







Исходные данные

Коэф. запаса:	safety = 1.3
Степень двухконтурности:	m2 = 6
РТ: Воздух	compressor = "КВД"
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" = 34.81</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" = 418.2</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" = 316.2·10<sup>3</sup></div><div>101325 otherwise</div></div></div>
Степень повышения давления КВД:	<div>π*<sub>К</sub> = <div><div>1.6 if compressor = "Вл" = 9.000</div><div><div>3.2</div><div>1.6</div> if compressor = "КНД"</div><div>9 if compressor = "КВД"</div></div></div>

Ожидаемый адиабатический КПД ОК:

$\eta^*_K = \begin{cases} 0.86 & \text{if compressor = "Вл"} \\ 0.87 & \text{if compressor = "КНД"} \\ 0.88 & \text{if compressor = "КВД"} \end{cases} = 88.00\cdot\%$

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

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

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

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

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

Частота вращения ротора (об/мин):

$n = \frac{60 \cdot \omega}{2 \cdot \pi} = 15000$

Закон профилирования проточной части (ЗППЧ):

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

Относ. параметры по относительным ступеням:

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

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

[16, с. 60]

[18, с. 24]

Уточнение параметров:

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

увеличение несущественно увеличивает  $\pi$

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

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	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
2	0.990	0.980	0.970	0.960	0.950	0.950	0.950	0.950
3	0.863	0.873	0.888	0.893	0.893	0.888	0.873	0.863
4	0.232	0.222	0.212	0.202	0.192	0.182	0.172	0.162
5	0.267	0.307	0.337	0.347	0.367	0.337	0.307	0.287

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

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

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

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

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

$$\overline{H}_{Tcp} = \frac{\sum_{i=1}^{rows(z_{\sim})} \overline{H}_{\sim T_i}}{rows(z_{\sim})} = 0.3198$$

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

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

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

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

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

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

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

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

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

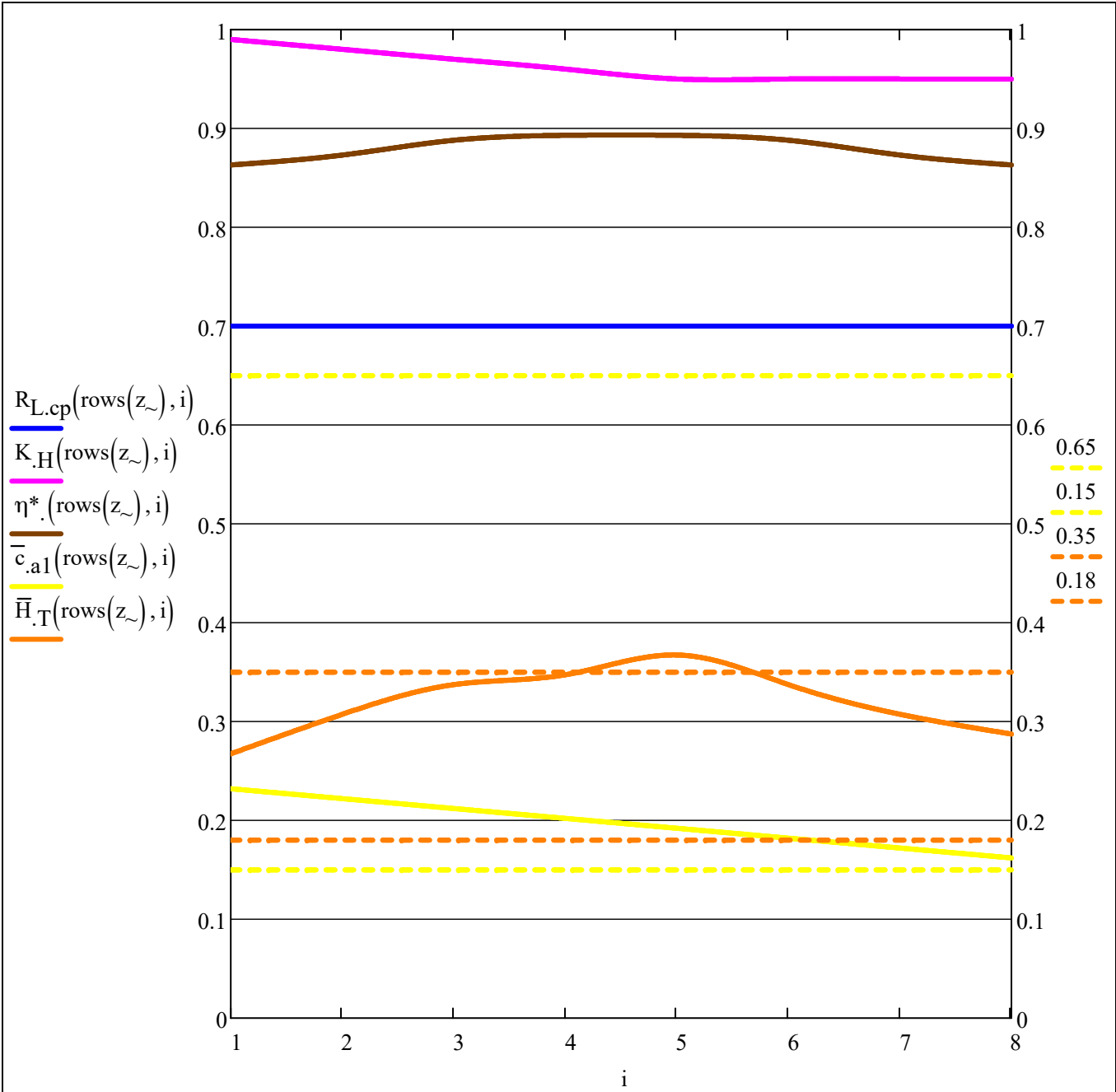
$$\begin{cases} \bar{c}_{\sim a1}\left(\frac{1}{rows(z_{\sim})}\right) & \text{if } i < 1 \\ \bar{c}_{\sim a1}(1) & \text{if } i > Z \\ \bar{c}_{\sim a1}\left(\frac{i}{Z}\right) & \text{otherwise} \end{cases}$$

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

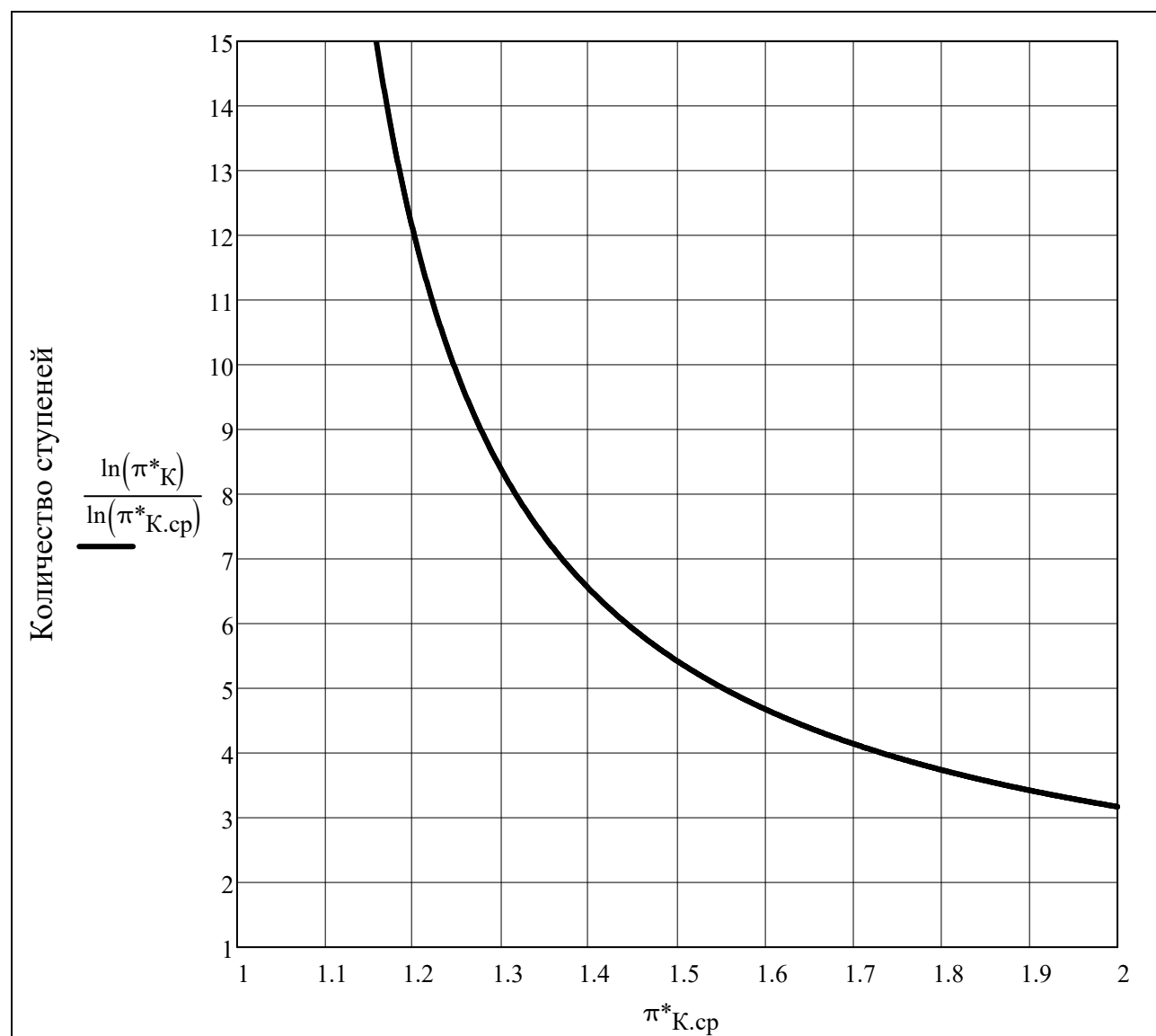
$$\left(R_{L.cp} \ K_{.H} \ \eta^*_{.} \ \bar{c}_{.a1} \ \bar{H}_{.T}\right)^T$$

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

$$\begin{pmatrix} R_{L.cp}(Z_{temp},i_{temp}) \\ K_{.H}(Z_{temp},i_{temp}) \\ \eta^*_{.}(Z_{temp},i_{temp}) \\ \bar{c}_{.a1}(Z_{temp},i_{temp}) \\ \bar{H}_{.T}(Z_{temp},i_{temp}) \end{pmatrix} = \begin{pmatrix} 0.700 \\ 0.950 \\ 0.863 \\ 0.162 \\ 0.287 \end{pmatrix}$$







Показатель адиабаты перед K []:  $k_{K1} = k_{ад}\left(Cp_{воздух}\left(P^*_{K1}, T^*_{K1}\right), R_B\right) = 1.394$

Полное давление после K [Па]:  $P^*_{K3} = \pi^*_K \cdot P^*_{K1} = 2846 \cdot 10^3$

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>)

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

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> = 2

Полная температура после K [K]: T<sup>\*</sup><sub>K3</sub> = 805.9

Показатель адиабаты после K []: k<sub>K3</sub> = 1.354

Полная плотность перед и после K [кг/м³]:  $\begin{pmatrix} \rho^*_{K1} \\ \rho^*_{K3} \end{pmatrix} = \frac{1}{R_B} \cdot \begin{pmatrix} \frac{P^*_{K1}}{T^*_{K1}} \\ \frac{P^*_{K3}}{T^*_{K3}} \end{pmatrix} = \begin{pmatrix} 2.633 \\ 12.297 \end{pmatrix}$

Критические скорости перед и после K [м/с]:  $\begin{pmatrix} a^*_{с.вх} \\ a^*_{с.вых} \end{pmatrix} = \begin{pmatrix} a_{кр}(k_{K1}, R_B, T^*_{K1}) \\ a_{кр}(k_{K3}, R_B, T^*_{K3}) \end{pmatrix} = \begin{pmatrix} 373.9 \\ 515.9 \end{pmatrix}$

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>) = 1.374

Теоретический напор [Дж/кг]:  $H_{TK} = \frac{Cp_{воздух.ср}(P^*_{K1}, P^*_{K3}, T^*_{K1}, T^*_{K3}) \cdot T^*_{K1} \cdot \left(\pi^*_K \frac{k_{ср}-1}{k_{ср}} - 1\right)}{\eta^*_K} = 410.3 \cdot 10^3$

iteration <sub>u</sub>	
u <sub>1пер</sub>	
Z <sub>recomend</sub>	
c <sub>ВХ</sub>	
λ <sub>ВХ</sub>	
ρ <sub>K1</sub>	
	<div> <div>=</div> <div> iteration<sub>u</sub> = 0  ρ<sub>K1</sub> = ρ*<sub>K1</sub>  while 0 &lt; 1  <div> iteration<sub>u</sub> = iteration<sub>u</sub> + 1  trace(concat("iteration.u = ", num2str(iteration<sub>u</sub>)))  <math display="block">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]}}</math>  <math display="block">Z_{recomend} = \max\left(\text{round}\left(\frac{H_{TK}}{\bar{H}_{Tcp} \cdot u_{1пер}^2}\right), 1\right)</math>  c<sub>ВХ</sub> = <math>\bar{c}_{.a1}(Z_{recomend}, 0) \cdot u_{1пер}</math>  <math display="block">\lambda_{ВХ} = \frac{c_{ВХ}}{a^*_{c.ВХ}}</math>  ρ'<sub>K1</sub> = ρ*<sub>K1</sub> · ГДФ("ρ", λ<sub>ВХ</sub>, k<sub>K1</sub>)  if  eps("rel", ρ'<sub>K1</sub>, ρ<sub>K1</sub>)  ≤ epsilon  <div> ρ<sub>K1</sub> = ρ'<sub>K1</sub>  break  ρ<sub>K1</sub> = ρ'<sub>K1</sub> </div> <div> iteration<sub>u</sub>  u<sub>1пер</sub>  Z<sub>recomend</sub>  c<sub>ВХ</sub>  λ<sub>ВХ</sub>  ρ<sub>K1</sub> </div> </div> </div> </div>

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

Окружная скорость на перифкрии перед K [м/с]:      u<sub>1пер</sub> = 430.5

Рекомендуемое количество ступеней []:      Z<sub>recomend</sub> = 7

Абс. скорость перед K [м/с]:      c<sub>ВХ</sub> = 99.9

Приведенная скорость перед K []:      λ<sub>ВХ</sub> = 0.2671

Плотность перед K [кг/м^3]:      ρ<sub>K1</sub> = 2.555

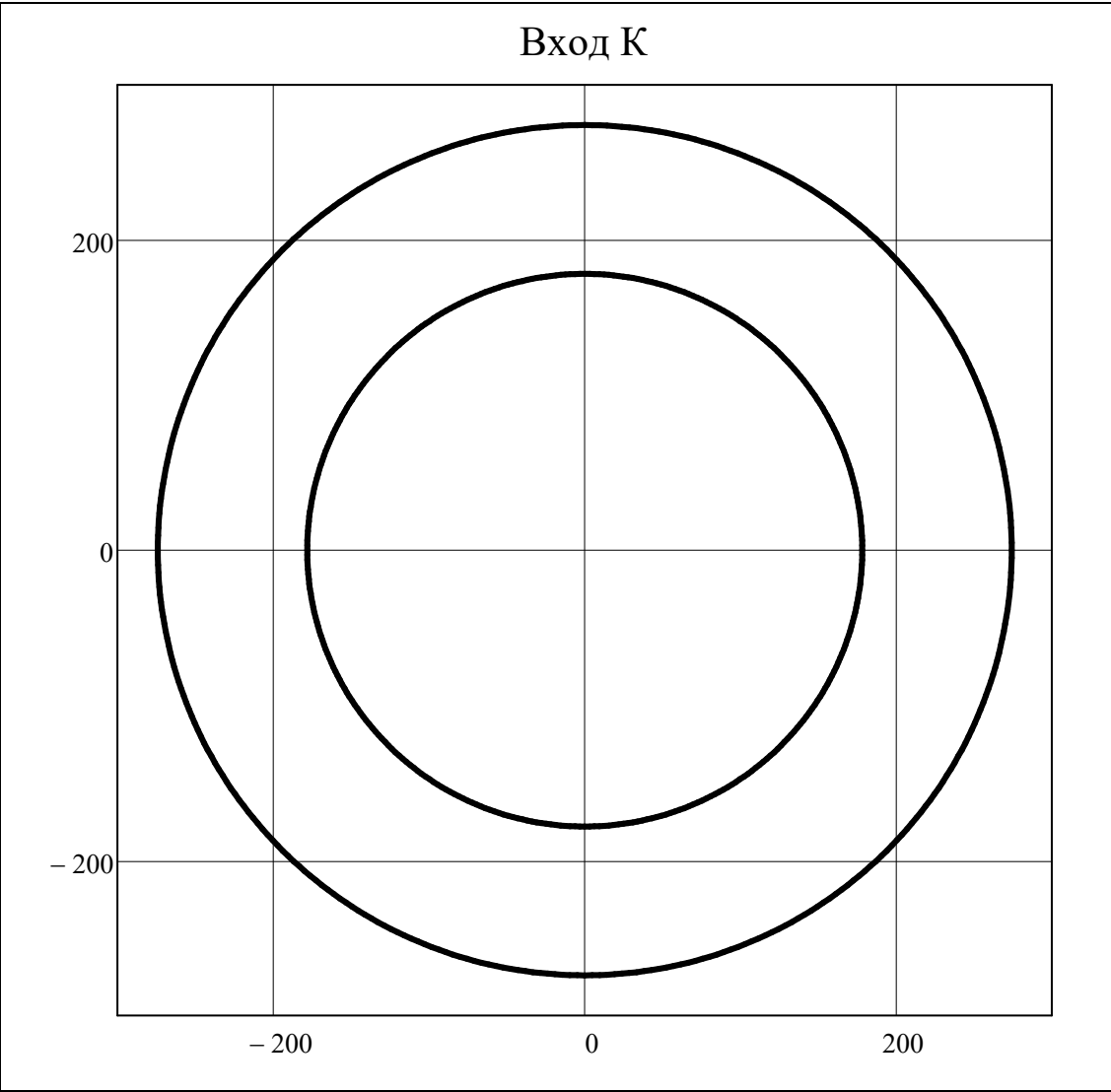
Кольцевая площадь перед K [м²]:       $F_{ВХ} = \frac{G \cdot \sqrt{R_B \cdot T^*_{K1}}}{m_q(k_{K1}) \cdot P^*_{K1} \cdot \Gamma Д \Phi("G", \lambda_{ВХ}, k_{K1})} = 0.1364$

$$D'_{пер1} = \frac{2 \cdot u_{1пер}}{\omega} = 548.2 \cdot 10^{-3}$$

Диаметры перед K [м]:      D'<sub>ср1</sub> =  $\bar{r}_{ср}(\bar{d}_1) \cdot D'_{пер1} = 462.3 \cdot 10^{-3}$

$$D'_{кор1} = \bar{d}_1 \cdot D'_{пер1} = 356.3 \cdot 10^{-3}$$

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



Рекомендуемое количество ступеней []: Z<sub>recomend</sub> = 7

Количество ступеней []:

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\text{submatrix}\left(T^*_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (418.2)$$

$$\text{submatrix}\left(T^*_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (418.2)$$

$$\text{submatrix}\left(P^*_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (316.2) \cdot 10^3$$

$$\text{submatrix}\left(P^*_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (315.6) \cdot 10^3$$

$$\text{submatrix}\left(\rho^*_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (2.633)$$

$$\text{submatrix}\left(\rho^*_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (2.628)$$

$$\text{submatrix}\left(k_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.394)$$

$$\text{submatrix}\left(k_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (1.394)$$

$$\text{submatrix}\left(a_{kp1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (373.9)$$

$$\text{submatrix}\left(a_{kp3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (373.9)$$

$$\text{submatrix}\left(\bar{c}_{a1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.232)$$

$$\text{submatrix}\left(\bar{c}_{a3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.233)$$

$$\text{submatrix}\left(\bar{c}_{u1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.095)$$

$$\text{submatrix}\left(\bar{c}_{u3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.097)$$

$$\text{submatrix}\left(c_{a1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (99.9)$$

$$\text{submatrix}\left(c_{a3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (99.9)$$

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

$$\text{submatrix}\left(c_{u3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (40.7)$$

$$\text{submatrix}\left(c_{1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (99.9)$$

$$\text{submatrix}\left(c_{3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (107.9)$$

$$\text{submatrix}\left(\lambda_{c1BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.267)$$

$$\text{submatrix}\left(\lambda_{c3BHA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (0.288)$$

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

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



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

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

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

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

for i ∈ 1..Z

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

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

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

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

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

$$iteration_{12} = 0$$

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

while 0 < 1

```
iteration12 = iteration12 + 1
```

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

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

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

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

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

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

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

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

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

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

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

break

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

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

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

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

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

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

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

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

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

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

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

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

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

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

while 0 < 1

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

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

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

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

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

if 3ПППϕi = "пер"

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

```

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

```

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

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

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

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

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

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

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

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

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

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

for a ∈ 1 .. 3

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

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

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

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

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

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

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

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

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

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

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

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

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

for radius  $\in 1..N_r$

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

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

for i  $\in 1..Z$

for a  $\in 1..3$

for r  $\in 1..N_r$

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

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



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

Расчет CA:

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

$$\sigma_{CA} = 0.9981$$

$$\text{submatrix}\left(\varepsilon_{CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (36.82) \cdot \text{deg}$$

$$\text{submatrix}\left(\alpha_{1CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (53.18) \cdot \text{deg}$$

$$\text{submatrix}\left(\alpha_{3CA}, \text{av}\left(N_r\right), \text{av}\left(N_r\right), 1, 1\right) = (90.00) \cdot \text{deg}$$

$$\begin{pmatrix} \overline{d}_{1CA} \\ \overline{d}_{3CA} \end{pmatrix} = \begin{pmatrix} 0.8390 \\ 0.8390 \end{pmatrix} \qquad \begin{pmatrix} F_{1CA} \\ F_{3CA} \end{pmatrix} = \begin{pmatrix} 0.0498 \\ 0.0598 \end{pmatrix}$$



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

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

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

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

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

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

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

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

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

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

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

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

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

$$\text{submatrix}\left(T^*_{1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (826.7)$$

$$\text{submatrix}\left(T^*_{3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (826.7)$$

$$\text{submatrix}\left(P^*_{1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (2841.7) \cdot 10^3$$

$$\text{submatrix}\left(P^*_{3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (2836.3) \cdot 10^3$$

$$\text{submatrix}\left(\rho^*_{1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (11.972)$$

$$\text{submatrix}\left(\rho^*_{3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (11.949)$$

$$\text{submatrix}\left(k_{1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (1.352)$$

$$\text{submatrix}\left(k_{3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (1.352)$$

$$\text{submatrix}\left(a_{kp1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (522.4)$$

$$\text{submatrix}\left(a_{kp3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (522.4)$$

$$\text{submatrix}\left(\overline{c}_{a1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.162)$$

$$\text{submatrix}\left(\overline{c}_{a3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.162)$$

$$\text{submatrix}\left(\overline{c}_{u1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.121)$$

$$\text{submatrix}\left(\overline{c}_{u3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.000)$$

$$\text{submatrix}\left(c_{a1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (58.9)$$

$$\text{submatrix}\left(c_{a3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (48.9)$$

$$\text{submatrix}\left(c_{u1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (44.1)$$

$$\text{submatrix}\left(c_{u3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.0)$$

$$\text{submatrix}\left(c_{1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (73.5)$$

$$\text{submatrix}\left(c_{3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (48.9)$$

$$\text{submatrix}\left(\lambda_{1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.141)$$

$$\text{submatrix}\left(\lambda_{3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.094)$$

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

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

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

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

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

$\overline{\Delta G}$

=

for i ∈ 1..Z

for a ∈ 1..3

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

$\overline{\Delta G}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.00	0.00	0.04	0.00	0.03	0.00	0.15	0.00	0.11	0.00	0.08	0.00	0.06	0.00	0.04	0.00	0.02	0.00	0.03

·%

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

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

Количество ступеней ОК: 

Z = 9

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

Дискретизация ступеней:      i = 1..Z

$\pi^{*T}$  =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.392	1.381	1.365	1.319	1.286	1.253	1.203	1.170	1.148						

[16, с 114]       $\pi^{*T} \leq 1.9$  =

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

Полученная степень повышения полного давления []:

$$\prod_{i=1}^Z \pi^*_{i} = 9.003$$

Степень повышения давления в ЛА:

$\pi^*_{\text{ЛА}} = \frac{P^*_{3CA_{av(N_r)}}}{P^*_{1BHA_{av(N_r)}} = 8.970$

$\pi^*_{\text{ЛА}} \geq \pi^*_{\text{К}} = 0$

$H_T^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	48.71	52.80	56.08	54.57	54.37	52.65	46.34	41.94	38.93						
2	48.71	52.80	56.08	54.57	54.37	52.65	46.34	41.94	38.93						
3	48.71	52.80	56.08	54.57	54.37	52.65	46.34	41.94	38.93						

