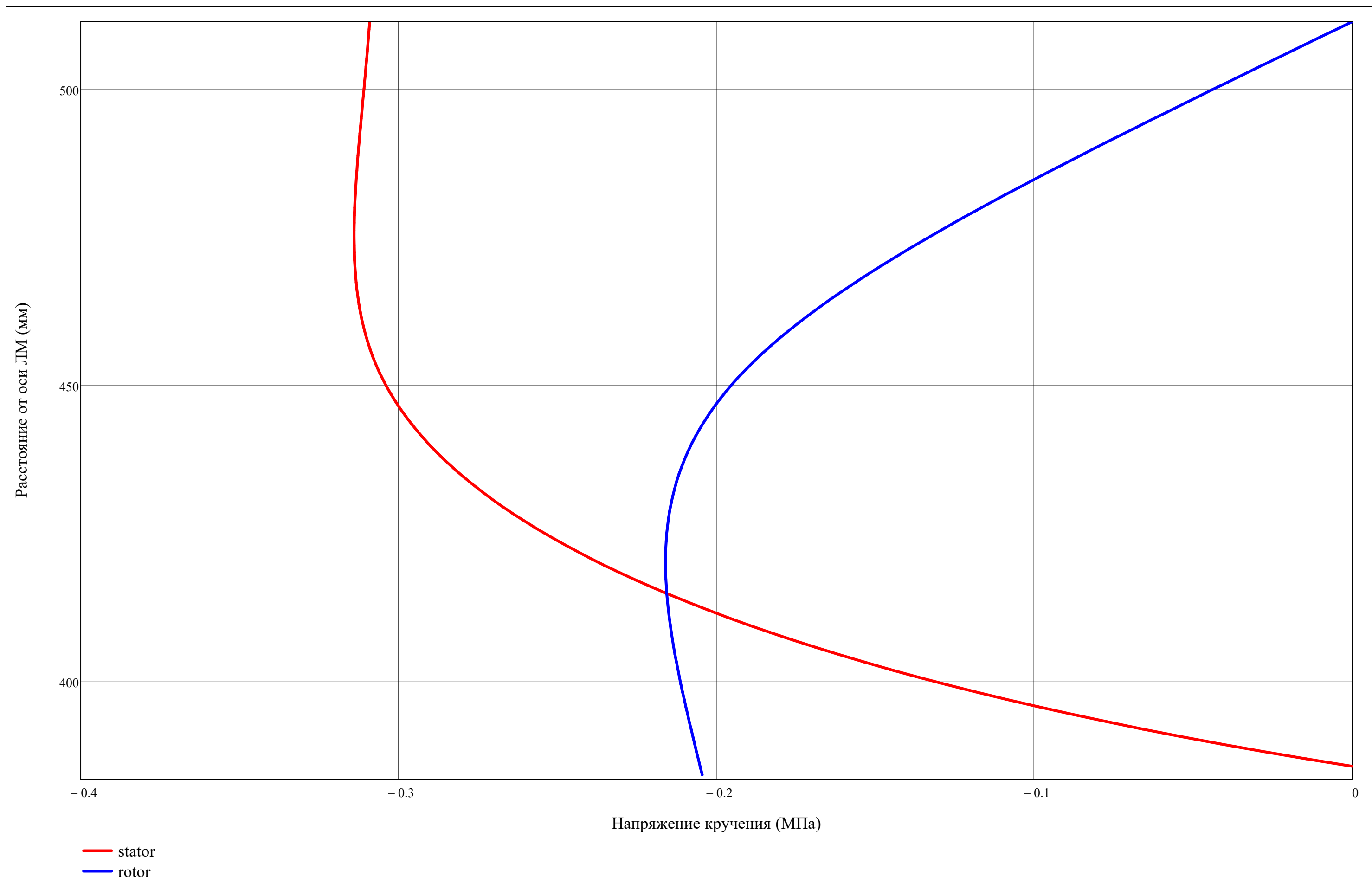


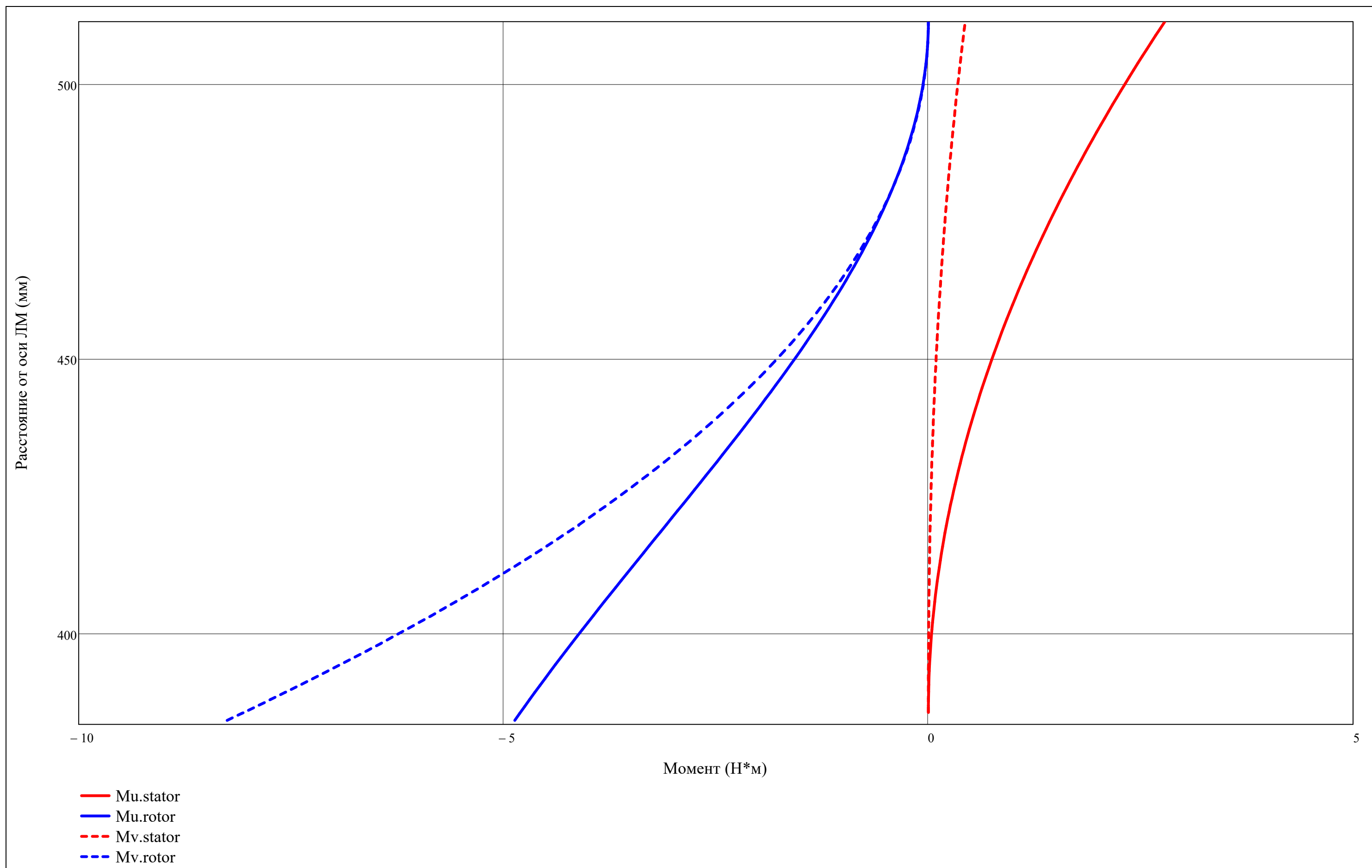


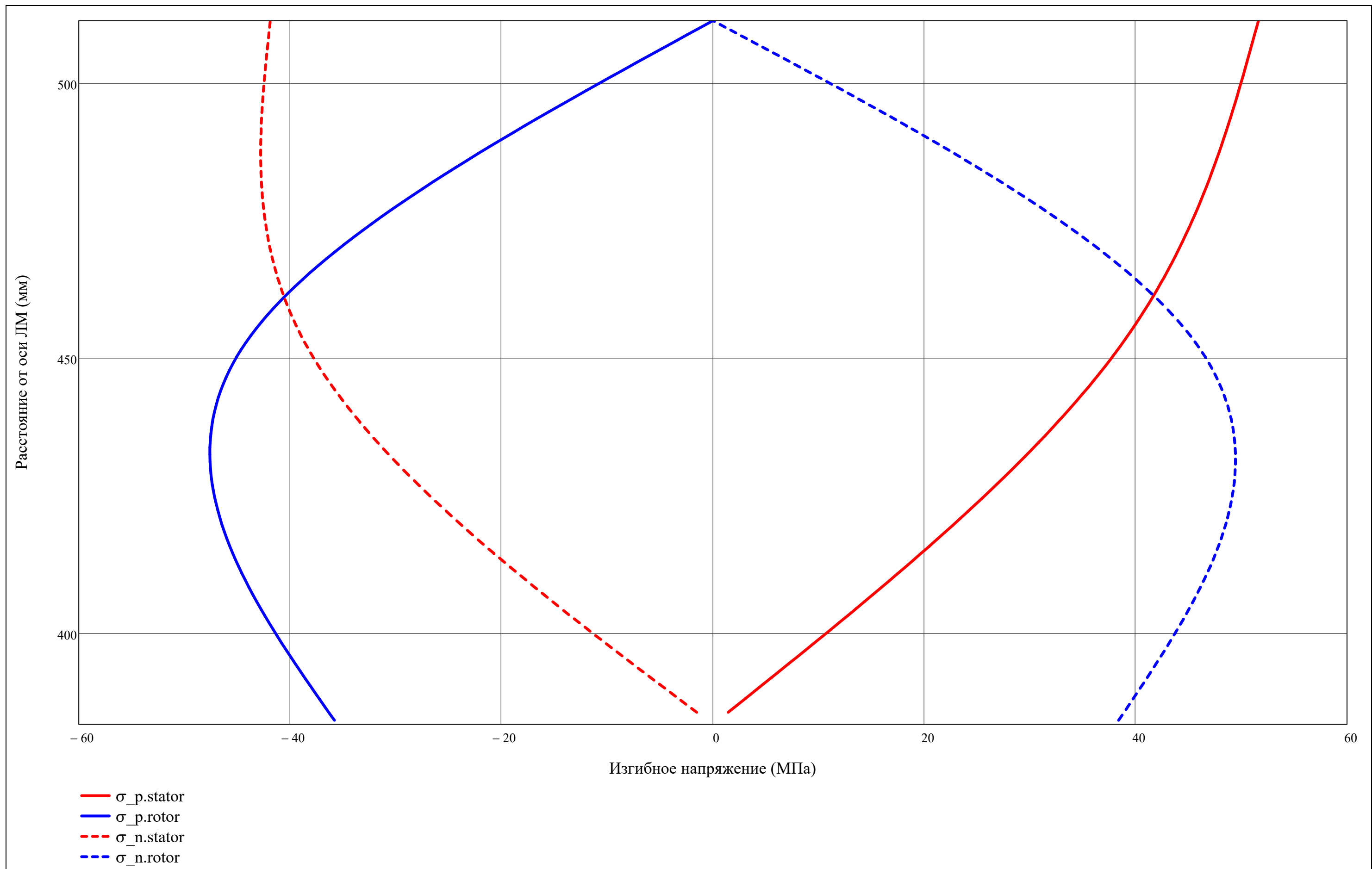


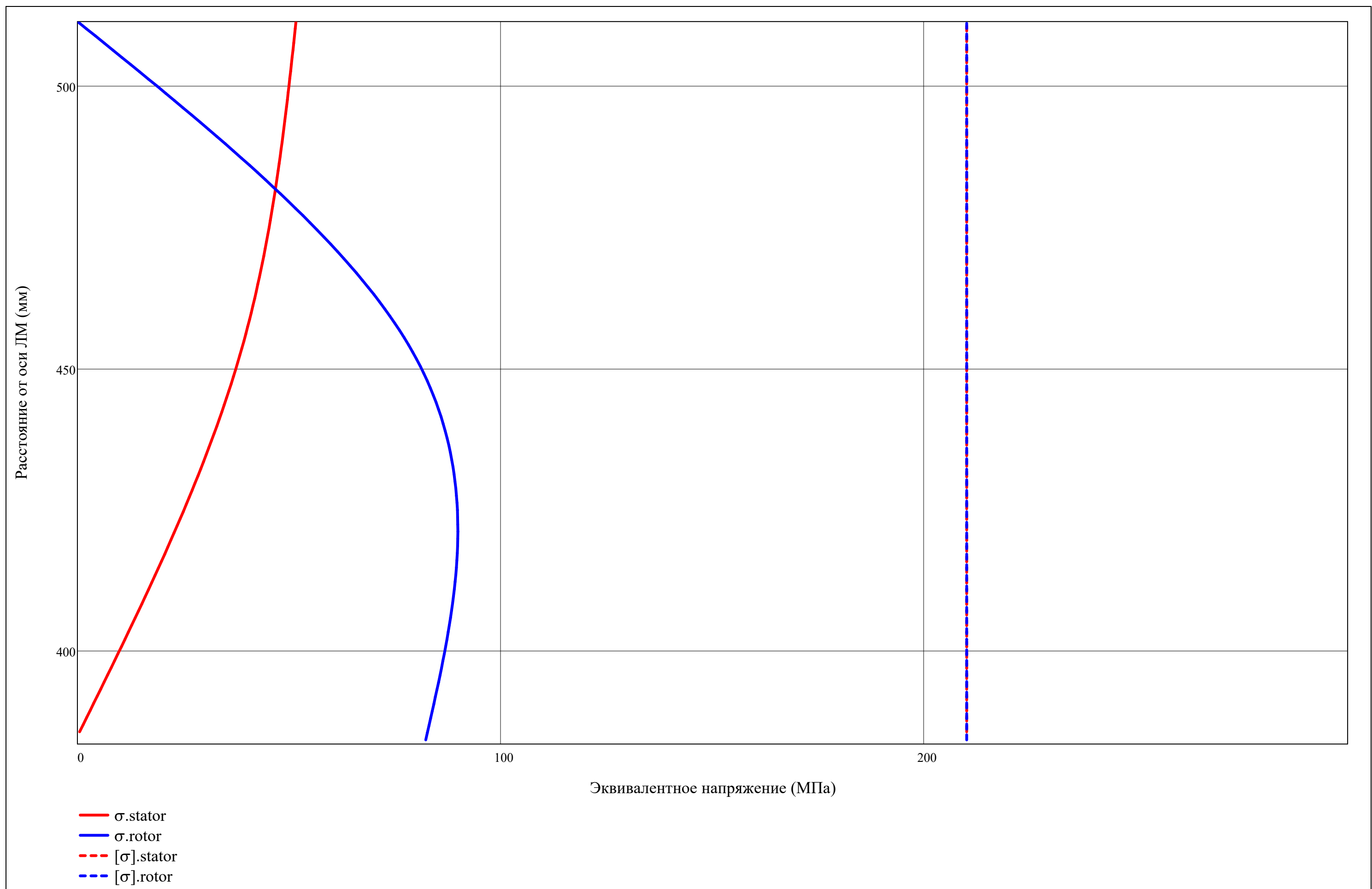












$$\begin{pmatrix} \text{blade} \\ \text{r} \end{pmatrix} = \begin{pmatrix} \text{"rotor"} \\ 1 \end{pmatrix}$$

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u_{u_{\text{rotor}_{j,r}}} & v_{u_{\text{rotor}_{j,r}}} \\ u_{l_{\text{rotor}_{j,r}}} & v_{l_{\text{rotor}_{j,r}}} \\ u_{u_{\text{stator}_{j,r}}} & v_{u_{\text{stator}_{j,r}}} \\ u_{l_{\text{stator}_{j,r}}} & v_{l_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{table}
	1	2
1	-1.89	3.09
2	33.99	-2.85
3	-0.05	0.87
4	19.30	-1.37

$$\text{Коэф. запаса: } \begin{pmatrix} \text{safety}_{\text{stator}_{j,r}} \\ \text{safety}_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{table}
	1
1	11543.032
2	2.547

$$\begin{pmatrix} v_p \\ v_n \end{pmatrix} = \begin{cases} \begin{pmatrix} v_{u_{\text{rotor}_{j,r}}} \\ v_{l_{\text{rotor}_{j,r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v_{u_{\text{stator}_{j,r}}} \\ v_{l_{\text{stator}_{j,r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{table}
	1
1	3.091
2	-2.853

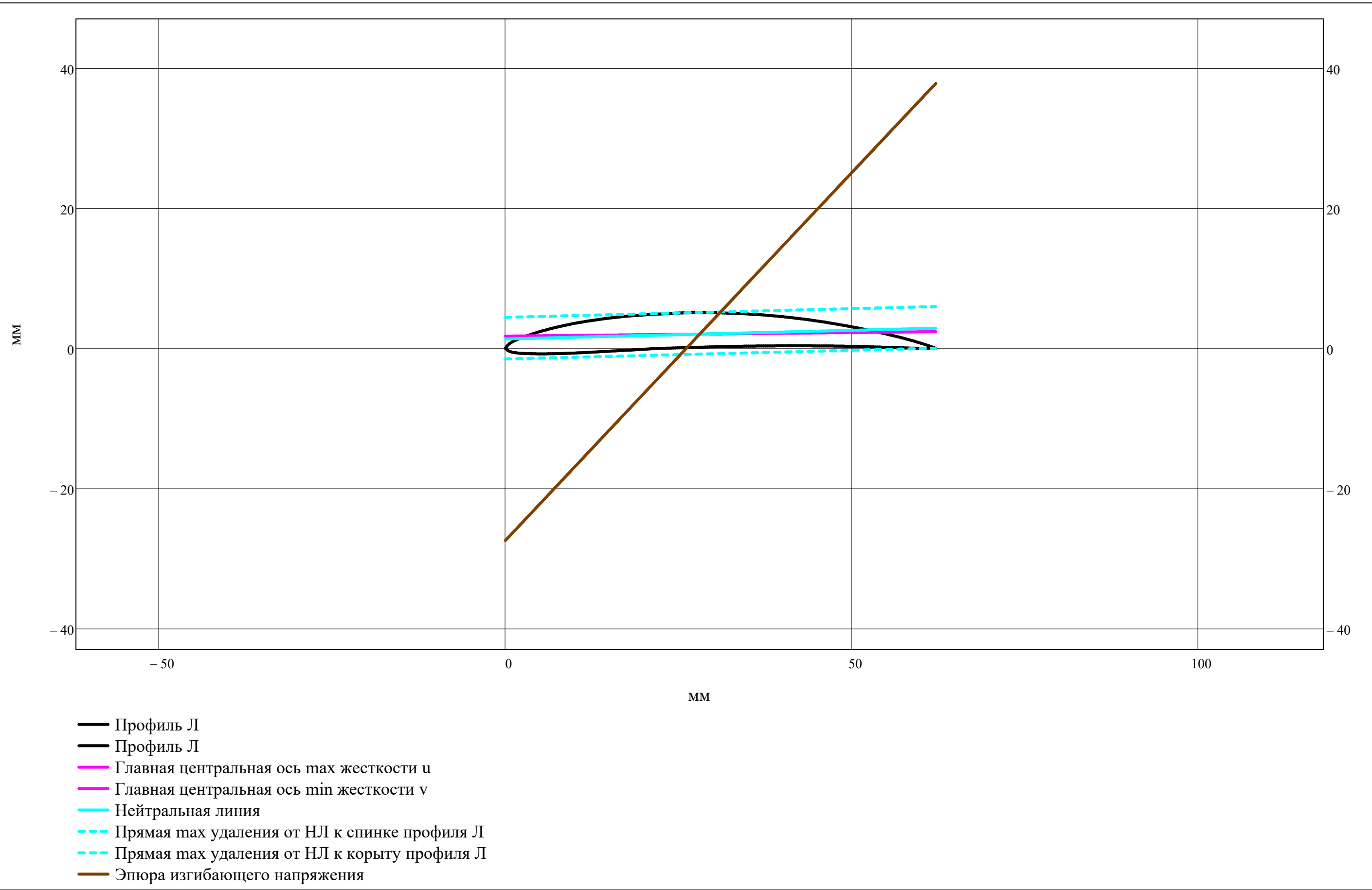
Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma_{p_{\text{rotor}_{j,r}}} & \sigma_{p_{\text{stator}_{j,r}}} \\ \sigma_{n_{\text{rotor}_{j,r}}} & \sigma_{n_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{pmatrix} -36 & 0 \\ 38 & -0 \end{pmatrix} \cdot 10^6$$

