

Исходные данные

Коэф. запаса:	safety = 1.3
Степень двухконтурности:	m2 = 6
РТ: Воздух	compressor = "Вл"
Число Маха:	M = 0
Геометрическая высота работы (м):	H <sub>ww</sub> = 0
Массовый расход (кг/с):	<div>G<sub>ww</sub> = <div><div>35.65 + 213.93 if compressor = "Вл" = 249.58</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*<sub>K1</sub> = <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*<sub>K1</sub> = <div><div>316.2·10<sup>3</sup> if compressor = "КВД" = 101.3·10<sup>3</sup></div><div>101325 otherwise</div></div></div>
Степень повышения давления КВД:	<div>π*<sub>K</sub> = <div><div>1.6 if compressor = "Вл" = 1.600</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:

$\eta^*_K = \begin{cases} 0.86 & \text{if compressor = "Вл"} \\ 0.87 & \text{if compressor = "КНД"} \\ 0.88 & \text{if compressor = "КВД"} \end{cases} = 86.00\cdot\%$

Частота вращения ротора (с<sup>-1</sup>):

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

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

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

$0.3 \leq \overline{d}_1 \leq 0.6 = 1$

Частота вращения ротора (об/мин):

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

Закон профилирования проточной части (ЗППЧ):

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

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  $\pi$

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

увеличение несущественно увеличивает  $\pi$

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

понижение существенно увеличивает  $\pi$

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

увеличение существенно увеличивает  $\pi$

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

	1	2	3	4	5	6	7	8
1	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
2	0.990	0.980	0.970	0.960	0.950	0.950	0.950	0.950
3	0.860	0.870	0.885	0.890	0.890	0.885	0.870	0.860
4	0.335	0.325	0.315	0.305	0.295	0.285	0.275	0.265
5	0.265	0.305	0.335	0.345	0.365	0.335	0.305	0.285

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

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

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

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

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

$$\overline{H}_{Tcp} = \frac{\sum_{i=1}^{rows(z_{\sim})} \overline{H}_{\sim T_i}}{rows(z_{\sim})} = 0.317$$

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

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:  $\widetilde{\eta^*_{\sim}}(i) = \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \eta^*_{\sim}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \eta^*_{\sim}, i\right)$

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

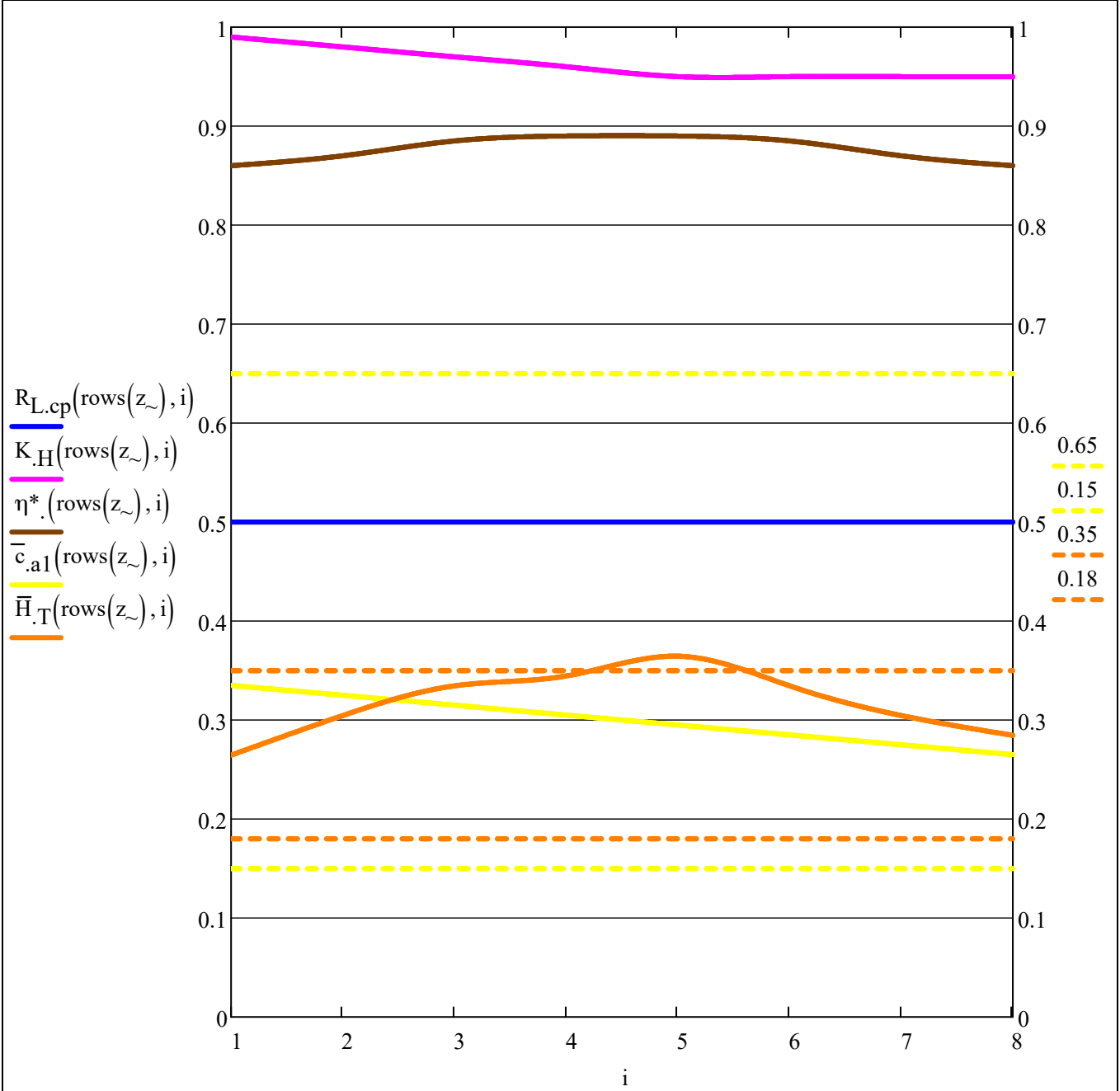
Коэф. напора:  $\overline{\widetilde{H_{\sim T}}}(i) = \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{H_{\sim T}}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{H_{\sim T}}, i\right)$

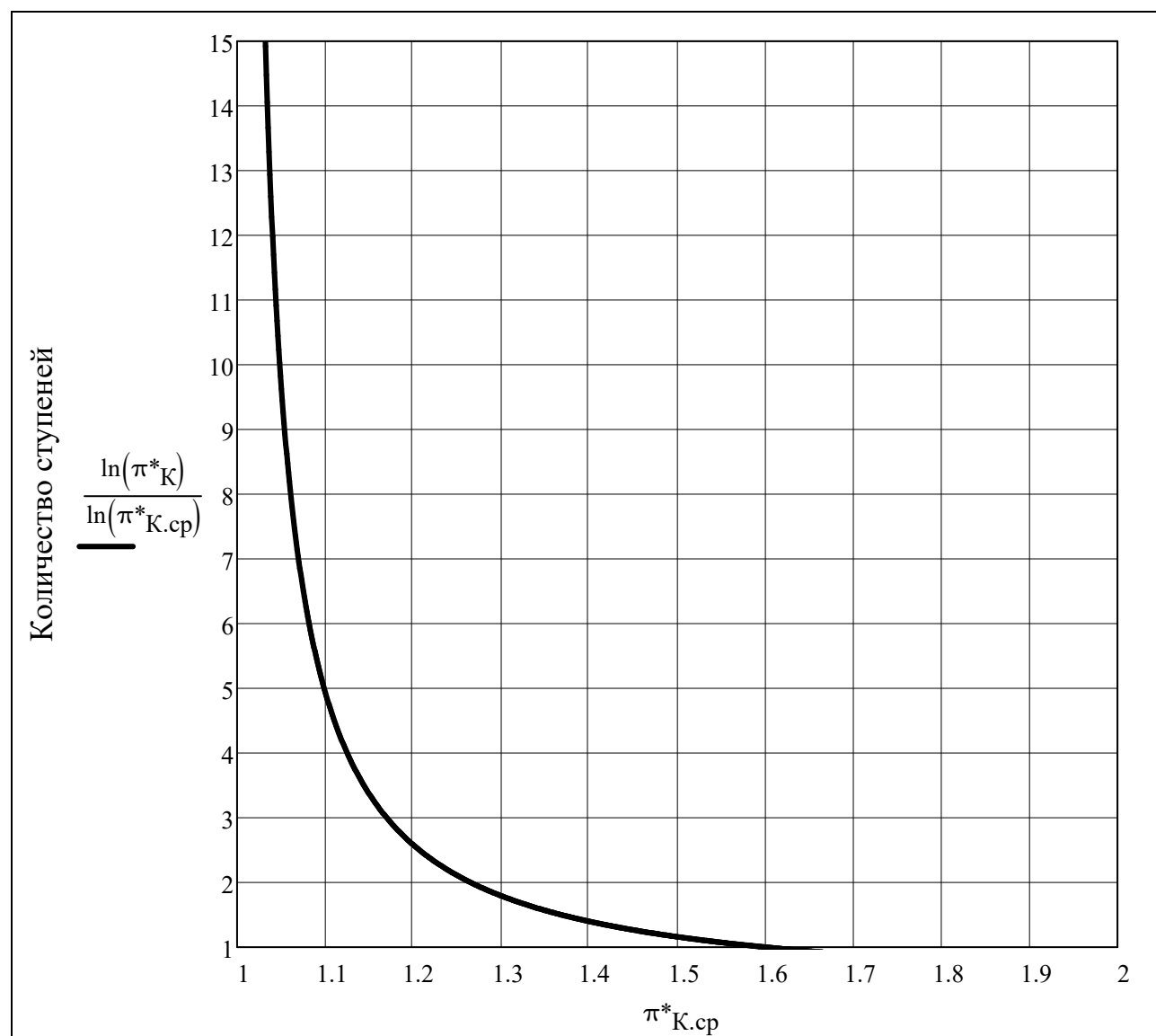
$$\begin{pmatrix} R_{L.cp} \\ K_{.H} \\ \eta^*_{.} \\ \bar{c}_{.a1} \\ \bar{H}_{.T} \end{pmatrix} = \begin{matrix} R_{L.cp}(Z,i) = \begin{cases} R_{L\sim cp}\left(\frac{1}{rows(z_{\sim})}\right) & \text{if } i < 1 \\ R_{L\sim cp}(1) & \text{if } i > Z \\ R_{L\sim cp}\left(\frac{i}{Z}\right) & \text{otherwise}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

$$\begin{pmatrix} R_{L.cp} & K_{.H} & \eta^*_{.} & \bar{c}_{.a1} & \bar{H}_{.T} \end{pmatrix}^T$$

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

$$\begin{pmatrix} R_{L.cp}(Z_{temp}, i_{temp}) \\ K_{.H}(Z_{temp}, i_{temp}) \\ \eta^*_{.}(Z_{temp}, i_{temp}) \\ \bar{c}_{.a1}(Z_{temp}, i_{temp}) \\ \bar{H}_{.T}(Z_{temp}, i_{temp}) \end{pmatrix} = \begin{pmatrix} 0.500 \\ 0.950 \\ 0.860 \\ 0.265 \\ 0.285 \end{pmatrix}$$





Показатель адиабаты перед K []:  $k_{K1} = k_{ад}(Cp_{воздух}(P^*_{K1}, T^*_{K1}), R_B) = 1.401$

Полное давление после K [Па]:  $P^*_{K3} = \pi^*_K \cdot P^*_{K1} = 162 \cdot 10^3$

iteration<sub>3</sub>

T<sup>\*</sup><sub>K3</sub>

k<sub>K3</sub>

=

iteration<sub>3</sub> = 0

k<sub>K3</sub> = k<sub>K1</sub>

while 0 < 1

iteration<sub>3</sub> = iteration<sub>3</sub> + 1

trace("iteration.3 = ", num2str(iteration<sub>3</sub>))

k<sub>ср</sub> = mean(k<sub>K1</sub>, k<sub>K3</sub>)

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

Cp<sub>K3</sub> = Cp<sub>воздух</sub>(P<sup>\*</sup><sub>K3</sub>, T<sup>\*</sup><sub>K3</sub>)

k'<sub>K3</sub> = k<sub>ад</sub>(Cp<sub>K3</sub>, R<sub>B</sub>)

if |eps("rel", k<sub>K3</sub>, k'<sub>K3</sub>)| ≤ epsilon

k<sub>K3</sub> = k'<sub>K3</sub>

break

k<sub>K3</sub> = k'<sub>K3</sub>

iteration<sub>3</sub>

T<sup>\*</sup><sub>K3</sub>

k<sub>K3</sub>

Количество итераций []: iteration<sub>3</sub> = 1

Полная температура после K [K]: T<sup>\*</sup><sub>K3</sub> = 336.5

Показатель адиабаты после K []: k<sub>K3</sub> = 1.399

Полная плотность перед и после K [кг/м³]:  $\begin{pmatrix} \rho^*_{K1} \\ \rho^*_{K3} \end{pmatrix} = \frac{1}{R_B} \cdot \begin{pmatrix} \frac{P^*_{K1}}{T^*_{K1}} \\ \frac{P^*_{K3}}{T^*_{K3}} \end{pmatrix} = \begin{pmatrix} 1.224 \\ 1.678 \end{pmatrix}$

Критические скорости перед и после K [м/с]:  $\begin{pmatrix} a^*_{с.вх} \\ a^*_{с.вых} \end{pmatrix} = \begin{pmatrix} a_{кр}(k_{K1}, R_B, T^*_{K1}) \\ a_{кр}(k_{K3}, R_B, T^*_{K3}) \end{pmatrix} = \begin{pmatrix} 310.8 \\ 335.7 \end{pmatrix}$

Ср. показатель адиабаты K []: k<sub>ср</sub> = k<sub>ад</sub>(Cp<sub>воздух.ср</sub>(P<sup>\*</sup><sub>K1</sub>, P<sup>\*</sup><sub>K3</sub>, T<sup>\*</sup><sub>K1</sub>, T<sup>\*</sup><sub>K3</sub>), R<sub>B</sub>) = 1.401

Теоретический напор [Дж/кг]:  $H_{TK} = \frac{Cp_{воздух.ср}(P^*_{K1}, P^*_{K3}, T^*_{K1}, T^*_{K3}) \cdot T^*_{K1} \cdot \left( \pi^*_K \frac{k_{ср}-1}{k_{ср}} - 1 \right)}{\eta^*_K} = 48.4 \cdot 10^3$

iteration<sub>u</sub>

u<sub>1пер</sub>

Z<sub>recomend</sub>

c<sub>вх</sub>

λ<sub>вх</sub>

ρ<sub>K1</sub>

=

iteration<sub>u</sub> = 0

ρ<sub>K1</sub> = ρ\*<sub>K1</sub>

while 0 < 1

iteration<sub>u</sub> = iteration<sub>u</sub> + 1

trace(concat("iteration.u = ", num2str(iteration<sub>u</sub>)))

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

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

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

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

$$\rho'_{K1} = \rho^*_{K1} \cdot \Gamma Д \Phi(" \rho", \lambda_{вх}, k_{K1})$$

if |eps("rel", ρ'<sub>K1</sub>, ρ<sub>K1</sub>)| ≤ epsilon

ρ<sub>K1</sub> = ρ'<sub>K1</sub>

break

ρ<sub>K1</sub> = ρ'<sub>K1</sub>

iteration<sub>u</sub>

u<sub>1пер</sub>

Z<sub>recomend</sub>

c<sub>вх</sub>

λ<sub>вх</sub>

ρ<sub>K1</sub>

Количество итераций []: iteration<sub>u</sub> = 2

Окружная скорость на перифкрии перед K [м/с]: u<sub>1пер</sub> = 425.9

Рекомендуемое количество ступеней []: Z<sub>recomend</sub> = 1

Абс. скорость перед K [м/с]: c<sub>вх</sub> = 142.7

Приведенная скорость перед K []: λ<sub>вх</sub> = 0.4591

Плотность перед K [кг/м^3]: ρ<sub>K1</sub> = 1.120

Кольцевая площадь перед K [м²]: 
$$F_{вх} = \frac{G \cdot \sqrt{R_B \cdot T^*_{K1}}}{m_q(k_{K1}) \cdot P^*_{K1} \cdot \Gamma Д \Phi("G", \lambda_{вх}, k_{K1})} = 1.5621$$

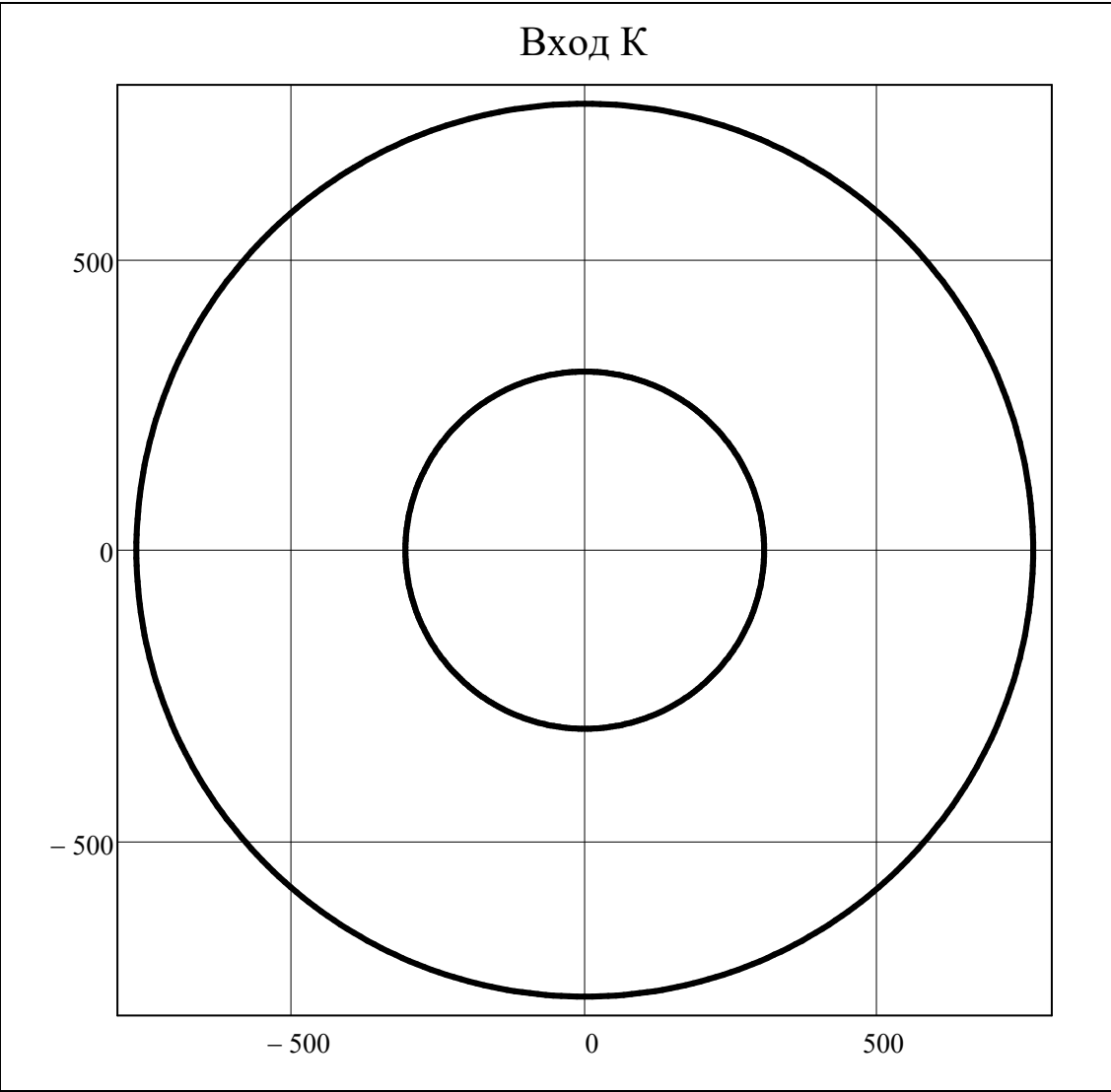
$$D'_{пер1} = \frac{2 \cdot u_{1пер}}{\omega} = 1534.9 \cdot 10^{-3}$$

Диаметры перед K [м]: 
$$D'_{ср1} = \bar{r}_{ср}(\bar{d}_1) \cdot D'_{пер1} = 1169 \cdot 10^{-3}$$

$$D'_{кор1} = \bar{d}_1 \cdot D'_{пер1} = 614 \cdot 10^{-3}$$



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



Рекомендуемое количество ступеней []: Z<sub>recomend</sub> = 1

Количество ступеней []:

$$Z = \begin{cases} 1 & \text{if compressor = "Вл"} \\ 3 & \text{if compressor = "КНД"} \\ 9 & \text{if compressor = "КВД"} \end{cases} = 1$$



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\text{submatrix}\left(\bar{c}_{a1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.335)$$

$$\text{submatrix}\left(\bar{c}_{a3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.335)$$

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

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

$$\text{submatrix}\left(c_{a1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (142.7)$$

$$\text{submatrix}\left(c_{a3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (142.7)$$

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

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

$$\text{submatrix}\left(c_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (142.7)$$

$$\text{submatrix}\left(c_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (142.7)$$

$$\text{submatrix}\left(\lambda_{c1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.459)$$

$$\text{submatrix}\left(\lambda_{c3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.459)$$

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

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

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

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

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

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

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

$$\text{iteration}_{12} = \text{iteration}_{12} + 1$$

    trace(concat("  iteration.12 = ", num2str(iteration<sub>12</sub>)))

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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



$$F_{\text{st}(i,3)} = F'_3$$

$$\overline{c}_{a_{\text{st}(i,2)},r} = \text{mean}\left(\overline{c}_{a_{\text{st}(i,1)},r}, \overline{c}_{a_{\text{st}(i,3)},r}\right)$$

$$\text{iteration}_2 = 0$$

$$F_{\text{st}(i,2)} = \text{mean}\left(F_{\text{st}(i,1)}, F_{\text{st}(i,3)}\right)$$

$$\text{while } 0 < 1$$

$$\text{iteration}_2 = \text{iteration}_2 + 1$$

$$\text{trace}\left(\text{concat}\left(" \text{ iteration.2} = ", \text{num2str}\left(\text{iteration}_2\right)\right)\right)$$

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

$$D_{\text{st}(i,2),N_r} = \text{mean}\left(D_{\text{st}(i,1),N_r}, D_{\text{st}(i,3),N_r}\right)$$

$$\overline{d}_{\text{st}(i,2)} = \sqrt{2 \cdot \text{mean}\left(\overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,1)}\right), \overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,3)}\right)\right)^2 - 1}$$

$$D_{\text{st}(i,2),r} = D_{\text{st}(i,2),N_r} \cdot \overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,2)}\right)$$

$$D_{\text{st}(i,2),1} = \overline{d}_{\text{st}(i,2)} \cdot D_{\text{st}(i,2),N_r}$$

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

$$D_{\text{st}(i,2),N_r} = D_{\text{st}(i,1),N_r}$$

$$\overline{d}_{\text{st}(i,2)} = \sqrt{2 \cdot \text{mean}\left(\overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,1)}\right), \overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,3)}\right)\right)^2 - 1}$$

$$D_{\text{st}(i,2),r} = D_{\text{st}(i,2),N_r} \cdot \overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,2)}\right)$$

$$D_{\text{st}(i,2),1} = \overline{d}_{\text{st}(i,2)} \cdot D_{\text{st}(i,2),N_r}$$

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

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

$$\overline{d}_{\text{st}(i,2)} = \sqrt{2 \cdot \text{mean}\left(\overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,1)}\right), \overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,3)}\right)\right)^2 - 1}$$

$$D_{\text{st}(i,2),N_r} = \frac{D_{\text{st}(i,2),1}}{\overline{d}_{\text{st}(i,2)}}$$

$$D_{\text{st}(i,2),r} = D_{\text{st}(i,2),N_r} \cdot \overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,2)}\right)$$

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

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

$$\overline{d}_{\text{st}(i,2)} = \sqrt{2 \cdot \text{mean}\left(\overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,1)}\right), \overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,3)}\right)\right)^2 - 1}$$

$$D_{\text{st}(i,2),N_r} = \frac{D_{\text{st}(i,2),r}}{\overline{r}_{\text{cp}}\left(\overline{d}_{\text{st}(i,2)}\right)}$$

$$D_{\text{st}(i,2),1} = \overline{d}_{\text{st}(i,2)} \cdot D_{\text{st}(i,2),N_r}$$

$$\left(\mathbf{D} \quad \quad \quad \right)^2$$

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

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

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

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

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

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

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

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

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

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

for a ∈ 1 .. 3

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

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

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

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

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

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

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

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

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

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

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

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

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

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  $\in 1..N_r$

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

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





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

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

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

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

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

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

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

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

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

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

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

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

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

$$\text{submatrix}\left(T^*_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (337.1)$$

$$\text{submatrix}\left(T^*_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (337.1)$$

$$\text{submatrix}\left(P^*_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (163.0) \cdot 10^3$$

$$\text{submatrix}\left(P^*_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (163.0) \cdot 10^3$$

$$\text{submatrix}\left(\rho^*_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.684)$$

$$\text{submatrix}\left(\rho^*_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.684)$$

$$\text{submatrix}\left(k_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.399)$$

$$\text{submatrix}\left(k_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.399)$$

$$\text{submatrix}\left(a_{kp1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (336.0)$$

$$\text{submatrix}\left(a_{kp3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (336.0)$$

$$\text{submatrix}\left(\overline{c}_{a1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.265)$$

$$\text{submatrix}\left(\overline{c}_{a3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.265)$$

$$\text{submatrix}\left(\overline{c}_{u1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.211)$$

$$\text{submatrix}\left(\overline{c}_{u3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.211)$$

$$\text{submatrix}\left(c_{a1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (112.9)$$

$$\text{submatrix}\left(c_{a3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (112.9)$$

$$\text{submatrix}\left(c_{u1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (90.0)$$

$$\text{submatrix}\left(c_{u3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (90.0)$$

$$\text{submatrix}\left(c_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (144.4)$$

$$\text{submatrix}\left(c_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (144.4)$$

$$\text{submatrix}\left(\lambda_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.430)$$

$$\text{submatrix}\left(\lambda_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.430)$$

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

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

$$\varepsilon_{CA_r} = \alpha_3 CA_r - \alpha_1 CA_r$$

$\alpha_{1CA}$	$\alpha_{3CA}$
$\sigma_{CA}$	$\sigma_{CA}$
$\bar{d}_{1CA}$	$\bar{d}_{3CA}$
$T^*_{1CA}$	$T^*_{3CA}$
$P^*_{1CA}$	$P^*_{3CA}$
$\rho^*_{1CA}$	$\rho^*_{3CA}$
$k_{1CA}$	$k_{3CA}$
$a_{kp1CA}$	$a_{kp3CA}$
$\bar{c}_{a1CA}$	$\bar{c}_{a3CA}$
$\bar{c}_{u1CA}$	$\bar{c}_{u3CA}$
$c_{a1CA}$	$c_{a3CA}$
$c_{u1CA}$	$c_{u3CA}$
$c_{1CA}$	$c_{3CA}$
$\lambda_{1CA}$	$\lambda_{3CA}$
$F_{1CA}$	$F_{3CA}$
$\varepsilon_{CA}$	$\varepsilon_{CA}$

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																

.%

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

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

Количество ступеней ОК: 

Z = 1

Дискритизация сечений:      ii = 1..2Z + 1

Дискритизация ступеней:      i = 1..Z

$\pi^{*T}$  =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.609														

[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														

Полученная степень повышения полного давления []:

$\prod_{i=1}^Z \pi^{*}_i = 1.609$

Степень повышения давления в ЛА:

$\pi^{*}_{\text{ЛА}} = \frac{P^{*}_{3CA_{av(N_r)}}}{P^{*}_{1BHA_{av(N_r)}} = 1.609$

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



$H_T^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	51.62														
2	51.62														
3	51.62														

$\cdot 10^3$

Действительная работа К (Дж/кг):
 $L_K = \sum_{i=1}^Z L_i = 49 \cdot 10^3$

Адиабатная работа К [Дж/кг]:
 $L^*_K = \sum_{i=1}^Z L^*_{i} = 42.2 \cdot 10^3$

Адиабатная КПД К []:
 $\eta^*_K = \frac{L^*_K}{L_K} = 86.00\%$

Мощность К (Вт):
 $N_K = G \cdot L_K = 12.24 \cdot 10^6$

submatrix(R<sub>L</sub>, 1, Z, av(N<sub>r</sub>), av(N<sub>r</sub>))<sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.50														

K<sub>H</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.95														

η<sup>\*</sup><sub>i</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	86.00														

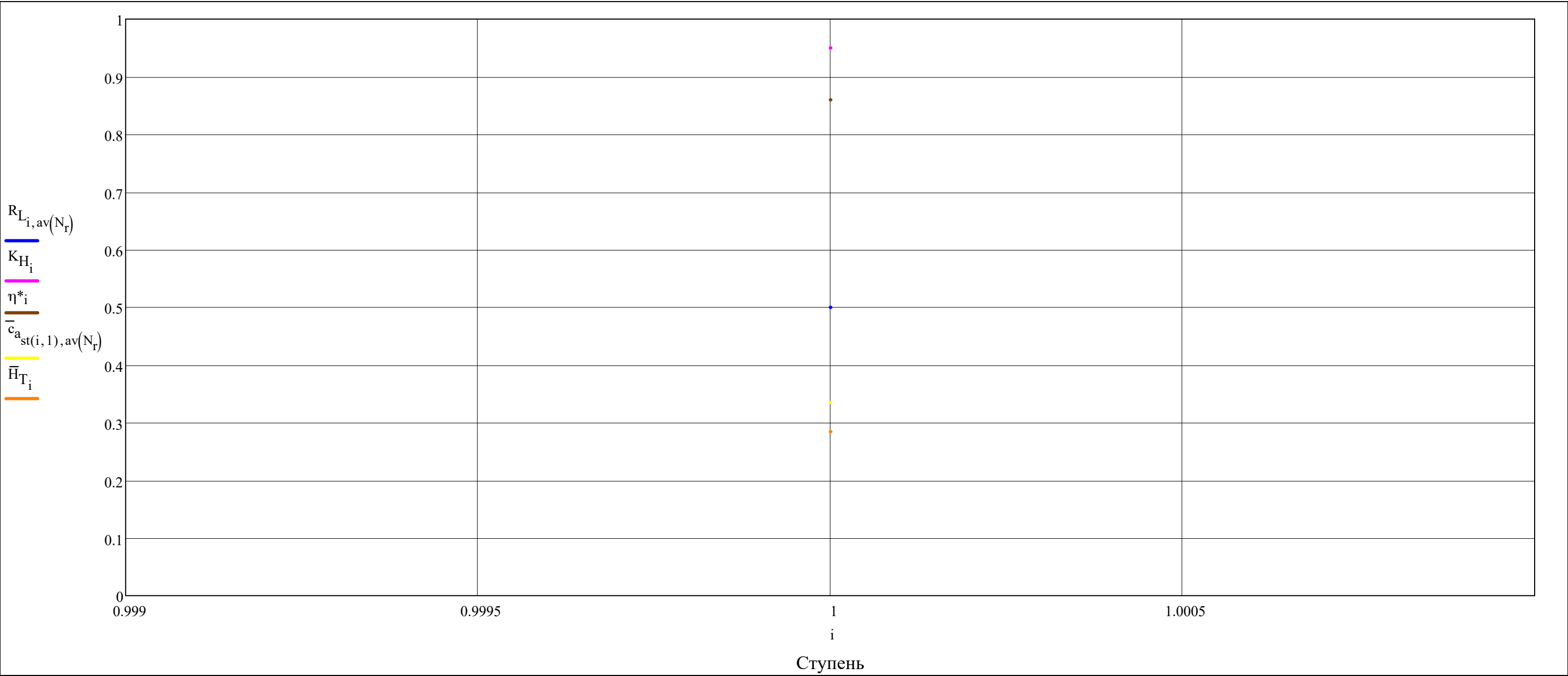
.%

submatrix(c̄<sub>a</sub>, 1, 2Z + 1, av(N<sub>r</sub>), av(N<sub>r</sub>))<sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.335	0.300	0.265																	