$\cdot 10^3$

Действительная работа К (Дж/кг):
$$L_K = \sum_{i=1}^Z L_i = 430.1 \cdot 10^3$$

Адиабатная работа К [Дж/кг]:
$$L_K^* = \sum_{i=1}^Z L_{*i}^* = 378.5 \cdot 10^3$$

Адиабатная КПД К []:

$$\eta_K^* = \frac{L_K^*}{L_K} = 88.00\%$$

Мощность К (Вт):
$$N_K = G \cdot L_K = 14.97 \cdot 10^6$$

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	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70						

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.991	0.982	0.973	0.965	0.955	0.949	0.95	0.95	0.95						

η<sup>\*</sup><sub>T</sub> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	86.21	87.02	88.35	89.20	89.33	89.23	88.51	87.15	86.30						

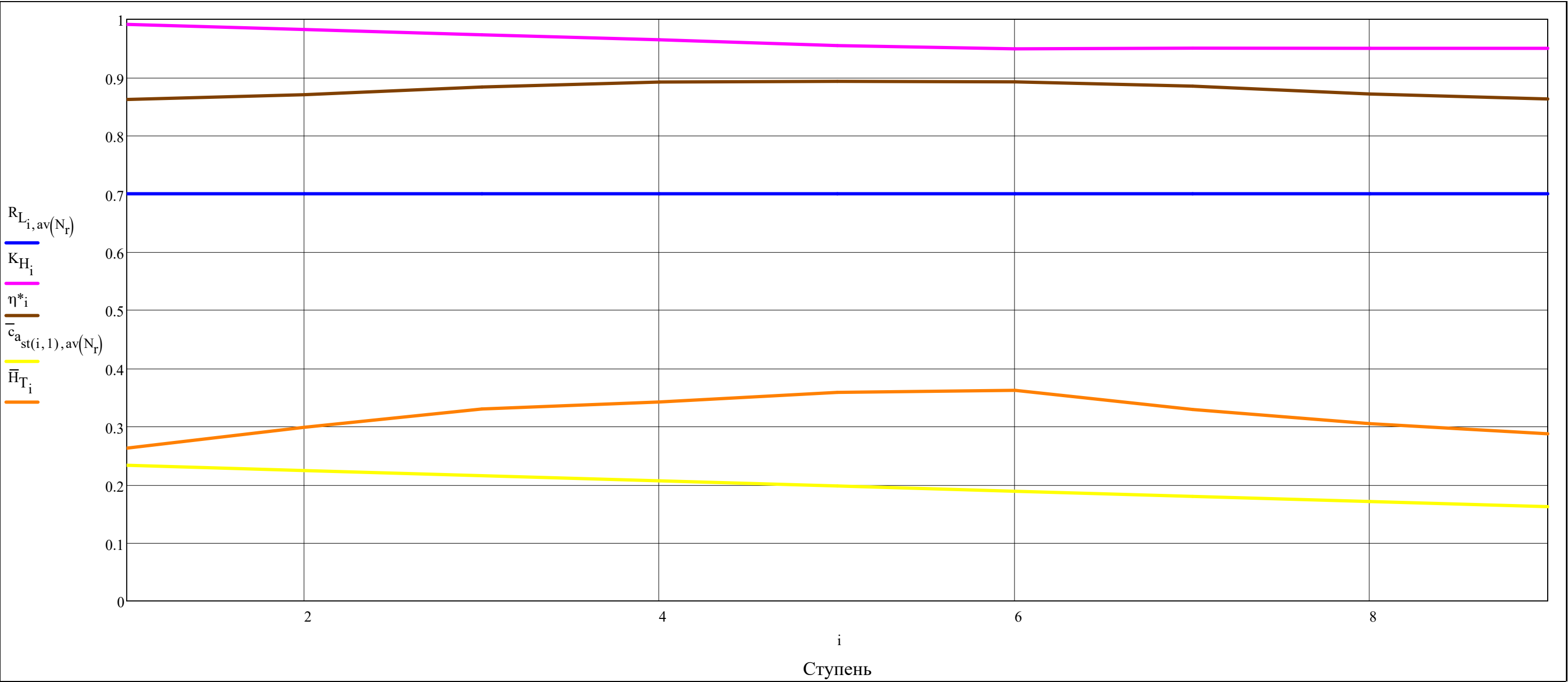
·%

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	0.233	0.229	0.224	0.220	0.215	0.211	0.206	0.202	0.198	0.193	0.189	0.184	0.180	0.175	0.171	0.166	0.162	0.162	0.162	

H̄<sub>T</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.26	0.30	0.33	0.34	0.36	0.36	0.33	0.30	0.29						



$$\text{submatrix}\Big(\text{Cp},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 \\ \hline 1 & 1016.2 & 1024.3 & 1024.3 & 1034.0 & 1034.0 & 1045.1 & 1045.1 & 1056.3 & 1056.3 & 1067.5 & 1067.5 & 1078.3 & 1078.3 & 1087.8 & 1087.8 & 1096.2 & 1096.2 & 1103.8 & 1103.8 \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{k},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 1.394 & 1.390 & 1.390 & 1.384 & 1.384 & 1.379 & 1.379 & 1.373 & 1.373 & 1.368 & 1.368 & 1.363 & 1.363 & 1.359 & 1.359 & 1.355 & 1.355 & 1.352 & 1.352 & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{T}^*,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 418.2 & 465.7 & 465.7 & 516.3 & 516.3 & 569.1 & 569.1 & 619.5 & 619.5 & 668.6 & 668.6 & 715.5 & 715.5 & 756.3 & 756.3 & 792.9 & 792.9 & 826.7 & 826.7 & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{T},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 412.5 & 445.9 & 460.7 & 496.3 & 512.1 & 548.7 & 565.4 & 600.3 & 616.3 & 650.2 & 665.9 & 698.1 & 712.8 & 740.9 & 753.7 & 778.9 & 790.4 & 813.5 & 824.2 & & \\ \hline \end{array}$$

$$\text{submatrix}\Big(\text{P}^*,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 \\ \hline 1 & 315.6 & 439.3 & 439.3 & 606.5 & 606.5 & 828 & 828 & 1091.8 & 1091.8 & 1404.5 & 1404.5 & 1759.5 & 1759.5 & 2117.2 & 2117.2 & 2476.2 & 2476.2 & ... \\ \hline \end{array} \cdot 10^3$$

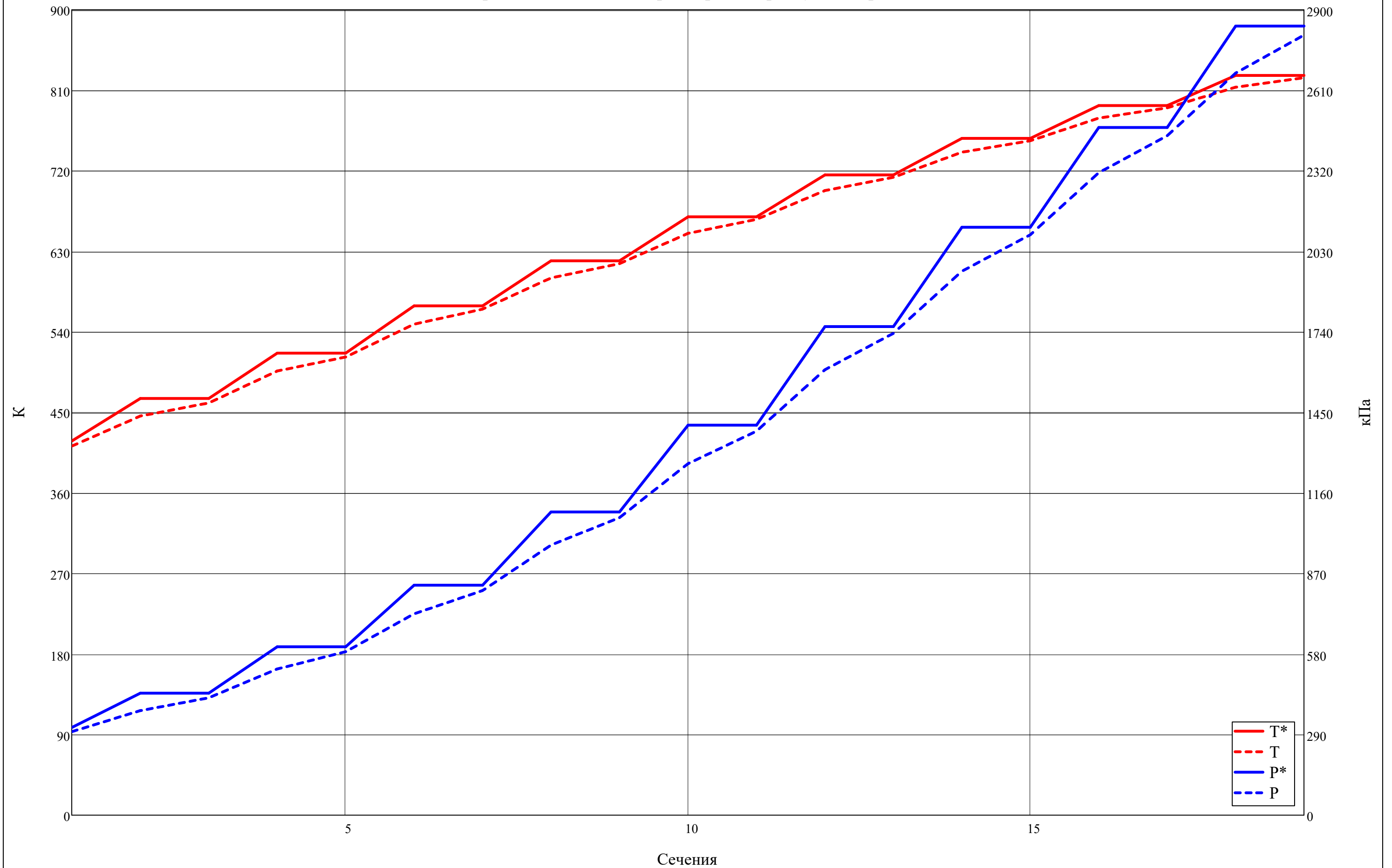
$$\text{submatrix}\Big(\text{P},1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 \\ \hline 1 & 300.6 & 376.3 & 422.8 & 526.1 & 588.5 & 724.9 & 808.7 & 972.5 & 1071.5 & 1266.0 & 1383.0 & 1604.1 & 1734.9 & 1958.5 & 2089.9 & 2313.5 & 2446.6 & ... \\ \hline \end{array} \cdot 10^3$$

$$\text{submatrix}\Big(\rho^*,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 \\ \hline 1 & 2.628 & 3.285 & 3.285 & 4.091 & 4.091 & 5.067 & 5.067 & 6.138 & 6.138 & 7.315 & 7.315 & 8.565 & 8.565 & 9.75 & 9.75 & 10.876 & 10.876 & 11.972 & 11.972 \\ \hline \end{array}$$

$$\text{submatrix}\Big(\rho,1,2Z+1,\text{av}\Big(\text{N}_{\text{r}}\Big),\text{av}\Big(\text{N}_{\text{r}}\Big)\Big)^{\text{T}} = \begin{array}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 \\ \hline 1 & 2.538 & 2.939 & 3.196 & 3.691 & 4.003 & 4.601 & 4.981 & 5.642 & 6.055 & 6.781 & 7.233 & 8.003 & 8.477 & 9.206 & 9.657 & 10.344 & 10.78 & 11.439 & 11.871 \\ \hline \end{array}$$

$$\textcolor{green}{k_{cp}} = k_{\text{ад}}\Big(\text{Cp}_{\text{воздух.ср}}\Big(\text{P}^*_{\text{st}(1,1),\text{av}\Big(\text{N}_{\text{r}}\Big)},\text{P}^*_{\text{st}(Z,3),\text{av}\Big(\text{N}_{\text{r}}\Big)},\text{T}^*_{\text{st}(1,1),\text{av}\Big(\text{N}_{\text{r}}\Big)},\text{T}^*_{\text{st}(Z,3),\text{av}\Big(\text{N}_{\text{r}}\Big)}\Big),\text{R}_{\text{Б}}\Big) = 1.373$$

Термодинамические параметры по тракту К на ср. ЛТ



$F^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.1373	0.1218	0.1155	0.1031	0.098	0.0884	0.0846	0.0775	0.0747	0.069	0.0668	0.0624	0.0608	0.0578	0.0568	0.0547	0.0541	0.0514	0.0498		

$\overline{d}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.6467	0.6726	0.6978	0.7190	0.7397	0.7517	0.7636	0.7734	0.7831	0.7913	0.7995	0.8061	0.8127	0.8173	0.8220	0.8252	0.8284	0.8337	0.8390				

$\overline{d}_{st(Z,3)} = 0.839$

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

$D^T =$

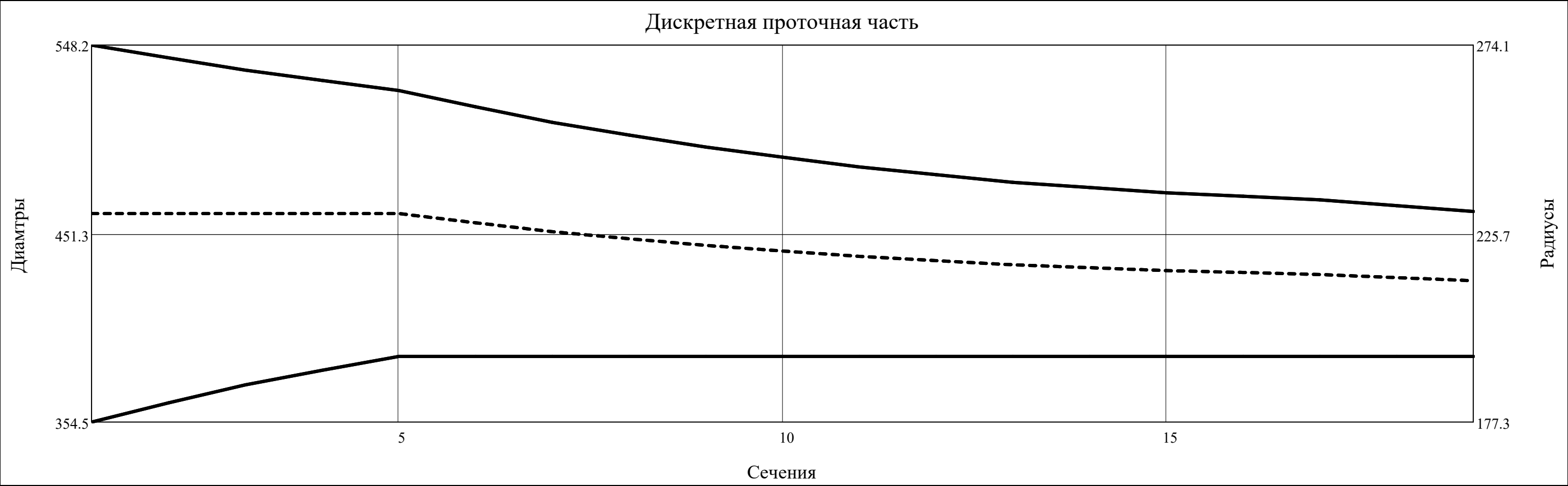
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	354.5	364.3	373.6	381.1	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2	388.2		
2	461.6	461.6	461.6	461.6	461.6	456.9	452.3	448.7	445.3	442.4	439.6	437.4	435.3	433.8	432.3	431.3	430.3	428.7	427.1		
3	548.2	541.7	535.4	530.0	524.8	516.5	508.4	502.0	495.8	490.6	485.6	481.6	477.7	475.0	472.3	470.5	468.7	465.7	462.7		

$\cdot 10^{-3}$

$R^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	177.3	182.2	186.8	190.5	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1	194.1						
2	230.8	230.8	230.8	230.8	230.8	228.4	226.2	224.4	222.6	221.2	219.8	218.7	217.6	216.9	216.2	215.7	215.2	214.4	213.6						
3	274.1	270.8	267.7	265.0	262.4	258.2	254.2	251.0	247.9	245.3	242.8	240.8	238.9	237.5	236.2	235.2	234.3	232.8	231.4						

$\cdot 10^{-3}$



$h^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	96.8	88.7	80.9	74.5	68.3	64.1	60.1	56.9	53.8	51.2	48.7	46.7	44.7	43.4	42.0	41.1	40.2	38.7	37.2						

$\cdot 10^{-3}$



submatrix( $\mathbf{a}_{\mathbf{c}}^*, 1, 2Z + 1, \text{av}(\mathbf{N}_{\mathbf{r}}), \text{av}(\mathbf{N}_{\mathbf{r}})$ ) <sup>T</sup> =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	373.9	394.4	394.4	414.9	414.9	435.3	435.3	453.7	453.7	471.0	471.0	486.8	486.8	500.2	500.2	511.9	511.9	522.4	522.4	

submatrix( $a_{3B}, 1, 2Z + 1, av(N_r), av(N_r)$ ) <sup>T</sup> =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	406.3	421.8	428.8	444.2	451.2	466.1	473.2	486.5	493.0	505.4	511.4	522.7	528.2	537.6	542.2	550.5	554.5	561.9	565.6	

submatrix $\left(c, 1, 2Z + 1, av(N_r), av(N_r)\right)^T =$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	107.9	201.3	100.9	203.3	94.2	206.6	87.7	201.3	81.6	198.3	77.0	193.7	75.9	183.0	75.0	175.2	74.0	170.2	73.5	

submatrix( $w, 1, 2Z, av(N_r), av(N_r)$ ) <sup>T</sup> =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	334.4	210.2	339.9	202.8	342.8	191	335.8	185.5	331.6	179.8	326	177.1	314.4	181.9	306.1	185.3	300.2	186.8		

$u^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	278.4	286.2	293.4	299.3	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9						
	2	362.5	362.5	362.5	362.5	362.5	358.8	355.3	352.4	349.7	347.5	345.3	343.6	341.9	340.7	339.6	338.8	338.0	336.7	335.5						
	3	430.5	425.4	420.5	416.3	412.2	405.6	399.3	394.3	389.4	385.3	381.4	378.3	375.2	373.1	371.0	369.5	368.1	365.7	363.4						

$$c_{a_{st(Z,3),av}(N_r)} = 58.88 \quad c_{a_{st(Z,3),av}(N_r)} \leq 130 = 1 \quad \text{Для КС}$$

submatrix( $c_a, 1, 2Z + 1, av(N_r), av(N_r)$ ) <sup>T</sup> =		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	99.9	97.3	94.3	91.5	88.8	85.5	82.4	79.6	76.9	74.4	72.0	69.7	67.5	65.4	63.4	61.5	59.6	59.3	58.9		

submatrix( $c_u, 1, 2Z + 1, av(N_r), av(N_r)$ ) <sup>T</sup> =		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	40.7	176.2	35.9	181.6	31.4	188	29.8	184.8	27.2	183.8	27.3	180.7	34.8	170.9	40.1	164	43.8	159.6	44.1		

$$\text{submatrix}(\mathbf{w}_u, 1, 2Z + 1, \text{av}(\mathbf{N}_r), \text{av}(\mathbf{N}_r))^T =$$

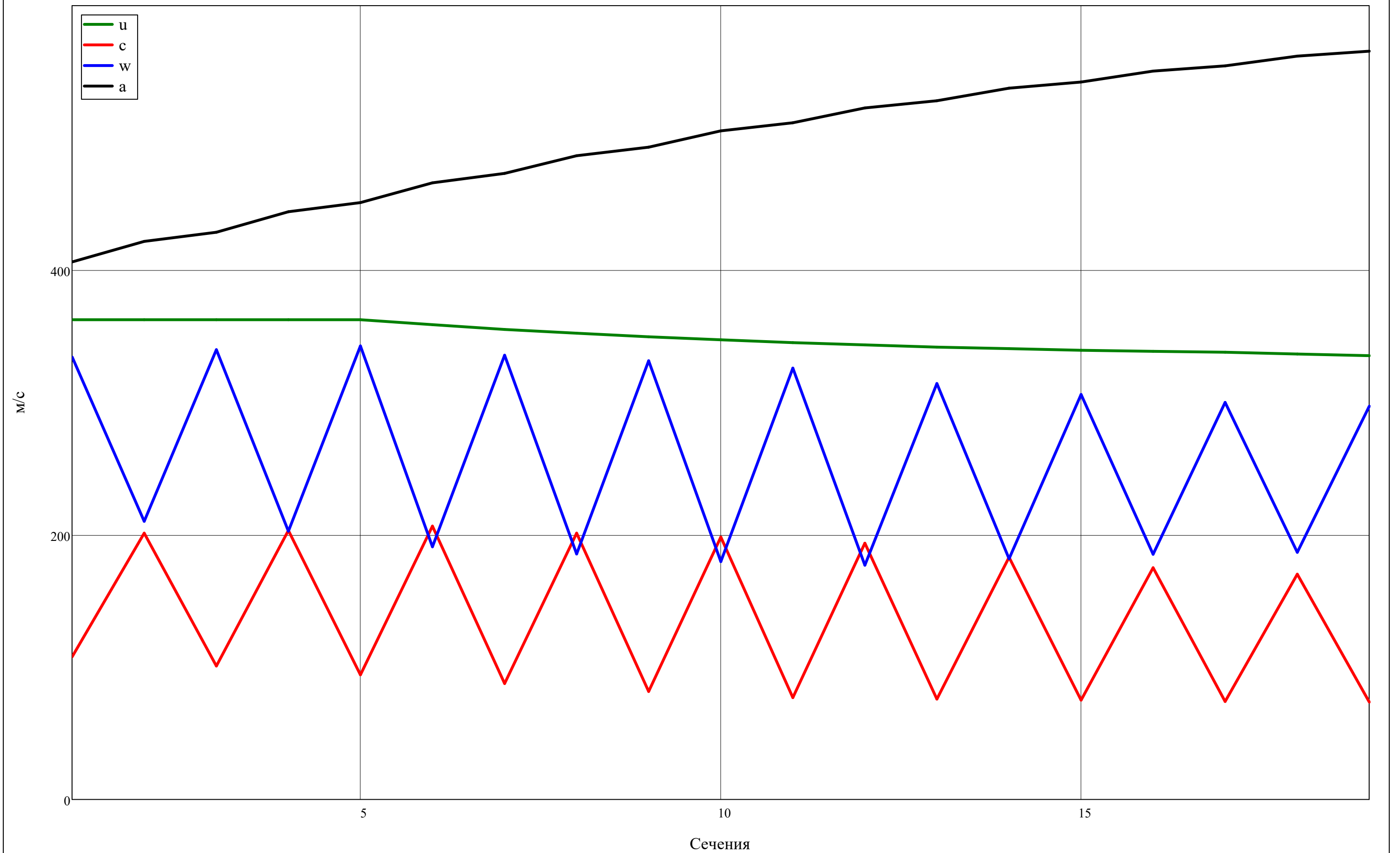
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	319.2	186.3	326.6	181.0	331.1	170.8	325.5	167.6	322.5	163.6	317.9	162.8	307.1	169.8	299.4	174.8	294.2	177.1	291.4		

$$\Delta \mathbf{c}_{\mathbf{a}, \text{av}(\mathbf{N}_{\mathbf{r}})} = \left( \mathbf{c}_{\text{st}(\mathbf{i}, 2), \text{av}(\mathbf{N}_{\mathbf{r}})} - \mathbf{c}_{\text{st}(\mathbf{i}, 1), \text{av}(\mathbf{N}_{\mathbf{r}})} \right)$$

submatrix( $\Delta c_a, 1, Z, av(N_r), av(N_r)$ ) <sup>T</sup> =		1	2	3	4	5	6	7	8	9	10	11	12
	1	-2.6	-2.79	-3.22	-2.8	-2.51	-2.27	-2.04	-1.89	-0.38			

[illegible]