Эквивалентные напряжения (Па):

$$\begin{pmatrix} \sigma_{\text{stator}_{j,r}} \\ \sigma_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{pmatrix} 0 \\ 82 \end{pmatrix} \cdot 10^6$$

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \begin{cases} \begin{pmatrix} x0_{\text{rotor}_{j,r}} \\ y0_{\text{rotor}_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{\text{stator}_{j,r}} \\ y0_{\text{stator}_{j,r}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{table}
	1
1	28.047
2	2.012



$$\begin{pmatrix} \text{blade} \\ \text{r} \end{pmatrix} = \begin{pmatrix} \text{"rotor"} \\ 2 \end{pmatrix}$$

Наиболее удаленные точки от НЛ (мм):

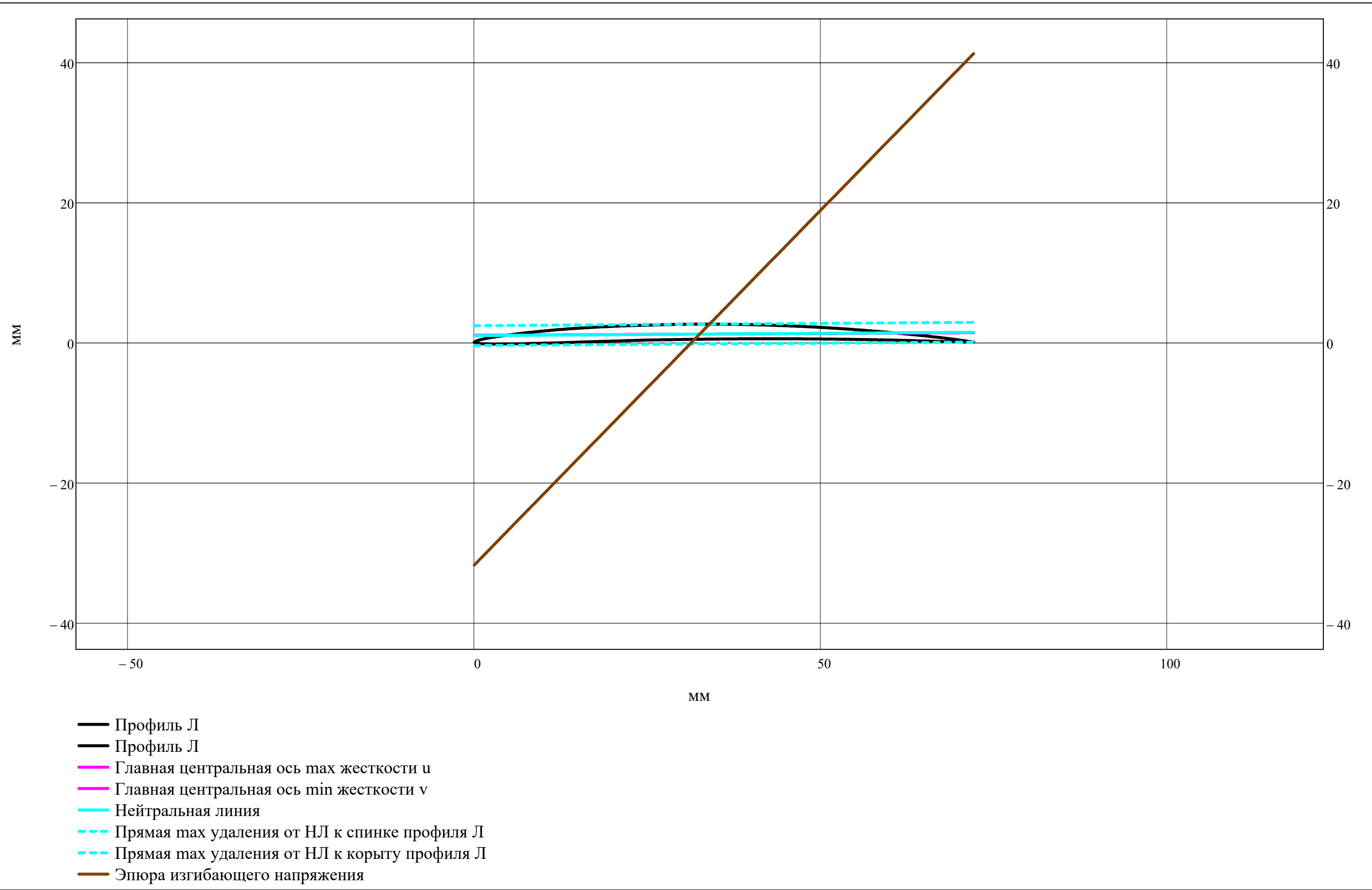
$$\begin{pmatrix} u_{u_{\text{rotor}_{j,r}}} & v_{u_{\text{rotor}_{j,r}}} \\ u_{l_{\text{rotor}_{j,r}}} & v_{l_{\text{rotor}_{j,r}}} \\ u_{u_{\text{stator}_{j,r}}} & v_{u_{\text{stator}_{j,r}}} \\ u_{l_{\text{stator}_{j,r}}} & v_{l_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{array}{|c|c|c|} \hline & 1 & 2 \\ \hline 1 & -0.83 & 1.42 \\ \hline 2 & 39.51 & -1.41 \\ \hline 3 & -0.44 & 1.55 \\ \hline 4 & 21.37 & -1.53 \\ \hline \end{array} \cdot 10^{-3}$$