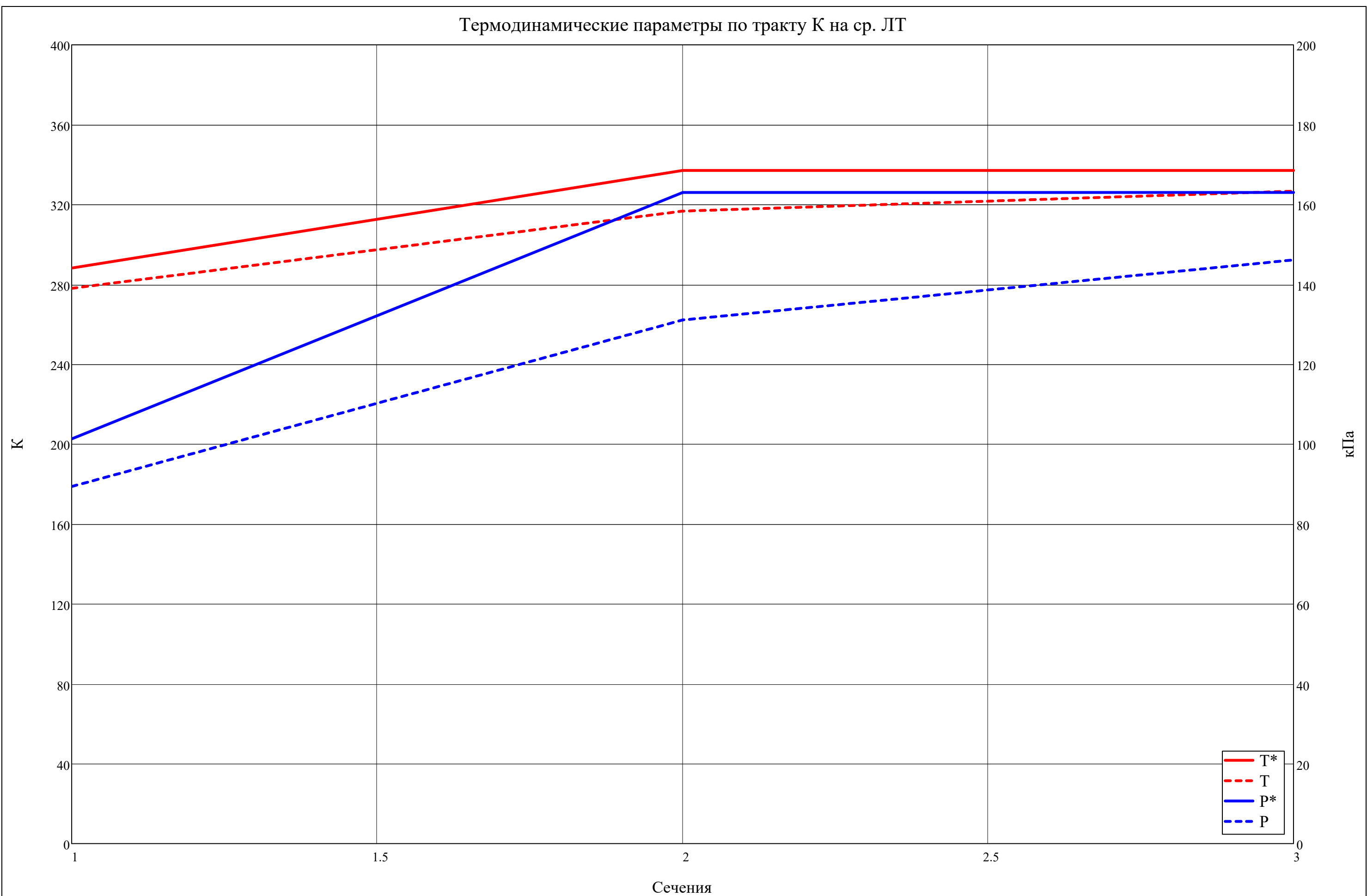
H̄<sub>T</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.28														





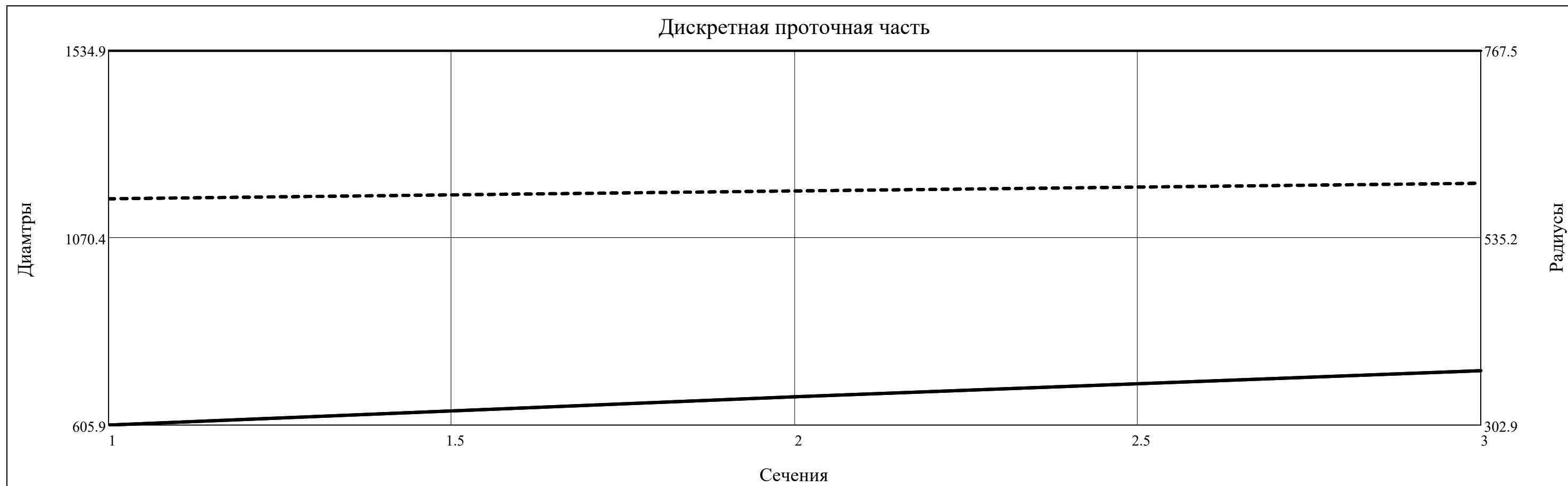
Термодинамические параметры по тракту К на ср. ЛТ



[illegible][illegible]

$$\overline{d}_{st}(Z, 3) = 0.4826$$

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

[illegible][illegible][illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

$$c_{a_{st(Z,3),av}(N_r)} = 112.87 \quad c_{a_{st(Z,3),av}(N_r)} \leq 130 = 1 \quad \text{Для КС}$$

[illegible]

[illegible]

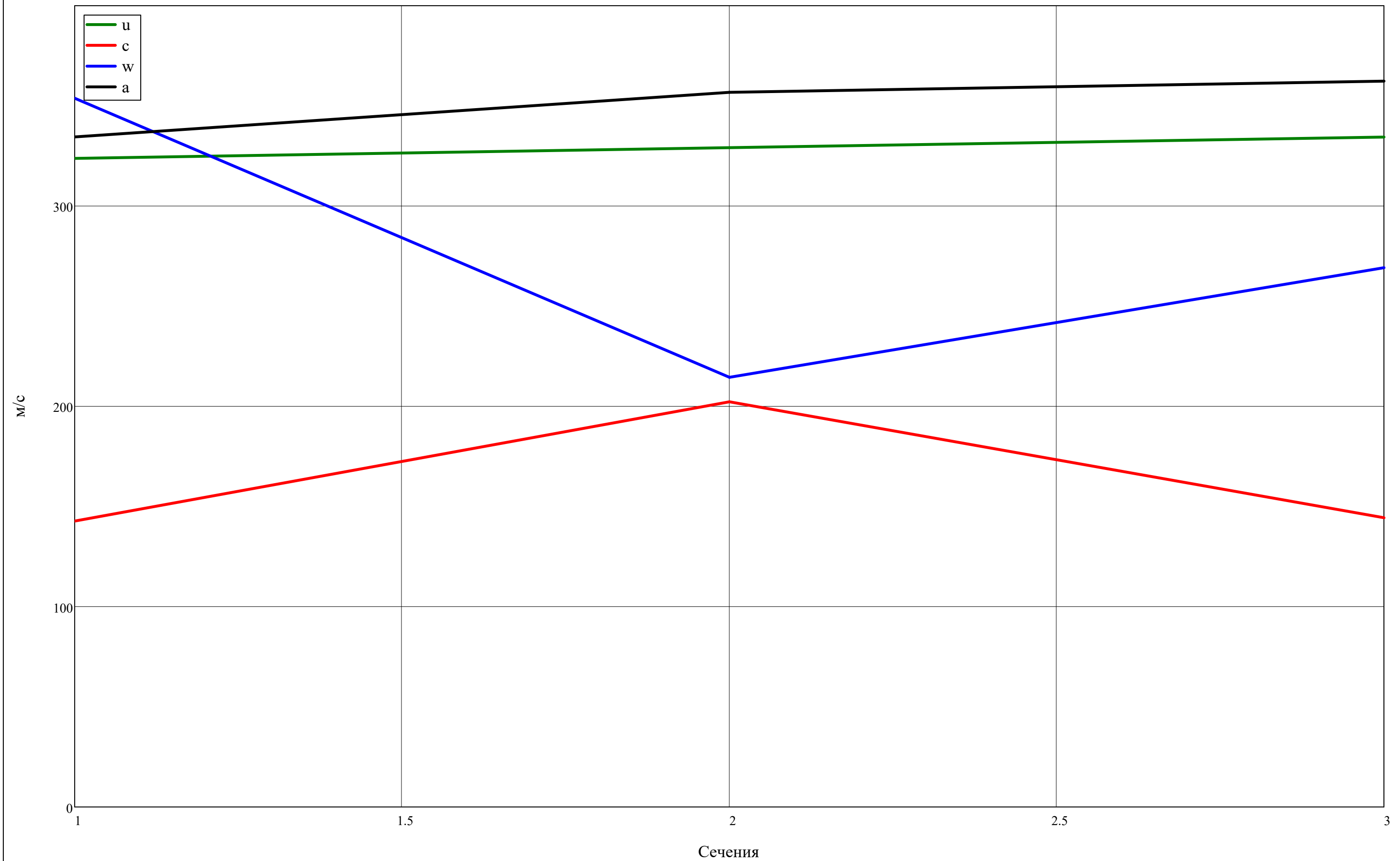
[illegible]

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

[illegible]

[illegible]

Скорости по тракту К на ср. ЛТ



$$\text{submatrix}\Big(\alpha, 1, 2\cdot Z + 1, \text{av}\Big(N_{\text{r}}\Big), \text{av}\Big(N_{\text{r}}\Big)\Big)^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	90.00	39.17	51.42																		

$$.$$

$$\text{submatrix}\Big(\beta, 1, 2\cdot Z + 1, \text{av}\Big(N_{\text{r}}\Big), \text{av}\Big(N_{\text{r}}\Big)\Big)^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	23.78	36.56	24.79																		

$$.$$

$$\text{submatrix}\Big(\varepsilon_{\text{rotor}}, 1, Z, \text{av}\Big(N_{\text{r}}\Big), \text{av}\Big(N_{\text{r}}\Big)\Big)^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	12.78																				

$$.$$

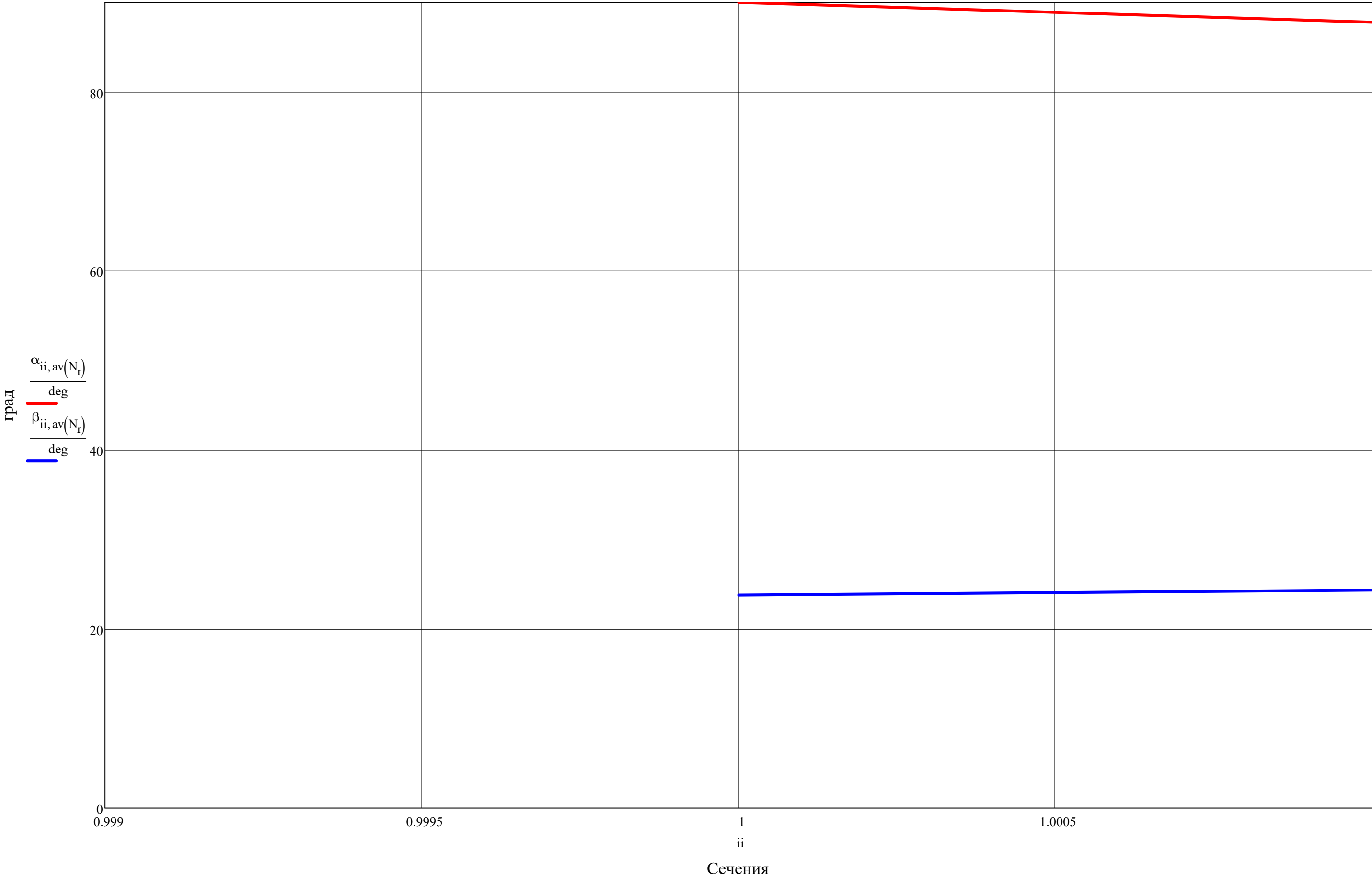
$$\text{submatrix}\Big(\varepsilon_{\text{stator}}, 1, Z, \text{av}\Big(N_{\text{r}}\Big), \text{av}\Big(N_{\text{r}}\Big)\Big)^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	12.25																				

$$.$$



Углы по тракту К на ср. ЛТ



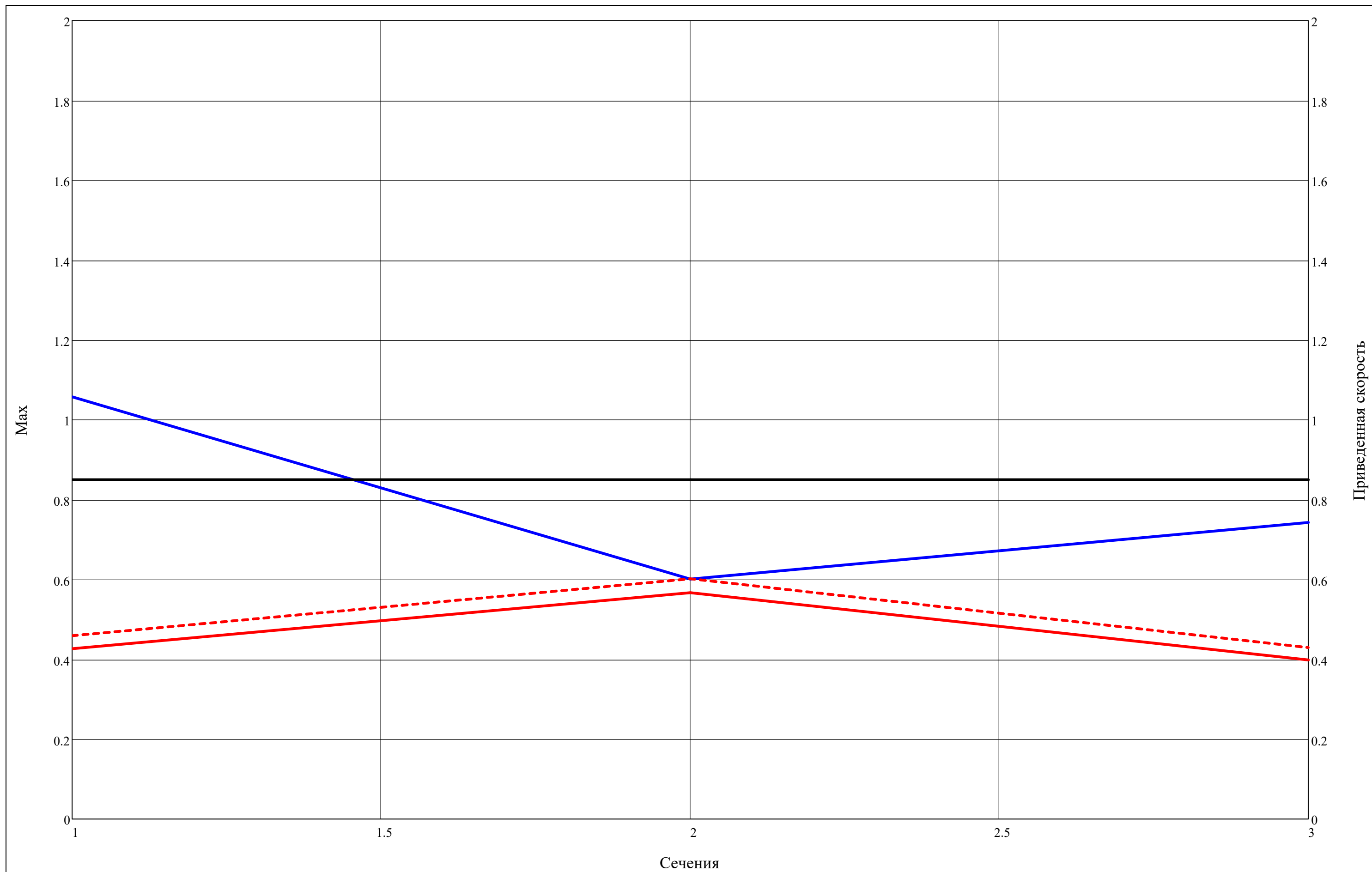
[illegible]

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

	1	2	3
1	1	1	1

[illegible]

[illegible]





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

$$\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}$$

$$\begin{aligned}
& \left( \begin{array}{cc} T^* & T \\ P^* & P \\ \rho^* & \rho \\ C_p & k \\ a^*_c & a_{3B} \\ c_u & c_a \\ \alpha & \beta \\ c & w \\ \lambda_c & w_u \\ M_w & M_c \\ R_L & R_L \\ \epsilon_{\text{rotor}} & \epsilon_{\text{stator}} \end{array} \right) = \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } a \in 1..3 \\ \quad \quad \text{for } r \in 1..N_r \\ \quad \quad \quad T^*_{\text{st}(i,a),r} = T^*_{\text{st}(i,a),\text{av}(N_r)} \\ \quad \quad \quad P^*_{\text{st}(i,a),r} = P^*_{\text{st}(i,a),\text{av}(N_r)} \\ \quad \quad \quad \rho^*_{\text{st}(i,a),r} = \rho^*_{\text{st}(i,a),\text{av}(N_r)} \\ \quad \quad \quad C_{p\text{st}(i,a),r} = C_{p\text{BO3ДУХ}}(P^*_{\text{st}(i,a),r}, T^*_{\text{st}(i,a),r}) \\ \quad \quad \quad k_{\text{st}(i,a),r} = k_{\text{aД}}(C_{p\text{st}(i,a),r}, R_B) \\ \quad \quad \quad a^*_c_{\text{st}(i,a),r} = \sqrt{\frac{2 \cdot k_{\text{st}(i,a),r}}{k_{\text{st}(i,a),r} + 1}} \cdot R_B \cdot T^*_{\text{st}(i,a),r} \\ \quad \quad \quad \text{if } \Delta H_{T\text{max}} = 0 \\ \quad \quad \quad \quad A_{\text{st}(i,a)} = \left(1 - R_{L_{i,\text{av}(N_r)}}\right) \cdot \omega \cdot \left(R_{\text{st}(i,a),\text{av}(N_r)}\right)^{m_i+1} \\ \quad \quad \quad \quad B_{\text{st}(i,a)} = \frac{H_{T_{i,\text{av}(N_r)}}}{2 \cdot \omega} \\ \quad \quad \quad \quad c_{u_{\text{st}(i,a),r}} = \begin{array}{l} \frac{R_{\text{st}(i,a),r}}{R_{\text{st}(i,a-1),r}} \cdot \frac{H_{T_{i,\text{av}(N_r)}}}{\omega \cdot R_{\text{st}(i,a),r}} \quad \text{if } a = 2 \\ \text{otherwise} \\ \left| \begin{array}{l} 0 \quad \text{if } (a = 1) \wedge (i = 1) \wedge (BHA = 0) \\ \frac{A_{\text{st}(i,a)}}{(R_{\text{st}(i,a),r})^{m_i}} - \frac{B_{\text{st}(i,a)}}{(R_{\text{st}(i,a),r})} \quad \text{otherwise} \end{array} \right| \\ c_{a3BHA_r} \quad \text{if } (a = 1) \wedge (i = 1) \wedge (BHA = 1) \end{array} \\ \quad \quad \quad \quad \sqrt{\left(c_{a_{\text{st}(i,a),\text{av}(N_r)}}\right)^2 - 2 \cdot (A_{\text{st}(i,a)})^2 \cdot \left[\left(R_{\text{st}(i,a),r}\right)^2 - \left(R_{\text{st}(i,a),\text{av}(N_r)}\right)^2\right] + 4 \cdot A_{\text{st}(i,a)} \cdot B_{\text{st}(i,a)} \cdot \ln\left(\frac{R_{\text{st}(i,a),r}}{R_{\text{st}(i,a),\text{av}(N_r)}}\right)} \cdot \left| \begin{array}{l} -1 \quad \text{if } a = 2 \\ 1 \quad \text{otherwise} \end{array} \right| \quad \text{if } m_i = -1 \\ \quad \quad \quad \quad \sqrt{\left(c_{a_{\text{st}(i,a),\text{av}(N_r)}}\right)^2 - 2 \cdot (A_{\text{st}(i,a)})^2 \cdot \ln\left(\frac{R_{\text{st}(i,a),r}}{R_{\text{st}(i,a),\text{av}(N_r)}}\right) - 2 \cdot A_{\text{st}(i,a)} \cdot B_{\text{st}(i,a)} \cdot \left(\frac{1}{R_{\text{st}(i,a),r}} - \frac{1}{R_{\text{st}(i,a),\text{av}(N_r)}}\right)} \cdot \left| \begin{array}{l} -1 \quad \text{if } a = 2 \\ 1 \quad \text{otherwise} \end{array} \right| \quad \text{if } m_i = 0 \end{array}
\end{array}$$

$$\sqrt{\left(\frac{c_{st(i,a),av(N_r)}}{A_{st(i,a)} \cdot (m_i - 1) \cdot \left[ -A_{st(i,a)} \cdot (m_i + 1) \cdot \left[ \frac{1}{(R_{st(i,a),r})^{2 \cdot m_i}} - \frac{1}{(R_{st(i,a),av(N_r)})^{2 \cdot m_i}} \right] \dots \right.} \right.} \left. \left. + 2 \cdot B_{st(i,a)} \cdot m_i \cdot \left[ \frac{1}{(R_{st(i,a),r})^{m_i+1}} - \frac{1}{(R_{st(i,a),av(N_r)})^{m_i+1}} \right] \cdot \begin{cases} -1 & \text{if } a = 2 \\ 1 & \text{otherwise} \end{cases} \right] \right)^2 + \frac{1}{m_i \cdot (m_i + 1)}} \quad \text{otherwise}$$

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

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

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

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

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

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

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

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



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

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

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

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

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

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

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

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

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

for  $r \in 1..N_r$

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

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

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

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

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

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

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

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

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

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

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

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

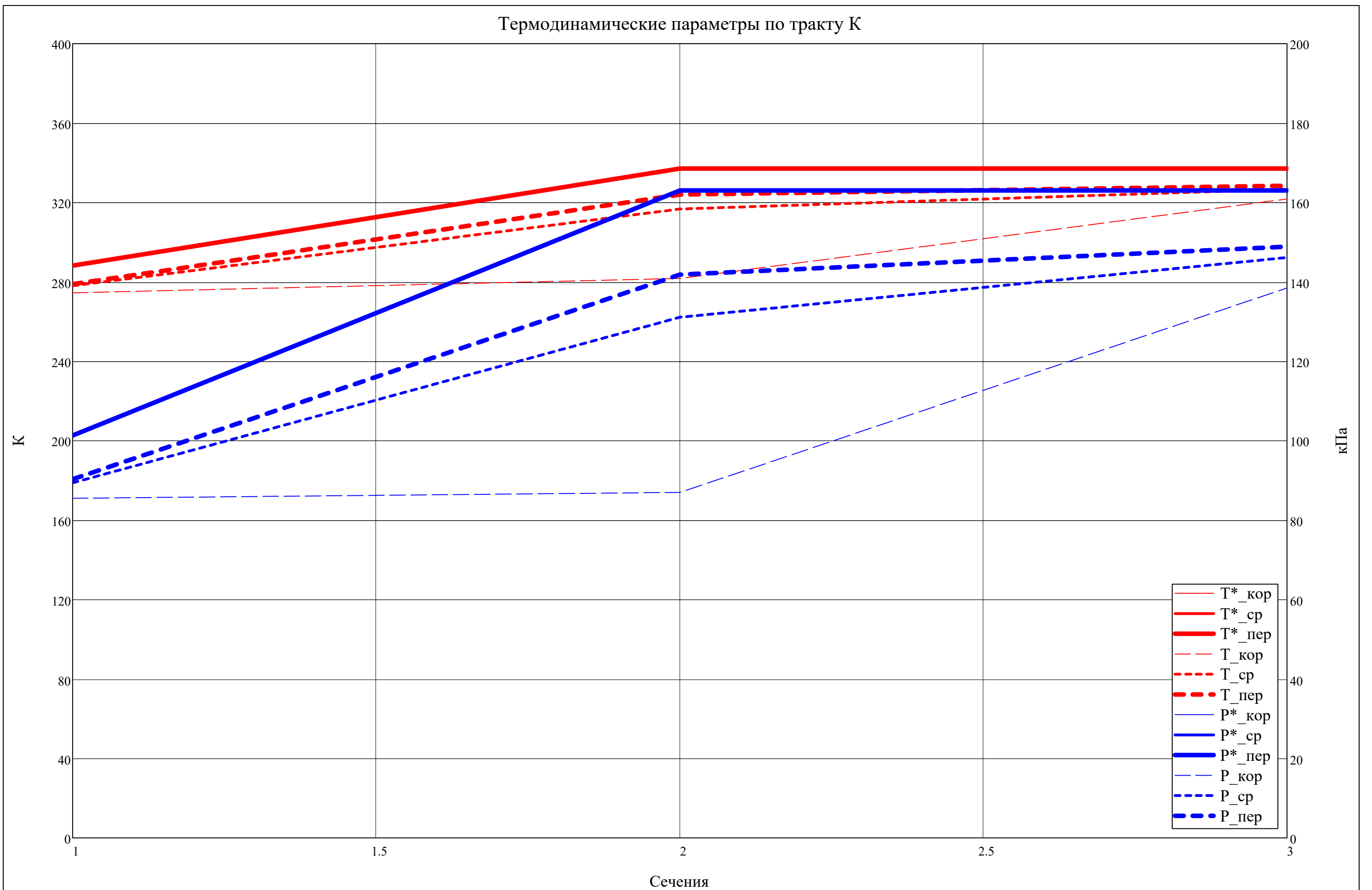
$$\begin{pmatrix} c_{u1CA_r} \\ c_{u3CA_r} \end{pmatrix} = \begin{pmatrix} c_{u_{st(i,3),r}} \\ c_{u3CA_{av}(N_r)} \text{ if } CA = 1 \end{pmatrix}$$



$T^*_{1BHA} = \begin{pmatrix} 288.2 \\ 288.2 \\ 288.2 \end{pmatrix}$	$T^*_{3BHA} = \begin{pmatrix} 288.2 \\ 288.2 \\ 288.2 \end{pmatrix}$	$a^*_{c1BHA} = \begin{pmatrix} 310.78 \\ 310.78 \\ 310.78 \end{pmatrix}$	$a^*_{c3BHA} = \begin{pmatrix} 310.78 \\ 310.78 \\ 310.78 \end{pmatrix}$	$\alpha_{1BHA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ^\circ$	$\alpha_{3BHA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ^\circ$
$P^*_{1BHA} = \begin{pmatrix} 101.3 \\ 101.3 \\ 101.3 \end{pmatrix} \cdot 10^3$	$P^*_{3BHA} = \begin{pmatrix} 101.3 \\ 101.3 \\ 101.3 \end{pmatrix} \cdot 10^3$	$c_{1BHA} = \begin{pmatrix} 142.7 \\ 142.7 \\ 142.7 \end{pmatrix}$	$c_{3BHA} = \begin{pmatrix} 142.7 \\ 142.7 \\ 142.7 \end{pmatrix}$	$\epsilon_{BHA} = \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \cdot ^\circ$	
$\rho^*_{1BHA} = \begin{pmatrix} 1.224 \\ 1.224 \\ 1.224 \end{pmatrix}$	$\rho^*_{3BHA} = \begin{pmatrix} 1.224 \\ 1.224 \\ 1.224 \end{pmatrix}$	$c_{u1BHA} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix}$	$c_{u3BHA} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix}$		
$Cp_{1BHA} = \begin{pmatrix} 1002.6 \\ 1002.6 \\ 1002.6 \end{pmatrix}$	$Cp_{3BHA} = \begin{pmatrix} 1002.6 \\ 1002.6 \\ 1002.6 \end{pmatrix}$	$c_{a1BHA} = \begin{pmatrix} 142.7 \\ 142.7 \\ 142.7 \end{pmatrix}$	$c_{a3BHA} = \begin{pmatrix} 142.7 \\ 142.7 \\ 142.7 \end{pmatrix}$	$\lambda_{c1BHA} = \begin{pmatrix} 0.459 \\ 0.459 \\ 0.459 \end{pmatrix}$	$\lambda_{c3BHA} = \begin{pmatrix} 0.459 \\ 0.459 \\ 0.459 \end{pmatrix}$
$k_{1BHA} = \begin{pmatrix} 1.401 \\ 1.401 \\ 1.401 \end{pmatrix}$	$k_{3BHA} = \begin{pmatrix} 1.401 \\ 1.401 \\ 1.401 \end{pmatrix}$				