Скорости по тракту К на ср. ЛТ



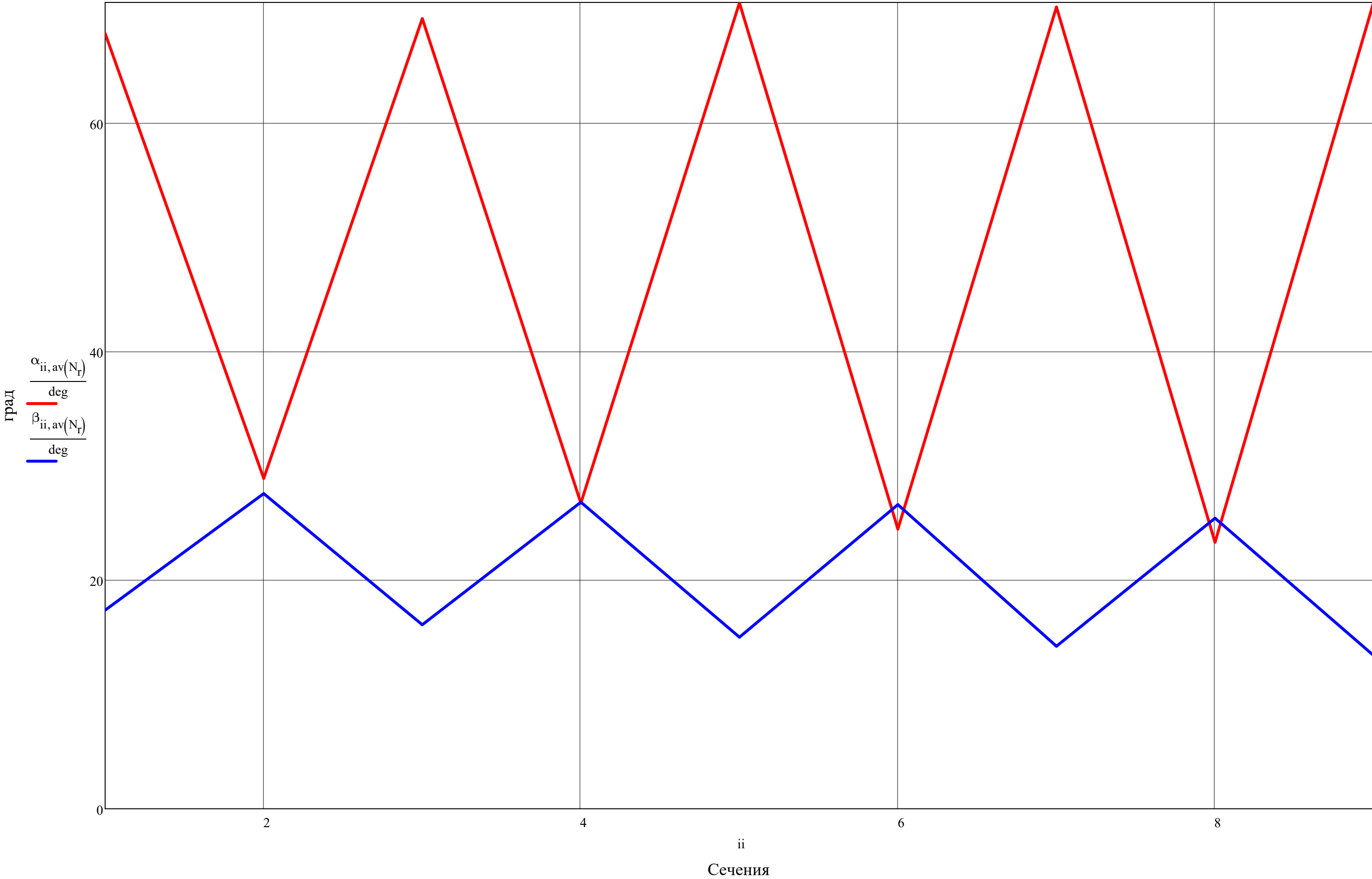
$$\text{submatrix}(\alpha, 1, 2 \cdot Z + 1, \text{av}(\mathbf{N}_r), \text{av}(\mathbf{N}_r))^T = \begin{array}{c|cccccccccccccccccccccccc} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 67.83 & 28.90 & 69.13 & 26.74 & 70.50 & 24.46 & 70.13 & 23.31 & 70.54 & 22.04 & 69.20 & 21.08 & 62.72 & 20.94 & 57.68 & 20.56 & 53.70 & 20.37 & 53.18 & & \end{array} \quad \circ$$

$$\text{submatrix}(\beta, 1, 2 \cdot Z + 1, \text{av}(\mathbf{N}_r), \text{av}(\mathbf{N}_r))^T = \begin{array}{c|cccccccccccccccccccccccc} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 \\ \hline 1 & 17.38 & 27.57 & 16.1 & 26.82 & 15.01 & 26.61 & 14.21 & 25.42 & 13.41 & 24.45 & 12.75 & 23.17 & 12.39 & 21.07 & 11.95 & 19.39 & 11.46 & 18.5 & 11.42 & & \end{array} \quad \circ$$

[illegible]

[illegible]

Углы по тракту К на ср. ЛТ



submatrix $\left(\lambda_{\mathbf{c}}, 1, 2Z + 1, \text{av}\left(\mathbf{N}_{\mathbf{r}}\right), \text{av}\left(\mathbf{N}_{\mathbf{r}}\right)\right)^{\text{T}} =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.2884	0.5104	0.2559	0.4900	0.2269	0.4746	0.2014	0.4436	0.1798	0.4211	0.1634	0.3979	0.1559	0.3659	0.1500	0.3422	0.1446	0.3259	0.1408

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

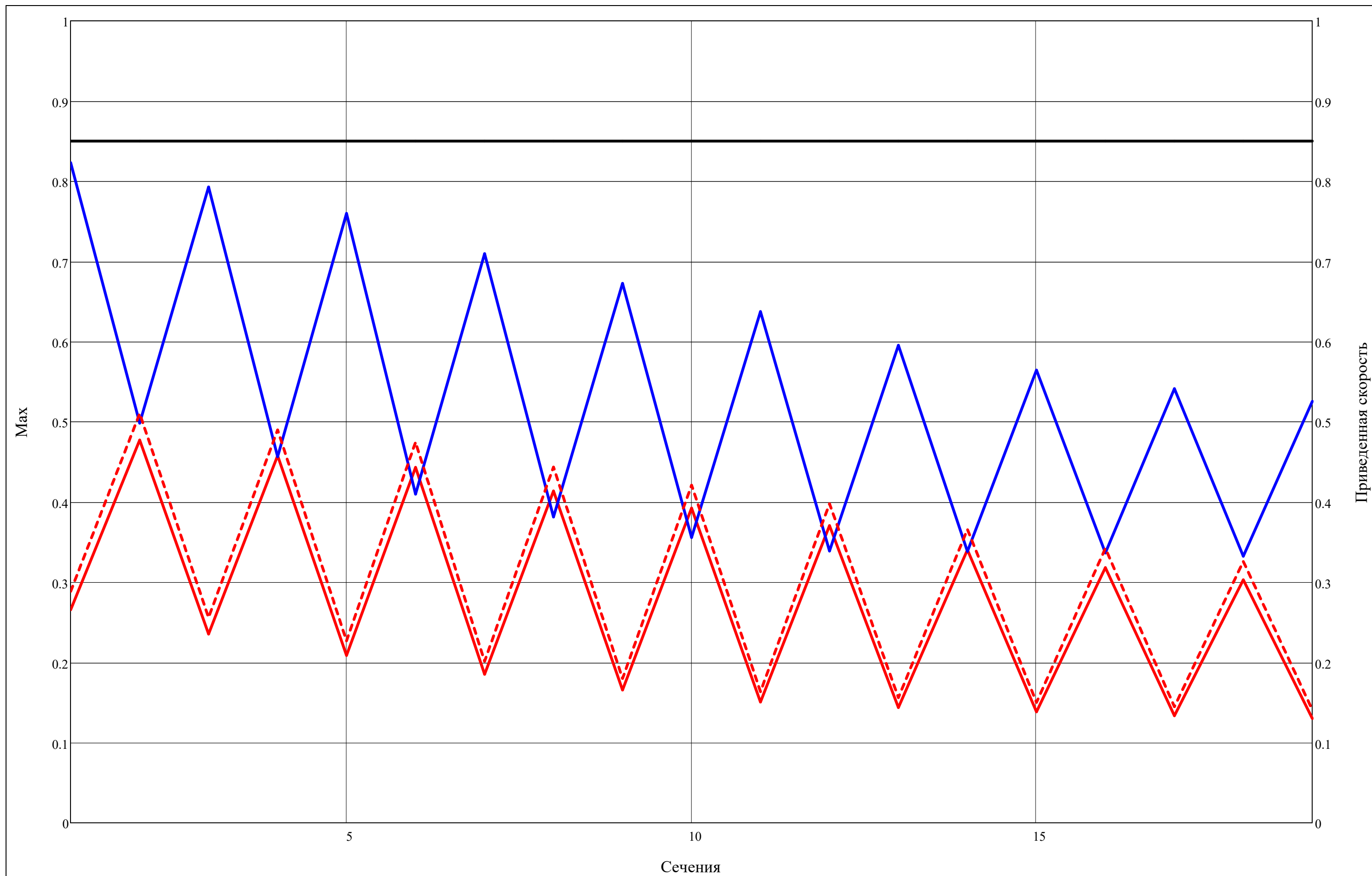
	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	...

submatrix $\left(\mathbf{M}_{\mathbf{w}}, 1, 2Z, \text{av}\left(\mathbf{N}_{\mathbf{r}}\right), \text{av}\left(\mathbf{N}_{\mathbf{r}}\right)\right)^{\text{T}} =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.8231	0.4984	0.7928	0.4565	0.7598	0.4098	0.7096	0.3814	0.6726	0.3557	0.6374	0.3388	0.5953	0.3384	0.5645	0.3365	0.5413	0.3324	

submatrix $\left(\mathbf{M}_{\mathbf{c}}, 1, 2Z + 1, \text{av}\left(\mathbf{N}_{\mathbf{r}}\right), \text{av}\left(\mathbf{N}_{\mathbf{r}}\right)\right)^{\text{T}} =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.2655	0.4772	0.2353	0.4577	0.2087	0.4432	0.1853	0.4137	0.1655	0.3924	0.1505	0.3706	0.1437	0.3404	0.1383	0.3182	0.1334	0.3030	0.1300











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

$$\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} \\ c_{a1BHA_{av(N_r)}} \text{ otherwise} \end{bmatrix} \end{bmatrix} \\
\begin{pmatrix} \alpha_{1BHA_r} \\ \alpha_{3BHA_r} \end{pmatrix} &= \begin{pmatrix} \text{triangle}\left(c_{a1BHA_r}, c_{u1BHA_r}\right) \\ \text{triangle}\left(c_{a3BHA_r}, c_{u3BHA_r}\right) \end{pmatrix} \\
\begin{pmatrix} c_{1BHA_r} \\ c_{3BHA_r} \end{pmatrix} &= \begin{pmatrix} \frac{c_{a1BHA_r}}{\sin\left(\alpha_{1BHA_r}\right)} \\ \frac{c_{a3BHA_r}}{\sin\left(\alpha_{3BHA_r}\right)} \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 \left(\alpha_{3BHA_r} - \alpha_{1BHA_r}\right) \\
\begin{pmatrix} T^*_{1BHA} & P^*_{1BHA} & \rho^*_{1BHA} & C_{P1BHA} & k_{1BHA} & a^*_{c1BHA} & c_{u1BHA} & c_{a1BHA} & \alpha_{1BHA} & c_{1BHA} & \lambda_{c1BHA} & \epsilon_{BHA} \\ T^*_{3BHA} & P^*_{3BHA} & \rho^*_{3BHA} & C_{P3BHA} & k_{3BHA} & a^*_{c3BHA} & c_{u3BHA} & c_{a3BHA} & \alpha_{3BHA} & c_{3BHA} & \lambda_{c3BHA} & \epsilon_{BHA} \end{pmatrix}^T
\end{aligned}$$

$T^*$	$T$
$P^*$	$P$
$\rho^*$	$\rho$
$C_p$	$k$
$a_c^*$	$a_{3B}$
$c_u$	$c_a$
$\alpha$	$\beta$
$c$	$w$
$\lambda_c$	$w_u$
$M_w$	$M_c$
$R_L$	$R_L$
$\epsilon_{rotor}$	$\epsilon_{stator}$

$$= \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_{st(i,a),r}^* = T_{st(i,a),av(N_r)}^* \\ \quad \quad \quad P_{st(i,a),r}^* = P_{st(i,a),av(N_r)}^* \\ \quad \quad \quad \rho_{st(i,a),r}^* = \rho_{st(i,a),av(N_r)}^* \\ \quad \quad \quad C_{p_{st(i,a),r}} = C_{p_{BO3DYX}}(P_{st(i,a),r}^*, T_{st(i,a),r}^*) \\ \quad \quad \quad k_{st(i,a),r} = k_{a\mathcal{D}}(C_{p_{st(i,a),r}}, R_B) \\ \quad \quad \quad a_{c_{st(i,a),r}}^* = \sqrt{\frac{2 \cdot k_{st(i,a),r}}{k_{st(i,a),r} + 1}} \cdot R_B \cdot T_{st(i,a),r}^* \\ \quad \quad \text{if } \Delta H_{Tmax} = 0 \\ \quad \quad \quad A_{st(i,a)} = \left(1 - R_{L_{i,av(N_r)}}\right) \cdot \omega \cdot \left(R_{st(i,a),av(N_r)}\right)^{m_i+1} \\ \quad \quad \quad B_{st(i,a)} = \frac{H_{T_{i,av(N_r)}}}{2 \cdot \omega} \\ \quad \quad \quad c_{u_{st(i,a),r}} = \begin{array}{l} c_{u_{st(i,a-1),r}} \cdot \frac{R_{st(i,a),r}}{R_{st(i,a-1),r}} + \frac{H_{T_{i,av(N_r)}}}{\omega \cdot R_{st(i,a),r}} \text{ if } a = 2 \\ \text{otherwise} \\ \left| \begin{array}{l} 0 \text{ if } (a = 1) \wedge (i = 1) \wedge (BHA = 0) \\ \frac{A_{st(i,a)}}{\left(R_{st(i,a),r}\right)^{m_i}} - \frac{B_{st(i,a)}}{\left(R_{st(i,a),r}\right)} \text{ otherwise} \end{array} \right| \\ c_{a_{st(i,a),r}} = \begin{array}{l} c_{a3BHA_r} \text{ if } (a = 1) \wedge (i = 1) \wedge (BHA = 1) \\ \sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 - 2 \cdot \left(A_{st(i,a)}\right)^2 \cdot \left[\left(R_{st(i,a),r}\right)^2 - \left(R_{st(i,a),av(N_r)}\right)^2\right] + 4 \cdot A_{st(i,a)} \cdot B_{st(i,a)} \cdot \ln\left(\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right)} \cdot \left| \begin{array}{l} -1 \text{ if } a = 2 \\ 1 \text{ otherwise} \end{array} \right| \text{ if } m_i = -1 \\ \sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 - 2 \cdot \left(A_{st(i,a)}\right)^2 \cdot \ln\left[\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right] - 2 \cdot A_{st(i,a)} \cdot B_{st(i,a)} \cdot \left(\frac{1}{R_{st(i,a),r}} - \frac{1}{R_{st(i,a),av(N_r)}}\right)} \cdot \left| \begin{array}{l} -1 \text{ if } a = 2 \\ 1 \text{ otherwise} \end{array} \right| \text{ if } m_i = 0 \end{array} \end{array} \end{array}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

for  $r \in 1..N_r$

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

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

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

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

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

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

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

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

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

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

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

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

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





$T^*_{1BHA} = \begin{pmatrix} 418.2 \\ 418.2 \\ 418.2 \end{pmatrix}$	$T^*_{3BHA} = \begin{pmatrix} 418.2 \\ 418.2 \\ 418.2 \end{pmatrix}$	$a^*_{c1BHA} = \begin{pmatrix} 373.95 \\ 373.95 \\ 373.95 \end{pmatrix}$	$a^*_{c3BHA} = \begin{pmatrix} 373.95 \\ 373.95 \\ 373.95 \end{pmatrix}$	$\alpha_{1BHA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ^\circ$	$\alpha_{3BHA} = \begin{pmatrix} 66.71 \\ 67.39 \\ 68.13 \end{pmatrix} \cdot ^\circ$
$P^*_{1BHA} = \begin{pmatrix} 316.2 \\ 316.2 \\ 316.2 \end{pmatrix} \cdot 10^3$	$P^*_{3BHA} = \begin{pmatrix} 315.6 \\ 315.6 \\ 315.6 \end{pmatrix} \cdot 10^3$	$c_{1BHA} = \begin{pmatrix} 99.9 \\ 99.9 \\ 99.9 \end{pmatrix}$	$c_{3BHA} = \begin{pmatrix} 112.6 \\ 108.2 \\ 105.6 \end{pmatrix}$	$\epsilon_{BHA} = \begin{pmatrix} 23.29 \\ 22.61 \\ 21.87 \end{pmatrix} \cdot ^\circ$	
$\rho^*_{1BHA} = \begin{pmatrix} 2.633 \\ 2.633 \\ 2.633 \end{pmatrix}$	$\rho^*_{3BHA} = \begin{pmatrix} 2.628 \\ 2.628 \\ 2.628 \end{pmatrix}$	$c_{u1BHA} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix}$	$c_{u3BHA} = \begin{pmatrix} 44.5 \\ 41.6 \\ 39.3 \end{pmatrix}$		
$Cp_{1BHA} = \begin{pmatrix} 1016.2 \\ 1016.2 \\ 1016.2 \end{pmatrix}$	$Cp_{3BHA} = \begin{pmatrix} 1016.2 \\ 1016.2 \\ 1016.2 \end{pmatrix}$	$c_{a1BHA} = \begin{pmatrix} 99.9 \\ 99.9 \\ 99.9 \end{pmatrix}$	$c_{a3BHA} = \begin{pmatrix} 103.5 \\ 99.9 \\ 98.0 \end{pmatrix}$	$\lambda_{c1BHA} = \begin{pmatrix} 0.267 \\ 0.267 \\ 0.267 \end{pmatrix}$	$\lambda_{c3BHA} = \begin{pmatrix} 0.301 \\ 0.289 \\ 0.282 \end{pmatrix}$
$k_{1BHA} = \begin{pmatrix} 1.394 \\ 1.394 \\ 1.394 \end{pmatrix}$	$k_{3BHA} = \begin{pmatrix} 1.394 \\ 1.394 \\ 1.394 \end{pmatrix}$				

$$\mathbf{T}^{*\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	418.2	465.7	465.7	516.3	516.3	569.1	569.1	619.5	619.5	668.6	668.6	715.5	715.5	756.3	756.3	792.9	792.9	826.7	826.7						
2	418.2	465.7	465.7	516.3	516.3	569.1	569.1	619.5	619.5	668.6	668.6	715.5	715.5	756.3	756.3	792.9	792.9	826.7	826.7						
3	418.2	465.7	465.7	516.3	516.3	569.1	569.1	619.5	619.5	668.6	668.6	715.5	715.5	756.3	756.3	792.9	792.9	826.7	826.7						

$$\mathbf{T}^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	412.0	436.9	460.4	488.5	511.9	542.2	565.3	594.9	616.2	645.5	665.8	694.0	712.6	737.6	753.5	776.0	790.2	811.0	824.1						
2	412.4	446.0	460.7	496.3	512.1	548.8	565.4	600.4	616.3	650.3	665.9	698.1	712.8	740.9	753.7	779.0	790.4	813.6	824.3						
3	412.7	450.3	460.9	500.3	512.2	552.5	565.5	603.7	616.4	653.3	665.9	700.8	712.9	743.2	753.8	780.9	790.6	815.4	824.4						

$$\mathbf{p}^{*\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	315.6	439.3	439.3	606.5	606.5	828.0	828.0	1091.8	1091.8	1404.5	1404.5	1759.5	1759.5	2117.2	2117.2	2476.2	2476.2	2841.7	2841.7		
2	315.6	439.3	439.3	606.5	606.5	828.0	828.0	1091.8	1091.8	1404.5	1404.5	1759.5	1759.5	2117.2	2117.2	2476.2	2476.2	2841.7	2841.7		
3	315.6	439.3	439.3	606.5	606.5	828.0	828.0	1091.8	1091.8	1404.5	1404.5	1759.5	1759.5	2117.2	2117.2	2476.2	2476.2	2841.7	2841.7		

.10<sup>3</sup>

$$\mathbf{p}^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	299.3	349.8	421.7	496.9	587.7	694.1	807.9	940.5	1070.8	1232.1	1382.2	1569.2	1733.6	1925.3	2088.1	2281.0	2444.2	2640.3	2807.9		
2	300.5	376.4	422.8	526.1	588.5	725.5	808.7	973.0	1071.5	1266.4	1383.0	1604.5	1734.9	1958.9	2089.9	2313.8	2446.6	2672.7	2810.2		
3	301.2	389.7	423.3	541.3	589.0	743.5	809.2	992.7	1071.9	1288.1	1383.5	1627.6	1735.8	1981.5	2091.2	2336.2	2448.2	2695.2	2811.8		

.10<sup>3</sup>

$$\rho^{*\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	2.628	3.285	3.285	4.091	4.091	5.067	5.067	6.138	6.138	7.315	7.315	8.565	8.565	9.750	9.750	10.876	10.876	11.972	11.972		
2	2.628	3.285	3.285	4.091	4.091	5.067	5.067	6.138	6.138	7.315	7.315	8.565	8.565	9.750	9.750	10.876	10.876	11.972	11.972		
3	2.628	3.285	3.285	4.091	4.091	5.067	5.067	6.138	6.138	7.315	7.315	8.565	8.565	9.750	9.750	10.876	10.876	11.972	11.972		

$$\rho^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	2.530	2.788	3.190	3.542	3.999	4.458	4.977	5.506	6.052	6.648	7.230	7.875	8.472	9.091	9.651	10.236	10.772	11.338	11.866		
2	2.537	2.940	3.196	3.691	4.003	4.604	4.981	5.644	6.055	6.782	7.233	8.004	8.477	9.207	9.657	10.345	10.780	11.441	11.873		
3	2.542	3.014	3.199	3.768	4.005	4.686	4.983	5.727	6.056	6.867	7.235	8.089	8.480	9.285	9.661	10.419	10.785	11.512	11.878		

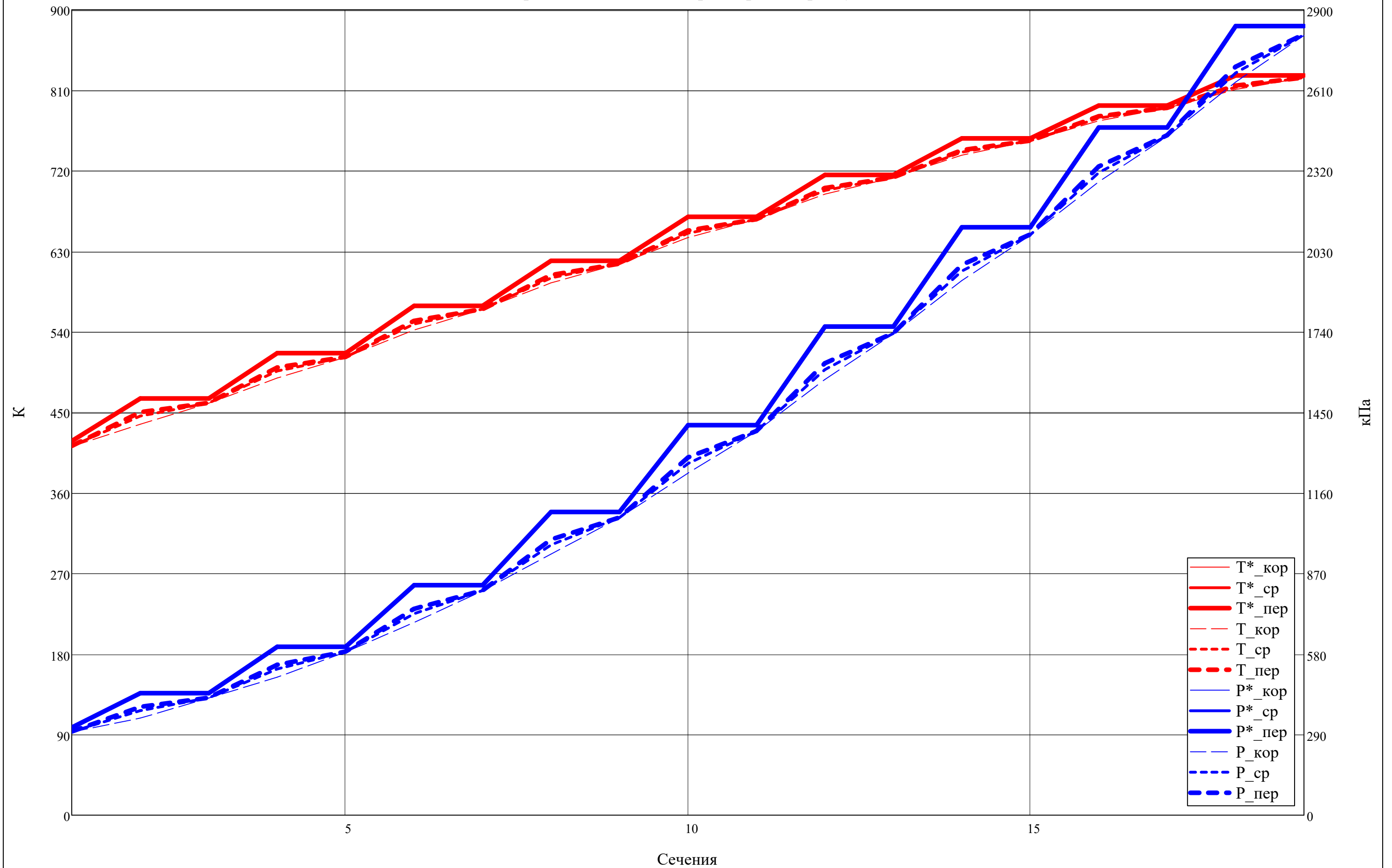
$$\mathbf{C_p}^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1016	1024	1024	1034	1034	1045	1045	1056	1056	1068	1068	1078	1078	1088	1088	1096	1096	1104	1104						
2	1016	1024	1024	1034	1034	1045	1045	1056	1056	1068	1068	1078	1078	1088	1088	1096	1096	1104	1104						
3	1016	1024	1024	1034	1034	1045	1045	1056	1056	1068	1068	1078	1078	1088	1088	1096	1096	1104	1104						

$$\mathbf{k}^{\text{T}} =$$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1.394	1.390	1.390	1.384	1.384	1.379	1.379	1.373	1.373	1.368	1.368	1.363	1.363	1.359	1.359	1.355	1.355	1.352	1.352						
2	1.394	1.390	1.390	1.384	1.384	1.379	1.379	1.373	1.373	1.368	1.368	1.363	1.363	1.359	1.359	1.355	1.355	1.352	1.352						
3	1.394	1.390	1.390	1.384	1.384	1.379	1.379	1.373	1.373	1.368	1.368	1.363	1.363	1.359	1.359	1.355	1.355	1.352	1.352						