$$\text{Коэф. запаса: } \begin{pmatrix} \text{safety}_{\text{stator}_{j,r}} \\ \text{safety}_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 5.462 \\ \hline 2 & 2.646 \\ \hline \end{array}$$

$$\begin{pmatrix} \text{v}_{\text{p}} \\ \text{v}_{\text{n}} \end{pmatrix} = \begin{cases} \begin{pmatrix} v_{u_{\text{rotor}_{j,r}}} \\ v_{l_{\text{rotor}_{j,r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v_{u_{\text{stator}_{j,r}}} \\ v_{l_{\text{stator}_{j,r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.420 \\ \hline 2 & -1.407 \\ \hline \end{array} \cdot 10^{-3}$$

$$\begin{pmatrix} \text{x0} \\ \text{y0} \end{pmatrix} = \begin{cases} \begin{pmatrix} x0_{\text{rotor}_{j,r}} \\ y0_{\text{rotor}_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{\text{stator}_{j,r}} \\ y0_{\text{stator}_{j,r}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 32.549 \\ \hline 2 & 1.147 \\ \hline \end{array} \cdot 10^{-3}$$

$$\text{chord} = \begin{cases} \text{chord}_{\text{rotor}_{j,r}} & \text{if blade = "rotor"} \\ \text{chord}_{\text{stator}_{j,r}} & \text{if blade = "stator"} \end{cases} = 72 \cdot 10^{-3}$$



$$\begin{pmatrix} \text{blade} \\ \text{r} \end{pmatrix} = \begin{pmatrix} \text{"stator"} \\ 2 \end{pmatrix}$$

Наиболее удаленные точки от НЛ (мм):

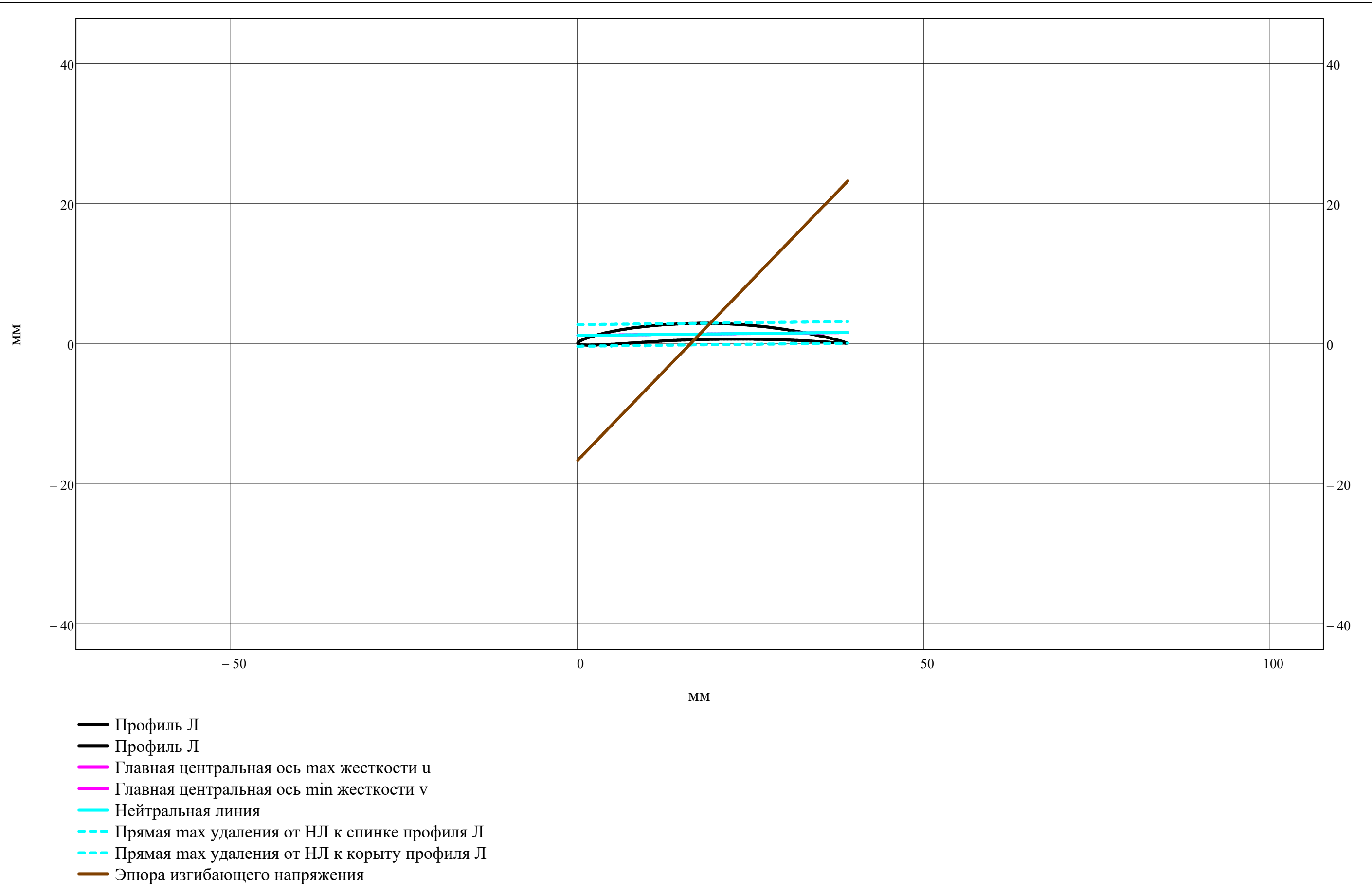
$$\begin{pmatrix} u_{u_{\text{rotor}_{j,r}}} & v_{u_{\text{rotor}_{j,r}}} \\ u_{l_{\text{rotor}_{j,r}}} & v_{l_{\text{rotor}_{j,r}}} \\ u_{u_{\text{stator}_{j,r}}} & v_{u_{\text{stator}_{j,r}}} \\ u_{l_{\text{stator}_{j,r}}} & v_{l_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{array}{|c|c|c|} \hline & 1 & 2 \\ \hline 1 & -0.83 & 1.42 \\ \hline 2 & 39.51 & -1.41 \\ \hline 3 & -0.44 & 1.55 \\ \hline 4 & 21.37 & -1.53 \\ \hline \end{array} \cdot 10^{-3}$$