Термодинамические параметры по тракту К





$$\Delta c_a = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \text{for } a \in 2..3 \\ \text{for } r \in 1..N_r \\ \Delta c_{a_{st(i,a),r}} = c_{a_{st(i,a),r}} - c_{a_{st(i,a-1),r}} \\ \Delta c_a \end{array} \right.$$

[illegible]

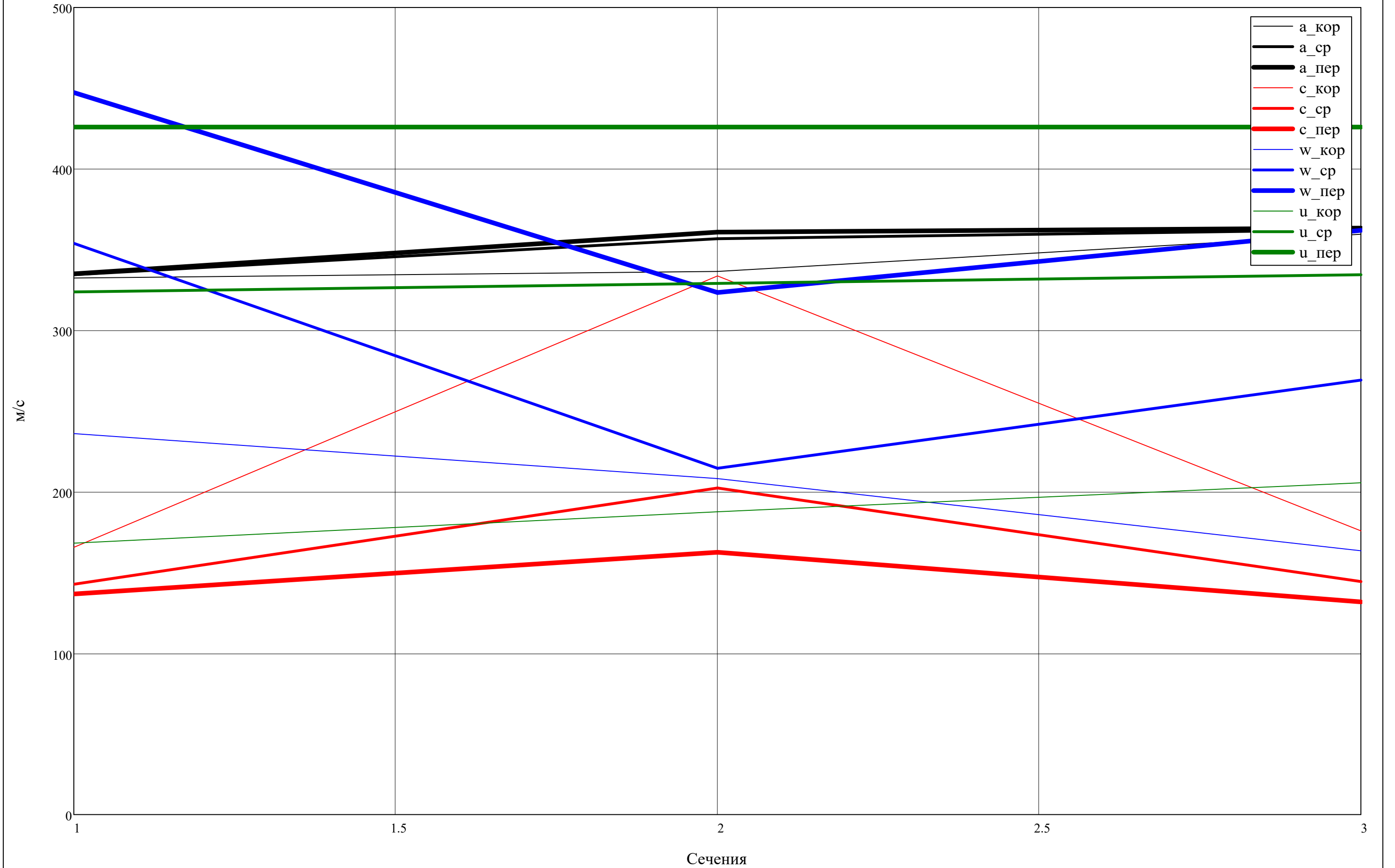
[illegible]

[illegible]

[illegible]



Скорости по тракту К

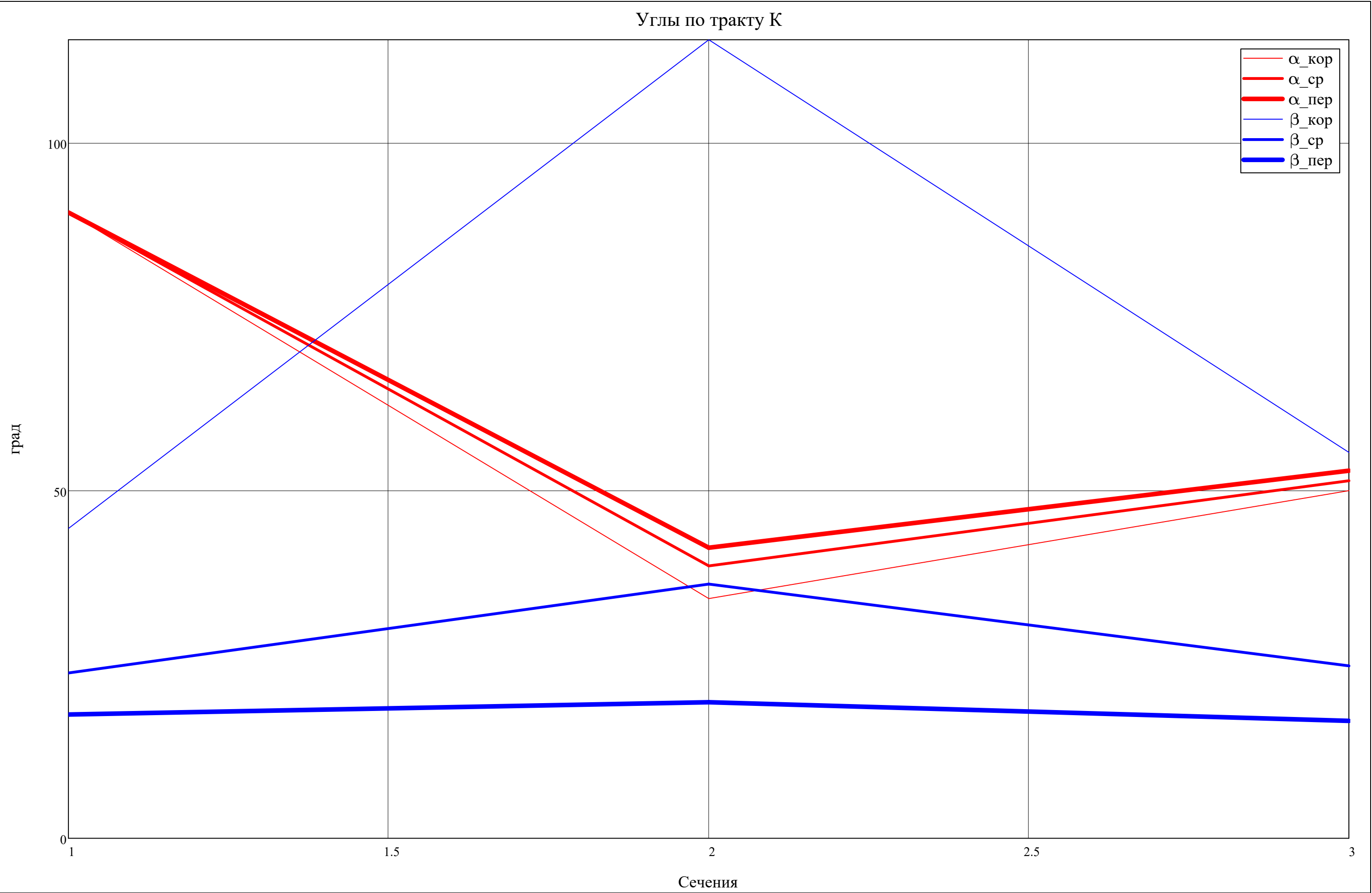


[illegible][illegible][illegible]

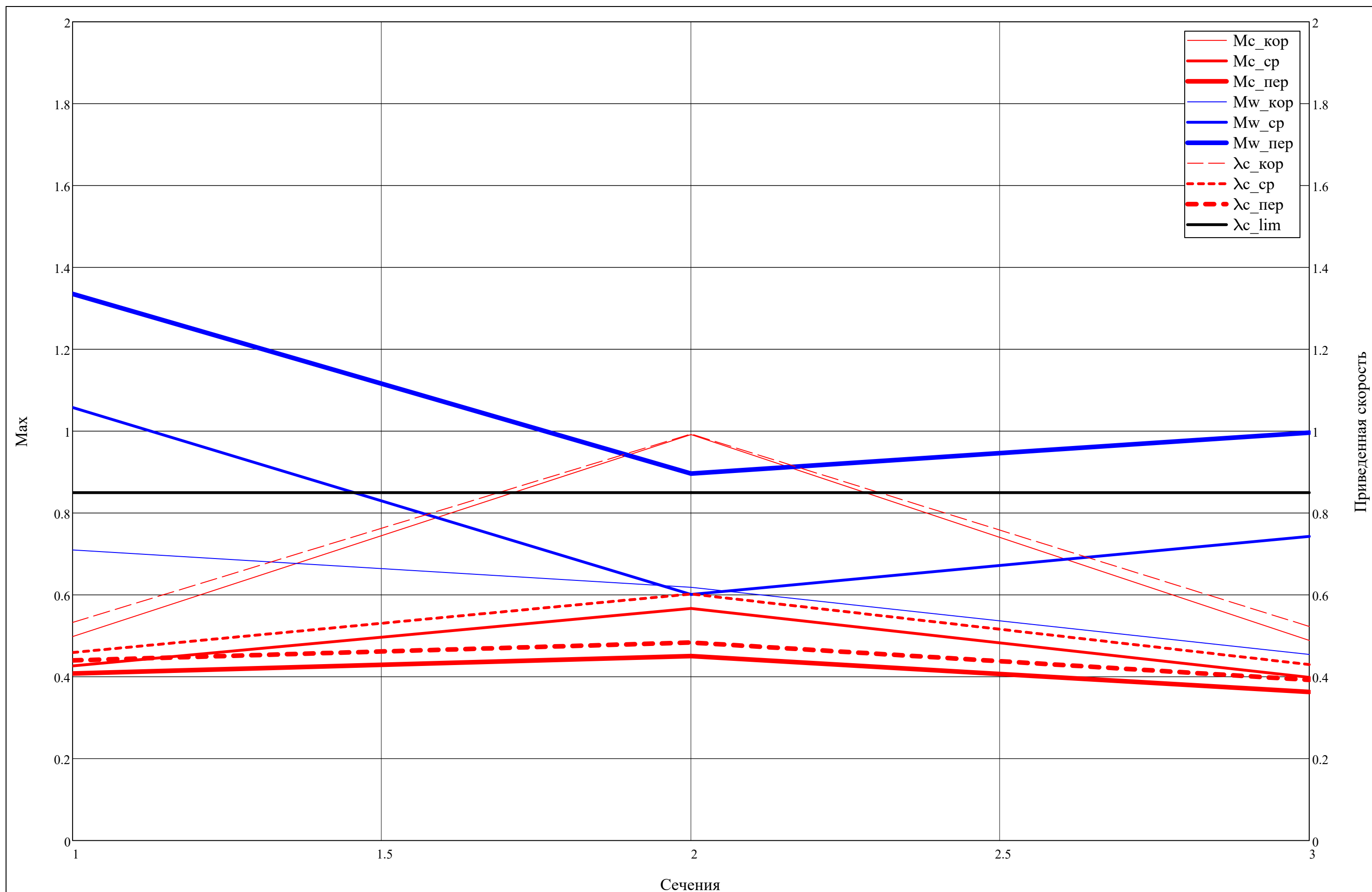
$\beta.2 > 91 \Rightarrow$  поменять 3-н профилирования

[illegible][illegible]

Углы по тракту К

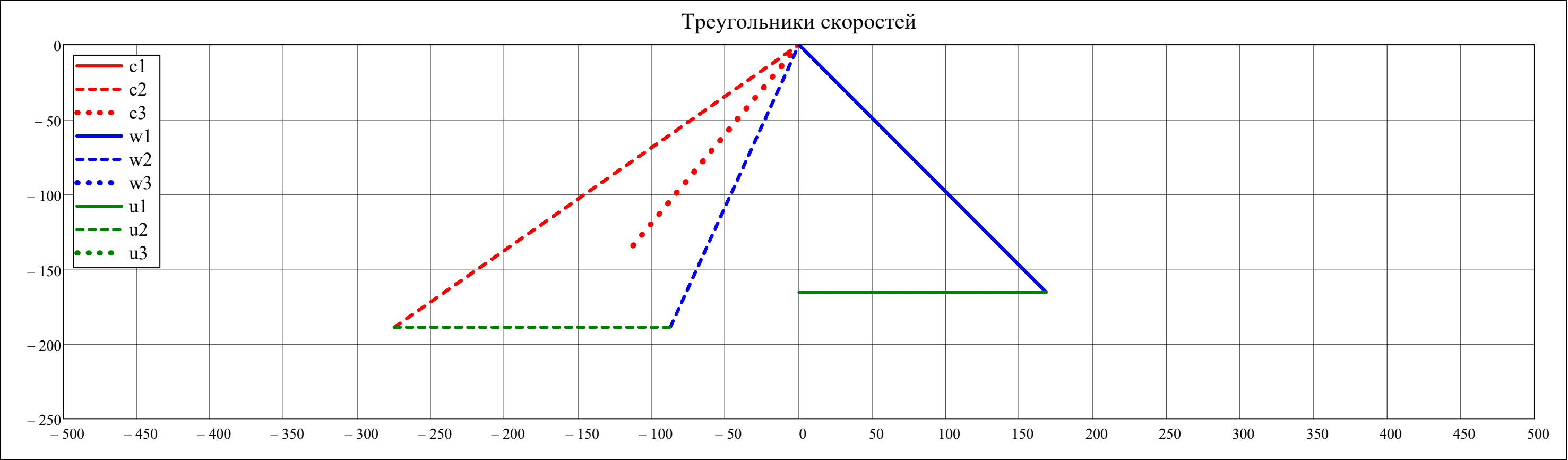




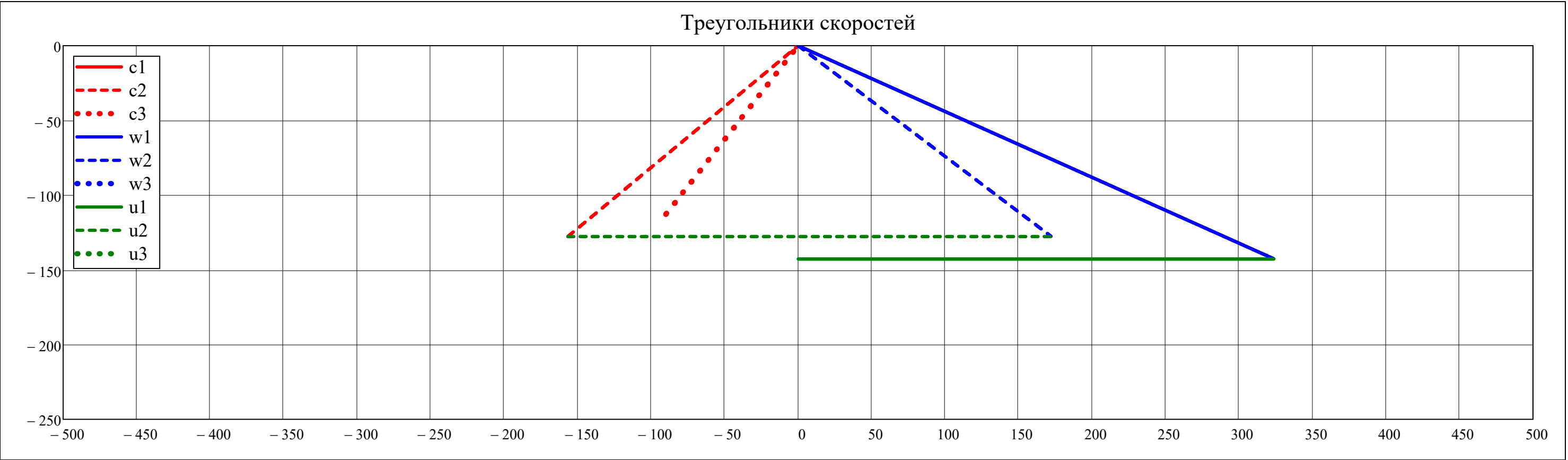


$T^*_{1CA} = \begin{pmatrix} 337.1 \\ 337.1 \\ 337.1 \end{pmatrix}$	$T^*_{3CA} = \begin{pmatrix} 337.1 \\ 337.1 \\ 337.1 \end{pmatrix}$	$a^*_{c1CA} = \begin{pmatrix} 336.0 \\ 336.0 \\ 336.0 \end{pmatrix}$	$a^*_{c3CA} = \begin{pmatrix} 336.0 \\ 336.0 \\ 336.0 \end{pmatrix}$	$\alpha_{1CA} = \begin{pmatrix} 49.99 \\ 51.42 \\ 52.87 \end{pmatrix} \cdot ^\circ$	$\alpha_{3CA} = \begin{pmatrix} 49.99 \\ 51.42 \\ 52.87 \end{pmatrix} \cdot ^\circ$
$P^*_{1CA} = \begin{pmatrix} 163.0 \\ 163.0 \\ 163.0 \end{pmatrix} \cdot 10^3$	$P^*_{3CA} = \begin{pmatrix} 163.0 \\ 163.0 \\ 163.0 \end{pmatrix} \cdot 10^3$	$c_{1CA} = \begin{pmatrix} 175.8 \\ 144.4 \\ 131.8 \end{pmatrix}$	$c_{3CA} = \begin{pmatrix} 175.8 \\ 144.4 \\ 131.8 \end{pmatrix}$	$\varepsilon_{CA} = \begin{pmatrix} 0.00 \\ 0.00 \\ 0.00 \end{pmatrix} \cdot ^\circ$	
$\rho^*_{1CA} = \begin{pmatrix} 1.684 \\ 1.684 \\ 1.684 \end{pmatrix}$	$\rho^*_{3CA} = \begin{pmatrix} 1.684 \\ 1.684 \\ 1.684 \end{pmatrix}$	$c_{u1CA} = \begin{pmatrix} 113.0 \\ 90.0 \\ 79.6 \end{pmatrix}$	$c_{u3CA} = \begin{pmatrix} 113.0 \\ 90.0 \\ 79.6 \end{pmatrix}$		
$Cp_{1CA} = \begin{pmatrix} 1006.0 \\ 1006.0 \\ 1006.0 \end{pmatrix}$	$Cp_{3CA} = \begin{pmatrix} 1006.0 \\ 1006.0 \\ 1006.0 \end{pmatrix}$	$c_{a1CA} = \begin{pmatrix} 134.6 \\ 112.9 \\ 105.1 \end{pmatrix}$	$c_{a3CA} = \begin{pmatrix} 134.6 \\ 112.9 \\ 105.1 \end{pmatrix}$	$\lambda_{c1CA} = \begin{pmatrix} 0.523 \\ 0.430 \\ 0.392 \end{pmatrix}$	$\lambda_{c3CA} = \begin{pmatrix} 0.523 \\ 0.430 \\ 0.392 \end{pmatrix}$
$k_{1CA} = \begin{pmatrix} 1.399 \\ 1.399 \\ 1.399 \end{pmatrix}$	$k_{3CA} = \begin{pmatrix} 1.399 \\ 1.399 \\ 1.399 \end{pmatrix}$				

r = 1

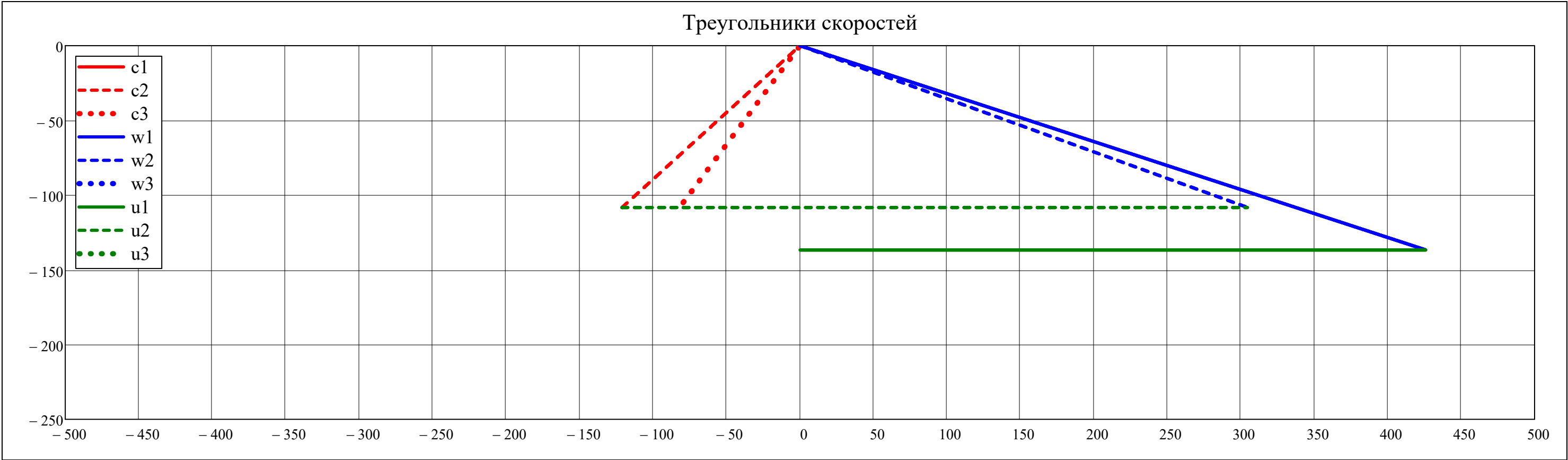


$\bar{r}_w = \text{av}(N_r)$





$r_w = N_r$



Построение треугольников скоростей в 3х сечениях

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


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Кольцевые площади (м<sup>2</sup>):

[illegible]

Радиус и диаметр двухконтурности (м):

[illegible]

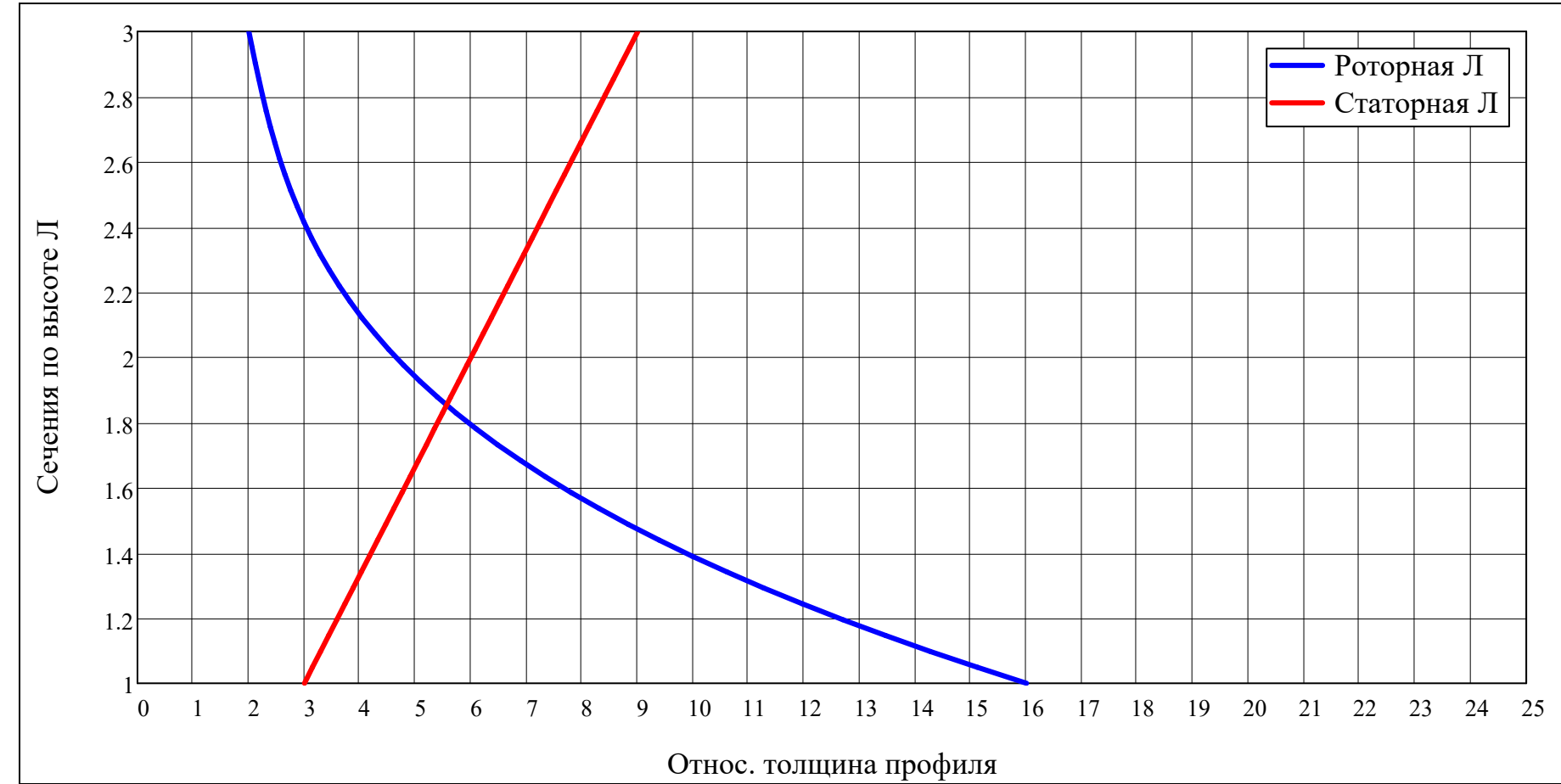


Относ. толщины ЛРК и СА:

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

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

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



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

$$\left( \begin{array}{c} \overline{c}_{\text{stator}} \\ \overline{c}_{\text{rotor}} \end{array} \right) =$$

for i ∈ 1..Z

for r ∈ 1..N<sub>r</sub>

$$\left( \begin{array}{c} \overline{c}_{\text{stator}_{i,r}} \\ \overline{c}_{\text{rotor}_{i,r}} \end{array} \right) = \left( \begin{array}{c} \overline{c}_{\text{stator.}(r)} \\ \overline{c}_{\text{rotor.}(r)} \end{array} \right)$$

$$\left( \begin{array}{c} \overline{c}_{\text{stator}} \\ \overline{c}_{\text{rotor}} \end{array} \right)$$

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

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

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

$$\overline{c}_{\text{rotor}}^{\text{T}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 16.00 \\ \hline 2 & 4.65 \\ \hline 3 & 2.00 \\ \hline \end{array} \cdot\%$$

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

$$\begin{pmatrix} \overline{r}_{inlet_{BHA}} \\ \overline{r}_{outlet_{BHA}} \end{pmatrix} = \begin{cases} \text{for } r \in 1..N_r & \text{if } BHA = 1 \\ \begin{pmatrix} \overline{r}_{inlet_{BHA_r}} \\ \overline{r}_{outlet_{BHA_r}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{stator.(r)} \\ \begin{pmatrix} \overline{r}_{inlet_{BHA}} \\ \overline{r}_{outlet_{BHA}} \end{pmatrix} \end{cases}$$

$$\begin{pmatrix} \overline{r}_{inlet_{CA}} \\ \overline{r}_{outlet_{CA}} \end{pmatrix} = \begin{cases} \text{for } r \in 1..N_r & \text{if } CA = 1 \\ \begin{pmatrix} \overline{r}_{inlet_{CA_r}} \\ \overline{r}_{outlet_{CA_r}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{stator.(r)} \\ \begin{pmatrix} \overline{r}_{inlet_{CA}} \\ \overline{r}_{outlet_{CA}} \end{pmatrix} \end{cases}$$

$$\overline{r}_{inlet_{BHA}} = 0.000 \cdot \%$$

$$\overline{r}_{inlet_{stator}}^T = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.300 \\ \hline 2 & 0.600 \\ \hline 3 & 0.900 \\ \hline \end{array} \cdot \%$$

$$\overline{r}_{outlet_{stator}}^T = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.150 \\ \hline 2 & 0.300 \\ \hline 3 & 0.450 \\ \hline \end{array} \cdot \%$$

$$\overline{r}_{outlet_{BHA}} = 0.000 \cdot \%$$

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

$$\overline{r}_{inlet_{CA}} = 0.000 \cdot \%$$

$$\overline{r}_{inlet_{rotor}}^T = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.600 \\ \hline 2 & 0.465 \\ \hline 3 & 0.200 \\ \hline \end{array} \cdot \%$$

$$\overline{r}_{outlet_{rotor}}^T = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.800 \\ \hline 2 & 0.233 \\ \hline 3 & 0.100 \\ \hline \end{array} \cdot \%$$

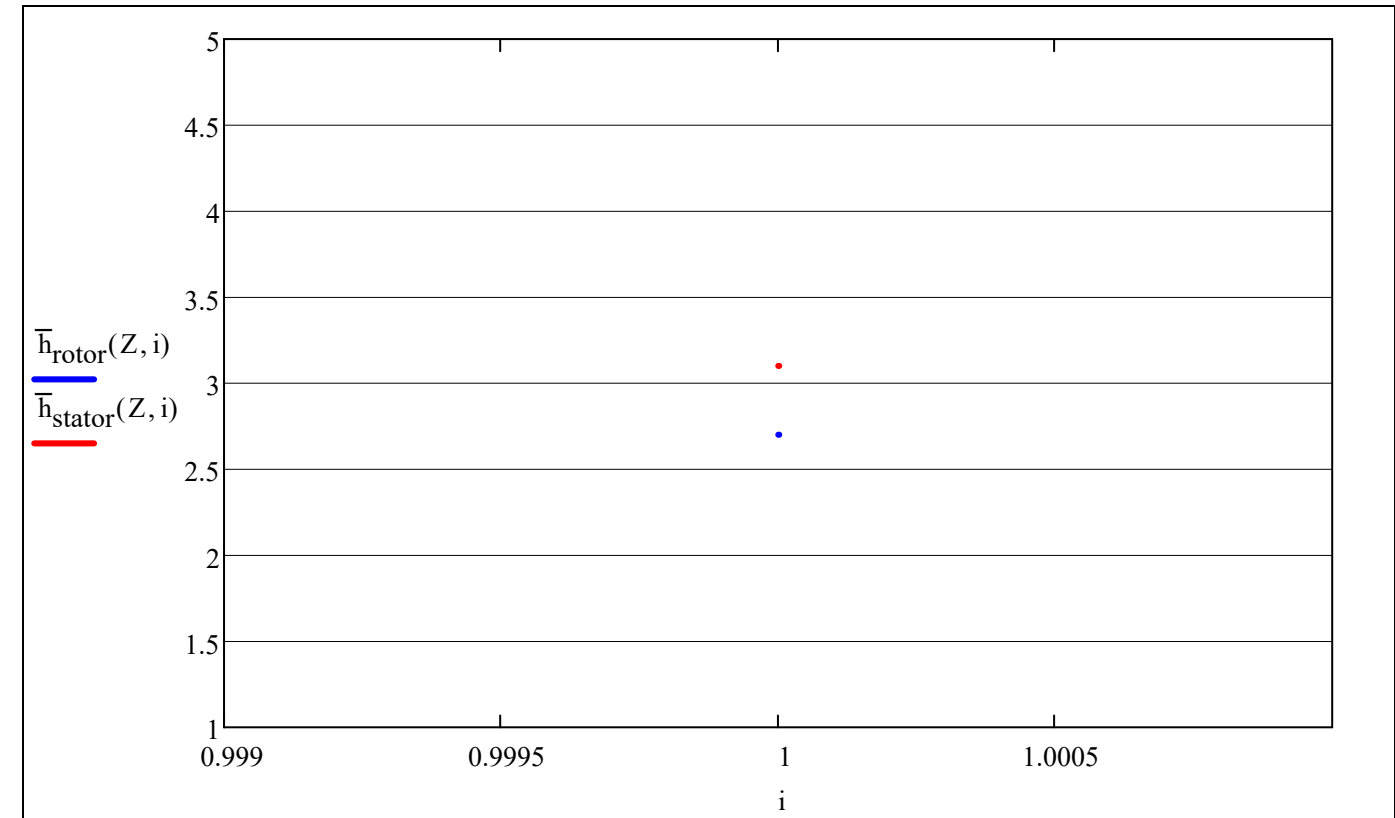
$$\overline{r}_{outlet_{CA}} = 0.000 \cdot \%$$