Термодинамические параметры по тракту К



$a_c^{*T} =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	373.9	394.4	394.4	414.9	414.9	435.3	435.3	453.7	453.7	471.0	471.0	486.8	486.8	500.2	500.2	511.9	511.9	522.4	522.4						
	2	373.9	394.4	394.4	414.9	414.9	435.3	435.3	453.7	453.7	471.0	471.0	486.8	486.8	500.2	500.2	511.9	511.9	522.4	522.4						
	3	373.9	394.4	394.4	414.9	414.9	435.3	435.3	453.7	453.7	471.0	471.0	486.8	486.8	500.2	500.2	511.9	511.9	522.4	522.4						

$a_{3B}^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	406.0	417.5	428.6	440.7	451.1	463.3	473.1	484.3	493.0	503.5	511.4	521.1	528.1	536.4	542.2	549.5	554.5	561.0	565.5						
	2	406.3	421.8	428.8	444.2	451.2	466.1	473.2	486.6	493.0	505.4	511.4	522.7	528.2	537.6	542.2	550.5	554.5	561.9	565.6						
	3	406.4	423.9	428.8	446.0	451.2	467.7	473.2	487.9	493.0	506.6	511.4	523.7	528.2	538.4	542.3	551.2	554.6	562.5	565.6						

$c_c^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	112.6	243.0	104.2	239.8	96.3	237.2	89.4	228.0	83.0	222.3	78.3	215.2	77.9	201.9	77.5	192.3	76.9	185.9	75.3						
	2	108.2	201.0	100.9	203.3	94.2	206.0	87.7	200.8	81.6	198.0	77.0	193.5	75.9	182.8	75.0	175.0	74.0	169.9	72.7						
	3	105.6	177.6	99.2	182.2	93.0	186.3	86.6	182.8	80.7	181.2	76.1	178.0	74.5	168.9	73.3	162.2	71.9	157.9	70.8						

$w^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	255.8	131.6	266.6	120.6	281.9	119.6	282.5	121.1	284.3	121.0	283.3	122.9	274.4	131.4	267.9	137.3	263.2	141.7	264.7						
	2	336.1	210.4	339.9	202.8	342.8	191.6	335.8	186.0	331.6	180.1	326.0	177.4	314.4	182.2	306.1	185.4	300.2	187.1	298.7						
	3	403.3	286.5	400.6	274.2	394.7	255.0	381.8	243.1	373.0	232.3	363.8	225.5	350.1	227.0	340.2	227.9	333.3	227.2	329.4						

$u^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	278.4	286.2	293.4	299.3	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9	304.9						
	2	362.5	362.5	362.5	362.5	362.5	358.8	355.3	352.4	349.7	347.5	345.3	343.6	341.9	340.7	339.6	338.8	338.0	336.7	335.5						
	3	430.5	425.4	420.5	416.3	412.2	405.6	399.3	394.3	389.4	385.3	381.4	378.3	375.2	373.1	371.0	369.5	368.1	365.7	363.4						

$c_a^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	103.5	111.3	94.4	92.0	88.8	85.5	82.4	79.6	76.9	74.4	72.0	69.7	67.5	65.4	63.4	61.5	59.6	59.3	58.9						
	2	99.9	97.3	94.3	91.5	88.8	85.5	82.4	79.6	76.9	74.4	72.0	69.7	67.5	65.4	63.4	61.5	59.6	59.3	58.9						
	3	98.0	89.6	94.2	91.2	88.8	85.5	82.4	79.6	76.9	74.4	72.0	69.7	67.5	65.4	63.4	61.5	59.6	59.3	58.9						

$c_u^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	44.5	216.0	44.1	221.4	37.4	221.3	34.7	213.7	31.2	209.5	31.0	203.6	39.0	191.0	44.7	182.2	48.6	176.2	46.9						
	2	41.6	175.9	35.9	181.6	31.4	187.4	29.8	184.4	27.2	183.5	27.3	180.5	34.8	170.7	40.1	163.8	43.8	159.3	42.6						
	3	39.3	153.3	31.1	157.7	27.6	165.5	26.5	164.6	24.4	165.2	24.7	163.7	31.7	155.7	36.7	150.1	40.2	146.4	39.3						

$w_u^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	1	233.9	70.2	249.3	77.9	267.6	83.6	270.2	91.3	273.7	95.5	274.0	101.3	265.9	113.9	260.3	122.7	256.4	128.7	258.0					
	2	321.0	186.6	326.6	181.0	331.1	171.4	325.5	168.1	322.5	164.0	317.9	163.1	307.1	170.0	299.4	174.9	294.2	177.5	292.8					
	3	391.2	272.1	389.3	258.6	384.6	240.2	372.8	229.7	365.0	220.1	356.6	214.5	343.5	217.3	334.3	219.5	327.9	219.3	324.1					

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

$$\Delta c_a$$

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

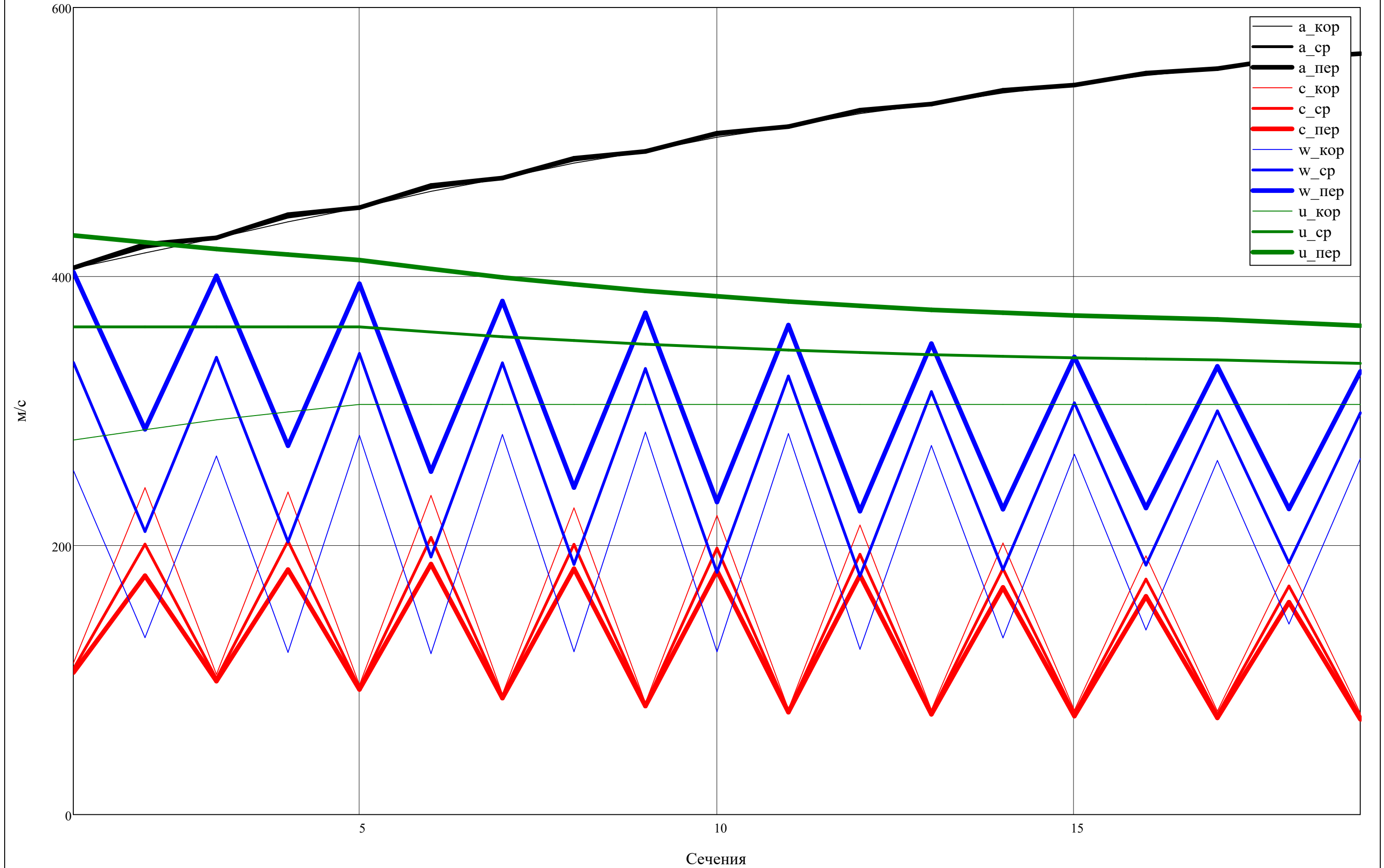
[16, c. 81]

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						

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

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

Скорости по тракту К



$\alpha^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	66.71	27.26	64.95	22.57	67.17	21.14	67.17	20.44	67.94	19.56	66.72	18.89	59.97	18.91	54.84	18.65	50.84	18.58	51.47						
2	67.39	28.94	69.13	26.74	70.50	24.54	70.13	23.36	70.54	22.08	69.20	21.11	62.72	20.97	57.68	20.58	53.70	20.41	54.10						
3	68.13	30.29	71.71	30.05	72.70	27.34	72.18	25.83	72.39	24.24	71.02	23.05	64.84	22.78	59.93	22.29	56.00	22.03	56.25						

 $\beta^T =$

$\beta^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	23.86	57.77	20.74	49.75	18.35	45.64	16.97	41.11	15.70	37.94	14.72	34.53	14.23	29.86	13.69	26.62	13.09	24.72	12.85		
2	17.29	27.53	16.10	26.82	15.01	26.52	14.21	25.36	13.41	24.41	12.75	23.14	12.39	21.04	11.95	19.37	11.46	18.46	11.37		
3	14.06	18.22	13.60	19.43	13.00	19.60	12.47	19.12	11.90	18.68	11.41	18.00	11.11	16.75	10.74	15.66	10.31	15.12	10.30		

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

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

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

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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	33.91	29.01	27.29	24.14	22.24	19.81	15.63	12.93	11.63						
2	10.25	10.72	11.51	11.14	10.99	10.38	8.66	7.42	7.01						
3	4.16	5.82	6.61	6.65	6.78	6.59	5.64	4.92	4.81						

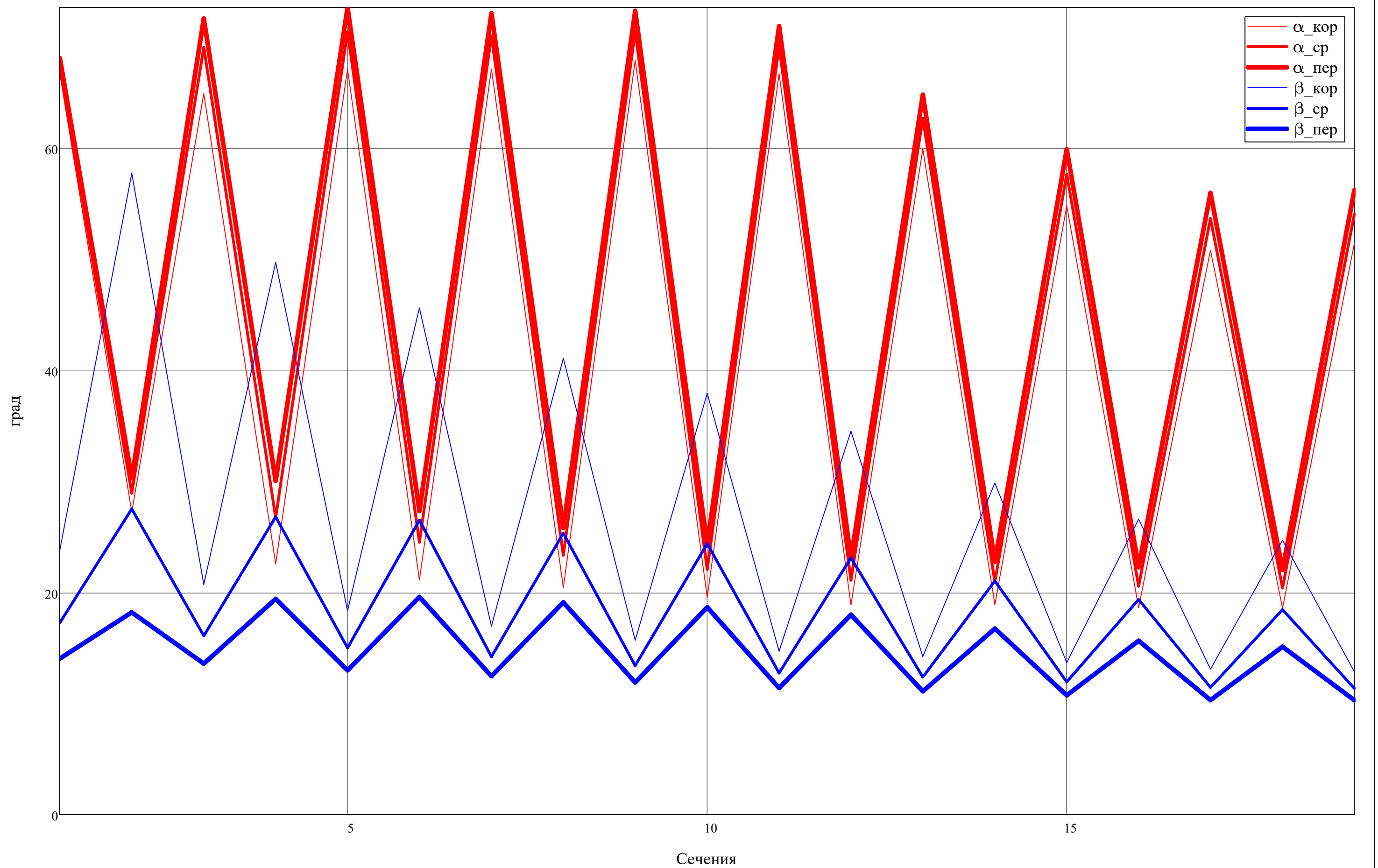
 $\epsilon_{\text{stator}}^T =$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	38.38	41.87	47.52	47.71	49.08	48.10	40.53	35.16	32.89						
2	37.26	41.21	46.92	47.37	48.87	48.14	41.09	36.00	33.70						
3	36.52	40.26	46.04	46.74	48.39	47.91	41.32	36.50	34.22						

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

Углы по тракту К





$\lambda_c^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.3012	0.6161	0.2642	0.5779	0.2321	0.5451	0.2055	0.5025	0.1829	0.4720	0.1663	0.4421	0.1600	0.4036	0.1550	0.3757	0.1502	0.3559	0.1441				
2	0.2893	0.5098	0.2559	0.4900	0.2269	0.4733	0.2014	0.4426	0.1798	0.4204	0.1634	0.3974	0.1559	0.3654	0.1500	0.3419	0.1446	0.3253	0.1391				
3	0.2823	0.4503	0.2516	0.4390	0.2240	0.4279	0.1989	0.4029	0.1779	0.3848	0.1616	0.3656	0.1531	0.3377	0.1465	0.3169	0.1405	0.3024	0.1355				

[16, c. 87]

$\lambda_c^T \leq 0.85 =$ 

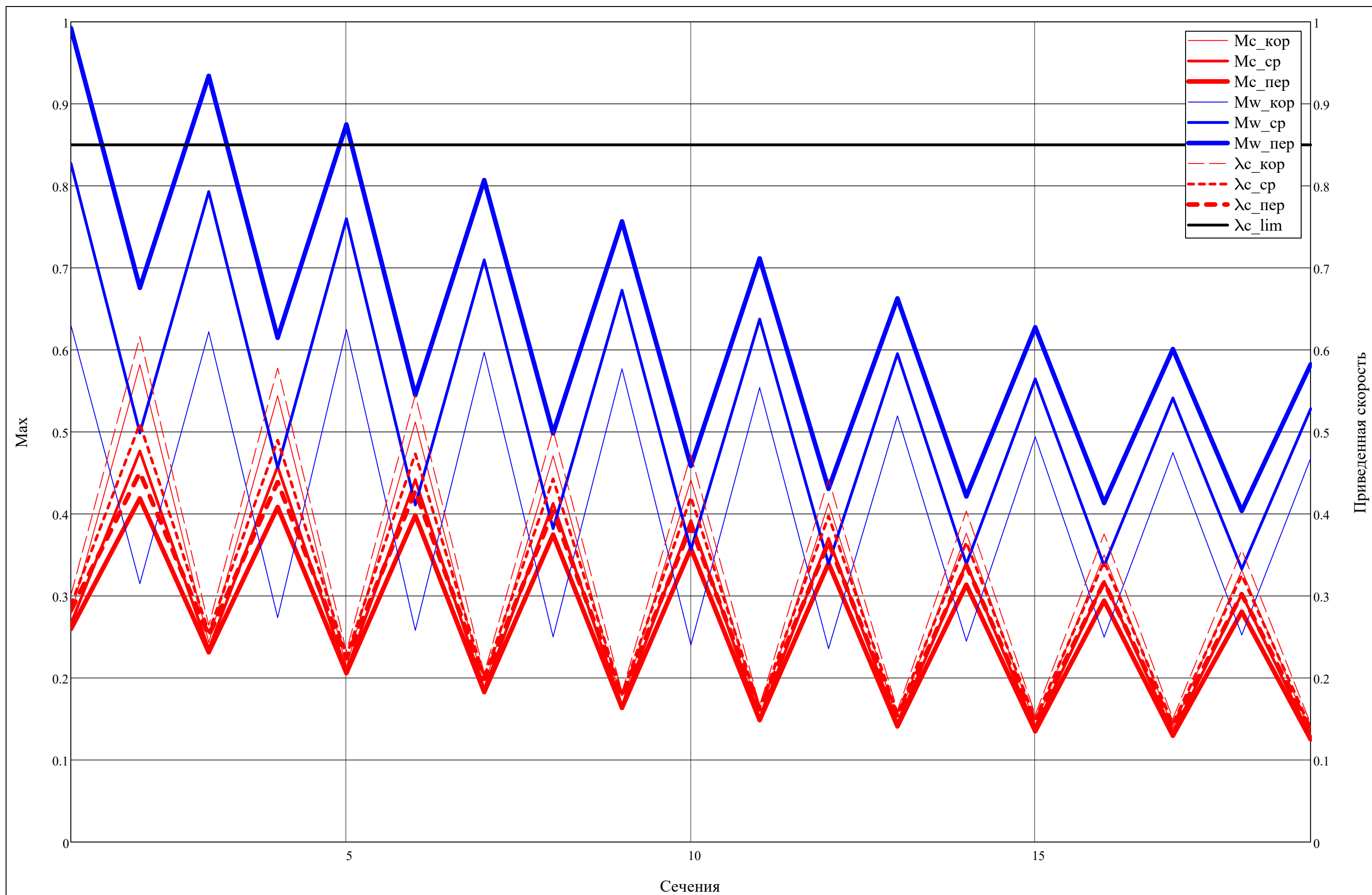
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

$M_c^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.2774	0.5820	0.2431	0.5441	0.2135	0.5120	0.1891	0.4708	0.1684	0.4415	0.1532	0.4130	0.1475	0.3763	0.1430	0.3500	0.1387	0.3314	0.1331				
2	0.2663	0.4766	0.2353	0.4577	0.2087	0.4419	0.1853	0.4128	0.1655	0.3918	0.1505	0.3701	0.1437	0.3400	0.1383	0.3179	0.1334	0.3024	0.1285				
3	0.2597	0.4189	0.2314	0.4084	0.2060	0.3982	0.1830	0.3747	0.1637	0.3578	0.1488	0.3398	0.1411	0.3137	0.1351	0.2942	0.1297	0.2808	0.1252				

$M_w^T =$ 

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.6299	0.3151	0.6220	0.2736	0.6249	0.2582	0.5972	0.2501	0.5768	0.2404	0.5539	0.2359	0.5195	0.2449	0.4941	0.2498	0.4747	0.2525	0.4680				
2	0.8274	0.4989	0.7928	0.4565	0.7598	0.4110	0.7096	0.3822	0.6726	0.3563	0.6374	0.3393	0.5953	0.3388	0.5645	0.3369	0.5413	0.3329	0.5281				
3	0.9923	0.6758	0.9341	0.6149	0.8747	0.5451	0.8069	0.4983	0.7565	0.4586	0.7114	0.4307	0.6628	0.4215	0.6274	0.4135	0.6009	0.4039	0.5824				



$$T^*_{1CA} = \begin{pmatrix} 826.7 \\ 826.7 \\ 826.7 \end{pmatrix}$$

$$P^*_{1CA} = \begin{pmatrix} 2841.7 \\ 2841.7 \\ 2841.7 \end{pmatrix} \cdot 10^3$$

$$\rho^*_{1CA} = \begin{pmatrix} 11.972 \\ 11.972 \\ 11.972 \end{pmatrix}$$

$$Cp_{1CA} = \begin{pmatrix} 1103.8 \\ 1103.8 \\ 1103.8 \end{pmatrix}$$

$$k_{1CA} = \begin{pmatrix} 1.352 \\ 1.352 \\ 1.352 \end{pmatrix}$$

$$T^*_{3CA} = \begin{pmatrix} 826.7 \\ 826.7 \\ 826.7 \end{pmatrix}$$

$$P^*_{3CA} = \begin{pmatrix} 2836.3 \\ 2836.3 \\ 2836.3 \end{pmatrix} \cdot 10^3$$

$$\rho^*_{3CA} = \begin{pmatrix} 11.949 \\ 11.949 \\ 11.949 \end{pmatrix}$$

$$Cp_{3CA} = \begin{pmatrix} 1103.8 \\ 1103.8 \\ 1103.8 \end{pmatrix}$$

$$k_{3CA} = \begin{pmatrix} 1.352 \\ 1.352 \\ 1.352 \end{pmatrix}$$

$$a^*_{c1CA} = \begin{pmatrix} 522.4 \\ 522.4 \\ 522.4 \end{pmatrix}$$

$$c_{1CA} = \begin{pmatrix} 75.3 \\ 72.7 \\ 70.8 \end{pmatrix}$$

$$c_{u1CA} = \begin{pmatrix} 46.9 \\ 42.6 \\ 39.3 \end{pmatrix}$$

$$c_{a1CA} = \begin{pmatrix} 58.9 \\ 58.9 \\ 58.9 \end{pmatrix}$$

$$a^*_{c3CA} = \begin{pmatrix} 522.4 \\ 522.4 \\ 522.4 \end{pmatrix}$$

$$c_{3CA} = \begin{pmatrix} 48.9 \\ 48.9 \\ 48.9 \end{pmatrix}$$

$$c_{u3CA} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix}$$

$$c_{a3CA} = \begin{pmatrix} 48.9 \\ 48.9 \\ 48.9 \end{pmatrix}$$

$$\alpha_{1CA} = \begin{pmatrix} 51.47 \\ 54.10 \\ 56.25 \end{pmatrix} \cdot ^\circ$$

$$\alpha_{3CA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ^\circ$$

$$\varepsilon_{CA} = \begin{pmatrix} 38.53 \\ 35.90 \\ 33.75 \end{pmatrix} \cdot ^\circ$$

$$\lambda_{c1CA} = \begin{pmatrix} 0.144 \\ 0.139 \\ 0.136 \end{pmatrix}$$

$$\lambda_{c3CA} = \begin{pmatrix} 0.094 \\ 0.094 \\ 0.094 \end{pmatrix}$$



Рассматриваемая ступень:

j =

j = 1

j =

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

j otherwise

= 1

Построение треугольников скоростей в 3х сечениях

Δ<sub>c</sub>(v,i,j,r) =

tan(α<sub>st(i,j),r</sub>)·v if (tan(α<sub>st(i,j),r</sub>) ≥ 0 ∧ −|c<sub>st(i,j),r</sub>·cos(α<sub>st(i,j),r</sub>)| ≤ v ≤ 0)

tan(α<sub>st(i,j),r</sub>)·v if (tan(α<sub>st(i,j),r</sub>) < 0 ∧ 0 ≤ v ≤ |c<sub>st(i,j),r</sub>·cos(α<sub>st(i,j),r</sub>)|)