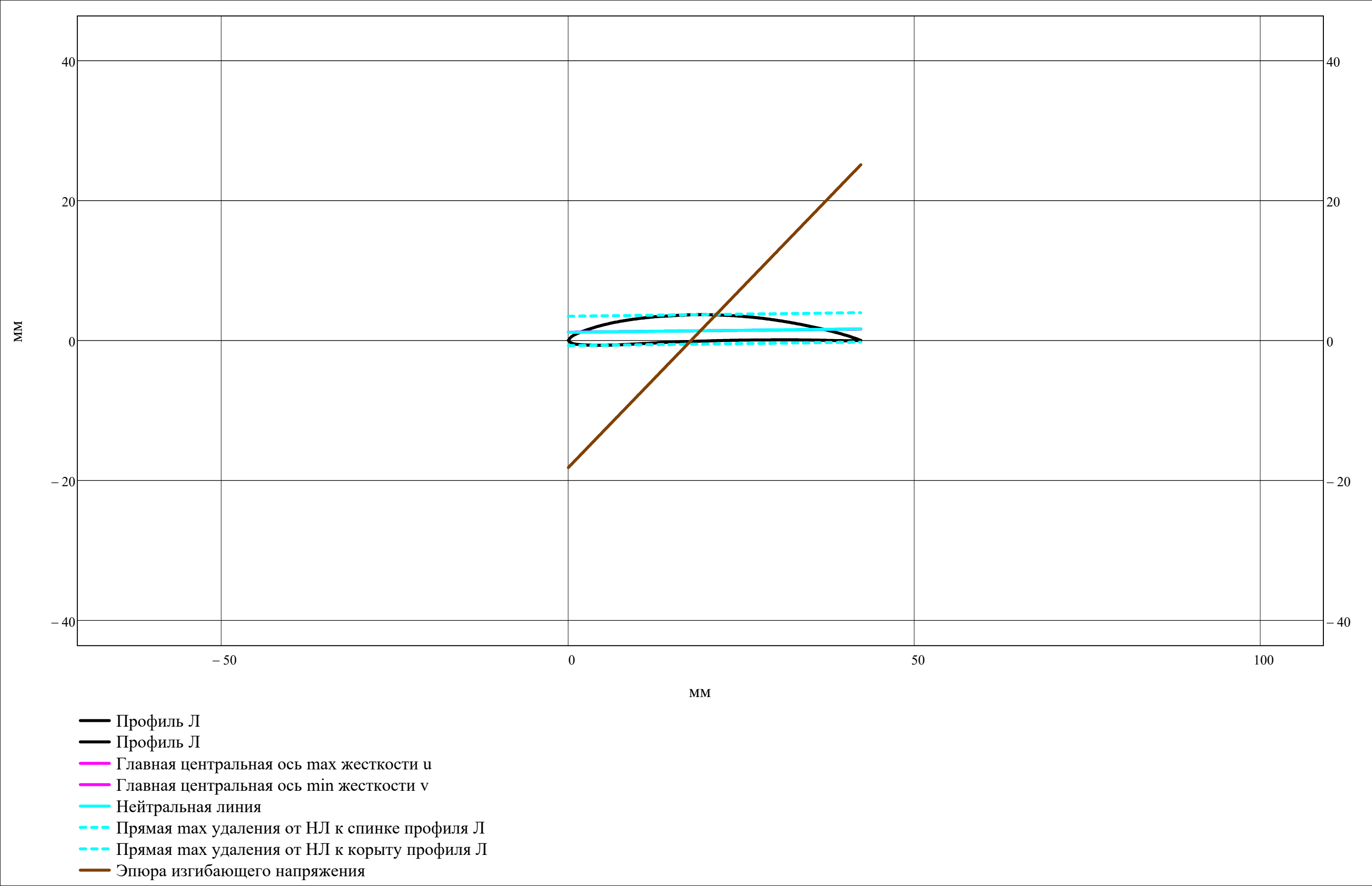
$$\text{Коэф. запаса: } \begin{pmatrix} \text{safety}_{\text{stator}_{j,r}} \\ \text{safety}_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 5.462 \\ \hline 2 & 2.646 \\ \hline \end{array}$$

$$\begin{pmatrix} \text{v}_{\text{p}} \\ \text{v}_{\text{n}} \end{pmatrix} = \begin{cases} \begin{pmatrix} v_{u_{\text{rotor}_{j,r}}} \\ v_{l_{\text{rotor}_{j,r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v_{u_{\text{stator}_{j,r}}} \\ v_{l_{\text{stator}_{j,r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.549 \\ \hline 2 & -1.531 \\ \hline \end{array} \cdot 10^{-3}$$

$$\begin{pmatrix} \text{x0} \\ \text{y0} \end{pmatrix} = \begin{cases} \begin{pmatrix} x0_{\text{rotor}_{j,r}} \\ y0_{\text{rotor}_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{\text{stator}_{j,r}} \\ y0_{\text{stator}_{j,r}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 17.610 \\ \hline 2 & 1.292 \\ \hline \end{array} \cdot 10^{-3}$$

$$\text{chord} = \begin{cases} \text{chord}_{\text{rotor}_{j,r}} & \text{if blade = "rotor"} \\ \text{chord}_{\text{stator}_{j,r}} & \text{if blade = "stator"} \end{cases} = 39 \cdot 10^{-3}$$





Запас по температуре (K): $\Delta T_{\text{safety}} = 0$

Выбранный материал Д: $\text{material_disk}_i = \begin{cases} \text{"BT23"} & \text{if compressor = "Вл"} \\ \text{"BT6"} & \text{if compressor = "КНД"} \\ \text{"BT9"} & \text{if compressor = "КВД"} \end{cases}$

Плотность материала Д (кг/м^3):

$$\rho_{\text{disk}_i} = \begin{cases} 8266 & \text{if material_disk}_i = \text{"ВЖ175"} \\ 8320 & \text{if material_disk}_i = \text{"ЭП742"} \\ 8393 & \text{if material_disk}_i = \text{"ЖС-6К"} \\ 7900 & \text{if material_disk}_i = \text{"BT41"} \\ 4500 & \text{if material_disk}_i = \text{"BT25"} \\ 4570 & \text{if material_disk}_i = \text{"BT23"} \\ 4510 & \text{if material_disk}_i = \text{"BT9"} \\ 4430 & \text{if material_disk}_i = \text{"BT6"} \\ \text{NaN} & \text{otherwise} \end{cases}$$