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

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

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

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



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

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

Для компрессора газогенератора

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

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

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

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

[16, с. 83-84]

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

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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
| |  $b_{\text{BHAkop}} = \frac{\text{chord}_{\text{BHA}_{\text{av}(N_r)}} \cdot \text{sail}}{\text{sail}_{\text{stator}} - 1 + \text{sail}}$ 
| | bBHAпер = bBHAkop·sailstator
| |  $b_{\text{BHA.}}(z) = \text{interp} \left[ \text{cspline} \left[ \begin{pmatrix} R_{\text{st}(i,1),1} \\ R_{\text{st}(i,1),\text{av}(N_r)} \\ R_{\text{st}(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{BHAkop}} \\ \text{chord}_{\text{BHA}_{\text{av}(N_r)}} \\ b_{\text{BHAпер}} \end{pmatrix} \right], \begin{pmatrix} R_{\text{st}(i,1),1} \\ R_{\text{st}(i,1),\text{av}(N_r)} \\ R_{\text{st}(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{\text{BHAkop}} \\ \text{chord}_{\text{BHA}_{\text{av}(N_r)}} \\ b_{\text{BHAпер}} \end{pmatrix}, z \right]$ 
| | chordBHAr = bBHA.(Rst(i,1),r)
chordBHA
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$(\text{chord}_{\text{rotor}} \quad \text{chord}_{\text{stator}}) =$	<div>for <math>i \in 1 \dots Z</math></div> <div> <math display="block">\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}</math> </div> <div> <math display="block">\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}}</math> </div> <div>for <math>r \in 1 \dots N_r</math></div> <div> <math display="block">b_{\text{PKkop}} = \frac{\text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \cdot \text{sail}}{\text{sail}_{\text{rotor}} - 1 + \text{sail}}</math> </div> <div> <math display="block">b_{\text{HAKop}} = \frac{\text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \cdot \text{sail}}{\text{sail}_{\text{stator}} - 1 + \text{sail}}</math> </div> <div> <math display="block">\begin{pmatrix} b_{\text{PKпер}} \\ b_{\text{HАпер}} \end{pmatrix} = \begin{pmatrix} b_{\text{PKkop}} \cdot \text{sail}_{\text{rotor}} \\ b_{\text{HAKop}} \cdot \text{sail}_{\text{stator}} \end{pmatrix}</math> </div> <div> <math display="block">\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]</math> </div> <div> <math display="block">\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{HАпер}} \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{HАпер}} \end{pmatrix}, z \right]</math> </div> <div> <math display="block">\text{chord}_{\text{rotor}_{i, r}} = \text{chord}_{\text{rotor.}}(R_{\text{st}(i, 2), r})</math> </div> <div> <math display="block">\text{chord}_{\text{stator}_{i, r}} = \text{chord}_{\text{stator.}}(R_{\text{st}(i, 2), r})</math> </div> <div><math>(\text{chord}_{\text{rotor}} \quad \text{chord}_{\text{stator}})</math></div>
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Ср. линия профиля:  
0.5 - дуга окружности  
0.45 - парабола

$\overline{x_f} = 0.5$

Определение количества Л РК и НА

$\epsilon_{BHA(b/t)=1}$   
 $Z_{BHA}$   
 $r_{inlet_{BHA}}$   
 $r_{outlet_{BHA}}$   
 $t_{BHA}$   
 $i_{BHA}$   
 $m_{BHA}$   
 $\theta_{BHA}$   
 $\delta_{BHA}$   
 $\chi_{BHA}$   
 $v_{BHA}$   
 $R_{CЛ.BHA}$   
 $K_{BHA}$   
 $D_{BHA}$

=

if BHA = 1

for  $r \in av(N_r)$

$\epsilon_{BHA(b/t)=1_r} = \epsilon_{(b/t)=1}(\alpha_{3BHA_r})$   
 $b/t_{BHA_r} = b/t=1 \left( \frac{\epsilon_{BHA_r}}{\epsilon_{BHA(b/t)=1_r}} \right)$   
 $t_{BHA_r} = \frac{chord_{BHA_r}}{b/t_{BHA_r}}$   
 $Z_{BHA} = \left\{ \begin{array}{l} \text{round}\left(\frac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right) \text{ if } \text{mod}\left(\text{round}\left(\frac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right), 2\right) = 0 \\ \text{round}\left(\frac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right) + 1 \text{ otherwise} \end{array} \right.$   
for  $r \in 1..N_r$

$\left(r_{inlet_{BHA_r}} \ r_{outlet_{BHA_r}}\right) = chord_{BHA_r} \cdot \left(\overline{r}_{inlet_{BHA_r}} \ \overline{r}_{outlet_{BHA_r}}\right)$   
 $t_{BHA_r} = \frac{D_{st(1,1),r}}{Z_{BHA}}$   
 $i_{BHA_r} = 2.5 \cdot \left(\frac{chord_{BHA_r}}{t_{BHA_r}} - 2\right) \cdot ^\circ$   
 $m_{BHA} = 0.23 \cdot \left(2 \cdot \overline{x_f}\right)^2 + 0.18 - \frac{0.002}{1 + \overline{x_f}} \cdot \left(\alpha_{3BHA}\right)$

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

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

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

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

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

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

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

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

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

=

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  $r \in 1 \dots N_r$

$$\begin{pmatrix} r_{\text{inlet\_stator}_{i,r}} & r_{\text{outlet\_stator}_{i,r}} \\ r_{\text{inlet\_rotor}_{i,r}} & r_{\text{outlet\_rotor}_{i,r}} \end{pmatrix} = \begin{pmatrix} \overline{r}_{\text{inlet\_stator}_{i,r}} \cdot \text{chord}_{\text{stator}_{i,r}} & \overline{r}_{\text{outlet\_stator}_{i,r}} \cdot \text{chord}_{\text{stator}_{i,r}} \\ \overline{r}_{\text{inlet\_rotor}_{i,r}} \cdot \text{chord}_{\text{rotor}_{i,r}} & \overline{r}_{\text{outlet\_rotor}_{i,r}} \cdot \text{chord}_{\text{rotor}_{i,r}} \end{pmatrix}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\varepsilon_{CA(b/t)=1}$ 
 $Z_{CA}$ 
 $r_{inlet_{CA}}$ 
 $r_{outlet_{CA}}$ 
 $t_{CA}$ 
 $i_{CA}$ 
 $m_{CA}$ 
 $\theta_{CA}$ 
 $\delta_{CA}$ 
 $\chi_{CA}$ 
 $v_{CA}$ 
 $R_{CJL.CA}$ 
 $K_{CA}$ 
 $D_{CA}$

=

if CA = 1

for r ∈ av(N<sub>r</sub>)

$\varepsilon_{CA(b/t)=1_r} = \varepsilon_{(b/t)=1}(\alpha_{3CA_r})$ 
 $b/t_{CA_r} = b/t=1\left(\frac{\varepsilon_{CA_r}}{\varepsilon_{CA(b/t)=1_r}}\right)$ 
 $t_{CA_r} = \frac{chord_{CA_r}}{b/t_{CA_r}}$ 
 $Z_{CA} = \left\{\begin{array}{l} \text{round}\left(\frac{\pi \cdot D_{st(Z,3),r}}{t_{CA_r}}\right) \text{ if } \text{mod}\left(\text{round}\left(\frac{\pi \cdot D_{st(Z,3),r}}{t_{CA_r}}\right), 2\right) = 0 \\ \text{round}\left(\frac{\pi \cdot D_{st(Z,3),r}}{t_{CA_r}}\right) + 1 \text{ otherwise} \end{array}\right.$

for r ∈ 1..N<sub>r</sub>

$\left(r_{inlet_{CA_r}} \ r_{outlet_{CA_r}}\right) = chord_{CA_r} \cdot \left(\overline{r_{inlet_{CA_r}}} \ \overline{r_{outlet_{CA_r}}}\right)$ 
 $t_{CA_r} = \frac{D_{st(Z,3),r}}{Z_{CA}}$ 
 $i_{CA_r} = 2.5 \cdot \left(\frac{chord_{CA_r}}{t_{CA_r}} - 2\right) \cdot ^\circ$ 
 $m_{CA_r} = 0.23 \cdot \left(2 \cdot \overline{x_f}\right)^2 + 0.18 - \frac{0.002}{deg} \cdot (\alpha_{3CA_r})$ 
 $\theta_{CA_r} = \frac{\varepsilon_{CA_r} - i_{CA_r}}{1 - m_{CA_r} \cdot \sqrt{\frac{t_{CA_r}}{chord_{CA_r}}}}$



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

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

$$v_{CA_r} = \chi_{CA_r} + \alpha_{1CA_r} + i_{CA_r}$$

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

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

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

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

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

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

=

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	140.51														
2	165.54														
3	182.66														

$\cdot 10^{-3}$

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	119.15														
2	133.30														
3	142.98														

$\cdot 10^{-3}$

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

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
1	2.25
2	0.77
3	0.37

$\cdot 10^{-3}$

$\text{r\_inlet}_{\text{stator}}^{\text{T}}$

=

	1
1	0.36
2	0.80
3	1.29

$\cdot 10^{-3}$

$\text{r\_outlet}_{\text{rotor}}^{\text{T}}$

=

	1
1	1.12
2	0.38
3	0.18

$\cdot 10^{-3}$

$\text{r\_outlet}_{\text{stator}}^{\text{T}}$

=

	1
1	0.18
2	0.40
3	0.64

$\cdot 10^{-3}$

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

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

$\epsilon_{\text{BHA}(\text{b/t})=1_{\text{av}\left(N_{\text{r}}\right)}} = \blacksquare^{\circ}$

Угол поворота потока:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	9.86														

 $\cdot^{\circ}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	15.65														

 $\cdot^{\circ}$

$\epsilon_{\text{CA}(\text{b/t})=1_{\text{av}\left(N_{\text{r}}\right)}} = \blacksquare^{\circ}$

$\frac{\text{chord}_{\text{BHA}}}{t_{\text{BHA}}} = \blacksquare$

Густота решетки:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	2.582														
2	1.657														
3	1.402														

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

	1
1	1.071
2	0.710
3	0.593

$\frac{\text{chord}_{\text{CA}}}{t_{\text{CA}}} = \blacksquare$

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

Количество Л:

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

	1
1	37

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	20														

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

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	54.43														
2	99.89														
3	130.33														

$\cdot 10^{-3}$

Шаг решетки (м):

$t_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	111.29														
2	187.80														
3	241.10														

$\cdot 10^{-3}$

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

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

$i_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3.954														
2	1.643														
3	1.004														

$\cdot ^\circ$

Угол атаки:

$i_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-2.323														
2	-3.226														
3	-3.517														

$\cdot ^\circ$

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

$m_{BHA} = 0.0000$

$m_{rotor}^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.1803														
2	0.3369														
3	0.3709														

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	0.3100														
2	0.3072														
3	0.3043														

$m_{CA} = 0.0000$

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

$\theta_{rotor}^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	74.71														
2	15.09														
3	1.13														

 $\cdot ^\circ$

Угол изгиба ср. линии профиля:

$\theta_{stator}^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	25.47														
2	24.35														
3	24.12														

 $\cdot ^\circ$

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

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

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

	1
1	8.384
2	3.948
3	0.353

 $\cdot ^\circ$

Угол отставания:

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

	1
1	7.631
2	8.878
3	9.530

 $\cdot ^\circ$

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

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

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

	1
1	85.87
2	32.97
3	19.36

 $\cdot ^\circ$

Угол установки Л:

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

	1
1	44.89
2	48.12
3	50.34

 $\cdot ^\circ$

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

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

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	115.79														
2	630.45														
3	9298.59														

$\cdot 10^{-3}$

$R_{\text{СЛ.stator}}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	270.24														
2	316.02														
3	342.17														

$\cdot 10^{-3}$

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

$K_{\text{ВНА}} = 0.0000$

Фактор диффузорности решетки:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.1408														
2	0.8955														
3	0.7926														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.7127														
2	0.8833														
3	0.9699														

$K_{\text{СА}} = 0.0000$

$D_{BHA} = 0.0000$

$D_{rotor}^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.3277														
2	0.5230														
3	0.3736														

Диффузорность решетки:

$D_{stator}^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.7001														
2	0.5188														
3	0.4051														

$D_{CA} = 0.0000$

$D_{BHA} \leq 0.6 = 1$

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

	1
1	1
2	1
3	1

[18, с. 71]

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

	1
1	0
2	1
3	1

$D_{CA} \leq 0.6 = 1$



Коэф. потерь полного давления:

### Качество профилей решеток РК и НА:

### Качество профилей решеток РК и НА:

КПД элементарной ступени:

КПД элементарной ступени:

EXCEL<sub>AIRFOIL.subsonic</sub> =  
... \A40.xlsx

$$X/B_{\text{subsonic}} = \text{submatrix}\left(\text{EXCEL}_{\text{AIRFOIL.subsonic}}, 2, \text{rows}\left(\text{EXCEL}_{\text{AIRFOIL.subsonic}}\right), \text{ORIGIN} + 0, \text{ORIGIN} + 0\right)$$
$$Y/B_{\text{subsonic}} = \text{submatrix}\left(\text{EXCEL}_{\text{AIRFOIL.subsonic}}, 2, \text{rows}\left(\text{EXCEL}_{\text{AIRFOIL.subsonic}}\right), \text{ORIGIN} + 1, \text{ORIGIN} + 1\right)$$

Предел использования дозвукового профиля: 

M<sub>lim</sub> = 0.95

EXCEL<sub>AIRFOIL.supersonic</sub> =  
... \Емин сверхзвуковой профиль.xlsx

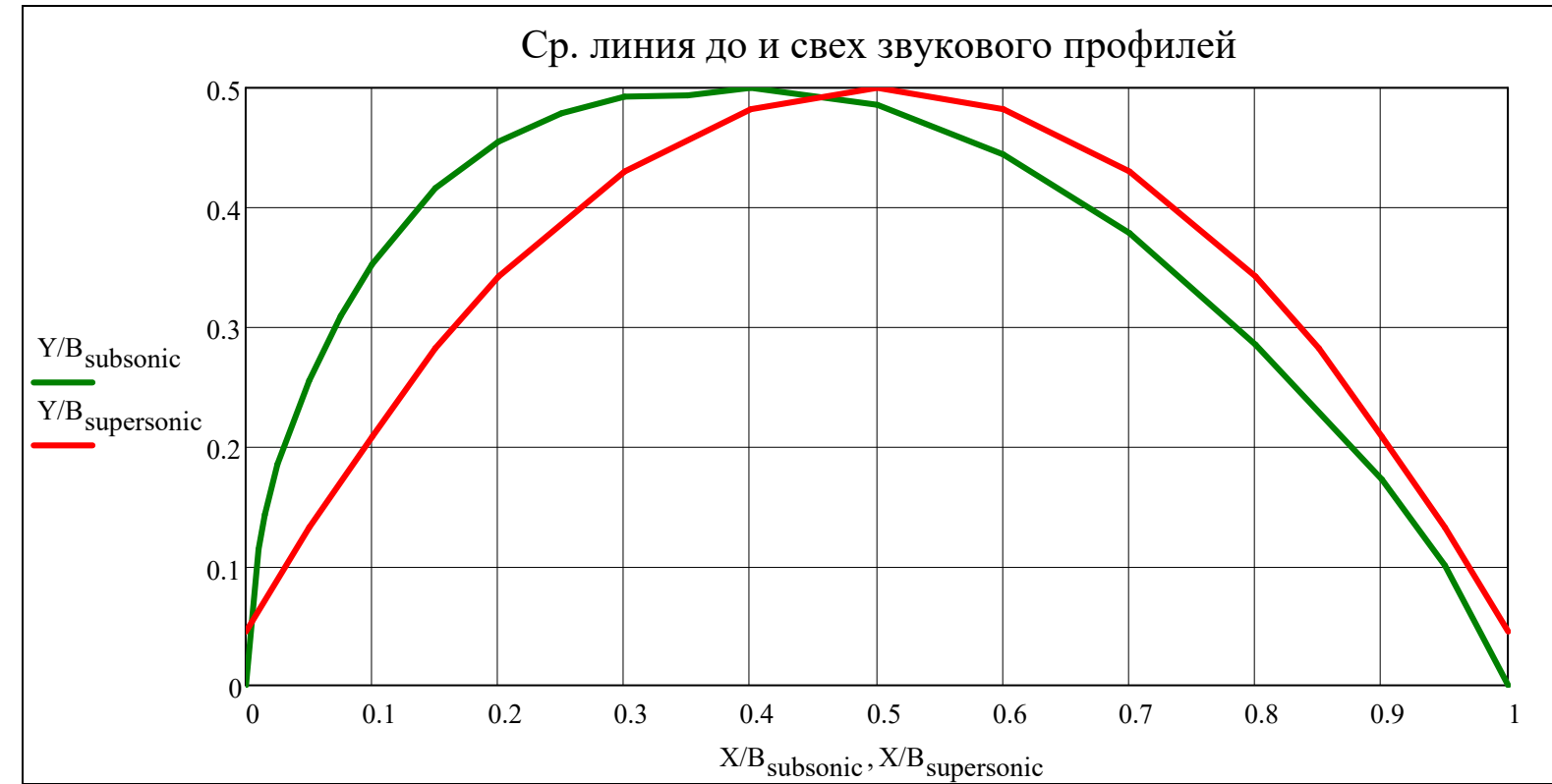
$$X/B_{\text{supersonic}} = \text{submatrix}\left(\text{EXCEL}_{\text{AIRFOIL.supersonic}}, 2, \text{rows}\left(\text{EXCEL}_{\text{AIRFOIL.supersonic}}\right), \text{ORIGIN} + 0, \text{ORIGIN} + 0\right)$$
$$Y/B_{\text{supersonic}} = \text{submatrix}\left(\text{EXCEL}_{\text{AIRFOIL.supersonic}}, 2, \text{rows}\left(\text{EXCEL}_{\text{AIRFOIL.supersonic}}\right), \text{ORIGIN} + 1, \text{ORIGIN} + 1\right)$$

augment(X/B<sub>subsonic</sub>, Y/B<sub>subsonic</sub>)<sup>T</sup> =

	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<sub>supersonic</sub>, Y/B<sub>supersonic</sub>)<sup>T</sup> =

	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



AIRFOIL<sub>subsonic</sub>(x,line, $\overline{c}$ , $\theta$ ) =

if 0 ≤ x ≤ 1

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

if line = "+"

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

if line = "0"

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

if line = "-"

NaN otherwise

AIRFOIL<sub>supersonic</sub>(x,line, $\overline{c}$ , $\theta$ ) =

if 0 ≤ x ≤ 1

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

if line = "+"

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

if line = "0"

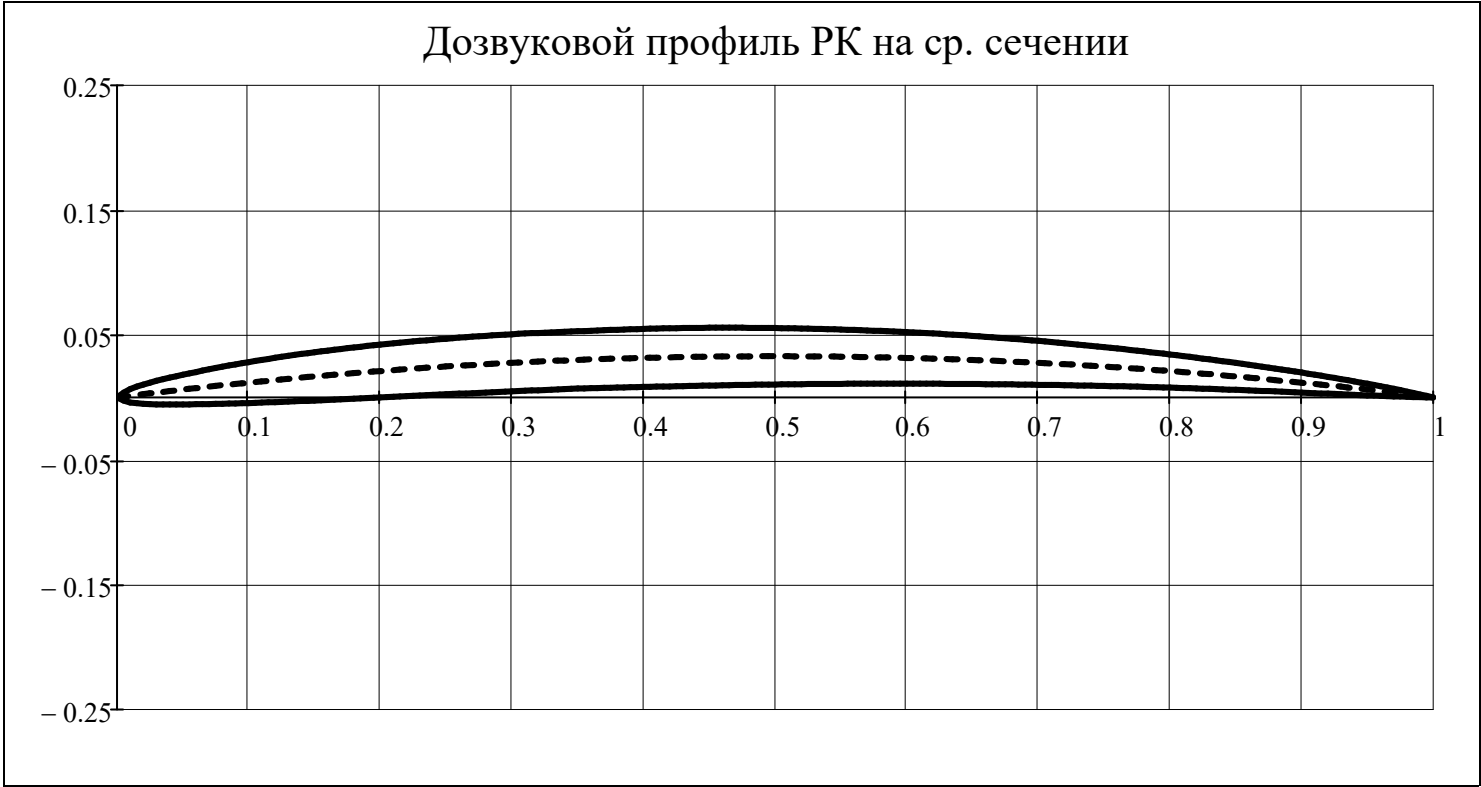
$\text{interp}\left(\text{cspline}\left(X/B_{\text{supersonic}},y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}},\theta\right)-Y/B_{\text{supersonic}}\cdot\overline{c}\right),X/B_{\text{supersonic}},y/b_{\text{cp.л}}\left(X/B_{\text{supersonic}},\theta\right)-Y/B_{\text{supersonic}}\cdot\overline{c},x\right)$

if line = "-"

NaN otherwise

x = 0,0.005.. 1

$\dot{i}_{\text{ш}} = 1$



$$l_{upper\_stator}^T =$$

	1
1	119.87
2	134.75
3	145.45

$$\cdot 10^{-3}$$

$$l_{lower\_stator}^T =$$

	1
1	119.28
2	133.54
3	143.73

$$\cdot 10^{-3}$$

$$area_{stator}^T =$$

	1
1	298.38
2	779.71
3	1345.64

$$\cdot 10^{-6}$$

$$Sx_{stator}^T =$$

	1
1	943.3
2	2120.7
3	3548.4

$$\cdot 10^{-9}$$

$$Sy_{stator}^T =$$

	1
1	17775.8
2	46938.5
3	86892.0

$$\cdot 10^{-9}$$

$$x0_{stator}^T =$$

	1
1	59.57
2	60.20
3	64.57

$$\cdot 10^{-3}$$

$$y0_{stator}^T =$$

	1
1	3.16
2	2.72
3	2.64

$$\cdot 10^{-3}$$

$$l_{upper\_rotor}^T =$$

	1
1	161.30
2	166.60
3	182.75

$$\cdot 10^{-3}$$

$$l_{lower\_rotor}^T =$$

	1
1	143.99
2	165.56
3	182.68

$$\cdot 10^{-3}$$

$$area_{rotor}^T =$$

	1	2	3	4	5	6	7	8	9
1	2310.37								
2	892.70								
3	467.52								

$$\cdot 10^{-6}$$

$$Sx_{rotor}^T =$$

	1
1	39814.7
2	3227.9
3	258.9

$$\cdot 10^{-9}$$

$$Sy_{rotor}^T =$$

	1
1	146612.4
2	73887.3
3	42699.6

$$\cdot 10^{-9}$$

$$x0_{rotor}^T =$$

	1
1	63.46
2	82.77
3	91.33

$$\cdot 10^{-3}$$

$$y0_{rotor}^T =$$

	1
1	17.23
2	3.62
3	0.55

$$\cdot 10^{-3}$$

$J_{x_{stator}}^T =$ 

	1
1	3461
2	9375
3	23841

 $\cdot 10^{-12}$

$J_{y_{stator}}^T =$ 

	1
1	1289727
2	3615129
3	7178656

 $\cdot 10^{-12}$

$J_{xy_{stator}}^T =$ 

	1
1	56198
2	132758
3	238268

 $\cdot 10^{-12}$

$J_{x0_{stator}}^T =$ 

	1
1	478.55
2	3606.90
3	14483.55

 $\cdot 10^{-12}$

$J_{y0_{stator}}^T =$ 

	1
1	230744
2	789412
3	1567759

 $\cdot 10^{-12}$

$J_{xy0_{stator}}^T =$ 

	1
1	-0.16
2	5089.12
3	9135.55

 $\cdot 10^{-12}$

$\alpha_{major_{stator}}^T =$ 

	1
1	-0.00
2	0.37
3	0.34

 $\cdot ^\circ$

$J_{x_{rotor}}^T =$ 

	1
1	819752
2	15738
3	516

 $\cdot 10^{-12}$

$J_{y_{rotor}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	11903414								
2	7448061								
3	4749588								

$J_{xy_{rotor}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	2623407								
2	267167								
3	23649								

 $\cdot 10$

$J_{x0_{rotor}}^T =$ 

	1	2	3	4	5	6	7	8	
1	133622.41								
2	4065.88								
3	372.62								

$J_{y0_{rotor}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	2599607								
2	1332528								
3	849757								

 $\cdot 10$

$J_{xy0_{rotor}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	96824.41								
2	-0.77								
3	0.00								

$\alpha_{major_{rotor}}^T =$ 

	1
1	2.25
2	-0.00
3	0.00

 $\cdot ^\circ$

$$\mathbf{J_{u_{stator}}}^T = \begin{bmatrix} & 1 \\ 1 & 478.55 \\ 2 & 3573.95 \\ 3 & 14429.82 \end{bmatrix} \cdot 10^{-12}$$

$$\mathbf{J_{v_{stator}}}^T = \begin{bmatrix} & 1 \\ 1 & 230744 \\ 2 & 789445 \\ 3 & 1567813 \end{bmatrix} \cdot 10^{-12}$$

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

$$\mathbf{J_{p_{stator}}}^T = \begin{bmatrix} & 1 \\ 1 & 231223 \\ 2 & 793019 \\ 3 & 1582242 \end{bmatrix} \cdot 10^{-12}$$

$$\mathbf{W_{p_{stator}}}^T = \begin{bmatrix} & 1 \\ 1 & 3875.8 \\ 2 & 10841.5 \\ 3 & 20168.9 \end{bmatrix} \cdot 10^{-9}$$

$$\mathbf{stiffness_{stator}}^T = \begin{bmatrix} & 1 \\ 1 & 880.14 \\ 2 & 12131.62 \\ 3 & 54200.70 \end{bmatrix} \cdot 10^{-12}$$

$$\mathbf{J_{u_{rotor}}}^T = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 129826.54 & & & & & & & \\ 2 & 4065.88 & & & & & & & \\ 3 & 372.62 & & & & & & & \end{bmatrix}$$

$$\mathbf{J_{v_{rotor}}}^T = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 1 & 2603403 & & & & & & & \\ 2 & 1332528 & & & & & & & \\ 3 & 849757 & & & & & & & \end{bmatrix} \cdot 10^{-}$$

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

$$\mathbf{J_{p_{rotor}}}^T = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 1 & 2733229 & & & & & & & \\ 2 & 1336594 & & & & & & & \\ 3 & 850130 & & & & & & & \end{bmatrix} \cdot 10^{-}$$

$$\mathbf{W_{p_{rotor}}}^T = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 1 & 34617.3 & & & & & & & \\ 2 & 16133.2 & & & & & & & \\ 3 & 9308.0 & & & & & & & \end{bmatrix} \cdot 10^{-9}$$

$$\mathbf{stiffness_{rotor}}^T = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 284045.72 & & & & & & & \\ 2 & 12211.28 & & & & & & & \\ 3 & 1440.55 & & & & & & & \end{bmatrix}$$

CP<sub>x</sub><sub>stator</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	41.702								
2	46.654								
3	50.042								

·10<sup>-3</sup>

CP<sub>x</sub><sub>rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	49.179								
2	57.938								
3	63.932								

·10<sup>-3</sup>

CP<sub>y</sub><sub>stator</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	0.0000								
2	0.0000								
3	0.0000								

·10<sup>-3</sup>

CP<sub>y</sub><sub>rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	0.0000								
2	0.0000								
3	0.0000								