Δ<sub>w</sub>(v,i,j,r) =

−tan(β<sub>st(i,j),r</sub>)·v if (−tan(β<sub>st(i,j),r</sub>) ≥ 0) ∧ (−|w<sub>st(i,j),r</sub>·cos(β<sub>st(i,j),r</sub>)| ≤ v ≤ 0) ∧ (j ≠ 3)

−tan(β<sub>st(i,j),r</sub>)·v if (−tan(β<sub>st(i,j),r</sub>) < 0) ∧ (0 ≤ v ≤ |w<sub>st(i,j),r</sub>·cos(β<sub>st(i,j),r</sub>)|) ∧ (j ≠ 3)

Δ<sub>u</sub>(v,i,j,r) =

−c<sub>a<sub>st(i,j),r</sub></sub> if (−c<sub>st(i,j),r</sub>·cos(α<sub>st(i,j),r</sub>) ≤ v ≤ w<sub>st(i,j),r</sub>·cos(β<sub>st(i,j),r</sub>)) ∧ (j ≠ 3)

NaN otherwise

v<sub>lim</sub> =

ceil

(

max(c,w,u)

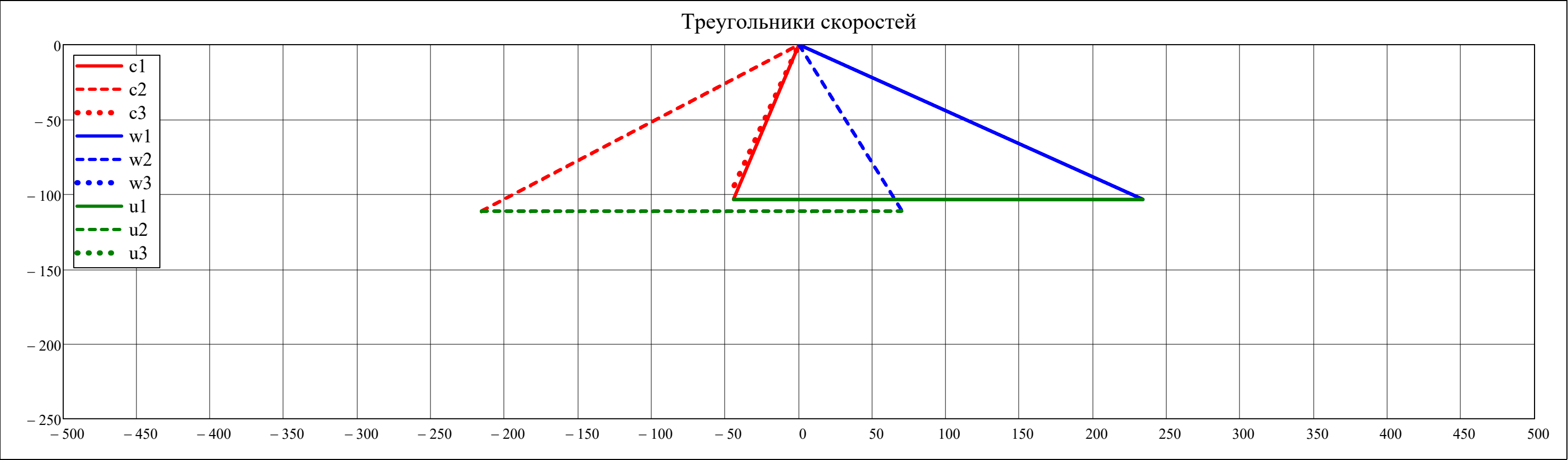
)

·10<sup>2</sup> = 500

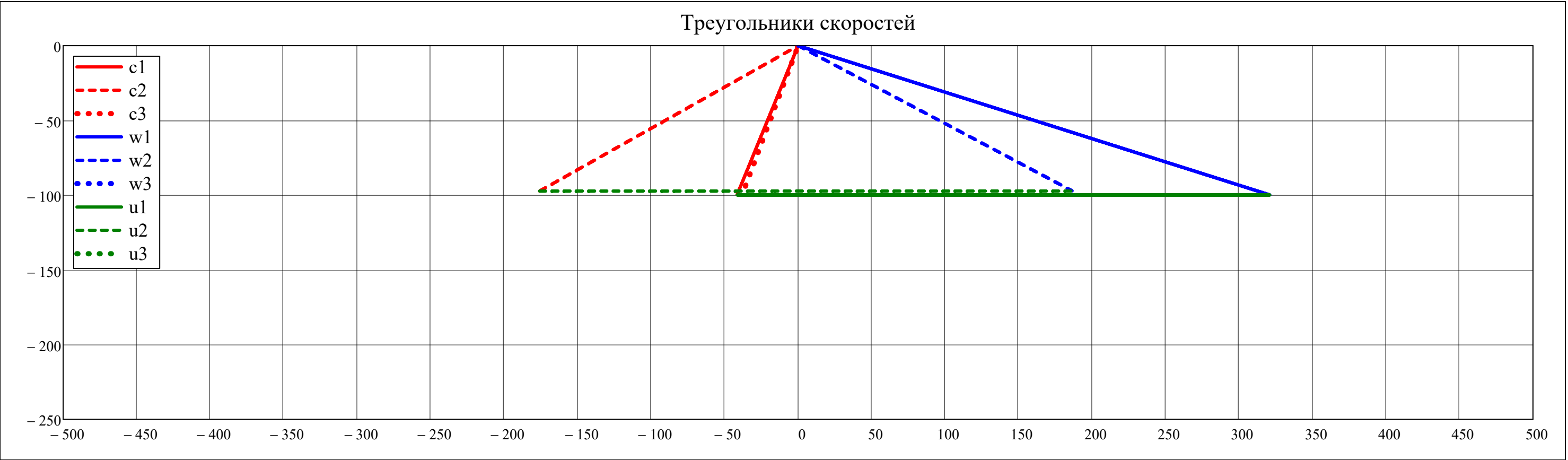
Дискретизация скорости:

v = −v<sub>lim</sub>, −v<sub>lim</sub> +  $\frac{v_{lim}}{3000}$  .. v<sub>lim</sub>

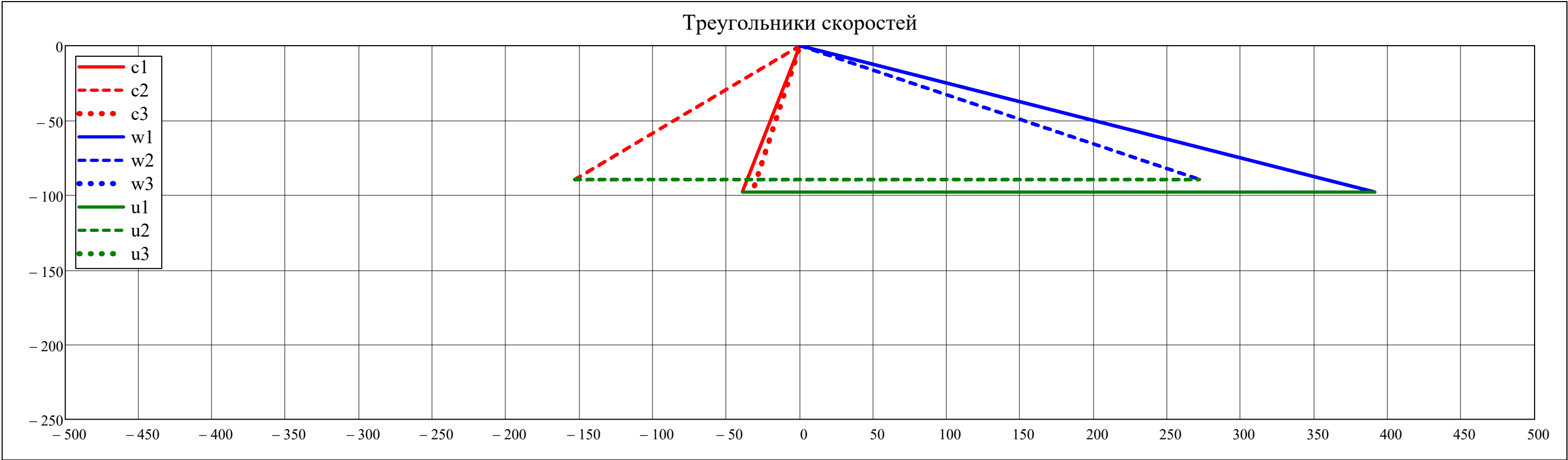
r = 1



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



$r_w = N_r$



Построение треугольников скоростей в 3х сечениях



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

Кольцевые площади (м<sup>2</sup>):

$\text{stack}\left(\mathbf{F}_I^T, \mathbf{F}_{II}^T, \mathbf{F}^T\right) =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	1	0.0196	0.0180	0.0165	0.0152	0.0140	0.0130	0.0121	0.0114	0.0107	0.0101	0.0095	0.0091	0.0087	0.0084	0.0081	0.0079	0.0077	0.0074	0.0071
	2	0.1177	0.1082	0.0990	0.0914	0.0840	0.0781	0.0726	0.0682	0.0640	0.0606	0.0573	0.0547	0.0522	0.0504	0.0487	0.0476	0.0464	0.0445	0.0427
	3	0.1373	0.1218	0.1155	0.1031	0.0980	0.0884	0.0846	0.0775	0.0747	0.0690	0.0668	0.0624	0.0608	0.0578	0.0568	0.0547	0.0541	0.0514	0.0498

Радиус и диаметр двухконтурности (м):

$\text{stack}(\mathbf{R2}^T, \mathbf{D2}^T) =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	$\cdot 10^{-3}$
	1	194.1	197.3	200.4	202.9	205.3	204.5	203.8	203.2	202.7	202.2	201.8	201.5	201.1	200.9	200.7	200.5	200.4	200.1	199.9	
	2	388.1	394.6	400.7	405.7	410.5	409.0	407.6	406.4	405.3	404.5	403.6	402.9	402.2	401.8	401.3	401.0	400.7	400.2	399.7	

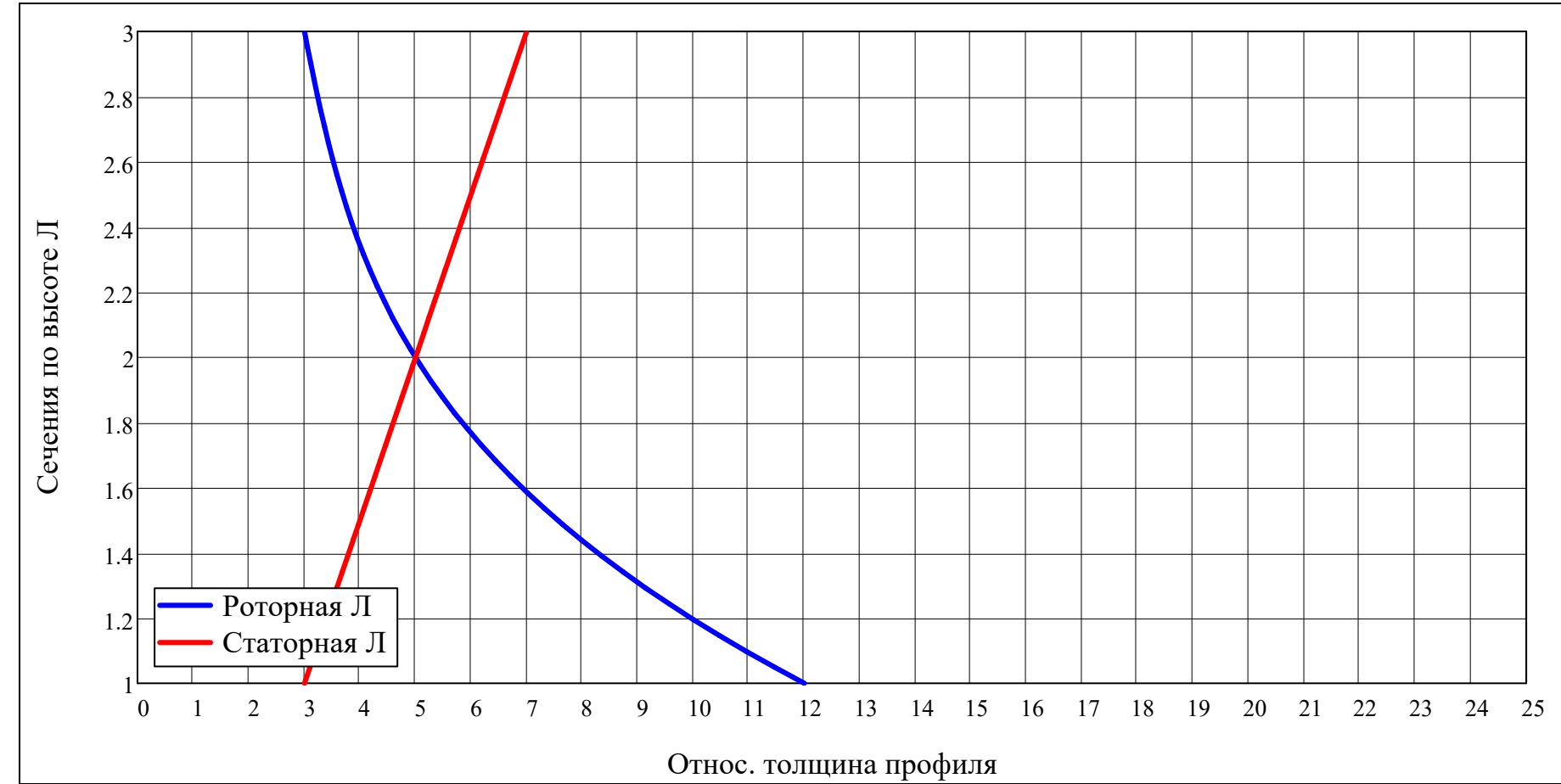


Относ. толщины ЛРК и СА:

$$\overline{c}_{\text{rotor.}}(r) = \text{interp} \left[ \text{cspline} \left[ \begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 13 + \begin{cases} 3 & \text{if compressor} = \text{"Вл"} \\ -3 & \text{if compressor} = \text{"КНД"} \\ -1 & \text{otherwise} \end{cases} \\ 5 + \begin{cases} 1 & \text{if compressor} = \text{"Вл"} \\ -1 & \text{if compressor} = \text{"КНД"} \\ 0 & \text{otherwise} \end{cases} \\ 3 \end{pmatrix} \% , \begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 13 + \begin{cases} 3 & \text{if compressor} = \text{"Вл"} \\ -3 & \text{if compressor} = \text{"КНД"} \\ -1 & \text{otherwise} \end{cases} \\ 5 + \begin{cases} 1 & \text{if compressor} = \text{"Вл"} \\ -1 & \text{if compressor} = \text{"КНД"} \\ 0 & \text{otherwise} \end{cases} \\ 3 \end{pmatrix} \% , r \right]$$

$$\overline{c}_{\text{stator.}}(r) = \text{interp} \left[ \text{cspline} \left[ \begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 3 \\ 5 \\ 7 \end{pmatrix} \% , \begin{pmatrix} 1 \\ \text{av}(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} 3 \\ 5 \\ 7 \end{pmatrix} \% , r \right]$$

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



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

$$\overline{c}_{\text{BHA}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.00 \\ \hline 2 & 5.00 \\ \hline 3 & 7.00 \\ \hline \end{array} \cdot\%$$

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

$$\overline{c}_{\text{stator}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 \\ \hline 2 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 \\ \hline 3 & 7.00 & 7.00 & 7.00 & 7.00 & 7.00 & 7.00 & 7.00 & 7.00 & 7.00 \\ \hline \end{array} \cdot\%$$

$$\overline{c}_{\text{rotor}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 12.00 & 12.00 & 12.00 & 12.00 & 12.00 & 12.00 & 12.00 & 12.00 & 12.00 \\ \hline 2 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 & 5.00 \\ \hline 3 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 & 3.00 \\ \hline \end{array} \cdot\%$$

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

$$\overline{c}_{\text{CA}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.00 \\ \hline 2 & 5.00 \\ \hline 3 & 7.00 \\ \hline \end{array} \cdot\%$$

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

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

	1
1	0.600
2	1.000
3	1.400

$\cdot\%$

	1	2	3	4	5	6	7	8	9
1	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3	1.400	1.400	1.400	1.400	1.400	1.400	1.400	1.400	1.400

$\cdot\%$

	1	2	3	4	5	6	7	8	9
1	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
2	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
3	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700

$\cdot\%$

	1
1	0.300
2	0.500
3	0.700

$\cdot\%$

$$\begin{pmatrix} \overline{r}_{inlet_{rotor}} & \overline{r}_{inlet_{stator}} \\ \overline{r}_{outlet_{rotor}} & \overline{r}_{outlet_{stator}} \end{pmatrix} = \begin{cases} \text{for } i \in 1..Z \\ \text{for } r \in 1..N_r \\ \begin{pmatrix} \overline{r}_{inlet_{stator_{i,r}}} \\ \overline{r}_{outlet_{stator_{i,r}}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{stator.(r)} \\ \begin{pmatrix} \overline{r}_{inlet_{rotor_{i,r}}} \\ \overline{r}_{outlet_{rotor_{i,r}}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{rotor.(r)} \\ \begin{pmatrix} \overline{r}_{inlet_{rotor}} & \overline{r}_{inlet_{stator}} \\ \overline{r}_{outlet_{rotor}} & \overline{r}_{outlet_{stator}} \end{pmatrix} \end{cases}$$

	1
1	0.600
2	1.000
3	1.400

$\cdot\%$

	1	2	3	4	5	6	7	8	9
1	2.400	2.400	2.400	2.400	2.400	2.400	2.400	2.400	2.400
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600

$\cdot\%$

	1	2	3	4	5	6	7	8	9
1	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
2	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
3	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300

$\cdot\%$

	1
1	0.300
2	0.500
3	0.700

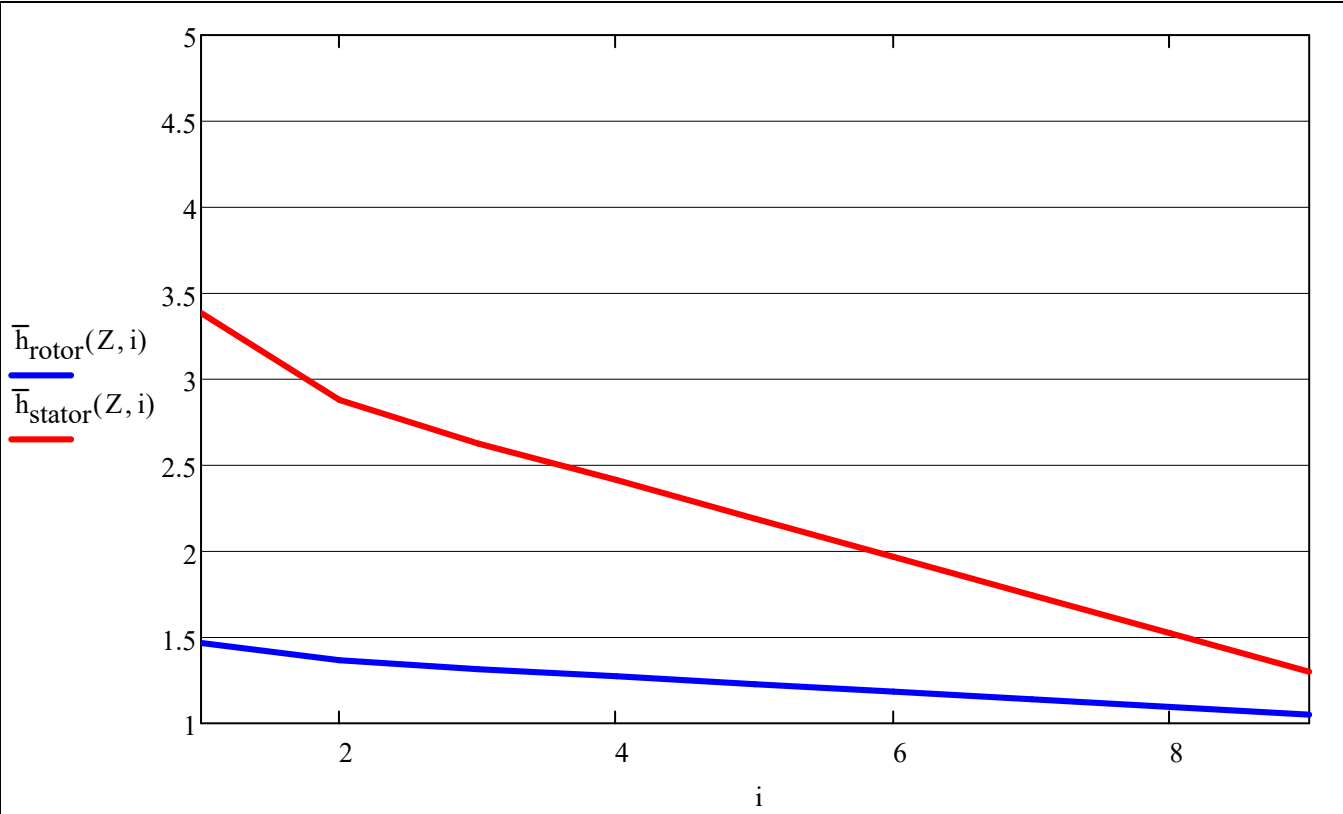
$\cdot\%$

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

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

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

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



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

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

Для компрессора газогенератора

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

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

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

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

[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

```
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
```

$\left( \text{chord}_{\text{rotor}} \quad \text{chord}_{\text{stator}} \right) =$	<div>for <math>i \in 1 \dots Z</math></div> <div style="border-left: 1px solid black; padding-left: 10px; margin-left: 10px;"> <math display="block">\left( \begin{array}{c} \text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \\ \text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \end{array} \right) = \left( \begin{array}{c} \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{array} \right)</math> <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>for <math>r \in 1 \dots N_r</math></div> <div style="border-left: 1px solid black; padding-left: 10px; margin-left: 10px;"> <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> <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> <math display="block">\left( \begin{array}{c} b_{\text{PKпер}} \\ b_{\text{HAпер}} \end{array} \right) = \left( \begin{array}{c} b_{\text{PKkop}} \cdot \text{sail}_{\text{rotor}} \\ b_{\text{HAKop}} \cdot \text{sail}_{\text{stator}} \end{array} \right)</math> <math display="block">\text{chord}_{\text{rotor.}}(z) = \text{interp} \left[ \text{cspline} \left[ \left( \begin{array}{c} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{array} \right), \left( \begin{array}{c} b_{\text{PKkop}} \\ \text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \\ b_{\text{PKпер}} \end{array} \right) \right], \left( \begin{array}{c} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{array} \right), \left( \begin{array}{c} b_{\text{PKkop}} \\ \text{chord}_{\text{rotor}_{i, \text{av}}(N_r)} \\ b_{\text{PKпер}} \end{array} \right), z \right]</math> <math display="block">\text{chord}_{\text{stator.}}(z) = \text{interp} \left[ \text{cspline} \left[ \left( \begin{array}{c} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{array} \right), \left( \begin{array}{c} b_{\text{HAKop}} \\ \text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \\ b_{\text{HAпер}} \end{array} \right) \right], \left( \begin{array}{c} R_{\text{st}(i, 2), 1} \\ R_{\text{st}(i, 2), \text{av}}(N_r) \\ R_{\text{st}(i, 2), N_r} \end{array} \right), \left( \begin{array}{c} b_{\text{HAKop}} \\ \text{chord}_{\text{stator}_{i, \text{av}}(N_r)} \\ b_{\text{HAпер}} \end{array} \right), z \right]</math> <math display="block">\text{chord}_{\text{rotor}_{i, r}} = \text{chord}_{\text{rotor.}}(R_{\text{st}(i, 2), r})</math> <math display="block">\text{chord}_{\text{stator}_{i, r}} = \text{chord}_{\text{stator.}}(R_{\text{st}(i, 2), r})</math> </div> </div> <div><math>\left( \text{chord}_{\text{rotor}} \quad \text{chord}_{\text{stator}} \right)</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