Предел длительной прочности Д (Па):

$$\sigma_{\text{disk_long}_i} = 10^6 \cdot \begin{cases} 620 & \text{if material_disk}_i = \text{"ВЖ175"} \\ 680 & \text{if material_disk}_i = \text{"ЭП742"} \\ 125 & \text{if material_disk}_i = \text{"ЖС-6К"} \\ 123 & \text{if material_disk}_i = \text{"BT41"} \\ 150 & \text{if material_disk}_i = \text{"BT25"} \\ 230 & \text{if material_disk}_i = \text{"BT23"} \\ 200 & \text{if material_disk}_i = \text{"BT9"} \\ 210 & \text{if material_disk}_i = \text{"BT6"} \\ \text{NaN} & \text{otherwise} \end{cases}$$

$\text{material_disk}^T =$

	1	2	3	4	5	6	7	8	9
1	"BT6"	"BT6"	"BT6"						

$\rho_{\text{disk}}^T =$

	1	2	3
1	4430	4430	4430

$\sigma_{\text{disk_long}}^T =$

	1	2	3
1	210	210	210

$\cdot 10^6$

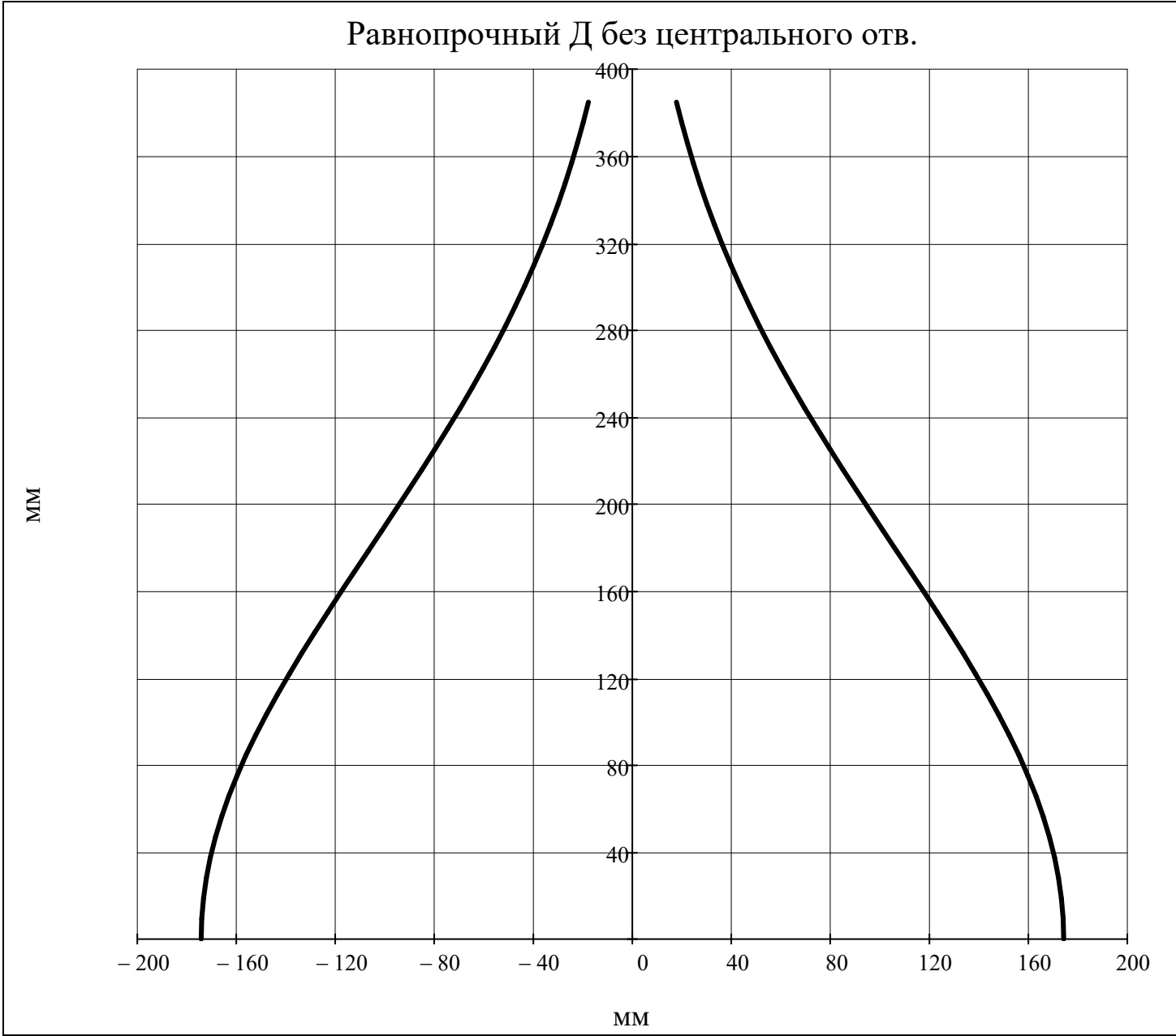
Рассматриваемая ступень:

$$j_w = \begin{cases} j = 1 & = 1 \\ j = & \text{"Такой ступени не существует!" if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{cases}$$

▼ Профилирование равнопрочного Д без центрального отв.

$$h(i,z) = \begin{cases} \left(\text{chord}_{\text{rotor}_i, \text{ORIGIN}} \cdot \sin\left(v_{\text{rotor}_i, \text{ORIGIN}}\right) \right) \cdot e^{\frac{\rho_{\text{disk}_i} \cdot \omega^2}{2} \cdot \frac{1}{\sigma_{z_{\text{rotor}}(i, R_{\text{st}}(i, 2), \text{ORIGIN})}} \cdot \left[\left(R_{\text{st}}(i, 2), \text{ORIGIN} \right)^2 - z^2 \right]} & \text{if } z \leq R_{\text{st}}(i, 2), \text{ORIGIN} \\ \text{NaN} & \text{otherwise} \end{cases}$$

$$z = 0, \frac{R_{\text{st}}(j, 2), \text{ORIGIN}}{N_{\text{dis}}} .. R_{\text{st}}(j, 2), \text{ORIGIN}$$