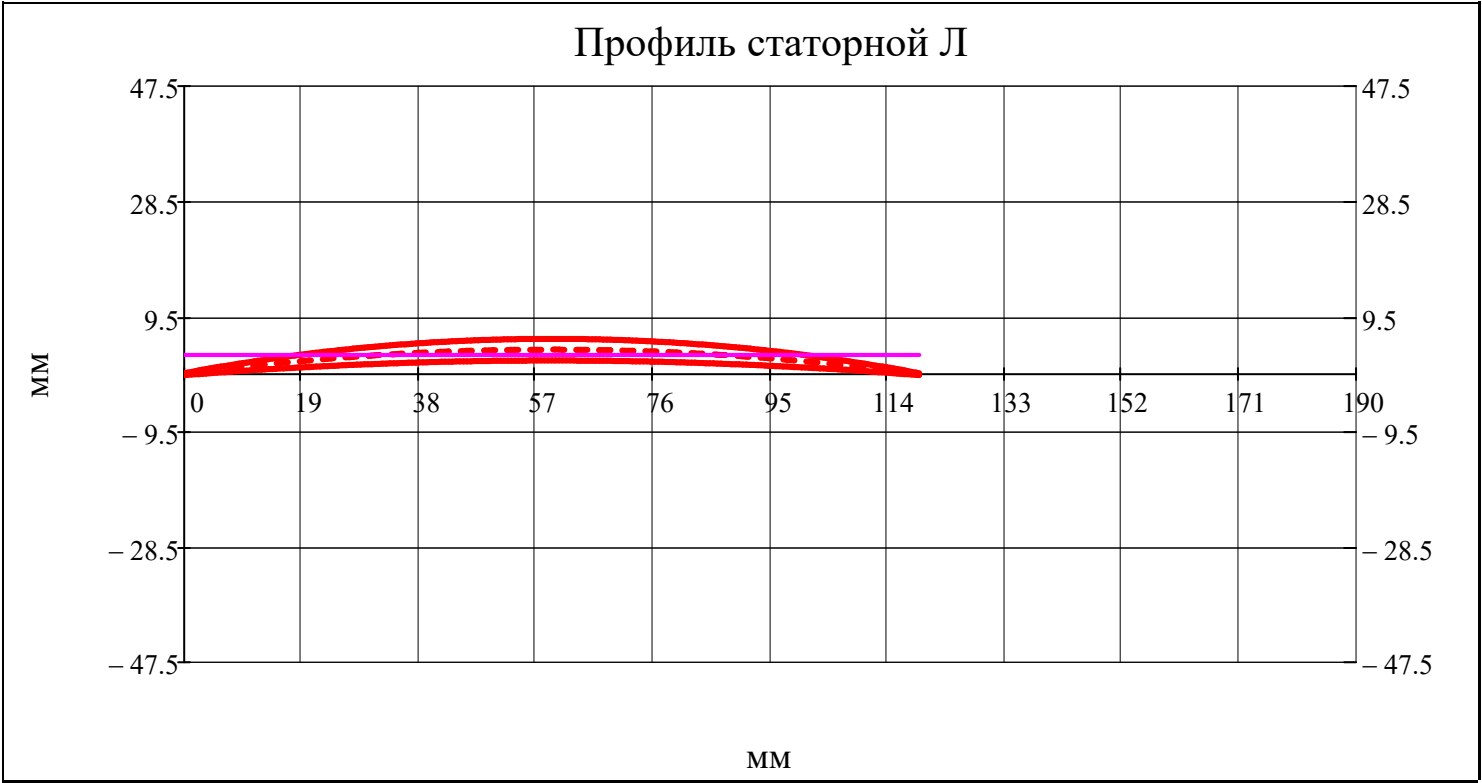
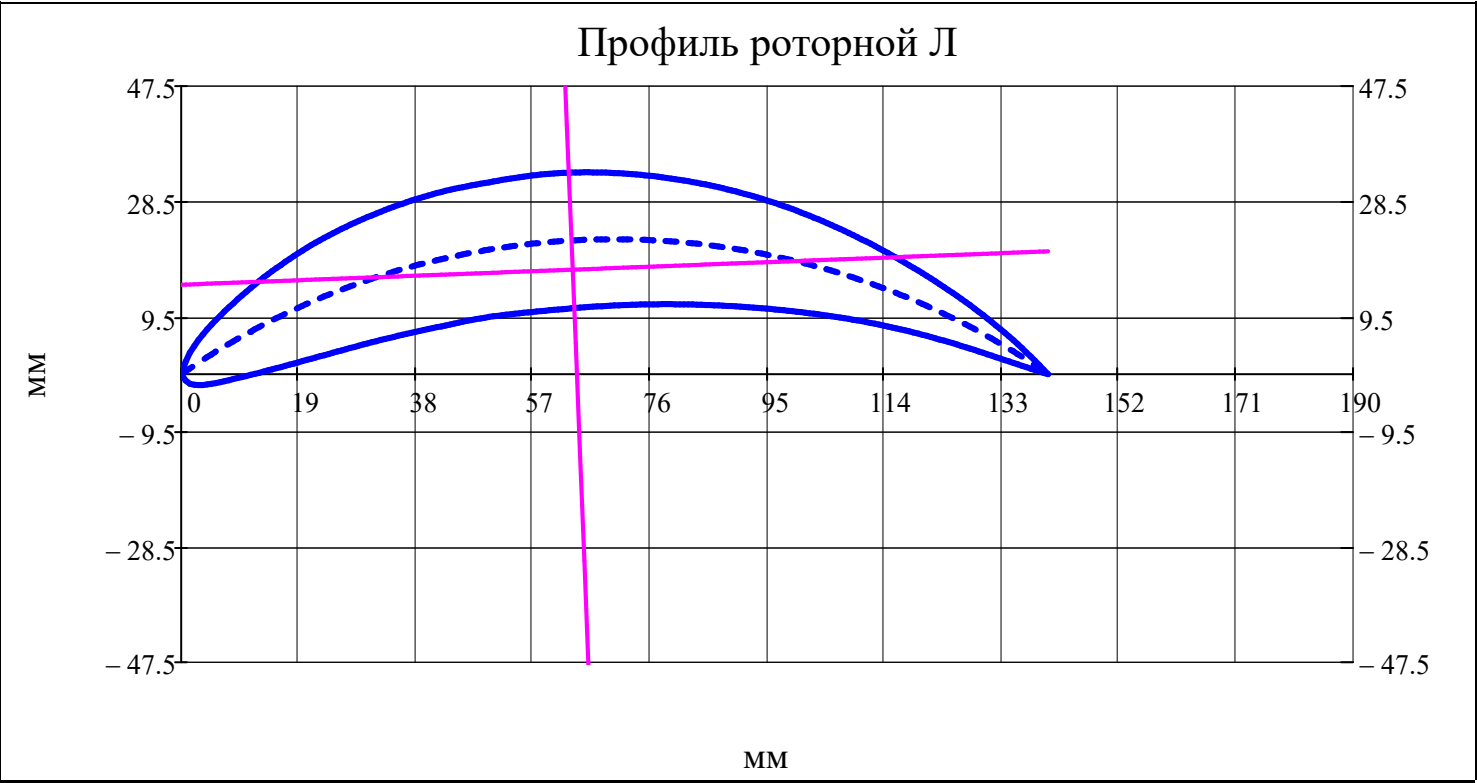
·10<sup>-3</sup>

Абс. координаты профиля:

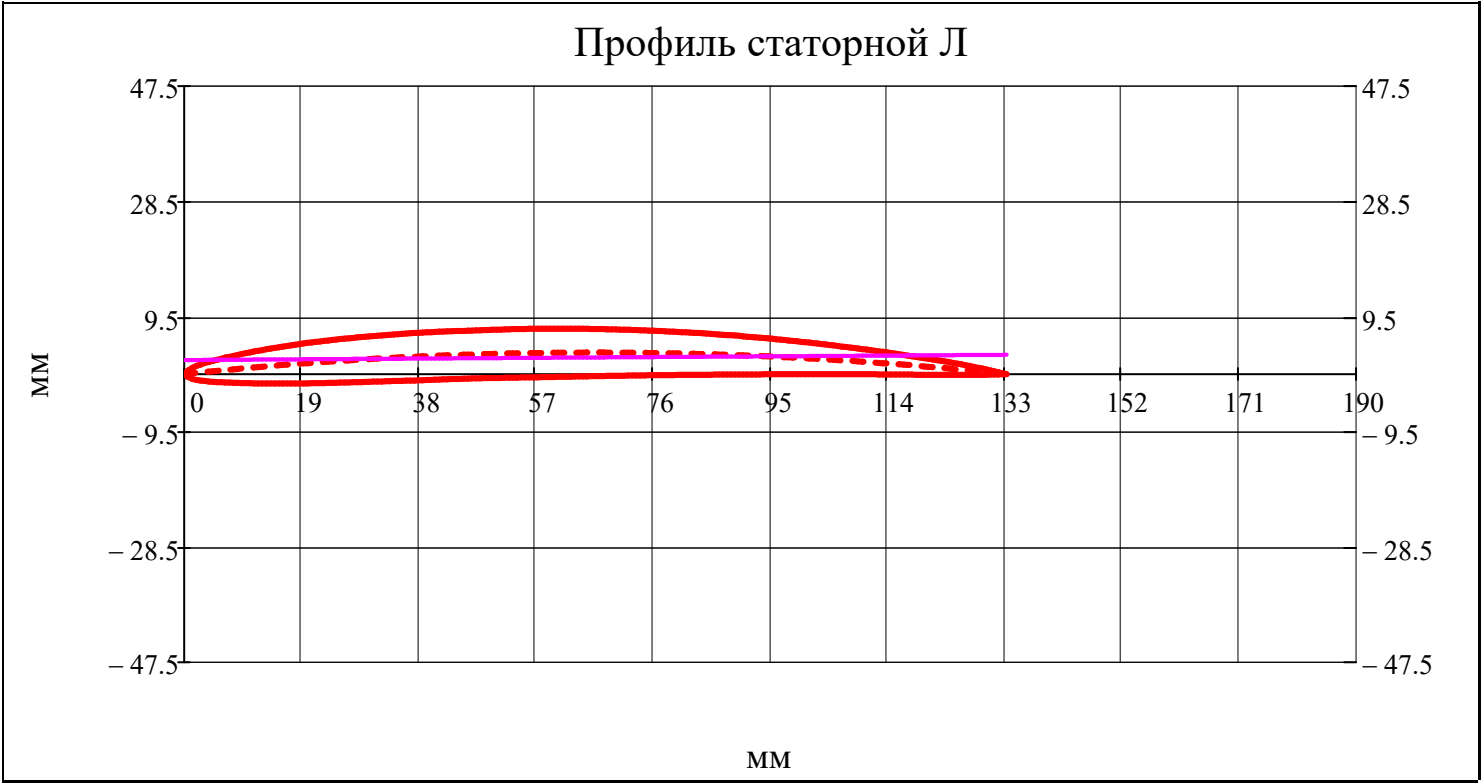
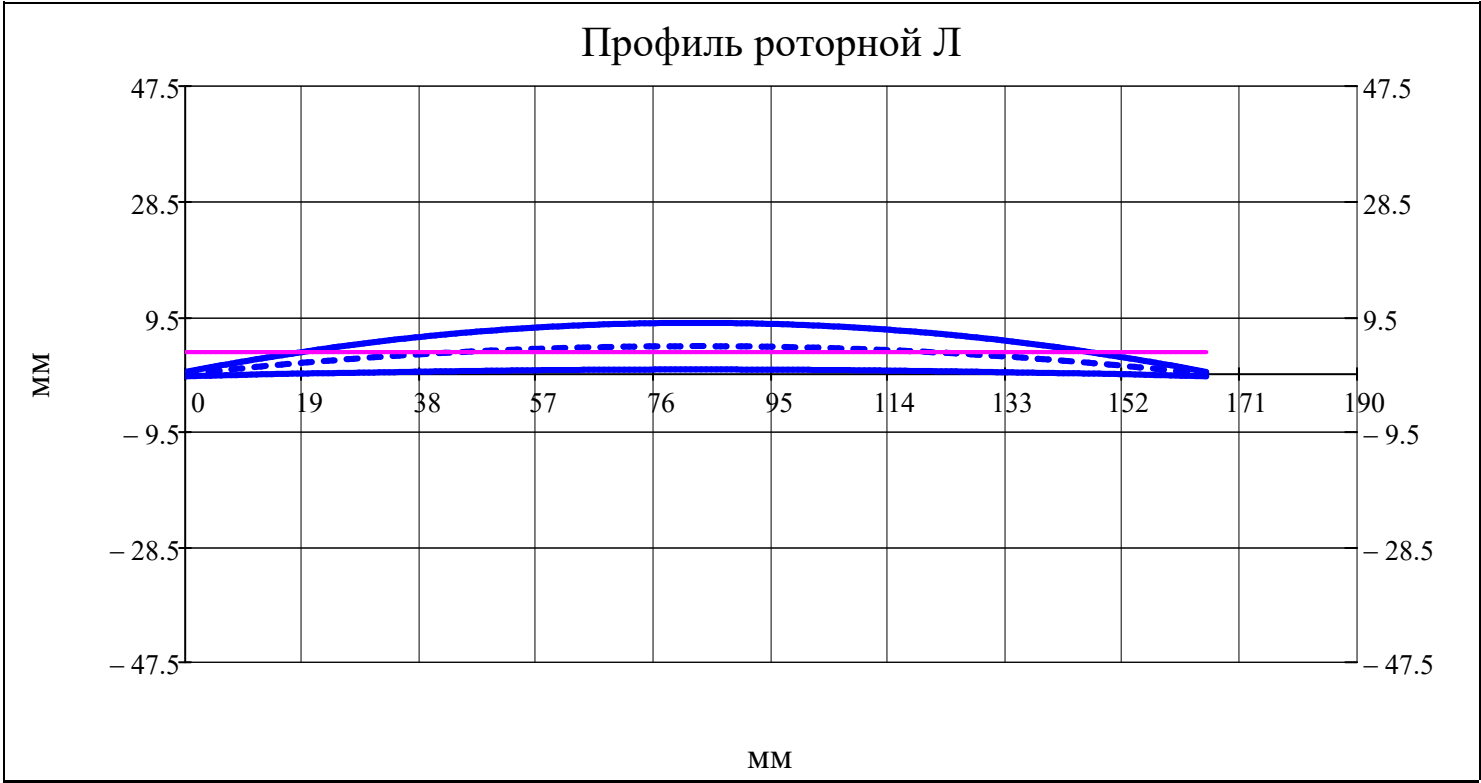
Airfoil(type,x,line,i,r) =	<div><div>if type = "BHA"</div><div><div>AIRFOIL<sub>subsonic</sub><math>\left(x, \text{line}, \overline{c}_{\text{BHA}_r}, \varepsilon_{\text{BHA}_r}\right)</math> if <math>M_{c_{\text{st}(1,1),r}} &lt; M_{\text{lim}}</math></div><div>AIRFOIL<sub>supersonic</sub><math>\left(x,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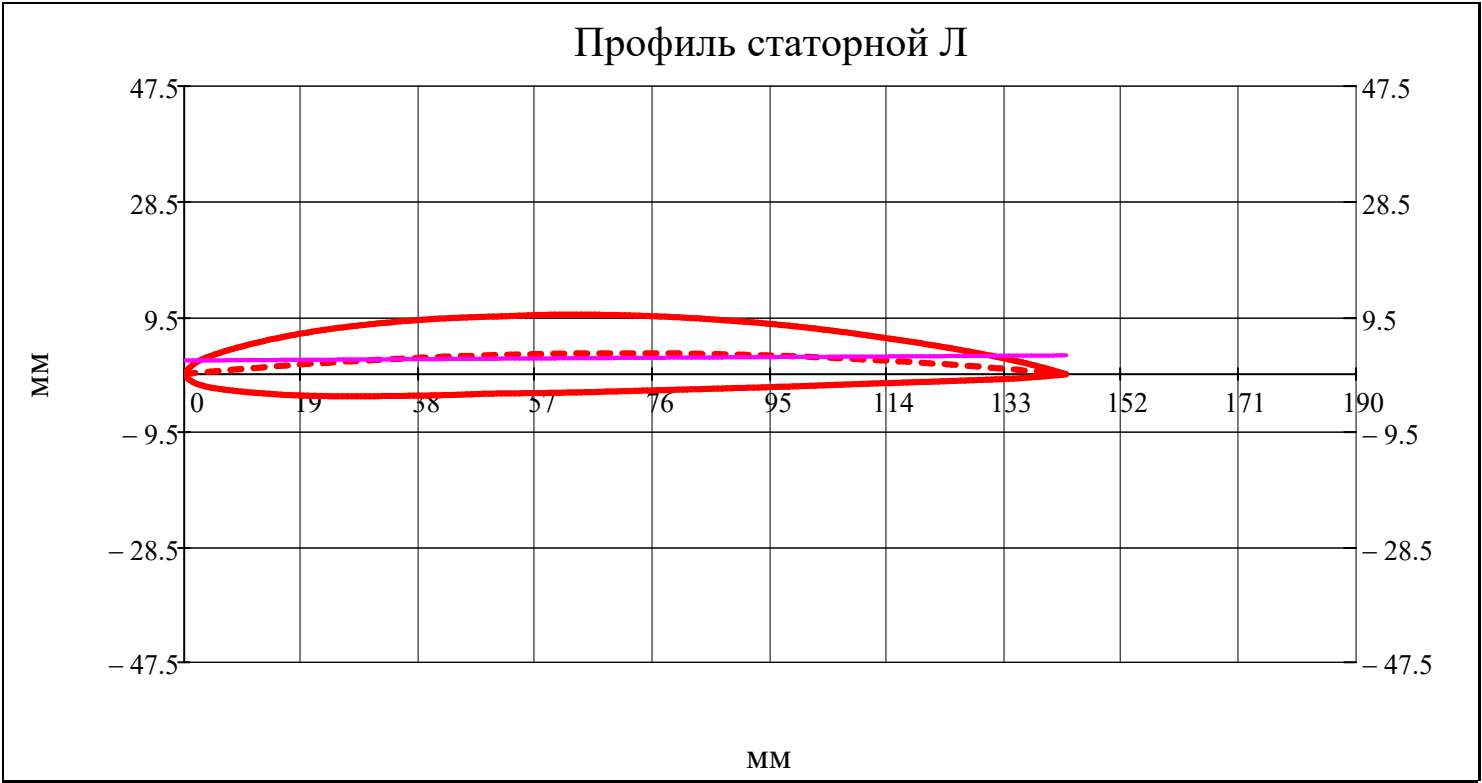
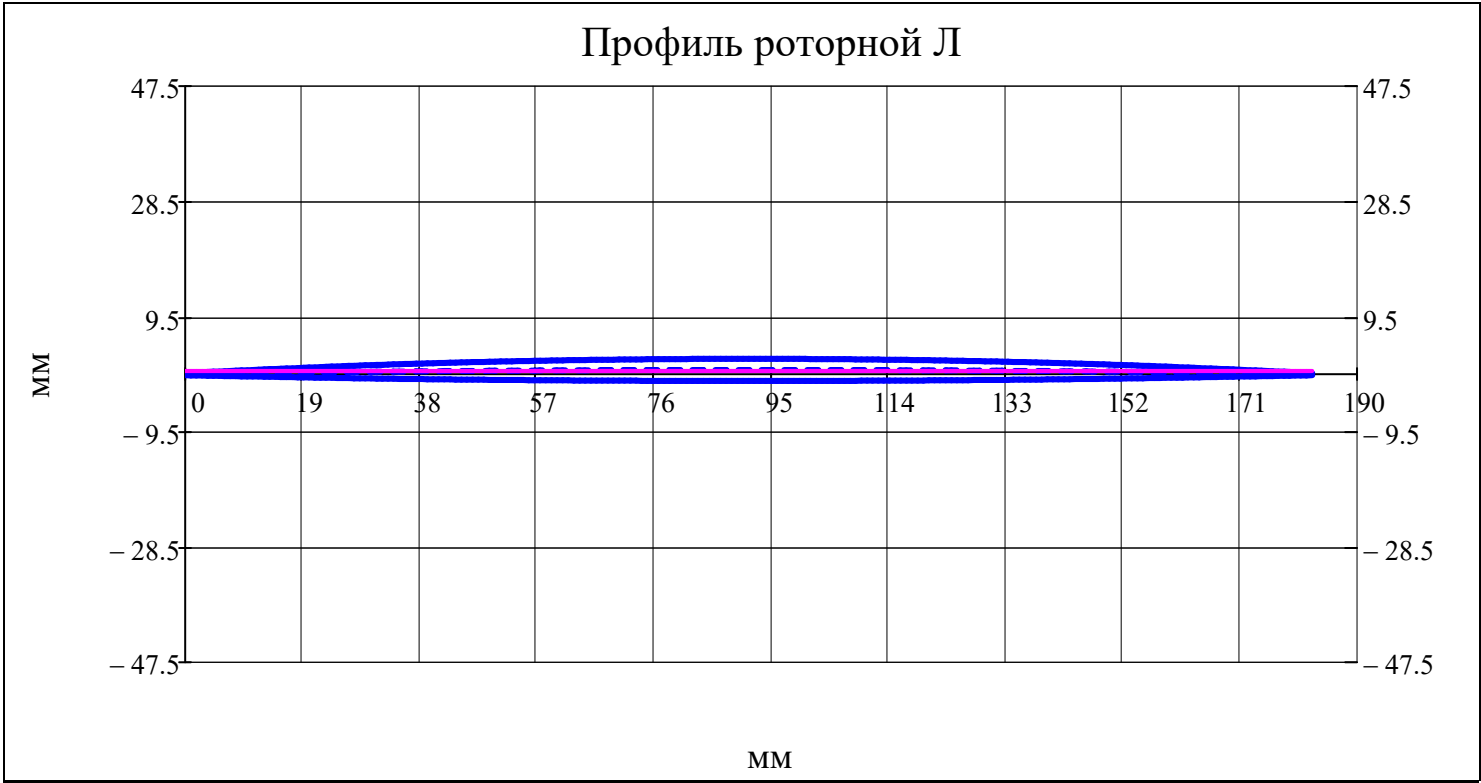
$r_w = 1$



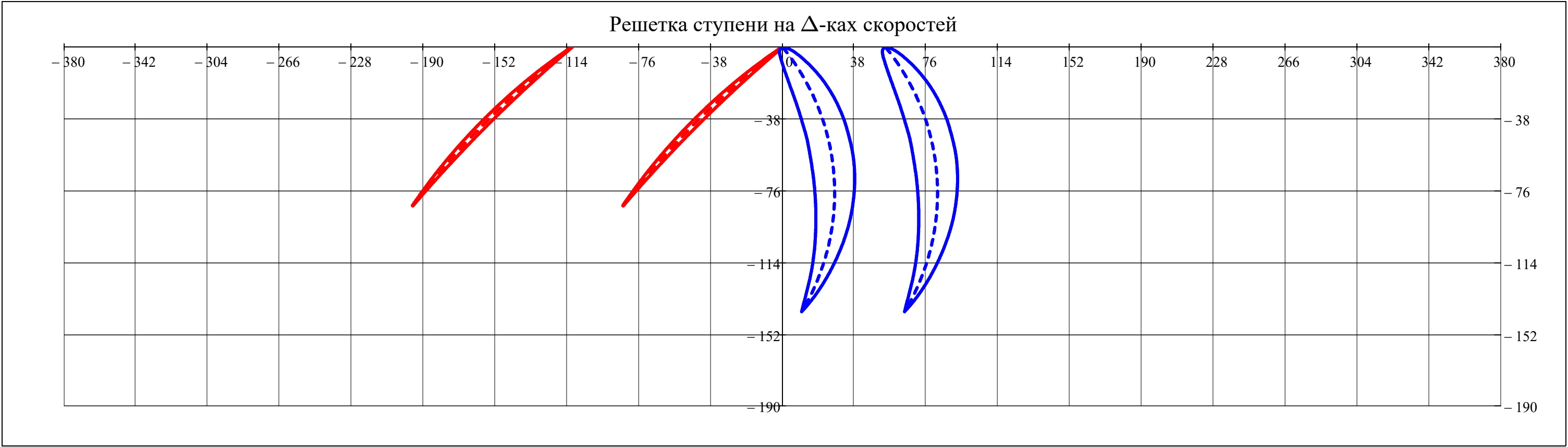
$r_w = av(N_r)$



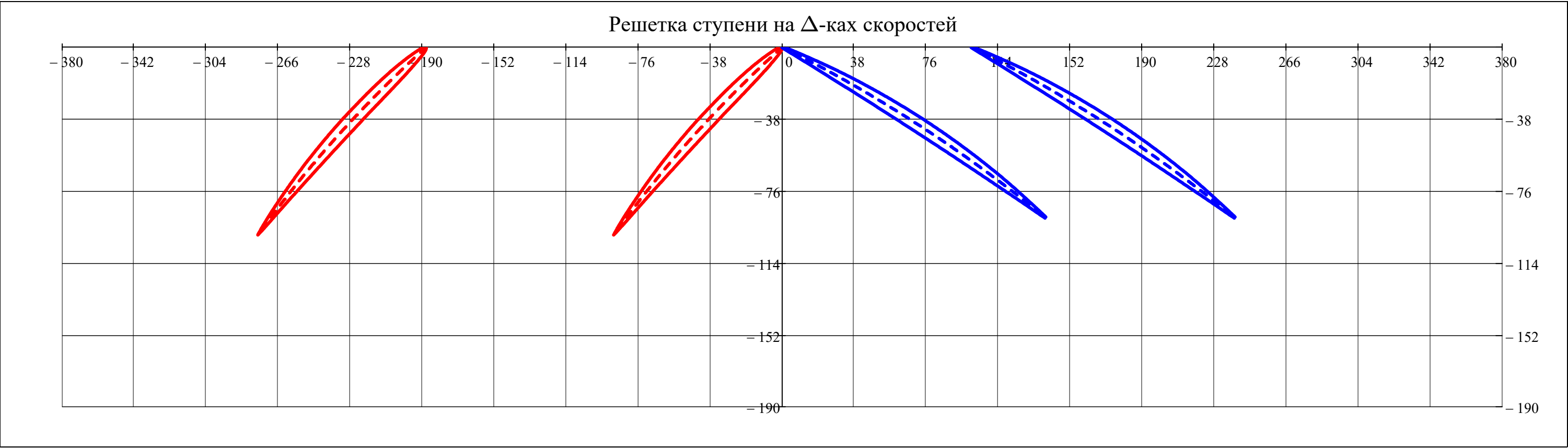
$r_w = N_r$



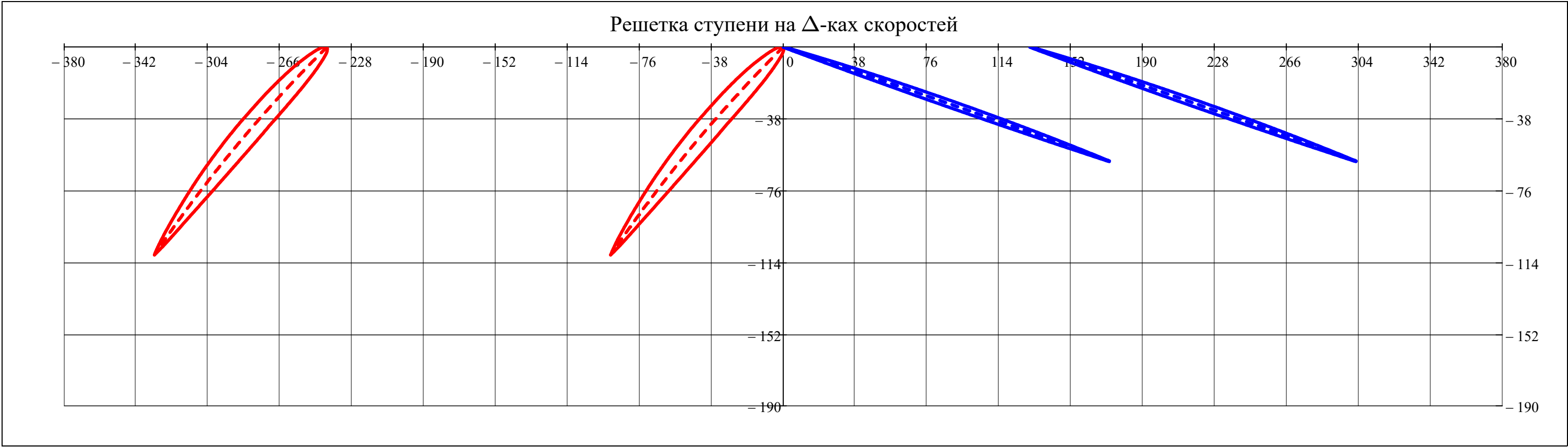
$r_w = 1$



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



$r_w = N_r$



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

Радиальный зазор (м)  
[с.64 казаджан]:  

$\overline{\Delta}_r = 0.0025$   
 $0.0015 \leq \overline{\Delta}_r \leq 0.0035 = 1$

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

$\Delta_r^T = \begin{bmatrix} & 1 \\ 1 & 3.84 \end{bmatrix} \cdot 10^{-3}$

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

$\overline{\Delta}_a = 0.17$   
 $0.1 \leq \overline{\Delta}_a \leq 0.2 = 1$

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

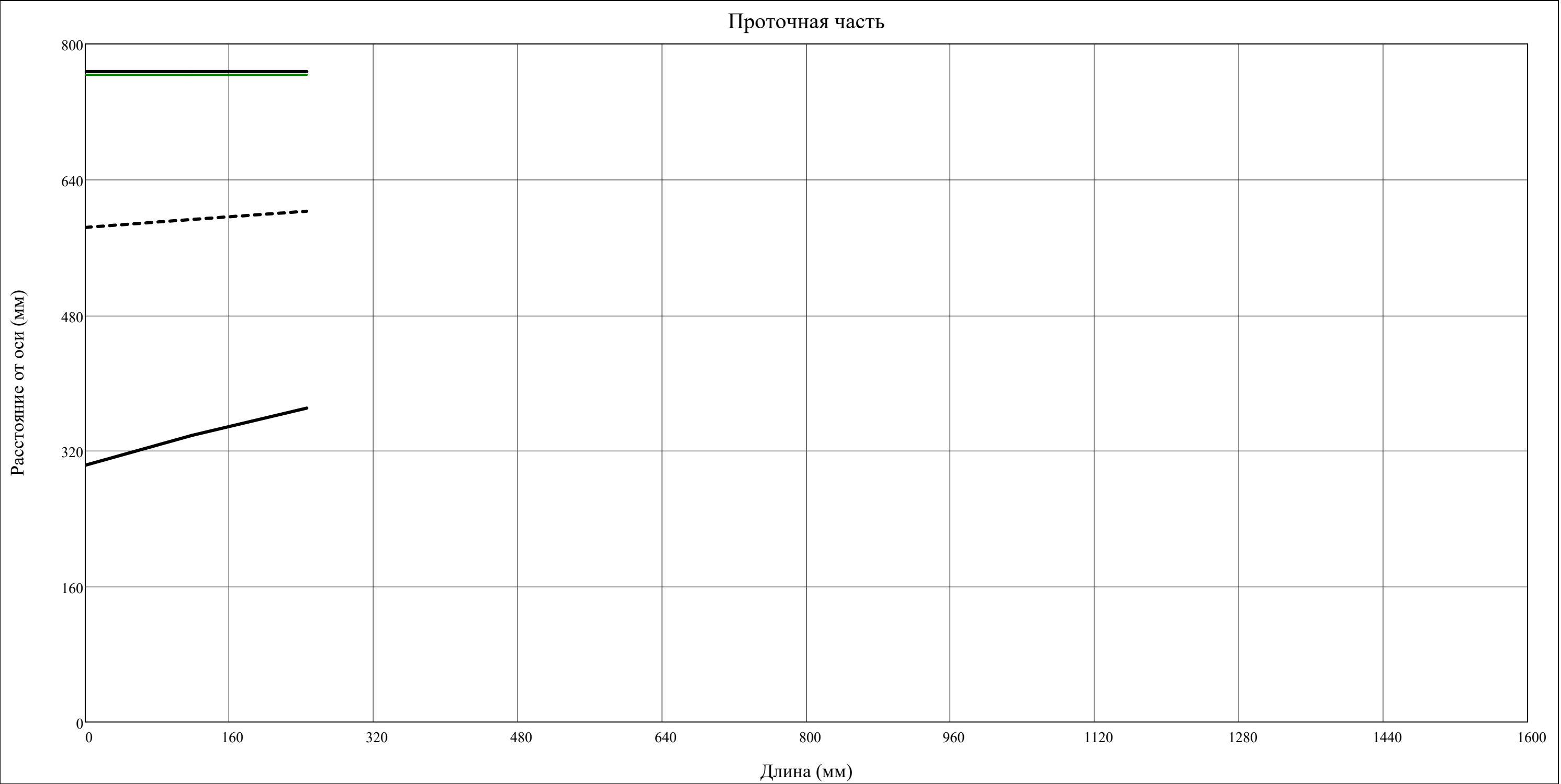
$\Delta a^T = \begin{bmatrix} & 1 \\ 1 & 28.14 \end{bmatrix} \cdot 10^{-3}$

Односторонний осевой зазор (м):