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

= if BHA = 1

for  $r \in av(N_r)$

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

for  $r \in 1..N_r$

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

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

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

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

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

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

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

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

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

$\epsilon_{\text{PK}(b/t)=1}$	$\epsilon_{\text{HA}(b/t)=1}$	=	for $i \in 1..Z$	for $r \in \text{av}(N_r)$	$\begin{pmatrix} \epsilon_{\text{PK}(b/t)=1_{i,r}} \\ \epsilon_{\text{HA}(b/t)=1_{i,r}} \end{pmatrix} = \begin{pmatrix} \epsilon_{(b/t)=1}(\beta_{\text{st}(i,2)}, r) \\ \epsilon_{(b/t)=1}(\alpha_{\text{st}(i,3)}, r) \end{pmatrix}$ $\begin{pmatrix} b/t_{\text{PK}_{i,r}} \\ b/t_{\text{HA}_{i,r}} \end{pmatrix} = \begin{pmatrix} b/t=1 \left( \frac{\epsilon_{\text{rotor}_{i,r}}}{\epsilon_{\text{PK}(b/t)=1_{i,r}}} \right) \\ b/t=1 \left( \frac{\epsilon_{\text{stator}_{i,r}}}{\epsilon_{\text{HA}(b/t)=1_{i,r}}} \right) \end{pmatrix}$ $\begin{pmatrix} t_{\text{rotor}_{i,r}} \\ t_{\text{stator}_{i,r}} \end{pmatrix} = \begin{pmatrix} \frac{\text{chord}_{\text{rotor}_{i,r}}}{b/t_{\text{PK}_{i,r}}} \\ \frac{\text{chord}_{\text{stator}_{i,r}}}{b/t_{\text{HA}_{i,r}}} \end{pmatrix}$ $\begin{pmatrix} t_{\text{rotor}_{i,r}} \\ t_{\text{stator}_{i,r}} \end{pmatrix} = \frac{2}{3} \begin{pmatrix} \text{chord}_{\text{rotor}_{i,r}} \cdot \cos(\beta_{\text{st}(i,1)}, r) \\ \text{chord}_{\text{stator}_{i,r}} \cdot \cos(\alpha_{\text{st}(i,2)}, r) \end{pmatrix}$ $Z_{\text{stator}_i} = \begin{cases} \text{round}\left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,2)}, r, D_{\text{st}(i,3)}, r)}{t_{\text{stator}_{i,r}}}\right) & \text{if } \text{mod}\left(\text{round}\left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,2)}, r, D_{\text{st}(i,3)}, r)}{t_{\text{stator}_{i,r}}}\right), 2\right) = 0 \\ \text{round}\left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,2)}, r, D_{\text{st}(i,3)}, r)}{t_{\text{stator}_{i,r}}}\right) + 1 & \text{otherwise} \end{cases}$ $Z_{\text{rotor}_i} = \begin{cases} Z_{\text{rotor}_i} = \text{round}\left(\frac{\pi \cdot \text{mean}(D_{\text{st}(i,1)}, r, D_{\text{st}(i,2)}, r)}{t_{\text{rotor}_{i,r}}}\right) \end{cases}$
$Z_{\text{rotor}}$	$Z_{\text{stator}}$				
$r_{\text{inlet}_{\text{rotor}}}$	$r_{\text{inlet}_{\text{stator}}}$				
$r_{\text{outlet}_{\text{rotor}}}$	$r_{\text{outlet}_{\text{stator}}}$				
$t_{\text{rotor}}$	$t_{\text{stator}}$				
$i_{\text{rotor}}$	$i_{\text{stator}}$				
$m_{\text{rotor}}$	$m_{\text{stator}}$				
$\theta_{\text{rotor}}$	$\theta_{\text{stator}}$				
$\delta_{\text{rotor}}$	$\delta_{\text{stator}}$				
$\chi_{\text{rotor}}$	$\chi_{\text{stator}}$				
$v_{\text{rotor}}$	$v_{\text{stator}}$				
$R_{\text{CJL.rotor}}$	$R_{\text{CJL.stator}}$				
$K_{\text{rotor}}$	$K_{\text{stator}}$				
$D_{\text{rotor}}$	$D_{\text{stator}}$				
$\zeta_{\text{rotor}}$	$\zeta_{\text{stator}}$				
$\text{quality}_{\text{rotor}}$	$\text{quality}_{\text{stator}}$				
$\eta_{\text{stage}}$	$\eta_{\text{stage}}$				

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

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

for  $r \in 1 \dots N_r$

$$\begin{pmatrix} r_{\text{inlet}_{\text{stator}_i, r}} & r_{\text{outlet}_{\text{stator}_i, r}} \\ r_{\text{inlet}_{\text{rotor}_i, r}} & r_{\text{outlet}_{\text{rotor}_i, r}} \end{pmatrix} = \begin{pmatrix} \bar{r}_{\text{inlet}_{\text{stator}_i, r}} \cdot \text{chord}_{\text{stator}_i, r} & \bar{r}_{\text{outlet}_{\text{stator}_i, r}} \cdot \text{chord}_{\text{stator}_i, r} \\ \bar{r}_{\text{inlet}_{\text{rotor}_i, r}} \cdot \text{chord}_{\text{rotor}_i, r} & \bar{r}_{\text{outlet}_{\text{rotor}_i, r}} \cdot \text{chord}_{\text{rotor}_i, r} \end{pmatrix}$$

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

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

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

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

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

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

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

$$\begin{aligned}
\begin{pmatrix} v_{\text{stator}_{i,r}}^{1,r} \end{pmatrix} &= \begin{pmatrix} x_{\text{stator}_{i,r}}^{1,r} + \alpha_{\text{st}(i,2),r} + i_{\text{stator}_{i,r}}^{1,r} \end{pmatrix} \\
\begin{pmatrix} R_{\text{CЛ.rotor}_{i,r}} \\ R_{\text{CЛ.stator}_{i,r}} \end{pmatrix} &= \frac{1}{2} \cdot \begin{pmatrix} \frac{\text{chord}_{\text{rotor}_{i,r}}}{\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{cn}})} \right)^2 - \frac{1}{\tan(\alpha_{\text{cn}})} \end{bmatrix}
\end{aligned}$$

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

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

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

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



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

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

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

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

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

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

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

chord<sub>BHA</sub> =

	1
1	26.42
2	29.35
3	31.71

·10<sup>-3</sup>

chord<sub>rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	54.30	48.94	43.38	39.63	36.89	34.80	33.42	32.84	32.50						
2	63.23	56.88	50.34	45.95	42.75	40.30	38.68	38.00	37.59						
3	70.59	63.63	56.39	51.52	47.96	45.24	43.45	42.69	42.25						

·10<sup>-3</sup>

Длина хорды Л (м):

chord<sub>stator</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	22.57	22.38	21.37	20.71	20.64	21.02	22.16	24.19	26.45						
2	25.05	24.80	23.66	22.92	22.82	23.24	24.49	26.72	29.22						
3	27.09	26.86	25.64	24.86	24.77	25.23	26.59	29.02	31.75						

·10<sup>-3</sup>

chord<sub>CA</sub> =

	1
1	25.80
2	28.65
3	30.96

·10<sup>-3</sup>

r\_inlet<sub>BHA</sub> =

	1
1	0.16
2	0.29
3	0.44

·10<sup>-3</sup>

r\_outlet<sub>BHA</sub> =

	1
1	0.08
2	0.15
3	0.22

·10<sup>-3</sup>

Радисы входных и выходных кромок профилей Л (мм):

r\_inlet<sub>rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	1.30	1.17	1.04	0.95	0.89	0.84	0.80	0.79	0.78
2	0.63	0.57	0.50	0.46	0.43	0.40	0.39	0.38	0.38
3	0.42	0.38	0.34	0.31	0.29	0.27	0.26	0.26	0.25

·10<sup>-3</sup>

r\_outlet<sub>rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	0.65	0.59	0.52	0.48	0.44	0.42	0.40	0.39	0.39
2	0.32	0.28	0.25	0.23	0.21	0.20	0.19	0.19	0.19
3	0.21	0.19	0.17	0.15	0.14	0.14	0.13	0.13	0.13

·10<sup>-3</sup>

r\_inlet<sub>stator</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	0.14	0.13	0.13	0.12	0.12	0.13	0.13	0.15	0.16
2	0.25	0.25	0.24	0.23	0.23	0.23	0.24	0.27	0.29
3	0.38	0.38	0.36	0.35	0.35	0.35	0.37	0.41	0.44

·10<sup>-3</sup>

r\_outlet<sub>stator</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.08
2	0.13	0.12	0.12	0.11	0.11	0.12	0.12	0.13	0.15
3	0.19	0.19	0.18	0.17	0.17	0.18	0.19	0.20	0.22

·10<sup>-3</sup>

r\_inlet<sub>CA</sub> =

	1
1	0.15
2	0.29
3	0.43

·10<sup>-3</sup>

r\_outlet<sub>CA</sub> =

	1
1	0.08
2	0.14
3	0.22

·10<sup>-3</sup>

$\epsilon_{\text{BHA}(\text{b/t})=1_{\text{av}}(\text{N}_\text{r})} = 23.47^\circ$

Угол поворота потока:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	7.41	7.26	7.19	6.95	6.76	6.52	6.16	5.91	5.78						

 .°

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	24.31	24.97	24.80	24.99	24.35	21.16	18.75	16.73	16.93						

 .°

$\epsilon_{\text{CA}(\text{b/t})=1_{\text{av}}(\text{N}_\text{r})} = 33.67^\circ$

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

	1
1	3.429
2	2.924
3	2.661

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	1.779	1.693	1.672	1.592	1.543	1.512	1.617	1.481	1.465						
2	1.613	1.608	1.640	1.591	1.564	1.550	1.672	1.541	1.532						
3	1.526	1.559	1.620	1.591	1.579	1.578	1.713	1.585	1.583						

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

	1	2	3	4	5	6	7	8	9
1	1.947	1.815	1.752	1.698	1.658	1.655	1.635	1.626	1.605
2	1.727	1.676	1.656	1.632	1.614	1.628	1.620	1.619	1.608
3	1.601	1.588	1.593	1.586	1.583	1.607	1.608	1.613	1.611

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

	1
1	3.455
2	3.488
3	3.479

$Z_{\text{BHA}} = 46$

Количество Л:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	37	41	47	49	51	53	59	55	55						

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	100	98	100	100	98	96	90	82	74						

$Z_{\text{CA}} = 52$

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

	1
1	7.71
2	10.04
3	11.92

$\cdot 10^{-3}$

$t_{\text{BHA}} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	30.52	28.91	25.95	24.89	23.92	23.01	20.67	22.18	22.18						
2	39.19	35.37	30.70	28.89	27.34	25.99	23.14	24.67	24.53						
3	46.27	40.82	34.80	32.39	30.38	28.67	25.36	26.93	26.69						

$\cdot 10^{-3}$

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

Шаг решетки (м):

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	11.59	12.33	12.20	12.20	12.45	12.71	13.55	14.87	16.48						
2	14.50	14.80	14.28	14.04	14.14	14.28	15.12	16.51	18.17						
3	16.92	16.91	16.10	15.67	15.65	15.70	16.53	17.99	19.71						

$\cdot 10^{-3}$

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

	1
1	7.47
2	8.21
3	8.90

$\cdot 10^{-3}$

$t_{\text{CA}} =$

	1
1	3.572
2	2.311
3	1.652

$\cdot ^{\circ}$

$i_{\text{BHA}} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.948	1.732	1.679	1.480	1.357	1.280	1.542	1.202	1.164						
2	1.533	1.520	1.600	1.477	1.409	1.376	1.680	1.351	1.331						
3	1.314	1.397	1.551	1.476	1.447	1.445	1.782	1.464	1.458						

$\cdot ^{\circ}$

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

Угол атаки:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-0.132	-0.463	-0.620	-0.754	-0.854	-0.863	-0.912	-0.935	-0.987						
2	-0.682	-0.810	-0.859	-0.920	-0.964	-0.931	-0.950	-0.953	-0.979						
3	-0.997	-1.029	-1.018	-1.035	-1.043	-0.982	-0.979	-0.967	-0.973						

$\cdot ^{\circ}$

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

	1
1	3.639
2	3.721
3	3.698

$\cdot ^{\circ}$

$i_{\text{CA}} =$

m<sub>BHA</sub> =

	1
1	0.2766
2	0.2752
3	0.2737

m<sub>rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.2945	0.3105	0.3187	0.3278	0.3341	0.3409	0.3503	0.3568	0.3606						
2	0.3549	0.3564	0.3570	0.3593	0.3612	0.3637	0.3679	0.3713	0.3731						
3	0.3736	0.3711	0.3708	0.3718	0.3726	0.3740	0.3765	0.3787	0.3798						

Коэф. формы ср. линии профиля по Ховеллу:

m<sub>stator</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.2801	0.2757	0.2757	0.2741	0.2766	0.2901	0.3003	0.3083	0.3071						
2	0.2717	0.2690	0.2697	0.2689	0.2716	0.2846	0.2946	0.3026	0.3018						
3	0.2666	0.2646	0.2656	0.2652	0.2680	0.2803	0.2901	0.2980	0.2975						

m<sub>CA</sub> =

	1
1	0.2300
2	0.2300
3	0.2300

θ<sub>BHA</sub> =

	1
1	23.18
2	24.19
3	24.29

.°

θ<sub>rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	41.01	35.83	33.99	30.62	28.57	25.64	19.44	16.60	14.90						
2	12.09	12.79	13.74	13.52	13.48	12.73	9.75	8.65	8.12						
3	4.08	6.30	7.13	7.34	7.58	7.33	5.42	4.94	4.80						

.°

Угол изгиба ср. линии профиля:

θ<sub>stator</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	48.19	53.22	60.80	61.37	63.59	63.22	54.16	47.61	44.71						
2	47.83	53.04	60.44	61.16	63.38	63.16	54.71	48.49	45.50						
3	47.53	52.26	59.60	60.52	62.81	62.77	54.85	48.95	45.97						

.°

θ<sub>CA</sub> =

	1
1	39.82
2	36.69
3	34.27

.°

1

1

3.462

2

3.893

3

4.076

$\delta_{\text{BHA}}$

=

.

°

1

2

3

4

5

6

7

8

9

1

9.054

8.552

8.379

7.953

7.687

7.109

5.356

4.865

4.438

2

3.380

3.595

3.831

3.850

3.892

3.717

2.774

2.589

2.448

3

1.234

1.872

2.078

2.164

2.248

2.181

1.558

1.485

1.449

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

=

.

°

Угол отставания:

1

2

3

4

5

6

7

8

1

9.672

10.889

12.661

12.908

13.656

14.254

12.720

11.511

2

9.889

11.021

12.668

12.875

13.548

14.088

12.665

11.532

3

10.013

10.971

12.545

12.745

13.378

13.878

12.549

...

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

=

.

°

1

1

4.926

2

4.519

3

4.226

$\delta_{\text{CA}}$

=

.

°

1

1

105.16

2

104.40

3

103.80

$v_{\text{BHA}}$

=

.

°

1

2

3

4

5

6

7

8

9

1

46.32

40.39

37.03

33.75

31.34

28.82

25.49

23.19

21.71

2

24.87

24.02

23.48

22.45

21.56

20.49

18.94

17.63

16.85

3

17.41

18.15

18.12

17.62

17.14

16.51

15.60

14.67

14.17

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

=

.

°

Угол установки Л:

1

2

3

4

5

6

7

8

9

1

51.22

48.72

50.91

50.37

50.50

49.64

45.07

41.52

39.95

2

52.17

52.45

53.90

53.02

52.80

51.76

47.37

43.87

42.18

3

53.05

55.15

56.12

55.05

54.61

53.45

49.23

45.80

44.05

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

=

.

°

1

1

75.02

2

76.17

3

77.09

$v_{\text{CA}}$

=

.

°

Радиус дуги ср. линии (м):

	1
1	65.77
2	70.03
3	75.35

$\cdot 10^{-3}$

R<sub>СЛ.ВНА</sub> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	77.50	79.54	74.20	75.05	74.75	78.41	98.97	113.77	125.30						
2	300.12	255.27	210.39	195.26	182.18	181.81	227.61	251.83	265.39						
3	991.62	579.26	453.14	402.35	362.80	354.08	459.67	495.38	504.50						

$\cdot 10^{-3}$

R<sub>СЛ.rotor</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	27.65	24.98	21.12	20.30	19.59	20.06	24.34	29.96	34.78						
2	30.90	27.77	23.50	22.52	21.72	22.19	26.65	32.54	37.78						
3	33.61	30.49	25.80	24.66	23.77	24.22	28.87	35.02	40.65						

$\cdot 10^{-3}$

R<sub>СЛ.stator</sub><sup>T</sup> =

	1
1	37.88
2	45.51
3	52.53

$\cdot 10^{-3}$

R<sub>СЛ.СА</sub> =

	1
1	1.0359
2	1.0000
3	0.9808

K<sub>ВНА</sub> =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.0757	0.9750	0.9637	0.9661	0.9673	0.9684	0.9698	0.9702	0.9936						
2	0.9740	0.9704	0.9637	0.9661	0.9673	0.9684	0.9698	0.9702	0.9936						
3	0.9142	0.9680	0.9637	0.9661	0.9673	0.9684	0.9698	0.9702	0.9936						

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

Фактор диффузорности решетки:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.8481	0.9644	0.9637	0.9659	0.9670	0.9680	0.9692	0.9695	0.9937						
2	0.9691	0.9701	0.9637	0.9659	0.9670	0.9680	0.9692	0.9695	0.9937						
3	1.0520	0.9732	0.9637	0.9659	0.9670	0.9680	0.9692	0.9695	0.9937						

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

	1
1	0.8302
2	0.8302
3	0.8302

K<sub>СА</sub> =

$$D_{\text{BHA}} =$$

	1
1	-0.1928
2	-0.1544
3	-0.1308

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.6655	0.7376	0.7707	0.7702	0.7776	0.7676	0.6925	0.6610	0.6272						
2	0.4978	0.5367	0.5831	0.5935	0.6098	0.6092	0.5510	0.5262	0.5036						
3	0.3865	0.4200	0.4669	0.4811	0.5001	0.5039	0.4569	0.4365	0.4211						

Диффузорность решетки:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.7528	0.8098	0.8474	0.8716	0.8897	0.8692	0.8375	0.8138	0.8119						
2	0.6997	0.7572	0.8054	0.8336	0.8555	0.8391	0.8101	0.7890	0.7857						
3	0.6561	0.7143	0.7693	0.8002	0.8250	0.8121	0.7854	0.7664	0.7621						

$$D_{\text{CA}} =$$

	1
1	0.4407
2	0.4115
3	0.3896

$$D_{\text{BHA}} \leq 0.6 =$$

	1
1	1
2	1
3	1

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

	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	0	0	0
2	1	1	1	1	0	0	1	1	1
3	1	1	1	1	1	1	1	1	1

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

	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0

$$D_{\text{CA}} \leq 0.6 =$$

	1
1	1
2	1
3	1

[18, с. 71]



Коэф. потерь полного давления:

$\zeta_{\text{rotor}}^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1	0.1472	0.1973	0.2313	0.2391	0.2536	0.2612	0.2490	0.2279	0.2151						
	2	0.1351	0.1588	0.1932	0.2027	0.2186	0.2275	0.2184	0.1993	0.1913						
	3	0.1267	0.1370	0.1672	0.1769	0.1924	0.2021	0.1984	0.1822	0.1781						

$\zeta_{\text{stator}}^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1	0.2008	0.2201	0.2381	0.2467	0.2562	0.2554	0.2432	0.2373	0.2308						
	2	0.1452	0.1685	0.1942	0.2080	0.2216	0.2237	0.2144	0.2104	0.2059						
	3	0.1143	0.1372	0.1647	0.1805	0.1960	0.1999	0.1925	0.1899	0.1865						

Качество профилей решеток РК и НА:

$\text{quality}_{\text{rotor}}^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1	9.978	7.402	6.602	6.625	6.478	6.462	6.726	7.482	8.367						
	2	10.079	9.181	7.969	7.898	7.611	7.495	7.586	8.395	9.353						
	3	7.703	9.988	8.832	8.737	8.409	8.206	7.956	8.673	9.652						

$\text{quality}_{\text{stator}}^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1	6.114	6.504	6.163	6.038	5.914	6.014	6.316	6.495	6.829						
	2	8.974	8.067	7.215	6.870	6.577	6.600	6.880	7.029	7.349						
	3	11.638	9.513	8.207	7.665	7.215	7.155	7.410	7.528	7.841						

КПД элементарной ступени:

$\eta_{\text{stage}}^T =$		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	.%
	1	77.09	74.02	71.32	70.40	69.08	68.33	68.43	69.31	70.49							
	2	77.74	75.36	72.05	70.96	69.41	68.45	68.12	69.06	70.25							
	3	70.64	74.15	71.27	70.32	68.85	67.78	66.71	67.55	68.82							



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

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

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

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

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

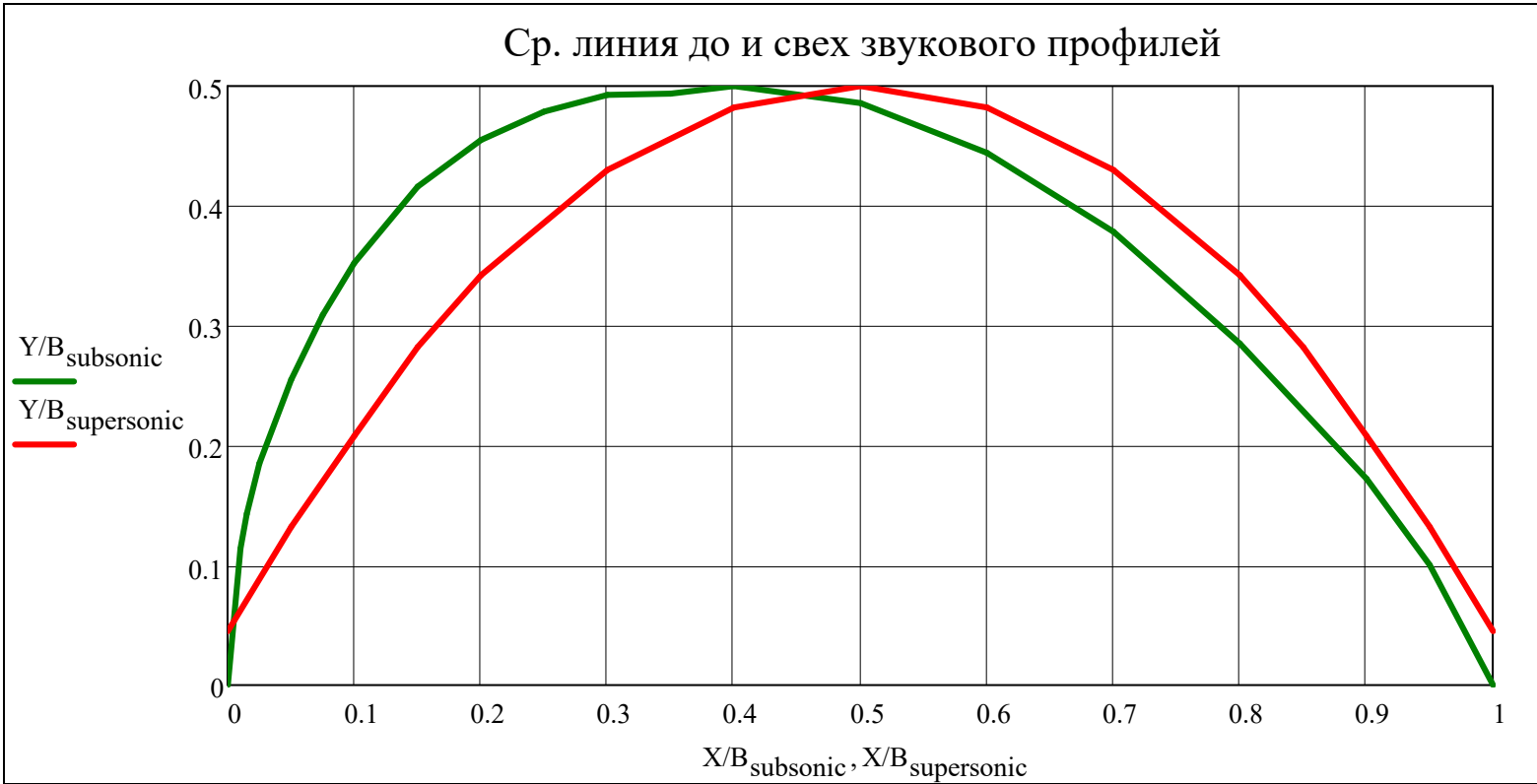
$Y/B_{supersonic} = \text{submatrix}\left( EXCEL_{AIRFOIL.supersonic}, 2, \text{rows}\left( EXCEL_{AIRFOIL.supersonic} \right), \text{ORIGIN} + 1, \text{ORIGIN} + 1 \right)$

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











$l_{upper\_stator}^T =$ 

	1	2	3	4	5	6	7	8	9
1	23.18	23.08	22.20	21.53	21.49	21.86	22.82	24.75	27.01
2	25.85	25.72	24.73	23.97	23.93	24.34	25.40	27.54	30.03
3	28.12	28.02	26.98	26.18	26.15	26.62	27.78	30.13	32.86

 $\cdot 10^{-3}$

$l_{lower\_stator}^T =$ 

	1	2	3	4	5	6	7	8	9
1	22.86	22.73	21.83	21.16	21.12	21.49	22.48	24.44	26.69
2	25.28	25.10	24.05	23.31	23.25	23.66	24.78	26.94	29.42
3	27.28	27.10	25.98	25.20	25.14	25.60	26.85	29.23	31.94

 $\cdot 10^{-3}$

$area_{stator}^T =$ 

	1	2	3	4	5	6	7	8	9
1	11.18	10.99	10.02	9.42	9.35	9.70	10.77	12.84	15.36
2	22.94	22.49	20.47	19.21	19.05	19.75	21.93	26.11	31.22
3	37.56	36.93	33.67	31.63	31.41	32.59	36.20	43.13	51.59

 $\cdot 10^{-6}$

$Sx_{stator}^T =$ 

	1	2	3	4	5	6	7	8	9
1	16.3	17.4	17.3	15.8	16.1	16.7	16.4	18.4	22.5
2	36.1	38.9	38.6	35.4	36.2	37.6	37.3	42.3	51.7
3	62.6	67.5	67.5	62.4	64.0	67.0	67.3	77.0	94.3

 $\cdot 10^{-9}$

$Sy_{stator}^T =$ 

	1	2	3	4	5	6	7	8	9
1	114.0	111.1	96.7	88.1	87.1	92.1	107.8	140.2	183.5
2	259.5	251.9	218.7	198.8	196.4	207.3	242.5	315.1	412.0
3	459.5	447.9	389.9	355.1	351.3	371.3	434.8	565.3	739.7

 $\cdot 10^{-9}$

$x0_{stator}^T =$ 

	1	2	3	4	5	6	7	8	9
1	10.19	10.11	9.65	9.36	9.32	9.50	10.01	10.92	11.95
2	11.31	11.20	10.68	10.35	10.31	10.50	11.06	12.07	13.20
3	12.23	12.13	11.58	11.23	11.19	11.39	12.01	13.11	14.34

 $\cdot 10^{-3}$

$y0_{stator}^T =$ 

	1	2	3	4	5	6	7	8	9
1	1.46	1.59	1.73	1.68	1.72	1.72	1.52	1.43	1.46
2	1.57	1.73	1.89	1.85	1.90	1.90	1.70	1.62	1.66
3	1.67	1.83	2.00	1.97	2.04	2.06	1.86	1.79	1.83

 $\cdot 10^{-3}$

$l_{upper\_rotor}^T =$ 

	1	2	3	4	5	6	7	8	9
1	57.22	51.24	45.31	41.23	38.30	36.02	34.44	33.75	33.36
2	63.72	57.33	50.77	46.33	43.10	40.61	38.95	38.23	37.82
3	70.74	63.80	56.56	51.67	48.11	45.37	43.56	42.79	42.35

 $\cdot 10^{-3}$

$l_{lower\_rotor}^T =$ 

	1	2	3	4	5	6	7	8	9
1	54.66	49.26	43.66	39.90	37.15	35.06	33.71	33.16	32.83
2	63.31	56.95	50.40	46.01	42.80	40.35	38.74	38.06	37.65
3	70.63	63.66	56.42	51.54	47.98	45.26	43.47	42.71	42.27

 $\cdot 10^{-3}$

$area_{rotor}^T =$ 

	1	2	3	4	5	6	7	8
1	258.75	210.23	165.14	137.84	119.46	106.28	98.03	94.65
2	146.21	118.31	92.68	77.22	66.83	59.38	54.73	52.81
3	109.32	88.82	69.77	58.24	50.47	44.90	41.42	...