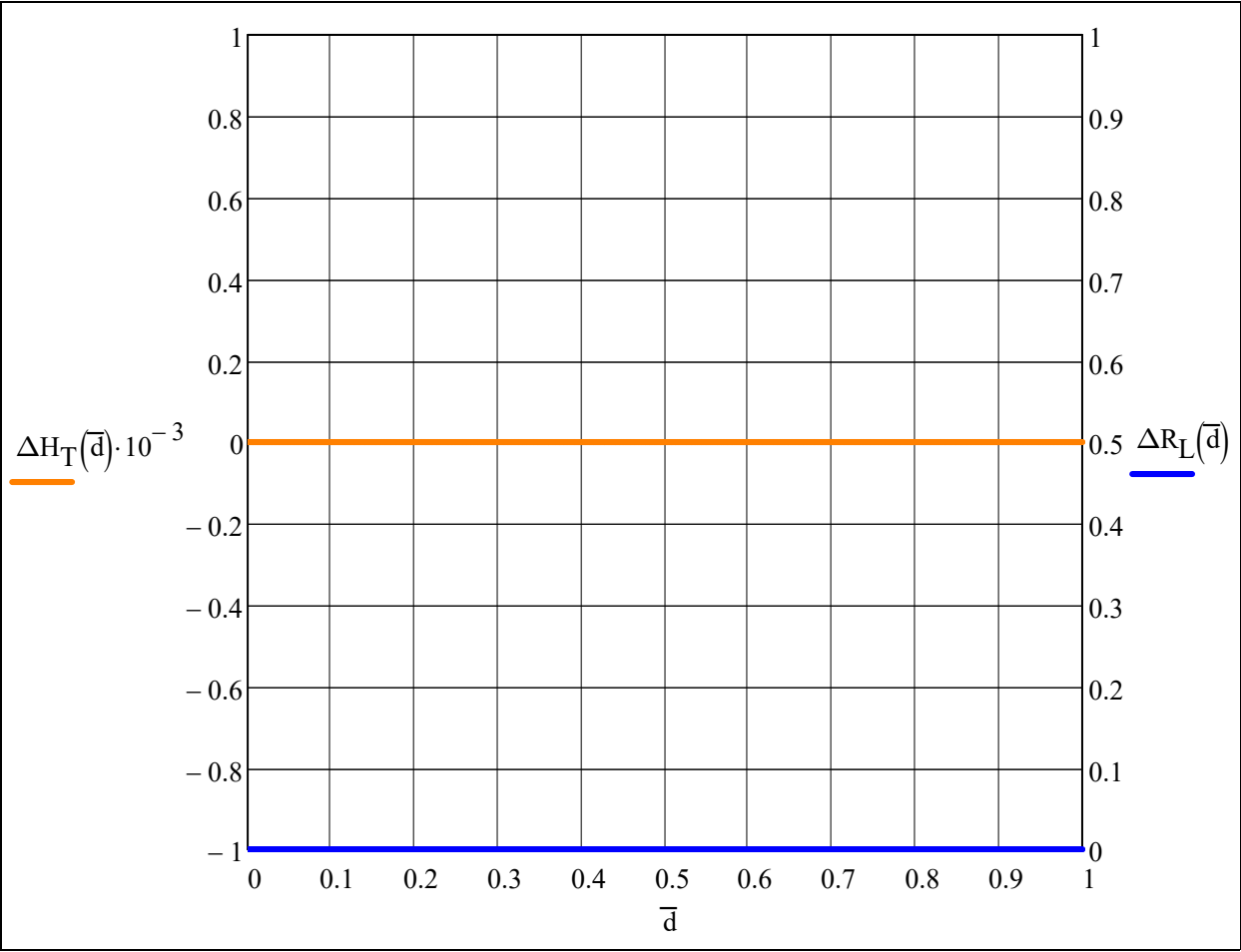
▲ Профилирование равнопрочного Д без центрального отв.

Мах разлика теор. напора ступени и реактивности
от периферии к корню по высоте Л (Дж/кг)
[16, с.118-119]:

$$\Delta H_{Tmax} = 0 \cdot 10^3$$

$$\Delta R_{Lmax} = 0.0$$

$$\Delta H_T(\bar{d}) = -\Delta H_{Tmax} \cdot \bar{d} + \Delta H_{Tmax} \qquad \Delta R_L(\bar{d}) = -\Delta R_{Lmax} \cdot \bar{d} + \Delta R_{Lmax}$$



$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 83.44 \\ 146.22 \\ 87.07 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 90.00 \\ 31.91 \\ 54.79 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{stator.j,r} = 19.79 \cdot ^\circ$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 83.44 \\ 77.29 \\ 71.14 \end{pmatrix}$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 212.81 \\ 213.62 \\ 214.42 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 228.58 \\ 118.25 \\ 178.97 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 21.41 \\ 40.81 \\ 23.42 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{rotor.j,r} = 19.4 \cdot ^\circ$$

$$\begin{pmatrix} c_{\text{st}(\text{j},1),\text{r}} \\ c_{\text{st}(\text{j},2),\text{r}} \\ c_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 83.44 \\ 130.83 \\ 83.02 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{\text{st}(\text{j},1),\text{r}} \\ \alpha_{\text{st}(\text{j},2),\text{r}} \\ \alpha_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 90 \\ 36.21 \\ 58.97 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{\text{stator}_{\text{j},\text{r}}} = 19.83 \cdot ^\circ$$

$$\begin{pmatrix} c_{\text{a}_{\text{st}(\text{j},1),\text{r}}} \\ c_{\text{a}_{\text{st}(\text{j},2),\text{r}}} \\ c_{\text{a}_{\text{st}(\text{j},3),\text{r}}} \end{pmatrix} = \begin{pmatrix} 83.44 \\ 77.29 \\ 71.14 \end{pmatrix}$$

$$\begin{pmatrix} u_{\text{st}(\text{j},1),\text{r}} \\ u_{\text{st}(\text{j},2),\text{r}} \\ u_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 250.84 \\ 251.18 \\ 251.52 \end{pmatrix}$$

$$\begin{pmatrix} w_{\text{st}(\text{j},1),\text{r}} \\ w_{\text{st}(\text{j},2),\text{r}} \\ w_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 264.35 \\ 164.86 \\ 220.52 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{\text{st}(\text{j},1),\text{r}} \\ \beta_{\text{st}(\text{j},2),\text{r}} \\ \beta_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 18.4 \\ 27.96 \\ 18.82 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{\text{rotor}_{\text{j},\text{r}}} = 9.56 \cdot ^\circ$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 83.44 \\ 121.25 \\ 80.62 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 83.44 \\ 77.29 \\ 71.14 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 295.83 \\ 205.48 \\ 255.98 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 90 \\ 39.6 \\ 61.94 \end{pmatrix} \cdot ^\circ$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 283.81 \\ 283.81 \\ 283.81 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 16.38 \\ 22.1 \\ 16.14 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{stator_{j,r}} = 19.57 \cdot ^\circ$$

$$\epsilon_{rotor_{j,r}} = 5.71 \cdot ^\circ$$











[illegible]



7	8	9