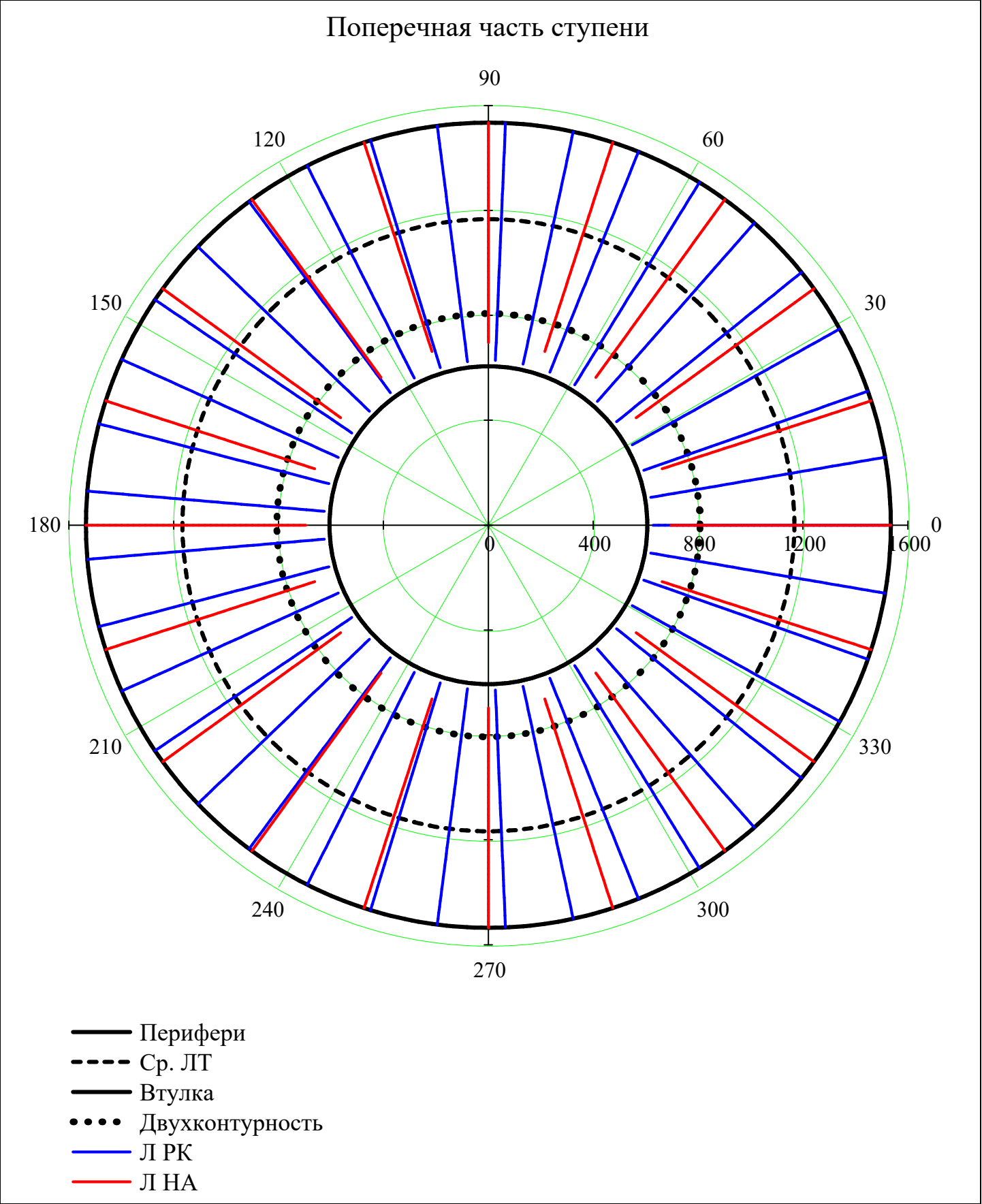
$\frac{\Delta a^T}{2} = \begin{bmatrix} & 1 \\ 1 & 14.07 \end{bmatrix} \cdot 10^{-3}$

Длина ОК (м):

$$\text{Length} = \left[ \begin{aligned} &\Delta a_1 + \begin{cases} \text{chord}_{\text{BHA}_{av}(N_r)} \cdot \sin\left(v_{\text{BHA}_{av}(N_r)}\right) & \text{if BHA} = 1 \quad \dots \\ 0 & \text{otherwise} \end{cases} \\ &+ \sum_{i=1}^Z \left( \text{chord}_{\text{rotor}_{i, av}(N_r)} \cdot \sin\left(v_{\text{rotor}_{i, av}(N_r)}\right) \right) + 2 \cdot \sum_{i=1}^Z \Delta a_i + \sum_{i=1}^Z \left( \text{chord}_{\text{stator}_{i, av}(N_r)} \cdot \sin\left(v_{\text{stator}_{i, av}(N_r)}\right) \right) \dots \\ &+ \begin{cases} \text{chord}_{\text{CA}_{av}(N_r)} \cdot \sin\left(v_{\text{CA}_{av}(N_r)}\right) & \text{if CA} = 1 \quad + \Delta a_Z \\ 0 & \text{otherwise} \end{cases} \end{aligned} \right] = 301.9 \cdot 10^{-3}$$







Запас по температуре (K):

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

Выбранный материал Л:

$$\text{material\_blade}_i = \begin{cases} \text{"ЖС-6К"} & \text{if } 1123 \leq T_{\text{st}(i,2),\text{av}(N_r)}^* + \Delta T_{\text{safety}} \\ \text{"BT41"} & \text{if } 873 \leq T_{\text{st}(i,2),\text{av}(N_r)}^* + \Delta T_{\text{safety}} < 1123 \\ \text{"BT25"} & \text{if } 753 \leq T_{\text{st}(i,2),\text{av}(N_r)}^* + \Delta T_{\text{safety}} < 873 \\ \text{"BT9"} & \text{otherwise} \end{cases}$$

$$\text{material\_blade}_i = \begin{cases} \text{"BT23"} & \text{if compressor = "Бл"} \\ \text{"BT6"} & \text{if compressor = "КНД"} \\ \text{material\_blade}_i & \text{otherwise} \end{cases}$$

Плотность материала Л (кг/м^3):

$$\rho_{\text{blade}_i} = \begin{cases} 8393 & \text{if material\_blade}_i = \text{"ЖС-6К"} \\ 7900 & \text{if material\_blade}_i = \text{"BT41"} \\ 4500 & \text{if material\_blade}_i = \text{"BT25"} \\ 4570 & \text{if material\_blade}_i = \text{"BT23"} \\ 4510 & \text{if material\_blade}_i = \text{"BT9"} \\ 4430 & \text{if material\_blade}_i = \text{"BT6"} \\ \text{NaN} & \text{otherwise} \end{cases}$$

Коэф. формы:

$k_n = 6.8$

Модуль Юнга Грода материала Л (Па):

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

Предел длительной прочности Л РК (Па):

$$\sigma_{\text{blade\_long}_i} = 10^6 \cdot \begin{cases} 125 & \text{if material\_blade}_i = \text{"ЖС-6К"} \\ 123 & \text{if material\_blade}_i = \text{"BT41"} \\ 150 & \text{if material\_blade}_i = \text{"BT25"} \\ 230 & \text{if material\_blade}_i = \text{"BT23"} \\ 200 & \text{if material\_blade}_i = \text{"BT9"} \\ 210 & \text{if material\_blade}_i = \text{"BT6"} \\ \text{NaN} & \text{otherwise} \end{cases}$$

Коэф. Пуассона материала Л():

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

$\text{material\_blade}^T =$

	1	2	3	4	5	6	7	8	9
1	"BT23"								

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

	1
1	4570

$\sigma_{\text{blade\_long}}^T =$

	1
1	230.0

$\cdot 10^6$

$\nu0_{изг.stator}$  $\nu0_{изг.rotor}$  $\nu0_{угл.stator}$  $\nu0_{угл.rotor}$  $\nu0_{угл.stator\_bondage}$  $\nu0_{угл.rotor\_bondage}$

=

for i ∈ 1..Z  
for r ∈ av(N<sub>r</sub>)  
for mode ∈ 1..6

$\nu0_{изг.stator_{i,mode}} = \nu0_{изгиб}\left(mode, mean(h_{st}(i,2), h_{st}(i,3)), E\_blade, \rho\_blade_i, area_{stator_{i,r}}, Ju_{stator_{i,r}}\right)$  $\nu0_{изг.rotor_{i,mode}} = \nu0_{изгиб}\left(mode, mean(h_{st}(i,1), h_{st}(i,2)), E\_blade, \rho\_blade_i, area_{rotor_{i,r}}, Ju_{rotor_{i,r}}\right)$  $\nu0_{угл.stator_{i,mode}} = \nu0_{угл}\left(mode, 0, mean(h_{st}(i,2), h_{st}(i,3)), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{stator_{i,r}}, Jp_{stator_{i,r}}\right)$  $\nu0_{угл.rotor_{i,mode}} = \nu0_{угл}\left(mode, 0, mean(h_{st}(i,1), h_{st}(i,2)), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{rotor_{i,r}}, Jp_{rotor_{i,r}}\right)$  $\nu0_{угл.stator\_bondage_{i,mode}} = \nu0_{угл}\left(mode, 1, mean(h_{st}(i,2), h_{st}(i,3)), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{stator_{i,r}}, Jp_{stator_{i,r}}\right)$  $\nu0_{угл.rotor\_bondage_{i,mode}} = \nu0_{угл}\left(mode, 1, mean(h_{st}(i,1), h_{st}(i,2)), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{rotor_{i,r}}, Jp_{rotor_{i,r}}\right)$

$\nu0_{изг.stator}$  $\nu0_{изг.rotor}$  $\nu0_{угл.stator}$  $\nu0_{угл.rotor}$  $\nu0_{угл.stator\_bondage}$  $\nu0_{угл.rotor\_bondage}$

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

$$\text{stack}\left(\nu_{0_{\text{угл.stator}}}, \nu_{0_{\text{угл.rotor}}}\right)^T =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	315	225																
2	944	674																
3	1573	1124																
4	2202	1573																
5	2831	2023																
6	3460	2472																

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

$$\text{stack}\left(\nu_{0_{\text{изг.stator}}}, \nu_{0_{\text{изг.rotor}}}\right)^T =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	48	41																
2	298	254																
3	835	711																
4	1637	1395																
5	2705	2305																
6	4039	3442																

$$\text{stack}\left(\nu_{0_{\text{угл.stator\_bondage}}}, \nu_{0_{\text{угл.rotor\_bondage}}}\right)^T =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	629	450																
2	1258	899																
3	1888	1349																
4	2517	1798																
5	3146	2248																
6	3775	2697																

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.	$\chi_{\text{rotor}}(i,z) = \frac{\text{area}_{\text{rotor},i,N_r}}{\text{area}_{\text{rotor},i,1}}$
Ju_rotor.	Ju_stator.	
Jv_rotor.	Jv_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.	CPx_stator.	
CPy_rotor.	CPy_stator.	$\sigma0_{\text{rotor.max}}(i,z) = \frac{\rho_{\text{blade}_i} \cdot \omega^2}{2} \cdot \begin{cases} \left[ \text{mean}(R_{\text{st}}(i,1),N_r,R_{\text{st}}(i,2),N_r)^2 - (R0_{\text{rotor}}(i,z))^2 \right] & \text{if type = "compressor"} \\ \left[ \text{mean}(R_{\text{st}}(i,2),N_r,R_{\text{st}}(i,3),N_r)^2 - (R0_{\text{rotor}}(i,z))^2 \right] & \text{if type = "turbine"} \end{cases}$
CPx_rotor.axis	CPx_stator.axis	
CPy_rotor.axis	CPy_stator.axis	$\left( \rho_{\text{blade}_i} \cdot \omega^2 \quad R0_{\text{rotor}}(i,z) \right)$



$$\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{stator}}}(i,z) dz
\end{aligned}$$

$$\begin{aligned}
\text{shift\_x}_{\text{rotor}}(i,z) &= \int_z^z \frac{\left[ \begin{array}{l} \text{mean}(R_{st(i,1),1}, R_{st(i,2),1}) \quad \text{if type="compressor"} \\ \text{mean}(R_{st(i,2),1}, R_{st(i,3),1}) \quad \text{if type="turbine"} \end{array} \right]}{N_{\text{rotor}}(i,z)} dz \\
\text{shift\_y}_{\text{rotor}}(i,z) &= z \cdot \int_z^z \frac{\left[ \begin{array}{l} \text{mean}(R_{st(i,1),N_r}, R_{st(i,2),N_r}) \quad \text{if type="compressor"} \\ \text{mean}(R_{st(i,2),N_r}, R_{st(i,3),N_r}) \quad \text{if type="turbine"} \end{array} \right] \left( qY_{\text{rotor}}(i,z) \cdot z \right) dz}{N_{\text{rotor}}(i,z) \cdot z^2} dz \\
x0_{\text{rotor}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(x0_{\text{rotor}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(x0_{\text{rotor}}, i, i, 1, N_r)^T\right) \\
x0_{\text{stator}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(x0_{\text{stator}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(x0_{\text{stator}}, i, i, 1, N_r)^T\right) \\
y0_{\text{rotor}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(y0_{\text{rotor}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(y0_{\text{rotor}}, i, i, 1, N_r)^T\right) \\
y0_{\text{stator}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(y0_{\text{stator}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(y0_{\text{stator}}, i, i, 1, N_r)^T\right) \\
\alpha_{\text{major}_{\text{rotor}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(\alpha_{\text{major}_{\text{rotor}}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(\alpha_{\text{major}_{\text{rotor}}}, i, i, 1, N_r)^T\right) \\
\alpha_{\text{major}_{\text{stator}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(\alpha_{\text{major}_{\text{stator}}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(\alpha_{\text{major}_{\text{stator}}}, i, i, 1, N_r)^T\right) \\
Ju_{\text{rotor}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Ju_{\text{rotor}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Ju_{\text{rotor}}, i, i, 1, N_r)^T\right) \\
Ju_{\text{stator}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Ju_{\text{stator}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Ju_{\text{stator}}, i, i, 1, N_r)^T\right) \\
Jv_{\text{rotor}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Jv_{\text{rotor}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Jv_{\text{rotor}}, i, i, 1, N_r)^T\right) \\
Jv_{\text{stator}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Jv_{\text{stator}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(Jv_{\text{stator}}, i, i, 1, N_r)^T\right) \\
CPx_{\text{rotor}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPx_{\text{rotor}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPx_{\text{rotor}}, i, i, 1, N_r)^T\right) \\
CPx_{\text{stator}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPx_{\text{stator}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPx_{\text{stator}}, i, i, 1, N_r)^T\right) \\
CPy_{\text{rotor}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPy_{\text{rotor}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPy_{\text{rotor}}, i, i, 1, N_r)^T\right) \\
CPy_{\text{stator}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPy_{\text{stator}}, i, i, 1, N_r)^T\right), \text{submatrix}(R, st(i,2), st(i,2), 1, N_r)^T, \text{submatrix}(CPy_{\text{stator}}, i, i, 1, N_r)^T\right) \\
CPx_{\text{rotor.axis}}(i,z) &= \text{axis}_x(CPx_{\text{rotor}}(i,z), CPy_{\text{rotor}}(i,z), x0_{\text{rotor}}(i,z), y0_{\text{rotor}}(i,z), \alpha_{\text{major}_{\text{rotor}}}(i,z), 1) \\
CPx_{\text{stator.axis}}(i,z) &= \text{axis}_x(CPx_{\text{stator}}(i,z), CPy_{\text{stator}}(i,z), x0_{\text{stator}}(i,z), y0_{\text{stator}}(i,z), \alpha_{\text{major}_{\text{stator}}}(i,z), 1) \\
CPy_{\text{rotor.axis}}(i,z) &= \text{axis}_y(CPx_{\text{rotor}}(i,z), CPy_{\text{rotor}}(i,z), x0_{\text{rotor}}(i,z), y0_{\text{rotor}}(i,z), \alpha_{\text{major}_{\text{rotor}}}(i,z), 1) \\
CPy_{\text{stator.axis}}(i,z) &= \text{axis}_y(CPx_{\text{stator}}(i,z), CPy_{\text{stator}}(i,z), x0_{\text{stator}}(i,z), y0_{\text{stator}}(i,z), \alpha_{\text{major}_{\text{stator}}}(i,z), 1)
\end{aligned}$$



$$\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}$$

Наиболее удаленные точки от НЛ (мм):

$u_{-u_{\text{rotor}}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	7.216								
2	-1.633								
3	-0.389								

$\cdot 10^{-3}$

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

	1
1	16.326
2	4.858
3	91.332

$\cdot 10^{-3}$

$u_{-l_{\text{rotor}}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	-59.370								
2	82.748								
3	-0.718								

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	-22.714								
2	-4.352								
3	-91.332								

$\cdot 10^{-3}$

$u_{-u_{\text{stator}}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	0.000								
2	-1.516								
3	-3.040								

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	2.665								
2	4.797								
3	7.211								

$\cdot 10^{-3}$

$u_{-l_{\text{stator}}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	59.574								
2	-42.901								
3	-34.592								

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	-3.335								
2	-3.952								
3	-6.018								

$\cdot 10^{-3}$

$$\begin{pmatrix} \sigma_{\text{p\_rotor}} & \sigma_{\text{n\_rotor}} \\ \sigma_{\text{p\_stator}} & \sigma_{\text{n\_stator}} \end{pmatrix} = \begin{array}{l} \text{for } i \in 1..Z \\ \text{for } r \in 1..N_r \\ \begin{pmatrix} \sigma_{\text{p\_rotor}_{i,r}} & \sigma_{\text{n\_rotor}_{i,r}} \\ \sigma_{\text{p\_stator}_{i,r}} & \sigma_{\text{n\_stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \frac{\text{Mu}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{rotor}_{i,r}}} \cdot \text{v\_u}_{\text{rotor}_{i,r}} - \frac{\text{Mv}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{rotor}_{i,r}}} \cdot \text{u\_u}_{\text{rotor}_{i,r}} & \frac{\text{Mu}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{rotor}_{i,r}}} \cdot \text{v\_l}_{\text{rotor}_{i,r}} - \frac{\text{Mv}_{\text{rotor}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{rotor}_{i,r}}} \cdot \text{u\_l}_{\text{rotor}_{i,r}} \\ \frac{\text{Mu}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{stator}_{i,r}}} \cdot \text{v\_u}_{\text{stator}_{i,r}} - \frac{\text{Mv}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{stator}_{i,r}}} \cdot \text{u\_u}_{\text{stator}_{i,r}} & \frac{\text{Mu}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Ju}_{\text{stator}_{i,r}}} \cdot \text{v\_l}_{\text{stator}_{i,r}} - \frac{\text{Mv}_{\text{stator}}(i, \text{Rst}(i, 2), r)}{\text{Jv}_{\text{stator}_{i,r}}} \cdot \text{u\_l}_{\text{stator}_{i,r}} \end{pmatrix} \end{array} \\ \begin{pmatrix} \sigma_{\text{p\_rotor}} & \sigma_{\text{n\_rotor}} \\ \sigma_{\text{p\_stator}} & \sigma_{\text{n\_stator}} \end{pmatrix} \end{pmatrix}$$

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

$\sigma_{\text{p\_rotor}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	26.78								
2	-59.26								
3	0.00								

 $\cdot 10^6$

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

	1
1	1
2	1
3	1

$\sigma_{\text{n\_rotor}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	-45.07								
2	57.75								
3	0.00								

 $\cdot 10^6$

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

	1
1	1
2	1
3	1

$\sigma_{\text{p\_stator}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	3.93								
2	184.89								
3	181.78								

 $\cdot 10^6$

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

	1
1	1
2	0
3	0

$\sigma_{\text{n\_stator}}^T =$ 

	1	2	3	4	5	6	7	8	9
1	-4.94								
2	-151.32								
3	-150.41								

 $\cdot 10^6$

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

	1
1	1
2	1
3	1

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

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

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

	1	2	3	4	5	6	7	8	9
1	178.06								
2	176.42								
3	0.00								

$\cdot 10^6$

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

	1	2	3	4	5	6	7	8	9
1	3.94								
2	184.89								
3	181.78								

$\cdot 10^6$



Рассматриваемая ступень:

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

$$b_{lim} = \frac{\text{ceil}\left(\max\left(\text{chord}_{\text{rotor}_{j,N_r}}, \text{chord}_{\text{stator}_{j,N_r}}\right) \cdot 10^2\right)}{10^2} = 190 \cdot 10^{-3}$$

Расстояния от оси ЛМ до рассматриваемой ступени (м):

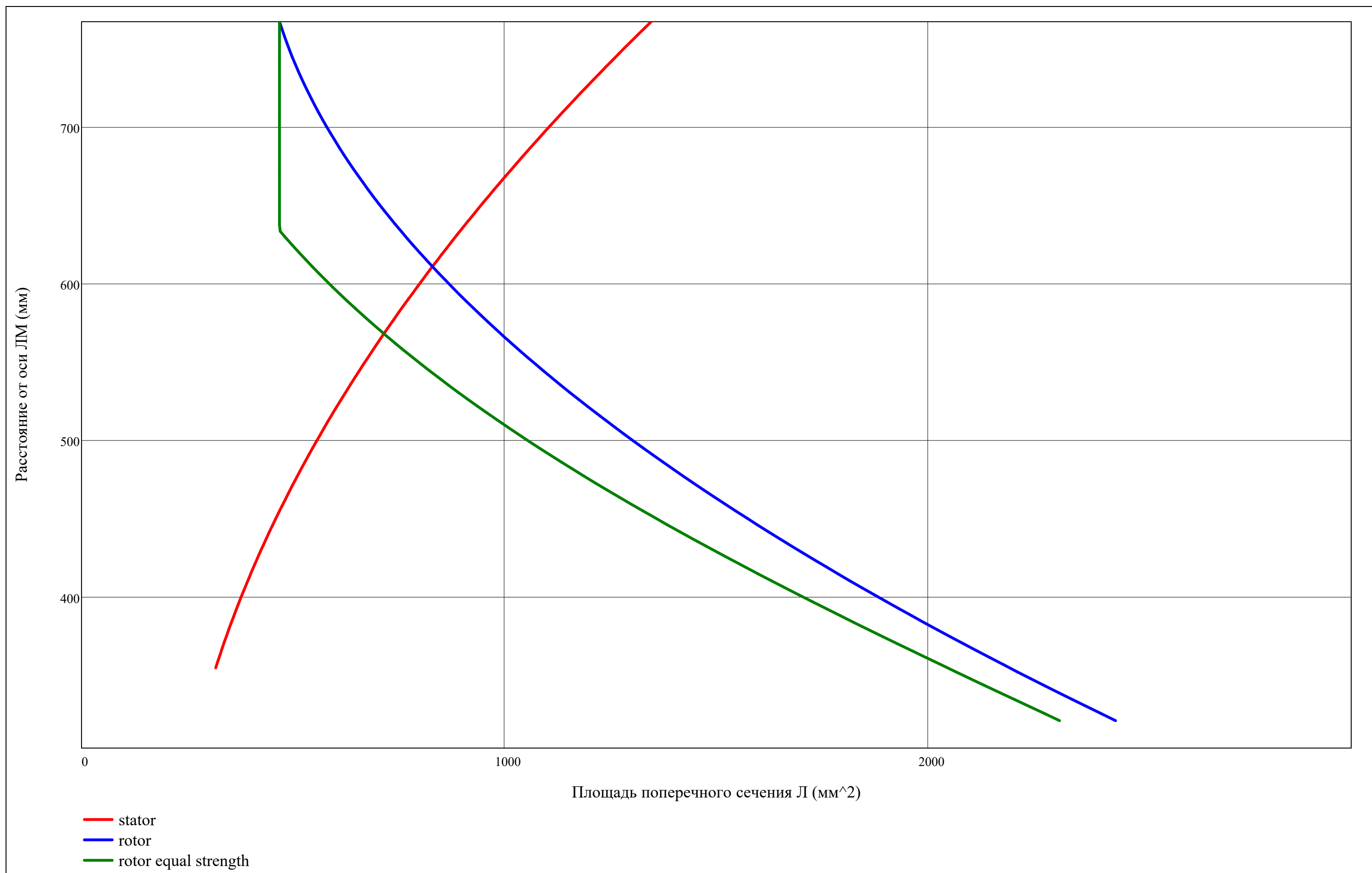
$$R_j = \text{submatrix}\left(R, 2 \cdot j - 1, 2 \cdot j + 1, 1, N_r\right) = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 302.9 & 583.4 & 767.5 \\ 2 & 338.1 & 593.0 & 767.5 \\ 3 & 370.4 & 602.6 & 767.5 \\ \hline \end{array} \cdot 10^{-3}$$

Дискретизация по высоте Л:

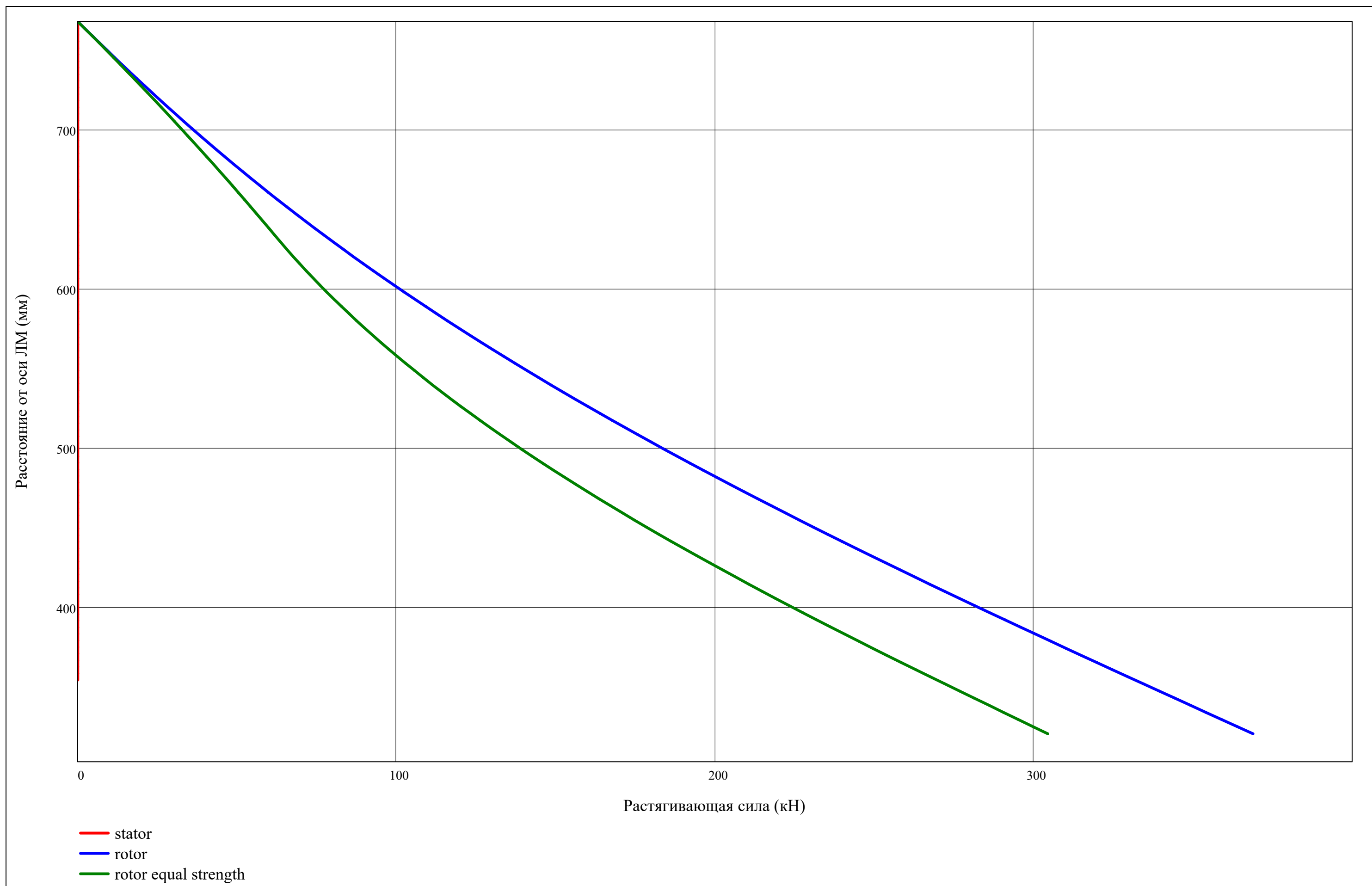
$$z = \min(R_j), \min(R_j) + \frac{\max(R_j) - \min(R_j)}{100} .. \max(R_j)$$

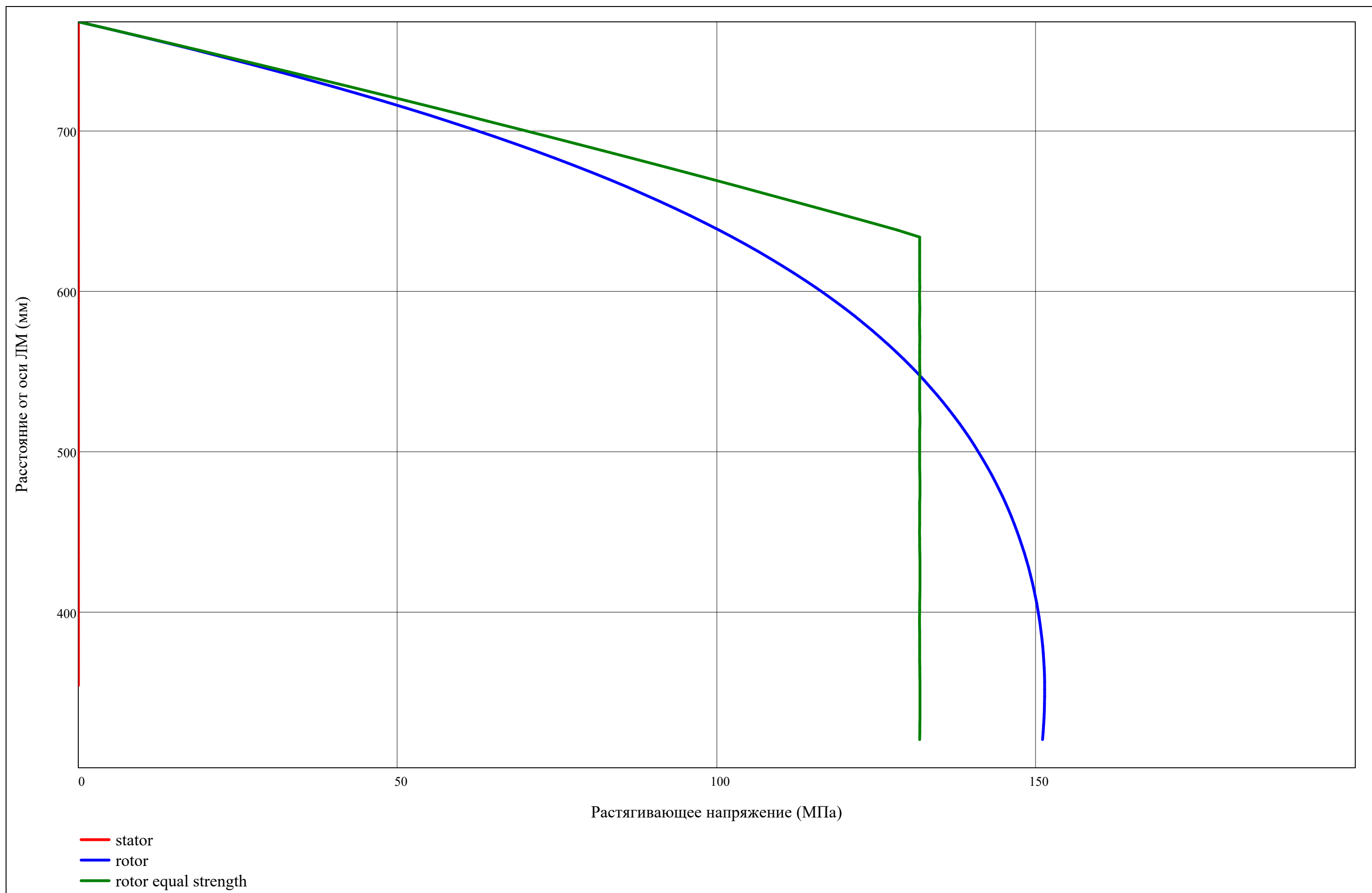
$$z_{\text{rotor}} = \begin{cases} \text{mean}\left(R_{j1,1}, R_{j2,1}\right), \text{mean}\left(R_{j1,1}, R_{j2,1}\right) + \frac{\text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) - \text{mean}\left(R_{j1,1}, R_{j2,1}\right)}{100} .. \text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) & \text{if type = "compressor"}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