 $\cdot 10^{-6}$

$Sx_{rotor}^T =$ 

	1	2	3	4	5	6	7	8	9
1	801.4	500.7	327.6	220.6	163.9	122.4	85.4	67.0	58.3
2	157.8	120.1	89.5	65.9	52.3	41.4	30.5	24.8	22.7
3	53.4	54.8	43.3	33.2	27.3	22.3	16.9	14.0	13.2

 $\cdot 10^{-9}$

$Sy_{rotor}^T =$ 

	1	2	3	4	5	6	7	8
1	6345.2	4646.9	3235.2	2467.1	1990.5	1670.2	1479.6	1403.7
2	4175.4	3039.3	2107.2	1602.6	1290.3	1080.7	956.1	906.2
3	3485.1	2552.3	1776.9	1355.0	1093.3	917.4	812.6	...

 $\cdot 10^{-9}$

$x0_{rotor}^T =$ 

	1	2	3	4	5	6	7	8	9
1	24.52	22.10	19.59	17.90	16.66	15.72	15.09	14.83	14.68
2	28.56	25.69	22.74	20.75	19.31	18.20	17.47	17.16	16.98
3	31.88	28.73	25.47	23.27	21.66	20.43	19.62	19.28	19.08

 $\cdot 10^{-3}$

$y0_{rotor}^T =$ 

	1	2	3	4	5	6	7	8	9
1	3.10	2.38	1.98	1.60	1.37	1.15	0.87	0.71	0.63
2	1.08	1.02	0.97	0.85	0.78	0.70	0.56	0.47	0.44
3	0.49	0.62	0.62	0.57	0.54	0.50	0.41	0.35	0.34

 $\cdot 10^{-3}$



$$J_{x_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 27 & 31 & 33 & 29 & 31 & 32 & 28 & 29 & 37 \\ \hline 2 & 65 & 76 & 82 & 73 & 77 & 80 & 72 & 78 & 98 \\ \hline 3 & 123 & 143 & 155 & 141 & 149 & 157 & 145 & 162 & 205 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 1486 & 1437 & 1194 & 1054 & 1039 & 1119 & 1381 & 1959 \\ \hline 2 & 3756 & 3610 & 2989 & 2633 & 2589 & 2784 & 3431 & 4865 \\ \hline 3 & 7191 & 6951 & 5777 & 5101 & 5028 & 5413 & 6680 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 173 & 183 & 173 & 154 & 156 & 165 & 170 & 209 & 279 \\ \hline 2 & 424 & 453 & 429 & 381 & 387 & 410 & 429 & 531 & 709 \\ \hline 3 & 796 & 850 & 812 & 728 & 744 & 793 & 840 & 1049 & 1405 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{x0_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 2.64 & 2.98 & 3.12 & 2.77 & 2.88 & 2.99 & 2.70 & 2.98 & 3.81 \\ \hline 2 & 7.73 & 8.62 & 8.74 & 7.82 & 8.09 & 8.49 & 8.16 & 9.53 & 12.44 \\ \hline 3 & 18.39 & 19.91 & 19.60 & 17.66 & 18.25 & 19.38 & 19.75 & 24.24 & 32.36 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y0_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 325 & 314 & 261 & 230 & 227 & 244 & 301 & 428 & 612 \\ \hline 2 & 820 & 788 & 653 & 575 & 565 & 608 & 749 & 1062 & 1519 \\ \hline 3 & 1571 & 1518 & 1262 & 1114 & 1098 & 1182 & 1459 & 2070 & 2963 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy0_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 6.57 & 6.93 & 6.54 & 5.80 & 5.88 & 6.21 & 6.45 & 7.94 & 10.62 \\ \hline 2 & 16.12 & 17.15 & 16.18 & 14.38 & 14.60 & 15.46 & 16.25 & 20.17 & 26.99 \\ \hline 3 & 30.25 & 32.25 & 30.63 & 27.46 & 28.02 & 29.87 & 31.82 & 39.86 & 53.47 \\ \hline \end{array} \cdot 10^{-12}$$

$$\alpha_{\text{major}_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 1.17 & 1.28 & 1.45 & 1.46 & 1.50 & 1.47 & 1.24 & 1.07 & 1.00 \\ \hline 2 & 1.14 & 1.26 & 1.44 & 1.45 & 1.50 & 1.48 & 1.26 & 1.10 & 1.03 \\ \hline 3 & 1.12 & 1.23 & 1.41 & 1.43 & 1.49 & 1.47 & 1.27 & 1.12 & 1.04 \\ \hline \end{array} \cdot \circ$$

$$J_{x_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 3392 & 1751 & 986 & 578 & 389 & 268 & 178 & 142 & 126 \\ \hline 2 & 276 & 192 & 131 & 87 & 64 & 46 & 31 & 24 & 22 \\ \hline 3 & 59 & 57 & 42 & 29 & 23 & 17 & 12 & 9 & 9 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ \hline 1 & 199075 & 131414 & 81089 & 56493 & 42434 & 33583 & 28572 \\ \hline 2 & 152550 & 99887 & 61296 & 42552 & 31870 & 25164 & 21371 \\ \hline 3 & 142139 & 93830 & 57897 & 40336 & 30298 & 23978 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 20427 & 11506 & 6672 & 4106 & 2839 & 1999 & 1340 & 1033 \\ \hline 2 & 4686 & 3209 & 2116 & 1421 & 1050 & 783 & 554 & 442 \\ \hline 3 & 1771 & 1636 & 1146 & 804 & 615 & 473 & 345 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{x0_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 910.63 & 558.14 & 336.05 & 224.46 & 164.68 & 126.68 & 103.28 & 94.10 \\ \hline 2 & 105.83 & 70.34 & 44.31 & 30.38 & 22.64 & 17.53 & 14.15 & 12.75 \\ \hline 3 & 32.42 & 23.05 & 14.82 & 10.35 & 7.83 & 6.13 & 4.97 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{y0_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 43476 & 28700 & 17709 & 12338 & 9267 & 7334 & 6240 & 5817 \\ \hline 2 & 33311 & 21812 & 13385 & 9292 & 6959 & 5495 & 4667 & 4345 \\ \hline 3 & 31038 & 20489 & 12643 & 8808 & 6616 & 5236 & 4455 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{xy0_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 776.02 & 438.10 & 254.22 & 156.90 & 108.56 & 76.51 & 51.33 & 39.59 \\ \hline 2 & 179.68 & 123.06 & 81.11 & 54.50 & 40.27 & 30.03 & 21.26 & 16.96 \\ \hline 3 & 67.94 & 62.77 & 43.96 & 30.84 & 23.60 & 18.16 & 13.23 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$\alpha_{\text{major}_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 1.04 & 0.89 & 0.84 & 0.74 & 0.68 & 0.61 & 0.48 & 0.40 & 0.36 \\ \hline 2 & 0.31 & 0.32 & 0.35 & 0.34 & 0.33 & 0.31 & 0.26 & 0.22 & 0.21 \\ \hline 3 & 0.13 & 0.18 & 0.20 & 0.20 & 0.20 & 0.20 & 0.17 & 0.15 & 0.15 \\ \hline \end{array} \cdot \circ$$

$$J_{u_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 2.50 & 2.82 & 2.95 & 2.63 & 2.73 & 2.83 & 2.56 & 2.84 & 3.62 \\ \hline 2 & 7.41 & 8.24 & 8.33 & 7.45 & 7.71 & 8.09 & 7.80 & 9.14 & 11.96 \\ \hline 3 & 17.81 & 19.21 & 18.85 & 16.98 & 17.52 & 18.61 & 19.05 & 23.46 & 31.39 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{v_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 325 & 314 & 261 & 230 & 227 & 244 & 302 & 428 & 613 \\ \hline 2 & 821 & 789 & 653 & 575 & 566 & 608 & 750 & 1063 & 1519 \\ \hline 3 & 1571 & 1519 & 1262 & 1115 & 1099 & 1183 & 1460 & 2071 & 2964 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{uv_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -0.00 & 0.00 \\ \hline 2 & -0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -0.00 & 0.00 & 0.00 \\ \hline 3 & 0.00 & -0.00 & 0.00 & -0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{p_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 327 & 317 & 264 & 233 & 230 & 247 & 304 & 431 & 616 \\ \hline 2 & 828 & 797 & 661 & 583 & 574 & 616 & 757 & 1072 & 1531 \\ \hline 3 & 1589 & 1538 & 1281 & 1132 & 1116 & 1202 & 1479 & 2095 & 2996 \\ \hline \end{array} \cdot 10^{-12}$$

$$W_{p_{\text{stator}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 26.3 & 25.6 & 22.3 & 20.3 & 20.1 & 21.2 & 24.8 & 32.3 & 42.3 \\ \hline 2 & 59.9 & 58.1 & 50.5 & 45.9 & 45.3 & 47.8 & 56.0 & 72.7 & 95.1 \\ \hline 3 & 106.3 & 103.6 & 90.2 & 82.2 & 81.3 & 85.9 & 100.6 & 130.8 & 171.1 \\ \hline \end{array} \cdot 10^{-9}$$

$$\text{stiffness}_{\text{stator}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 1.25 & 1.21 & 1.00 & 0.88 & 0.87 & 0.94 & 1.16 & 1.64 & 2.35 \\ \hline 2 & 8.75 & 8.41 & 6.97 & 6.14 & 6.03 & 6.49 & 8.00 & 11.34 & 16.21 \\ \hline 3 & 32.85 & 31.75 & 26.39 & 23.30 & 22.96 & 24.73 & 30.51 & 43.30 & 61.97 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{u_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 896.49 & 551.33 & 332.33 & 222.43 & 163.39 & 125.87 & 102.85 & 93.83 \\ \hline 2 & 104.86 & 69.65 & 43.82 & 30.06 & 22.41 & 17.37 & 14.05 & 12.69 \\ \hline 3 & 32.27 & 22.86 & 14.67 & 10.24 & 7.74 & 6.07 & 4.93 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{v_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 43491 & 28707 & 17713 & 12340 & 9269 & 7335 & 6240 & 5817 \\ \hline 2 & 33312 & 21812 & 13385 & 9292 & 6959 & 5495 & 4667 & 4345 \\ \hline 3 & 31038 & 20489 & 12643 & 8808 & 6616 & 5236 & 4455 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{uv_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ \hline 1 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -0.00 & 0.00 \\ \hline 2 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ \hline 3 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -0.00 & 0.00 \\ \hline \end{array} \cdot 10^{-12}$$

$$J_{p_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 44387 & 29258 & 18045 & 12562 & 9432 & 7461 & 6343 & 5911 \\ \hline 2 & 33417 & 21882 & 13429 & 9322 & 6982 & 5512 & 4681 & 4358 \\ \hline 3 & 31070 & 20512 & 12657 & 8818 & 6624 & 5242 & 4460 & ... \\ \hline \end{array} \cdot 10^{-12}$$

$$W_{p_{\text{rotor}}}^T = \begin{array}{|c|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ \hline 1 & 1482.7 & 1085.9 & 756.0 & 576.5 & 465.1 & 390.3 & 345.7 & 328.0 \\ \hline 2 & 963.3 & 701.2 & 486.1 & 369.7 & 297.7 & 249.3 & 220.6 & 209.1 \\ \hline 3 & 802.6 & 587.8 & 409.2 & 312.1 & 251.8 & 211.3 & 187.2 & ... \\ \hline \end{array} \cdot 10^{-9}$$

$$\text{stiffness}_{\text{rotor}}^T = \begin{array}{|c|c|c|c|c|c|c|c|} \hline & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ \hline 1 & 2672.12 & 1763.93 & 1088.43 & 758.29 & 569.58 & 450.78 & 383.51 \\ \hline 2 & 355.50 & 232.78 & 142.84 & 99.16 & 74.27 & 58.64 & 49.80 \\ \hline 3 & 119.25 & 78.72 & 48.57 & 33.84 & 25.42 & 20.12 & ... \\ \hline \end{array} \cdot 10^{-12}$$

CP<sub>x</sub><sub>stator</sub>

T

=

	1	2	3	4	5	6	7	8
1	7.900	7.833	7.479	7.250	7.224	7.359	7.756	8.465
2	8.767	8.680	8.280	8.021	7.988	8.134	8.570	9.352
3	9.480	9.400	8.975	8.700	8.669	8.830	9.307	...

·10<sup>-3</sup>

CP<sub>y</sub><sub>stator</sub>

T

=

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

·10<sup>-3</sup>

CP<sub>x</sub><sub>rotor</sub>

T

=

	1	2	3	4	5	6	7	8
1	19.004	17.130	15.182	13.871	12.913	12.179	11.697	11.494
2	22.131	19.908	17.620	16.083	14.962	14.104	13.540	13.300
3	24.705	22.269	19.737	18.032	16.787	15.833	15.206	...

·10<sup>-3</sup>

CP<sub>y</sub><sub>rotor</sub>

T

=

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

·10<sup>-3</sup>

▲

Результат расчета абсолютных геометрических характеристик сечений Л



Абс. координаты профиля:

Airfoil(type,x,line,i,r) =	<div><div>if type = "BHA"<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; 1</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><div>if type = "rotor"<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; 1</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><div>if type = "stator"<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; 1</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><div>if type = "CA"<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; 1</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></div>
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Рассматриваемая ступень:

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

Построение профилей Л РК и НА

AXLE0(type,x,i,r) =

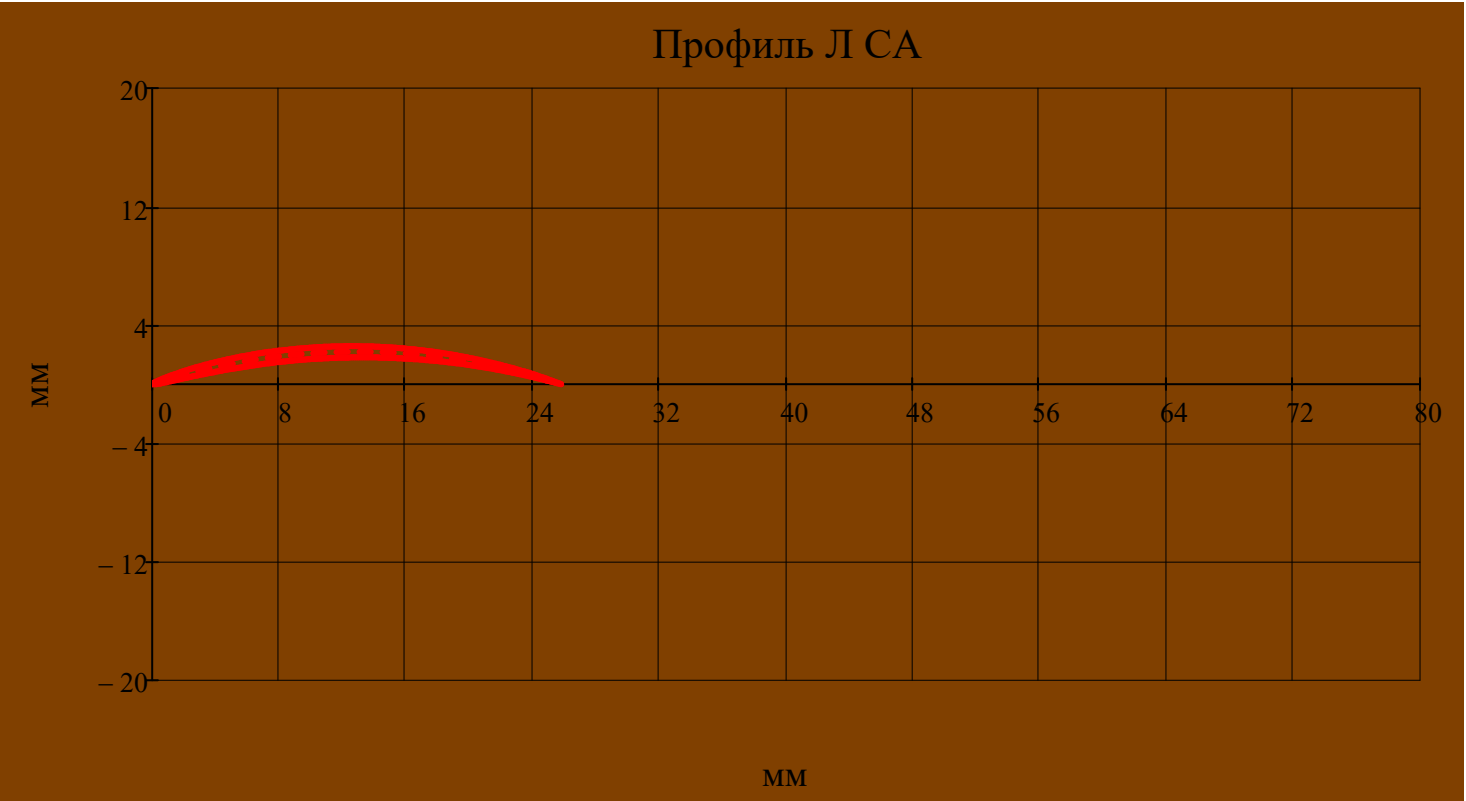
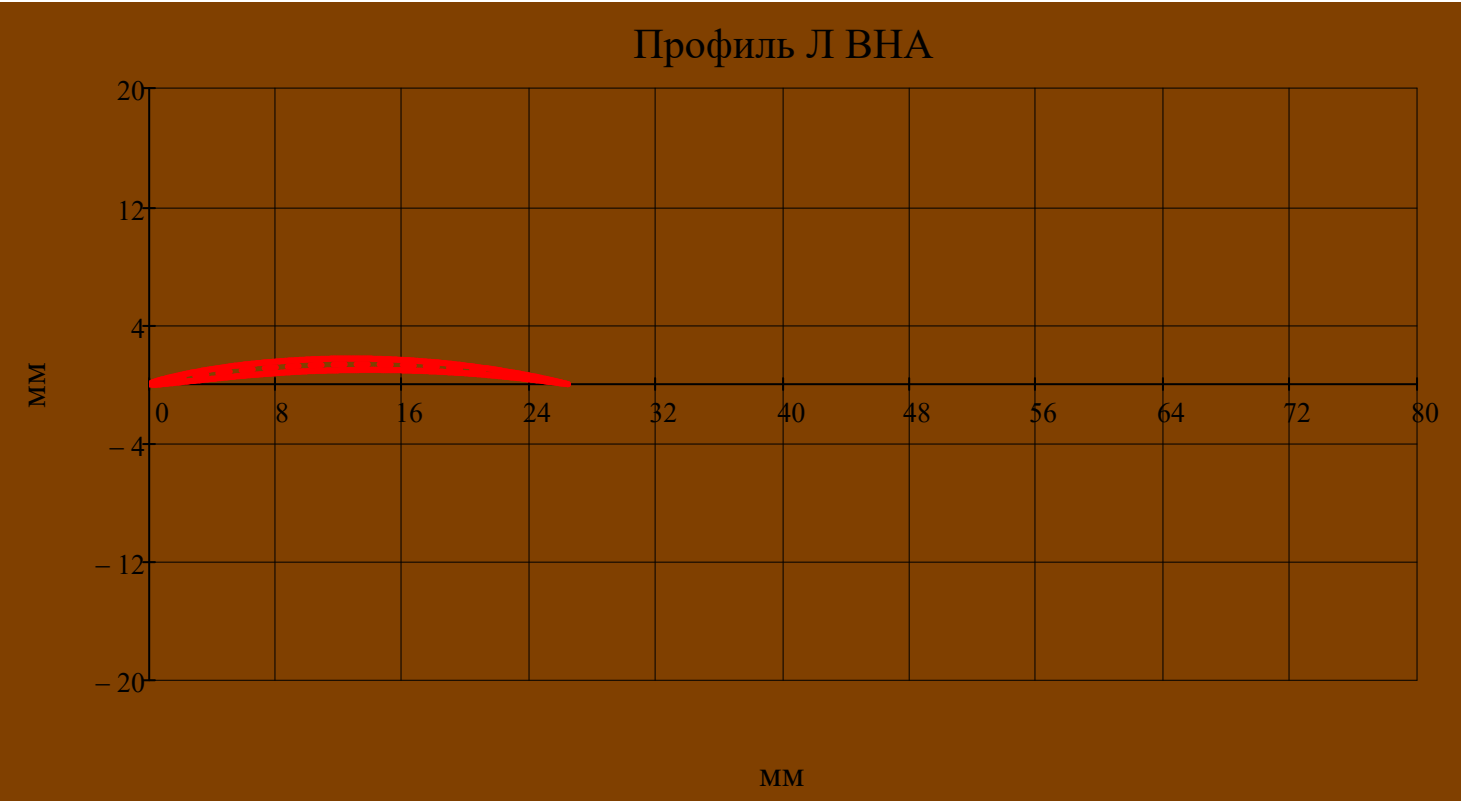
$$\begin{cases} \frac{y0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}} + \tan\left(\alpha_{\text{major}_{\text{rotor}_{i,r}}}\right) \cdot \left(x - \frac{x0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}}\right) & \text{if type = "rotor"} \\ \frac{y0_{\text{stator}_{i,r}}}{\text{chord}_{\text{stator}_{i,r}}}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