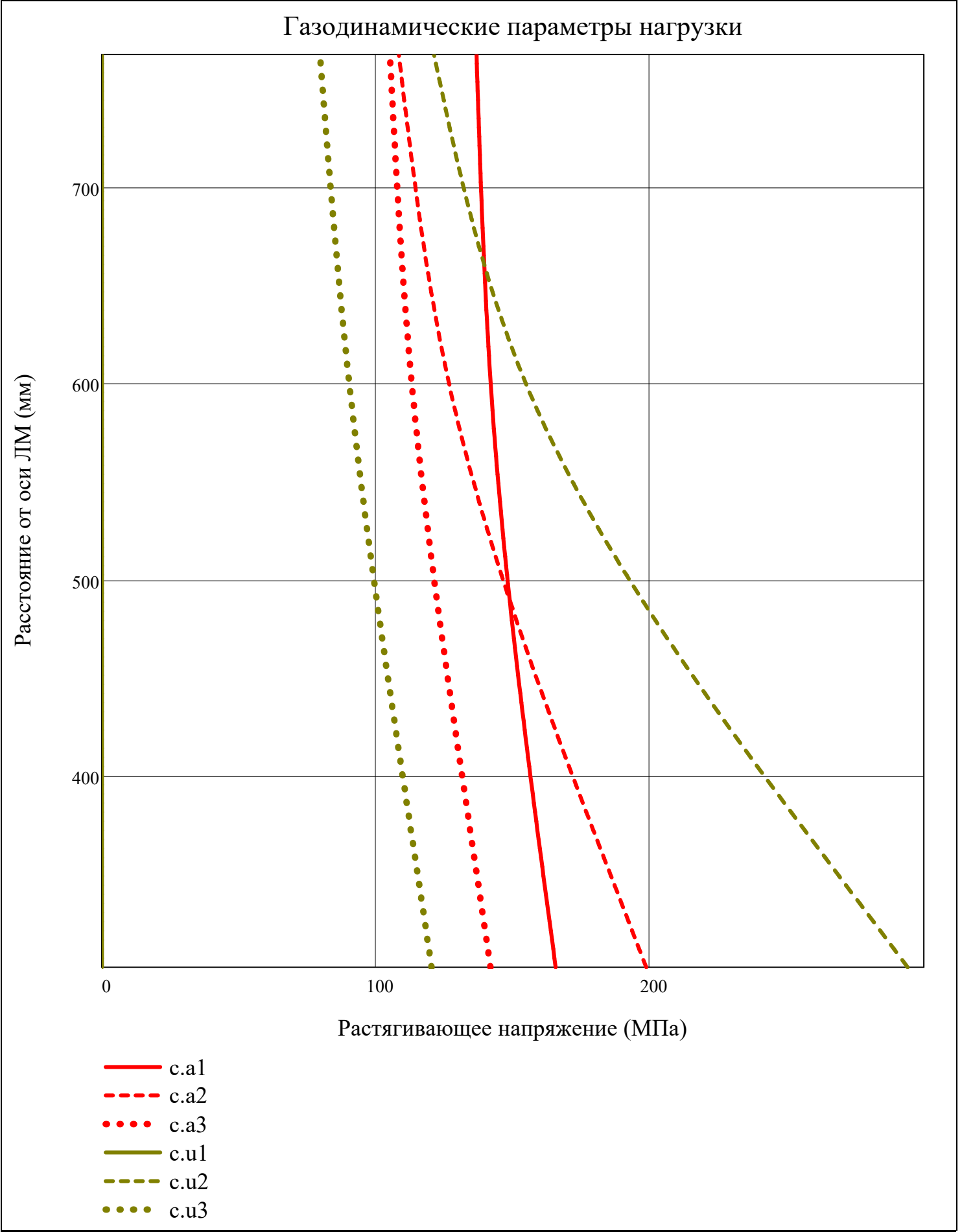
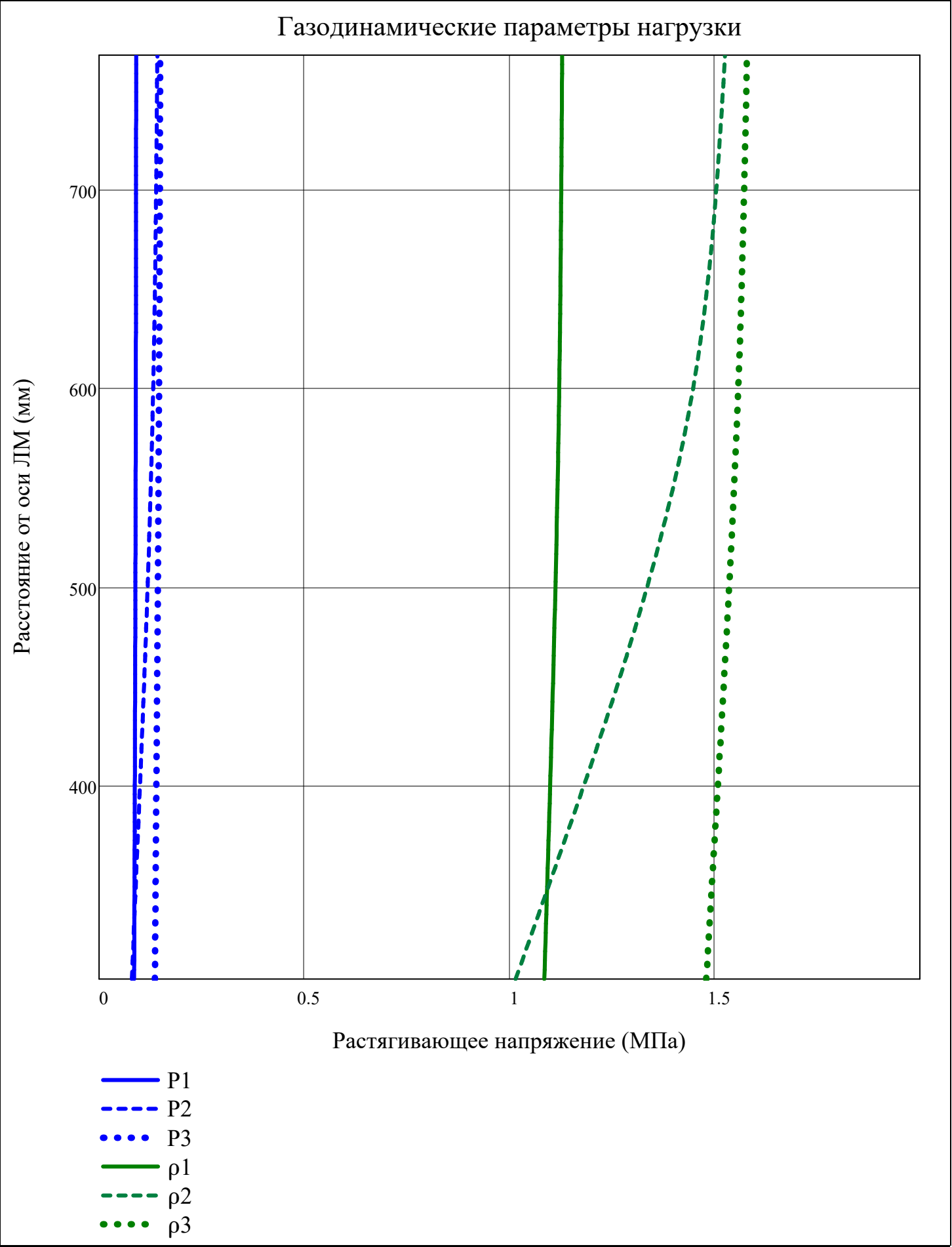
$$z_{\text{stator}} = \begin{cases} \text{mean}\left(R_{j2,1}, R_{j3,1}\right), \text{mean}\left(R_{j2,1}, R_{j3,1}\right) + \frac{\text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) - \text{mean}\left(R_{j2,1}, R_{j3,1}\right)}{100} .. \text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) & \text{if type = "compressor"}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

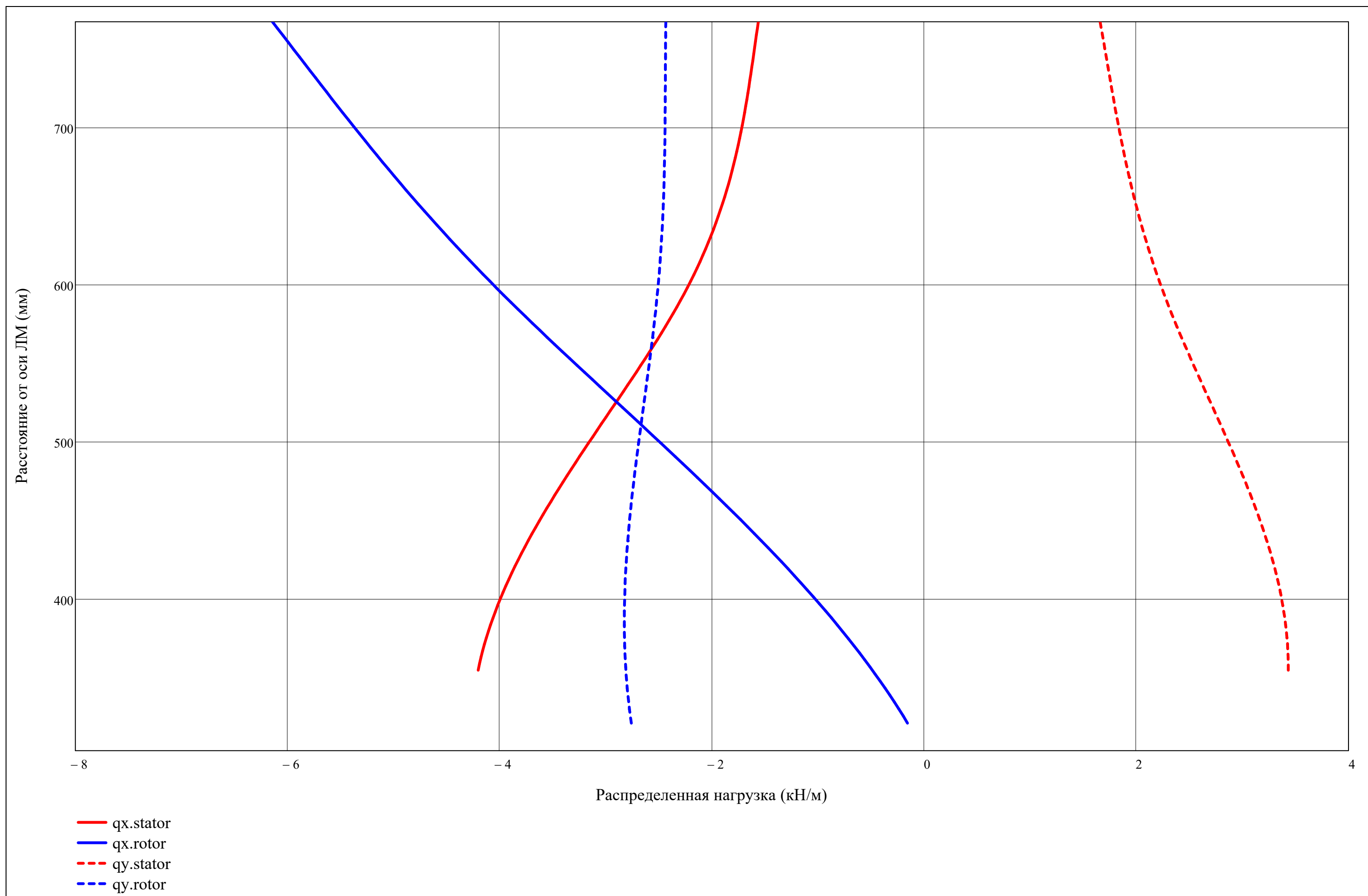


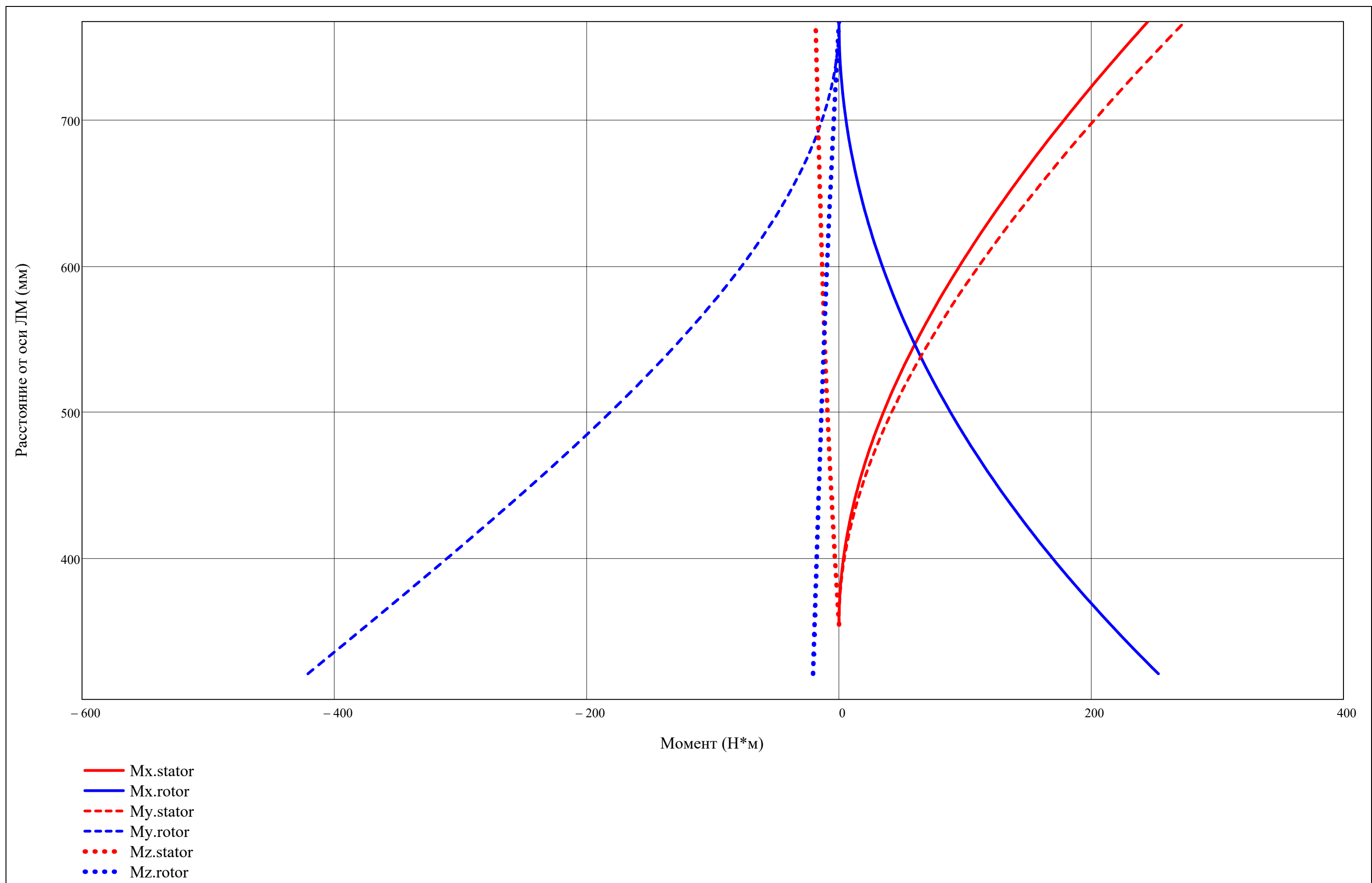


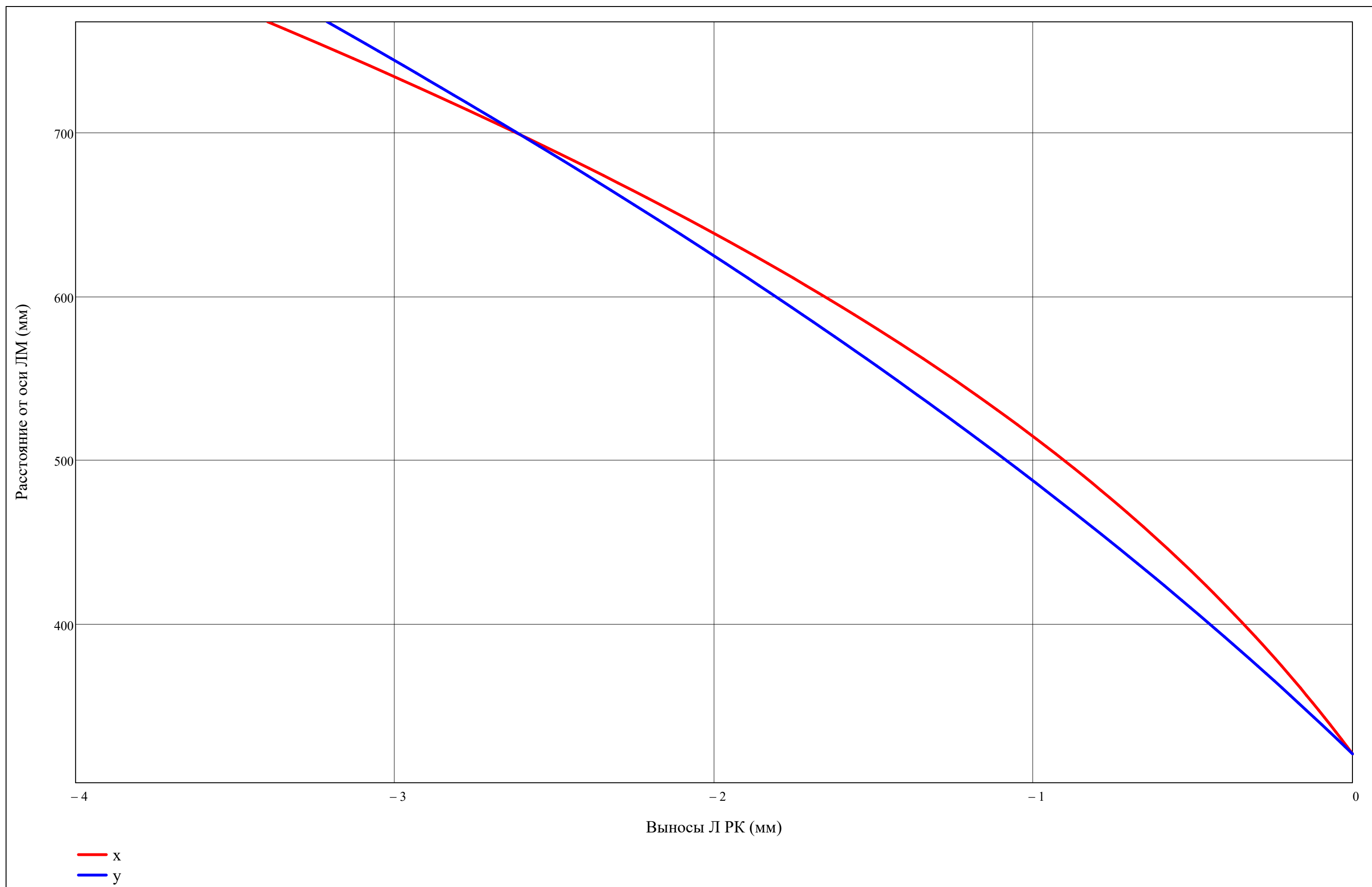


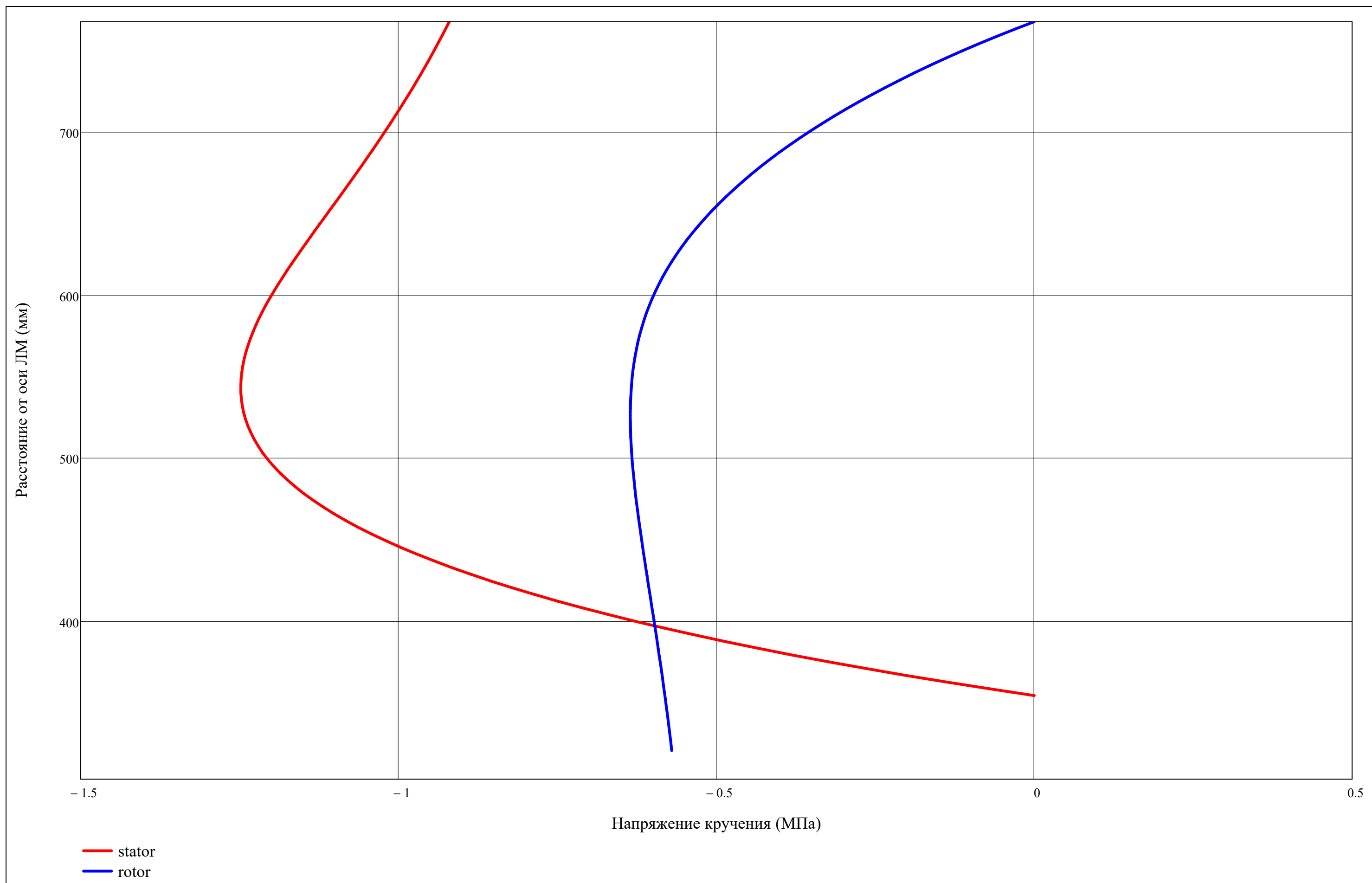


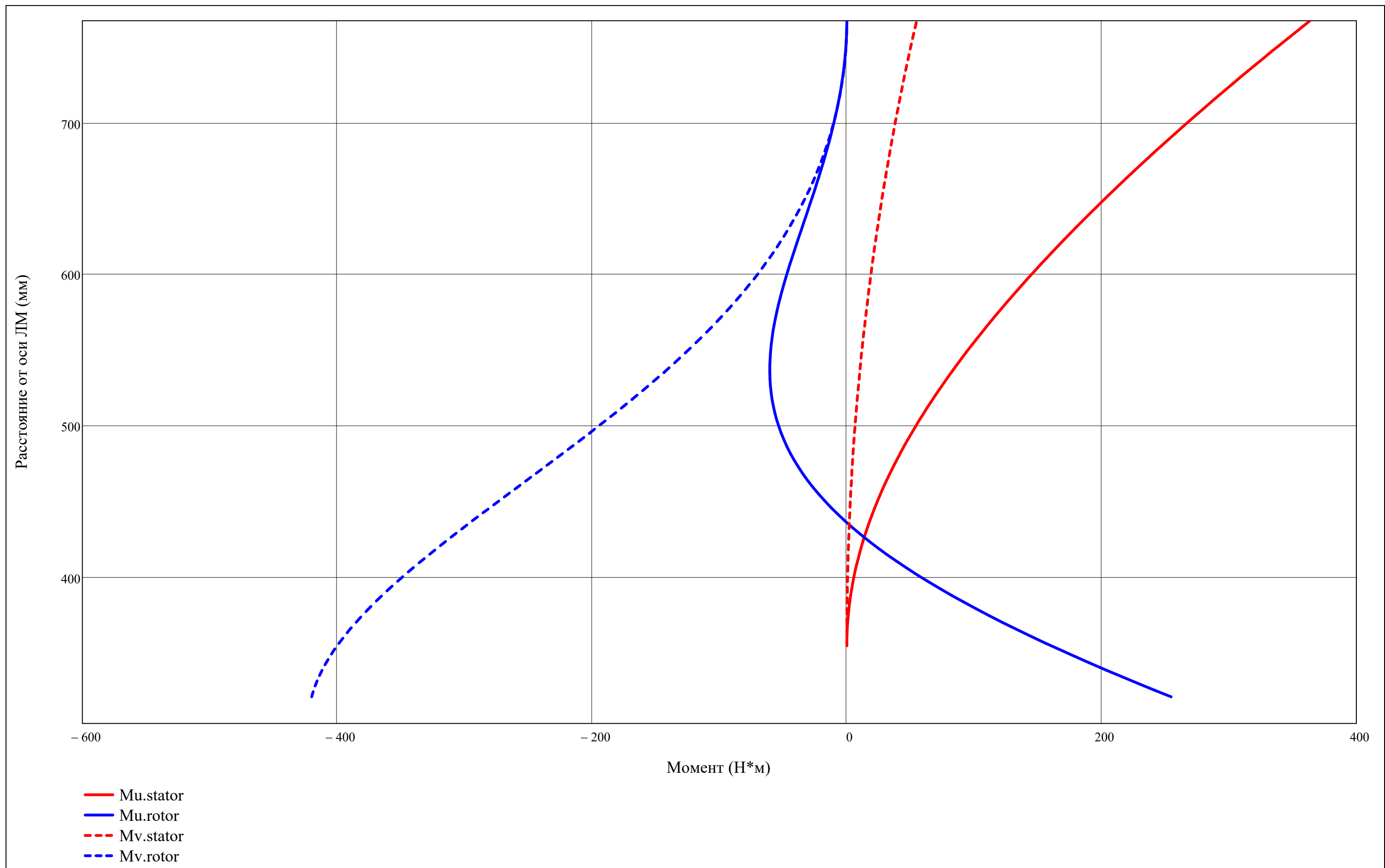




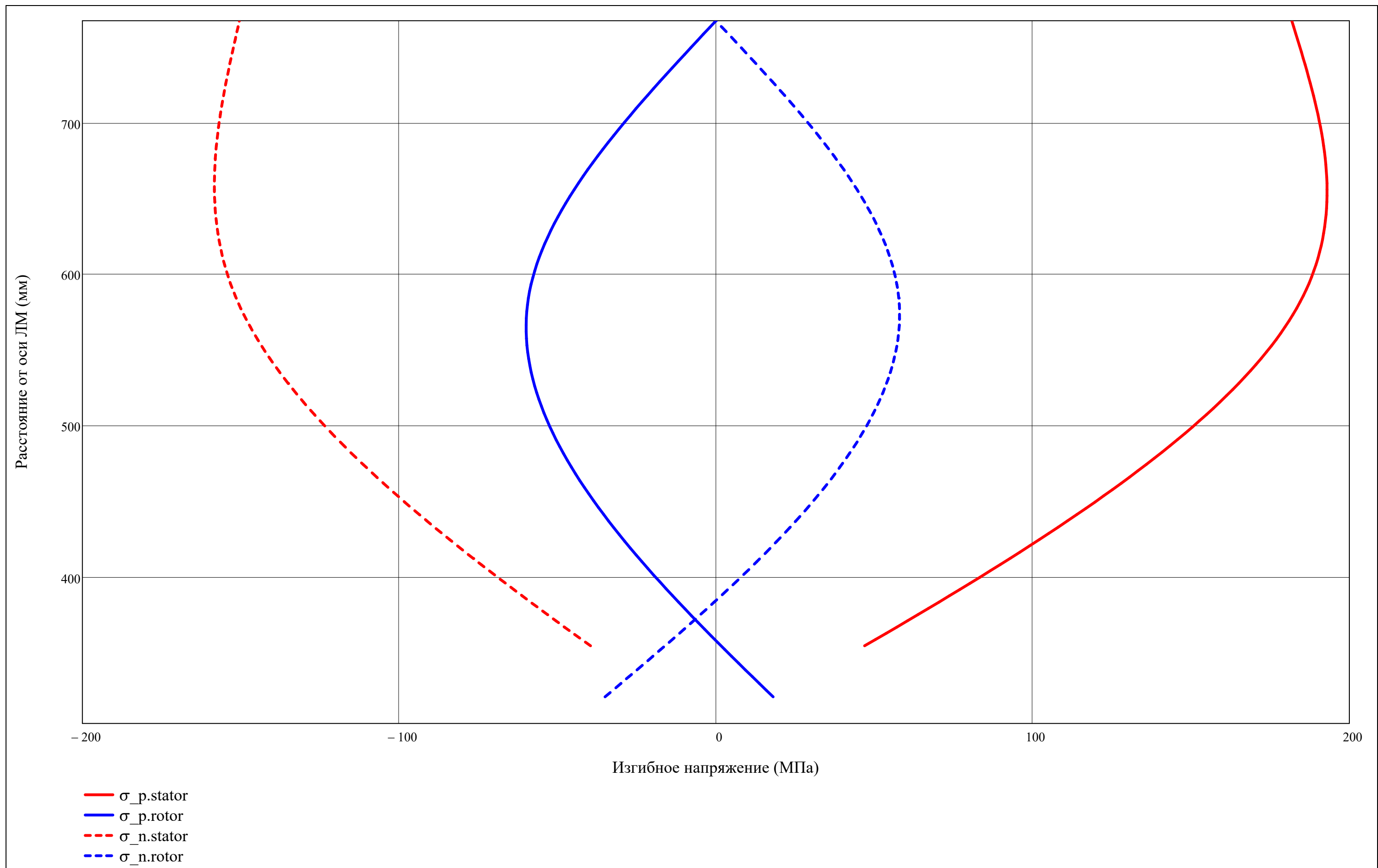


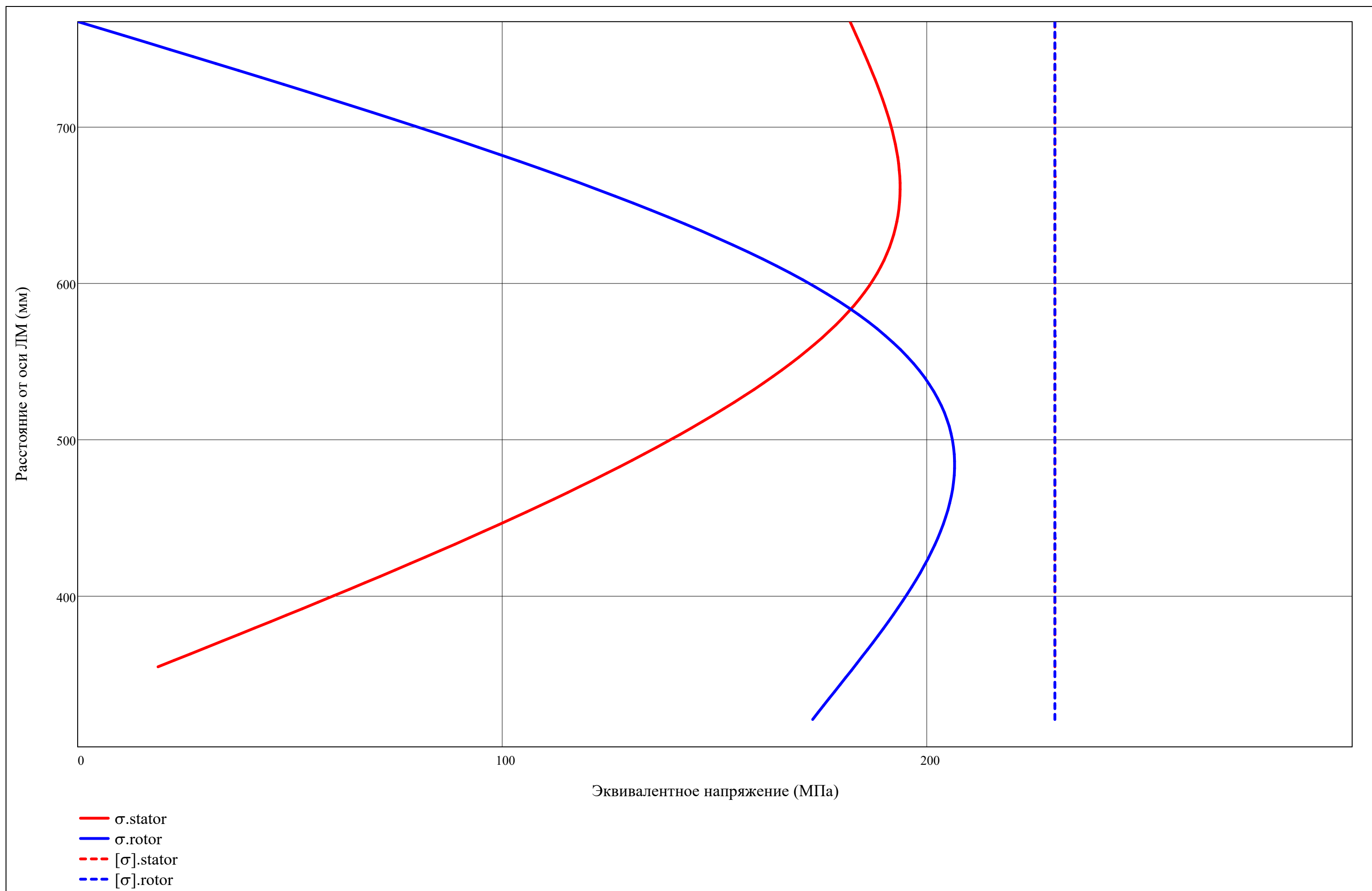












$$\begin{pmatrix} \text{blade} \\ \text{r} \end{pmatrix} = \begin{pmatrix} \text{"rotor"} \\ 1 \end{pmatrix}$$

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u_{u_{\text{rotor}_{j,r}}} & v_{u_{\text{rotor}_{j,r}}} \\ u_{l_{\text{rotor}_{j,r}}} & v_{l_{\text{rotor}_{j,r}}} \\ u_{u_{\text{stator}_{j,r}}} & v_{u_{\text{stator}_{j,r}}} \\ u_{l_{\text{stator}_{j,r}}} & v_{l_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{array}{|c|c|c|} \hline & 1 & 2 \\ \hline 1 & 7.22 & 16.33 \\ \hline 2 & -59.37 & -22.71 \\ \hline 3 & 0.00 & 2.67 \\ \hline 4 & 59.57 & -3.33 \\ \hline \end{array} \cdot 10^{-3}$$

$$\text{Коэф. запаса: } \begin{pmatrix} \text{safety}_{\text{stator}_{j,r}} \\ \text{safety}_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 58.312 \\ \hline 2 & 1.292 \\ \hline \end{array}$$

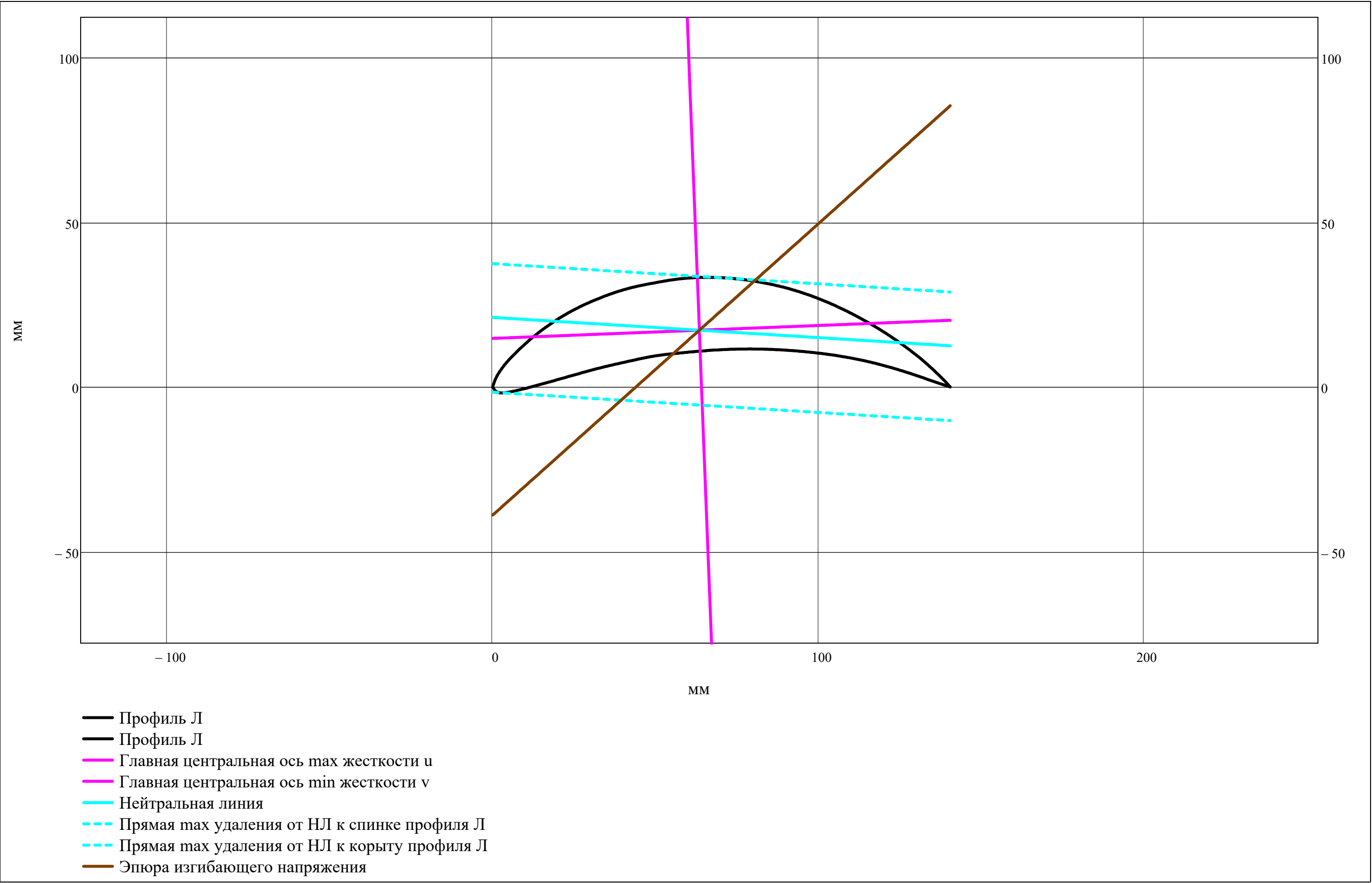
$$\begin{pmatrix} v_p \\ v_n \end{pmatrix} = \begin{cases} \begin{pmatrix} v_{u_{\text{rotor}_{j,r}}} \\ v_{l_{\text{rotor}_{j,r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v_{u_{\text{stator}_{j,r}}} \\ v_{l_{\text{stator}_{j,r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 16.326 \\ \hline 2 & -22.714 \\ \hline \end{array} \cdot 10^{-3} \qquad \begin{pmatrix} x0 \\ y0 \end{pmatrix} = \begin{cases} \begin{pmatrix} x0_{\text{rotor}_{j,r}} \\ y0_{\text{rotor}_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{\text{stator}_{j,r}} \\ y0_{\text{stator}_{j,r}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 63.459 \\ \hline 2 & 17.233 \\ \hline \end{array} \cdot 10^{-3} \qquad \text{chord} = \begin{cases} \text{chord}_{\text{rotor}_{j,r}} & \text{if blade = "rotor"} \\ \text{chord}_{\text{stator}_{j,r}} & \text{if blade = "stator"} \end{cases} = 141 \cdot 10^{-3}$$

Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma_{p_{\text{rotor}_{j,r}}} & \sigma_{p_{\text{stator}_{j,r}}} \\ \sigma_{n_{\text{rotor}_{j,r}}} & \sigma_{n_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{pmatrix} 27 & 4 \\ -45 & -5 \end{pmatrix} \cdot 10^6$$

Эквивалентные напряжения (Па):

$$\begin{pmatrix} \sigma_{\text{stator}_{j,r}} \\ \sigma_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{pmatrix} 4 \\ 178 \end{pmatrix} \cdot 10^6$$



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

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u_{u_{\text{rotor}_{j,r}}} & v_{u_{\text{rotor}_{j,r}}} \\ u_{l_{\text{rotor}_{j,r}}} & v_{l_{\text{rotor}_{j,r}}} \\ u_{u_{\text{stator}_{j,r}}} & v_{u_{\text{stator}_{j,r}}} \\ u_{l_{\text{stator}_{j,r}}} & v_{l_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{array}{|c|c|c|} \hline & 1 & 2 \\ \hline 1 & -1.63 & 4.86 \\ \hline 2 & 82.75 & -4.35 \\ \hline 3 & -1.52 & 4.80 \\ \hline 4 & -42.90 & -3.95 \\ \hline \end{array} \cdot 10^{-3}$$

$$\text{Коэф. запаса: } \begin{pmatrix} \text{safety}_{\text{stator}_{j,r}} \\ \text{safety}_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.244 \\ \hline 2 & 1.304 \\ \hline \end{array}$$

$$\begin{pmatrix} v_p \\ v_n \end{pmatrix} = \begin{cases} \begin{pmatrix} v_{u_{\text{rotor}_{j,r}}} \\ v_{l_{\text{rotor}_{j,r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v_{u_{\text{stator}_{j,r}}} \\ v_{l_{\text{stator}_{j,r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 4.858 \\ \hline 2 & -4.352 \\ \hline \end{array} \cdot 10^{-3}$$

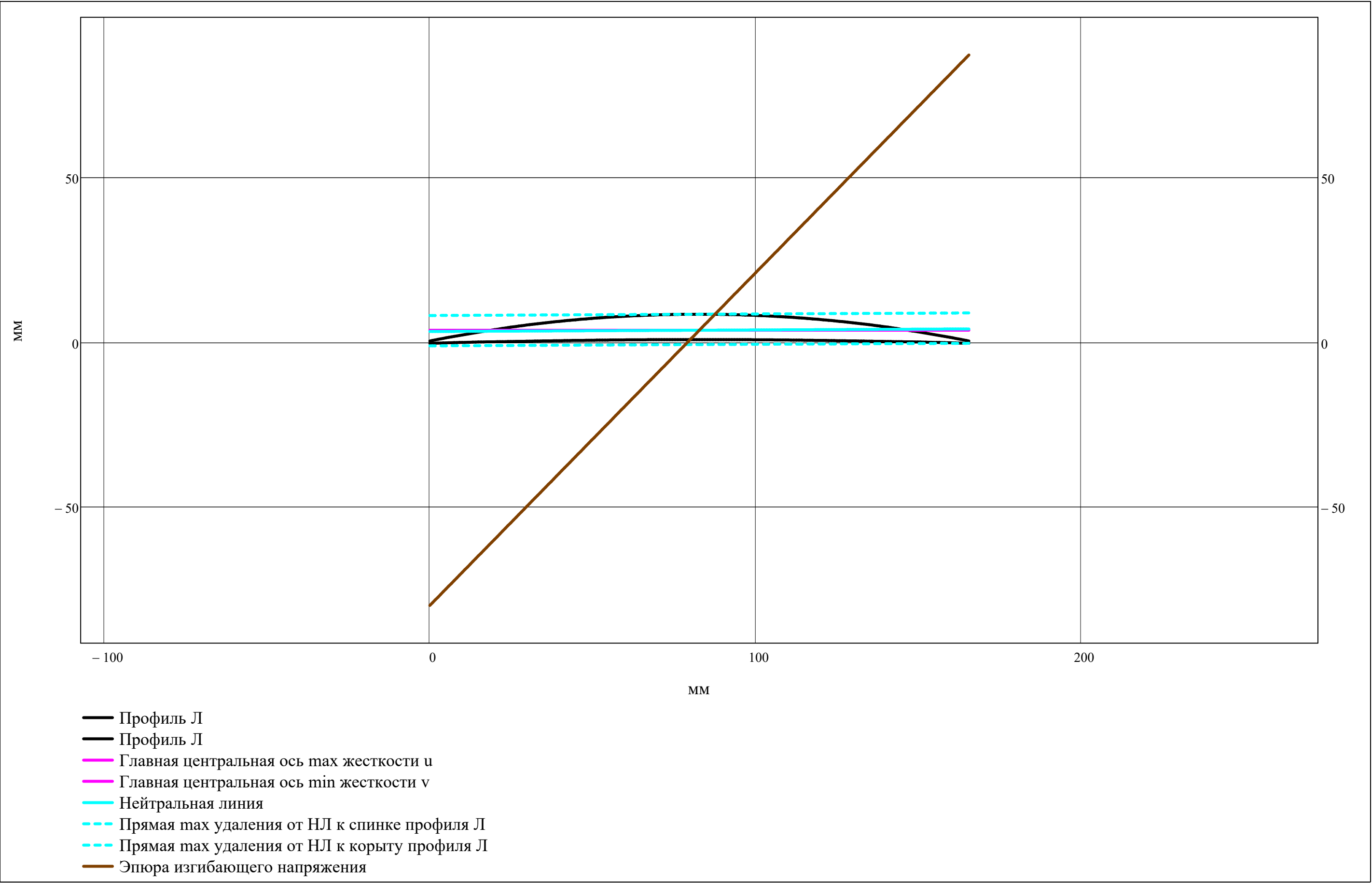
Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma_{p_{\text{rotor}_{j,r}}} & \sigma_{p_{\text{stator}_{j,r}}} \\ \sigma_{n_{\text{rotor}_{j,r}}} & \sigma_{n_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{pmatrix} -59 & 185 \\ 58 & -151 \end{pmatrix} \cdot 10^6$$

Эквивалентные напряжения (Па):

$$\begin{pmatrix} \sigma_{\text{stator}_{j,r}} \\ \sigma_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{pmatrix} 185 \\ 176 \end{pmatrix} \cdot 10^6$$

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \begin{cases} \begin{pmatrix} x0_{\text{rotor}_{j,r}} \\ y0_{\text{rotor}_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{\text{stator}_{j,r}} \\ y0_{\text{stator}_{j,r}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 82.768 \\ \hline 2 & 3.616 \\ \hline \end{array} \cdot 10^{-3} \quad \text{chord} = \begin{cases} \text{chord}_{\text{rotor}_{j,r}} & \text{if blade = "rotor"} \\ \text{chord}_{\text{stator}_{j,r}} & \text{if blade = "stator"} \end{cases} = 166 \cdot 10^{-3}$$



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

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u_{u_{\text{rotor}_{j,r}}} & v_{u_{\text{rotor}_{j,r}}} \\ u_{l_{\text{rotor}_{j,r}}} & v_{l_{\text{rotor}_{j,r}}} \\ u_{u_{\text{stator}_{j,r}}} & v_{u_{\text{stator}_{j,r}}} \\ u_{l_{\text{stator}_{j,r}}} & v_{l_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{array}{|c|c|c|} \hline & 1 & 2 \\ \hline 1 & -1.63 & 4.86 \\ \hline 2 & 82.75 & -4.35 \\ \hline 3 & -1.52 & 4.80 \\ \hline 4 & -42.90 & -3.95 \\ \hline \end{array} \cdot 10^{-3}$$

$$\text{Коэф. запаса: } \begin{pmatrix} \text{safety}_{\text{stator}_{j,r}} \\ \text{safety}_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.244 \\ \hline 2 & 1.304 \\ \hline \end{array}$$

$$\begin{pmatrix} v_p \\ v_n \end{pmatrix} = \begin{cases} \begin{pmatrix} v_{u_{\text{rotor}_{j,r}}} \\ v_{l_{\text{rotor}_{j,r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v_{u_{\text{stator}_{j,r}}} \\ v_{l_{\text{stator}_{j,r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 4.797 \\ \hline 2 & -3.952 \\ \hline \end{array} \cdot 10^{-3}$$

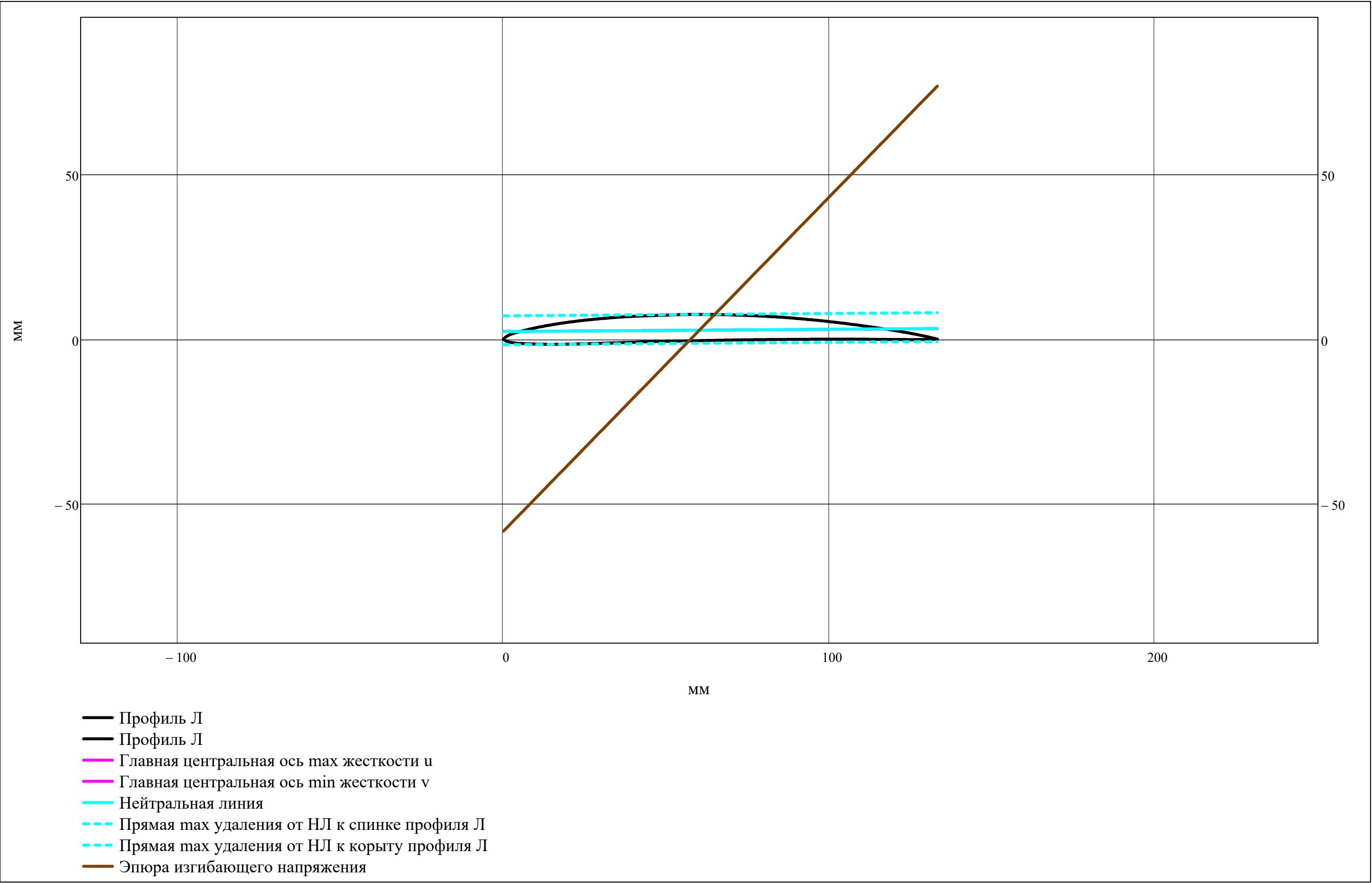
Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma_{p_{\text{rotor}_{j,r}}} & \sigma_{p_{\text{stator}_{j,r}}} \\ \sigma_{n_{\text{rotor}_{j,r}}} & \sigma_{n_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{pmatrix} -59 & 185 \\ 58 & -151 \end{pmatrix} \cdot 10^6$$

Эквивалентные напряжения (Па):

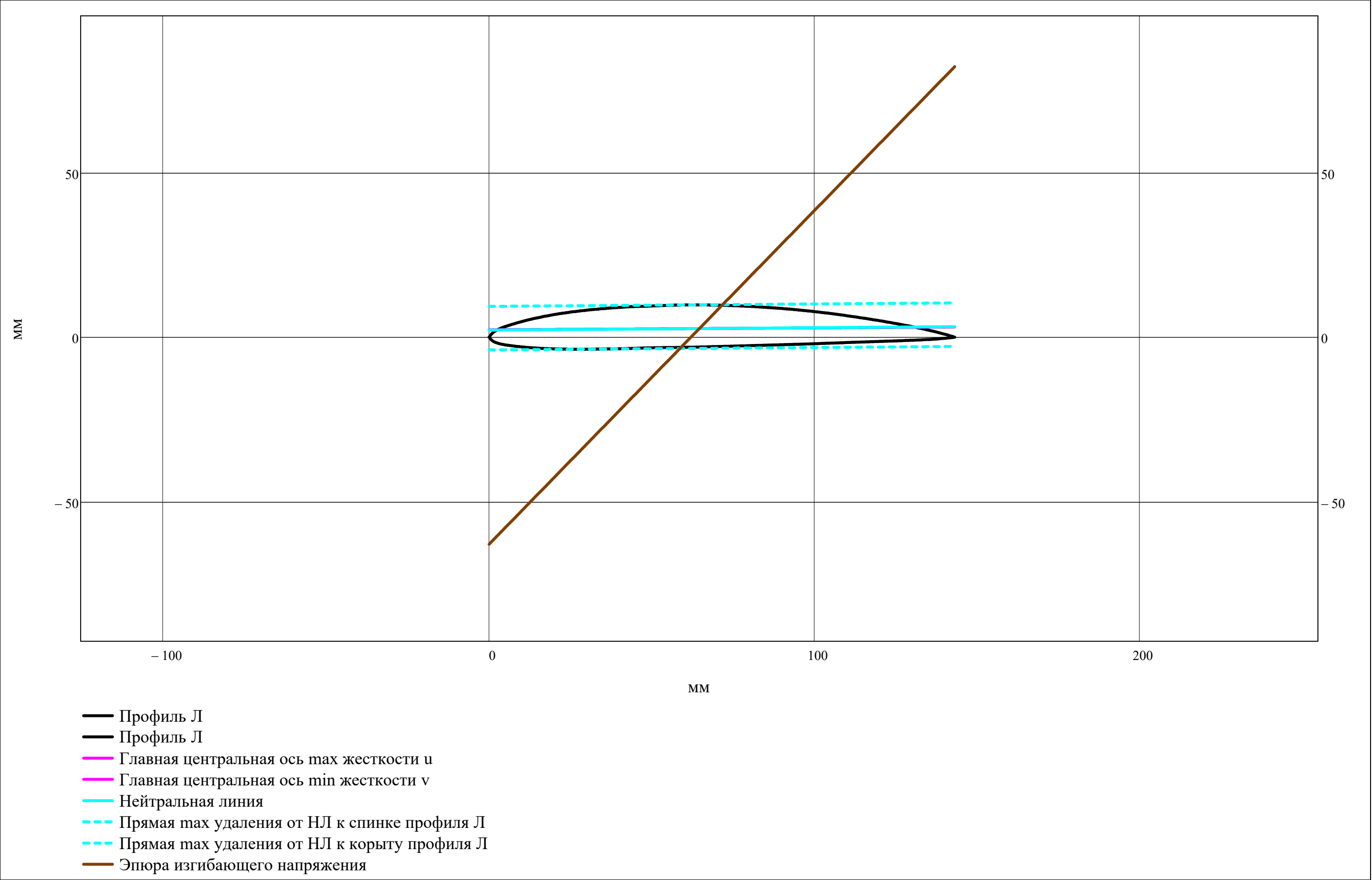
$$\begin{pmatrix} \sigma_{\text{stator}_{j,r}} \\ \sigma_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{pmatrix} 185 \\ 176 \end{pmatrix} \cdot 10^6$$

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \begin{cases} \begin{pmatrix} x0_{\text{rotor}_{j,r}} \\ y0_{\text{rotor}_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{\text{stator}_{j,r}} \\ y0_{\text{stator}_{j,r}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 60.200 \\ \hline 2 & 2.720 \\ \hline \end{array} \cdot 10^{-3} \quad \text{chord} = \begin{cases} \text{chord}_{\text{rotor}_{j,r}} & \text{if blade = "rotor"} \\ \text{chord}_{\text{stator}_{j,r}} & \text{if blade = "stator"} \end{cases} = 133 \cdot 10^{-3}$$









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

Выбранный материал Д:

material\_disk<sub>i</sub> =

"BT23" if compressor = "Вл"  
"BT6" if compressor = "КНД"  
"BT9" if compressor = "КВД"

Плотность материала Д (кг/м^3):

$\rho_{disk_i} =$ 

8266 if material\_disk<sub>i</sub> = "ВЖ175"  
8320 if material\_disk<sub>i</sub> = "ЭП742"  
8393 if material\_disk<sub>i</sub> = "ЖС-6К"  
7900 if material\_disk<sub>i</sub> = "BT41"  
4500 if material\_disk<sub>i</sub> = "BT25"  
4570 if material\_disk<sub>i</sub> = "BT23"  
4510 if material\_disk<sub>i</sub> = "BT9"  
4430 if material\_disk<sub>i</sub> = "BT6"  
NaN otherwise

Предел длительной прочности Д (Па):

$\sigma_{disk\_long_i} = 10^6 \cdot$ 

620 if material\_disk<sub>i</sub> = "ВЖ175"  
680 if material\_disk<sub>i</sub> = "ЭП742"  
125 if material\_disk<sub>i</sub> = "ЖС-6К"  
123 if material\_disk<sub>i</sub> = "BT41"  
150 if material\_disk<sub>i</sub> = "BT25"  
230 if material\_disk<sub>i</sub> = "BT23"  
200 if material\_disk<sub>i</sub> = "BT9"  
210 if material\_disk<sub>i</sub> = "BT6"  
NaN otherwise

material\_disk<sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	"BT23"								

ρ<sub>disk</sub><sup>T</sup> =

	1
1	4570

σ<sub>disk\_long</sub><sup>T</sup> =

	1
1	230

·10<sup>6</sup>

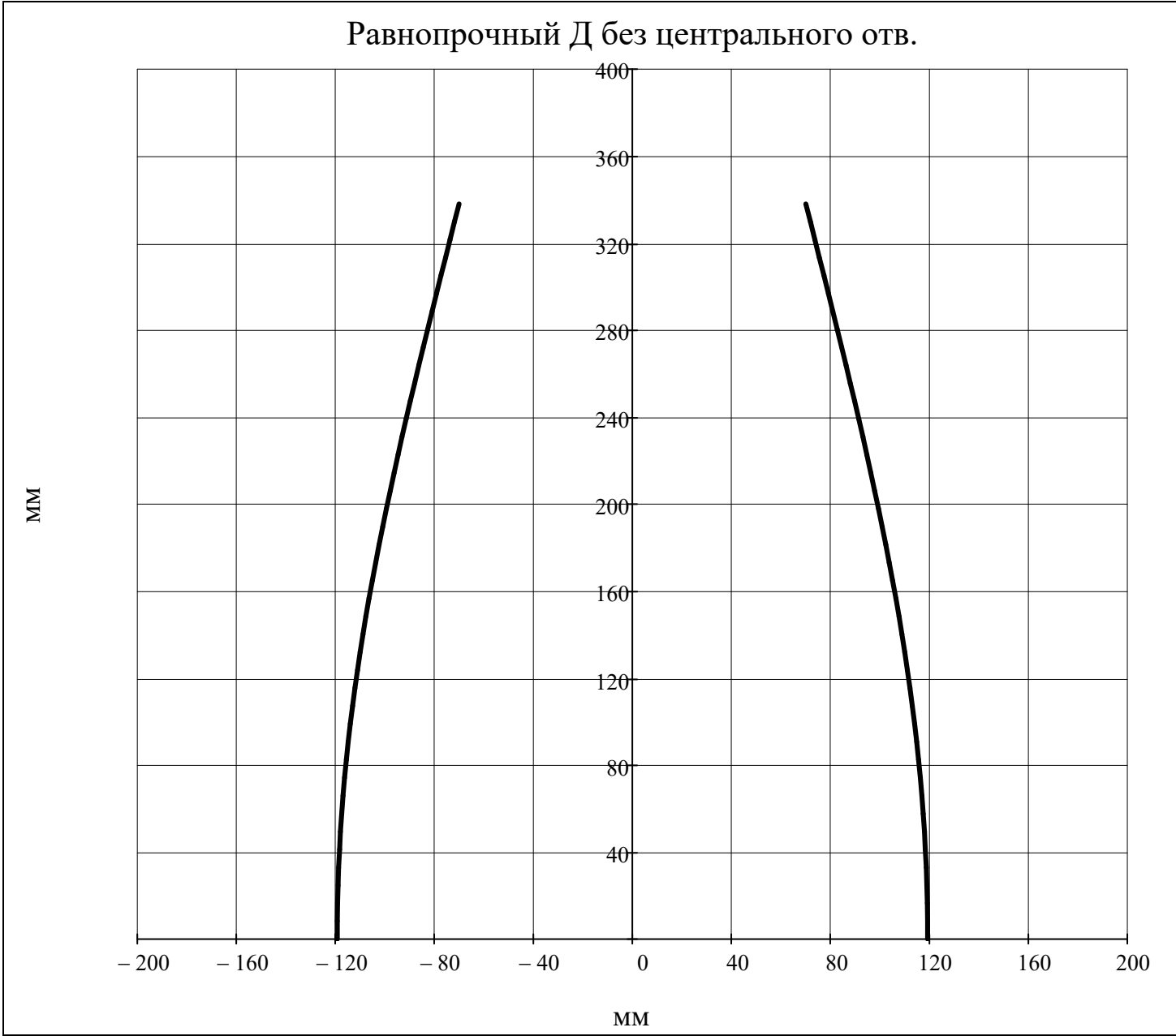
Рассматриваемая ступень:

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

▼ 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.