AXLE90(type,x,i,r) =

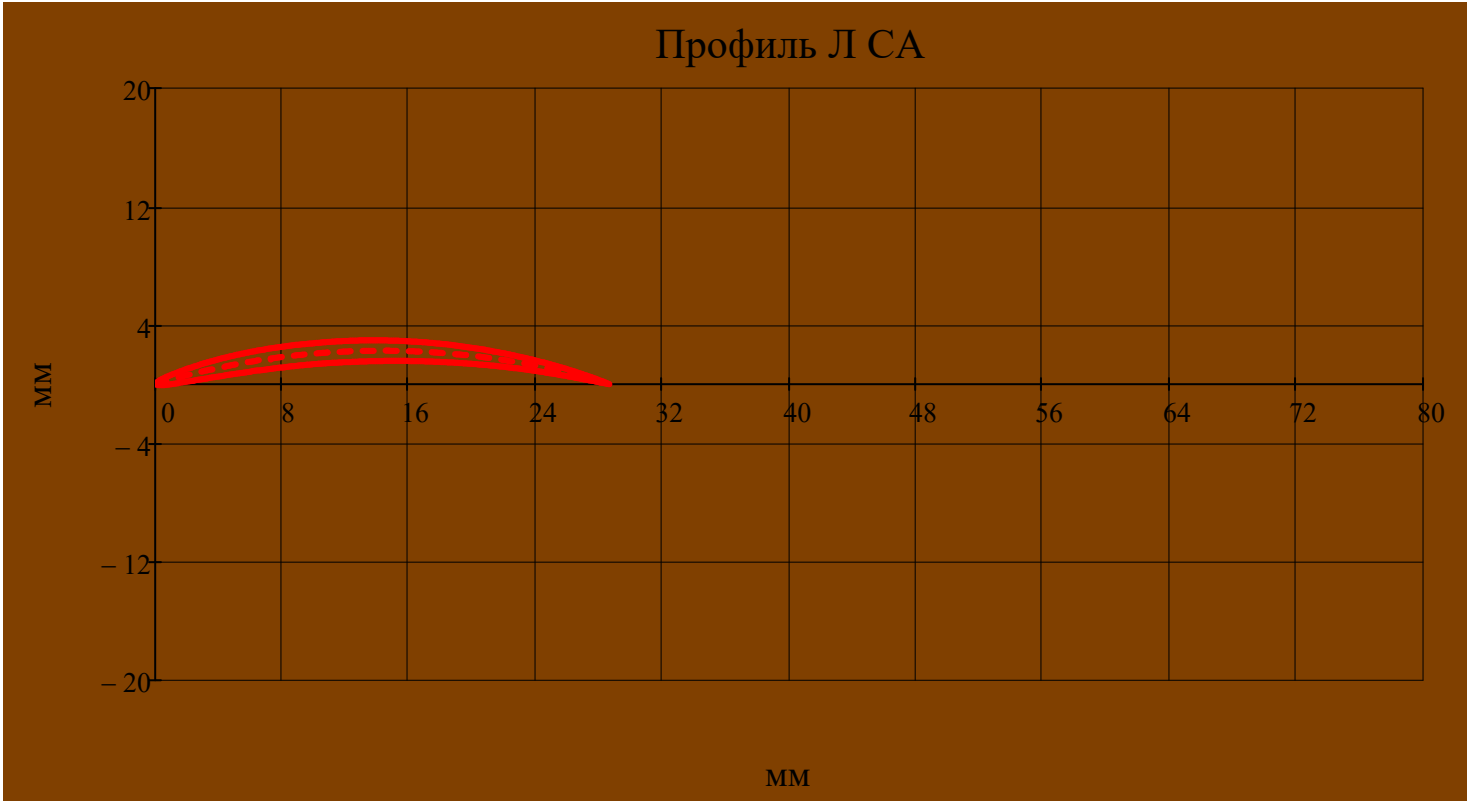
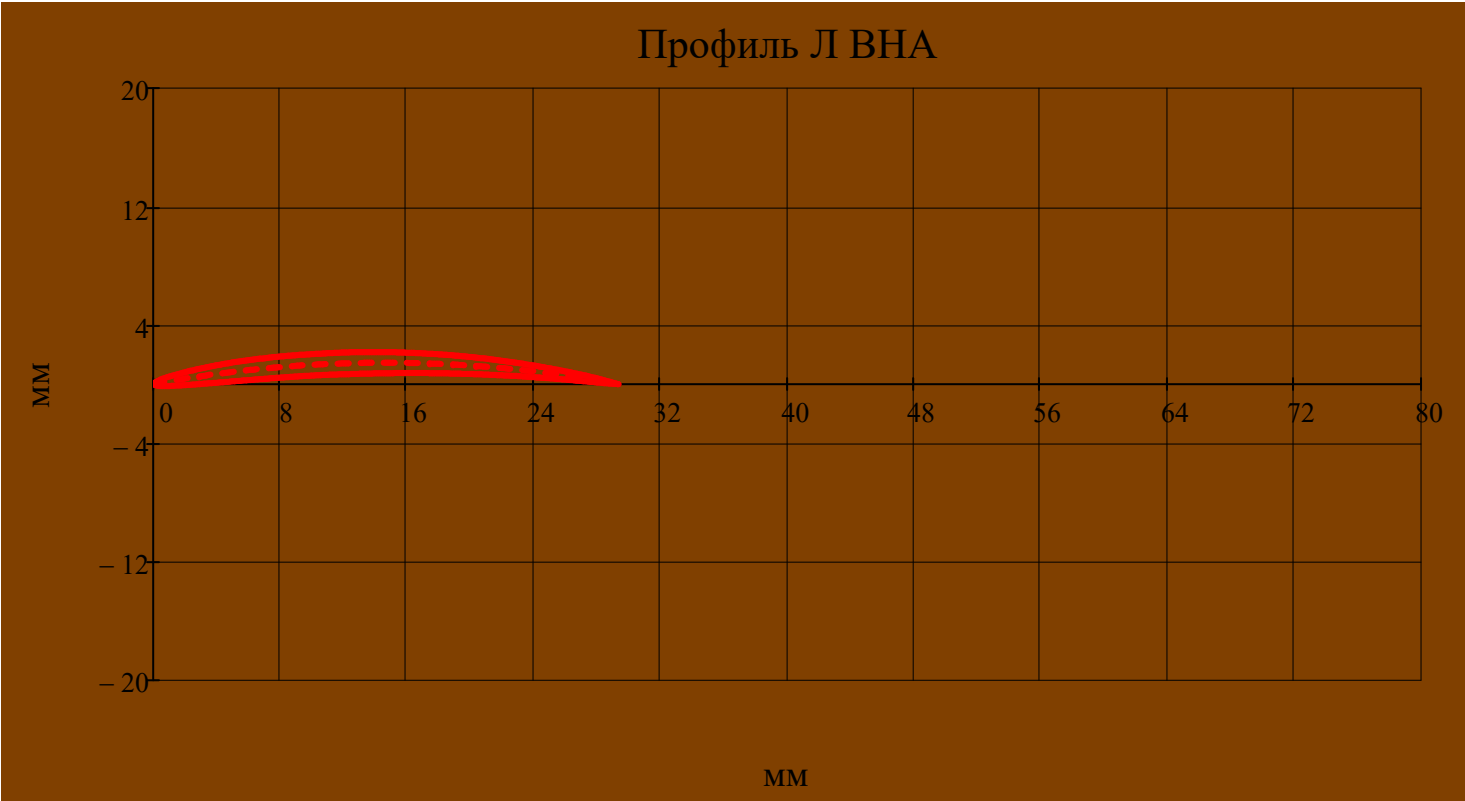
$$\begin{cases} \frac{y0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}} + \tan\left(\alpha_{\text{major}_{\text{rotor}_{i,r}}} + \frac{\pi}{2}\right) \cdot \left(x - \frac{x0_{\text{rotor}_{i,r}}}{\text{chord}_{\text{rotor}_{i,r}}}\right) & \text{if (type = "rotor") } \wedge \left|\alpha_{\text{major}_{\text{rotor}_{i,r}}}\right|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

$$b_{\text{lim}} = \frac{\text{ceil}\left(\max\left(\text{chord}_{\text{rotor}_{j,N_r}}, \text{chord}_{\text{stator}_{j,N_r}}\right) \cdot 10^2\right)}{10^2} = 80 \cdot 10^{-3}$$

$r = 1$

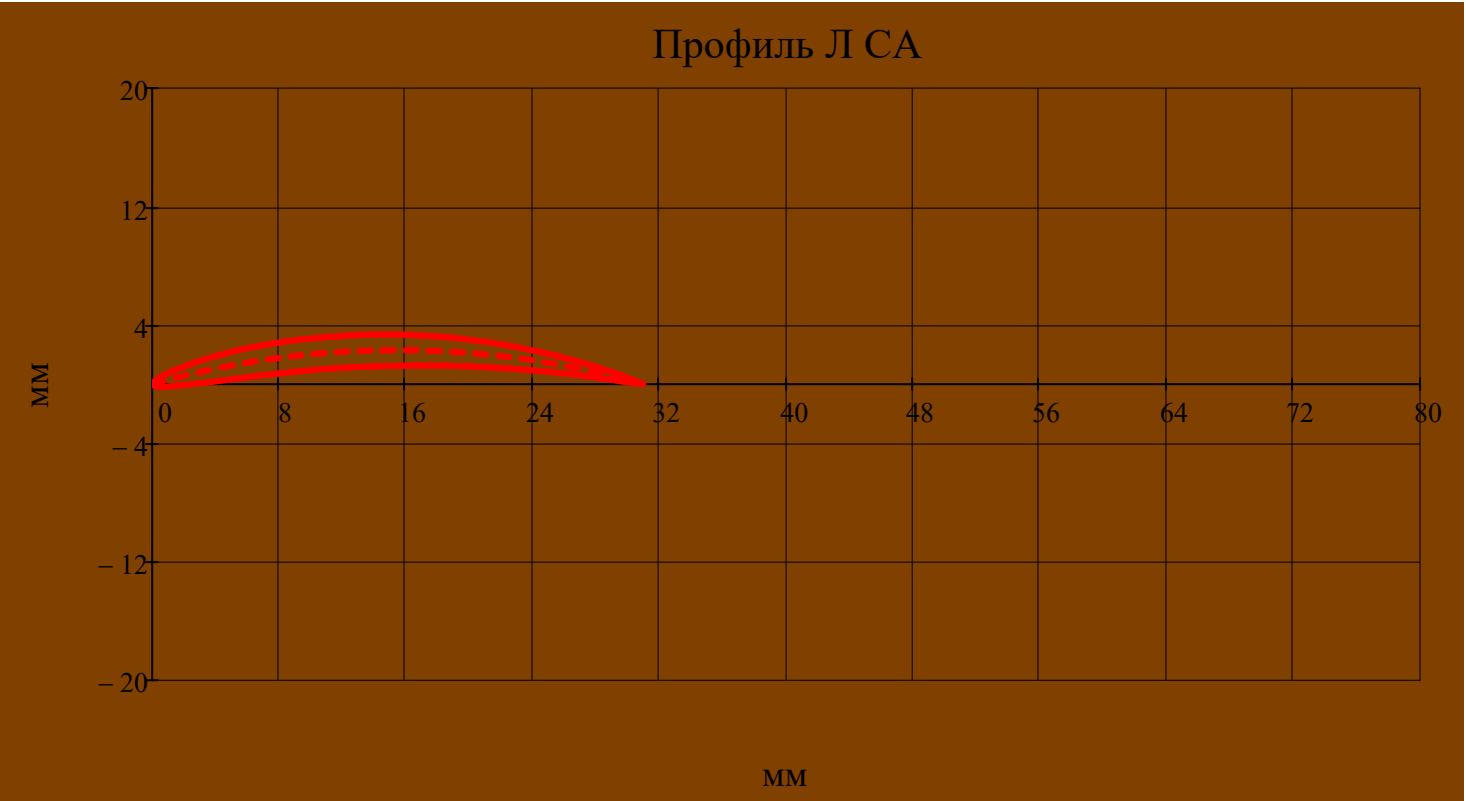
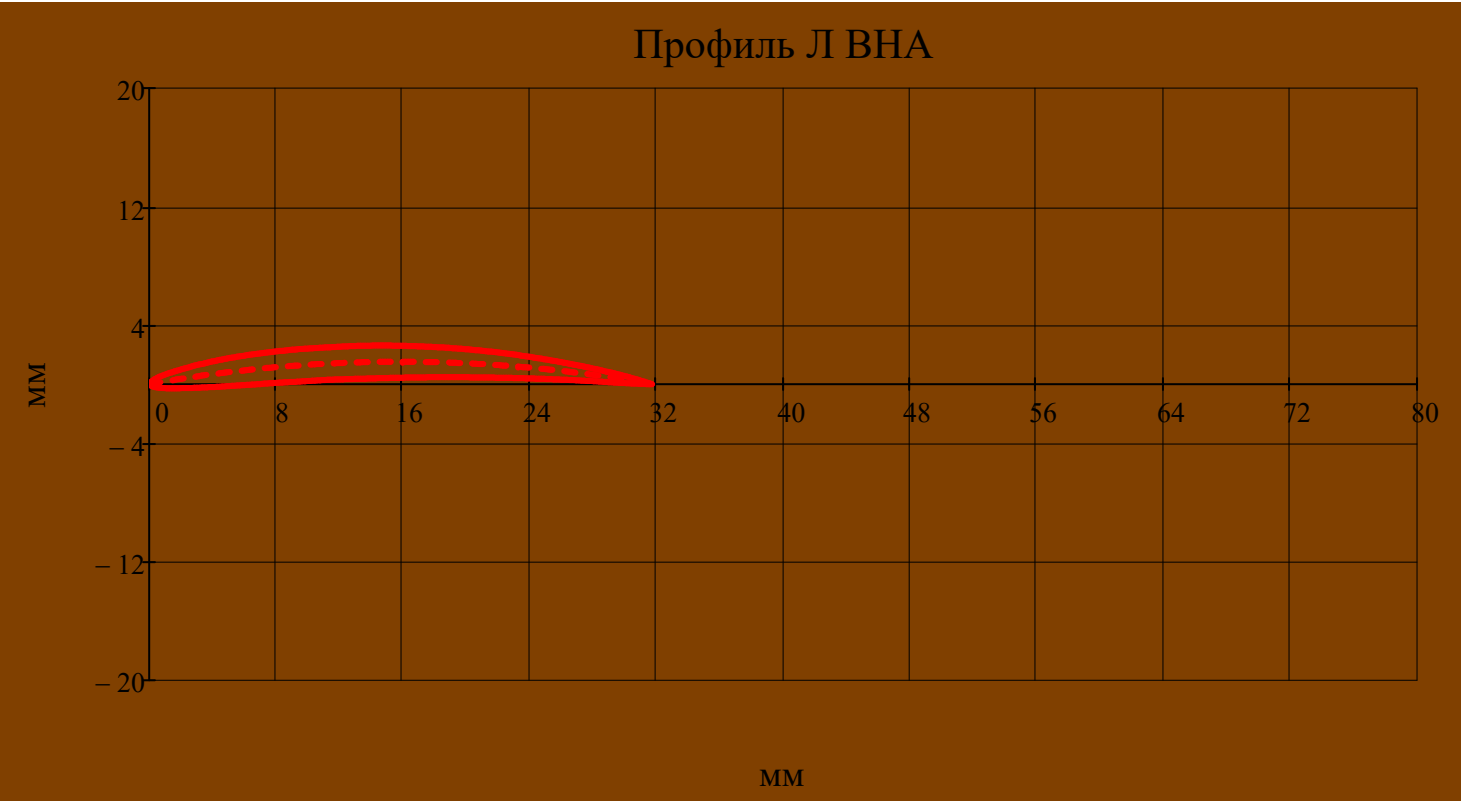


$r_w = av(N_r)$

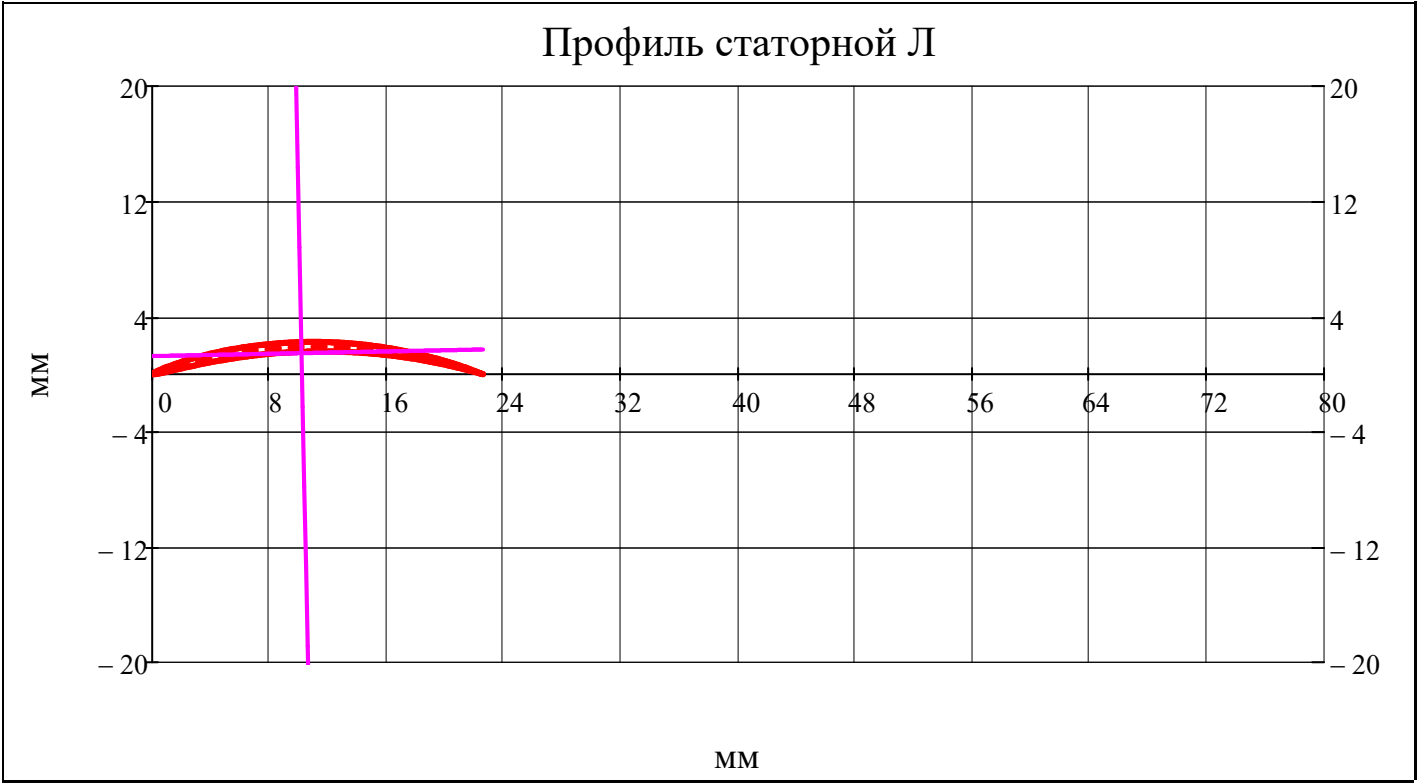
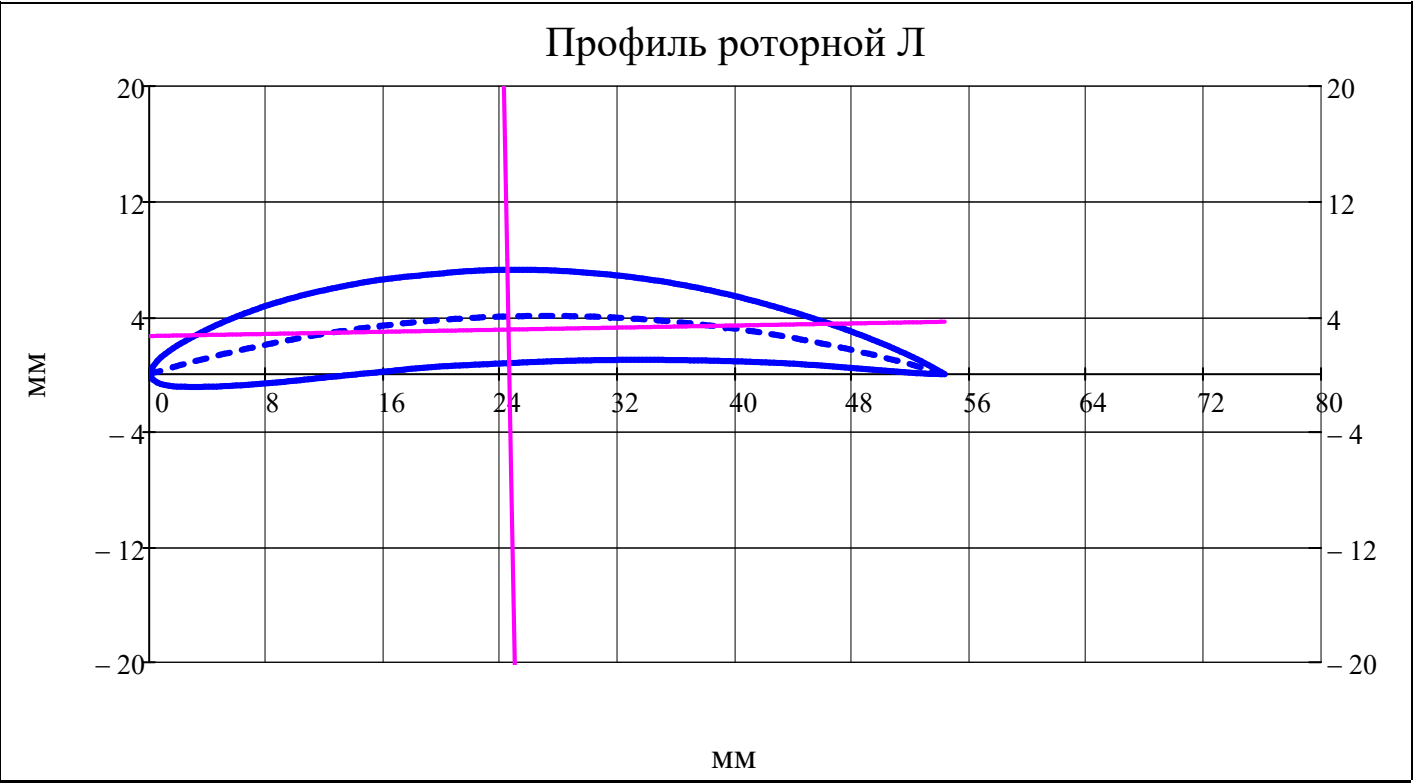




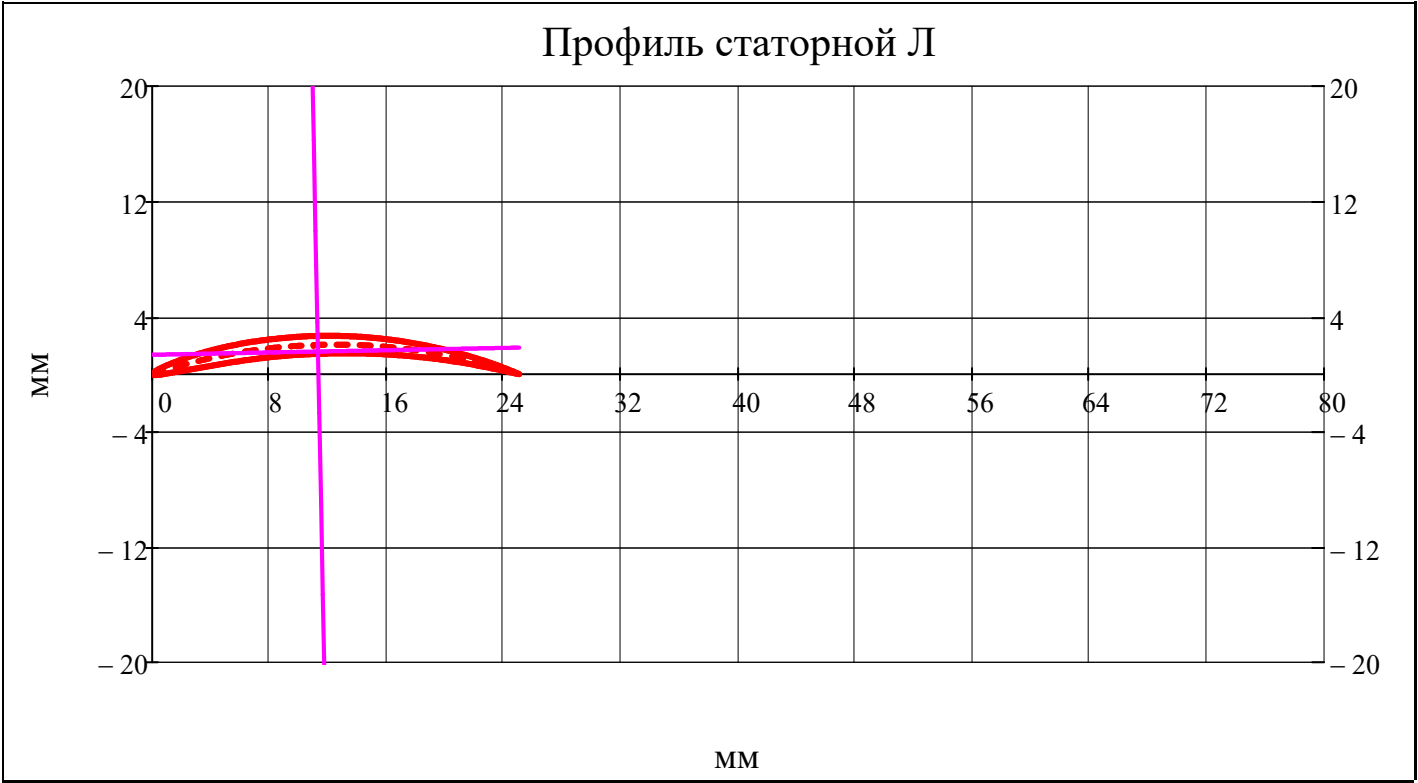
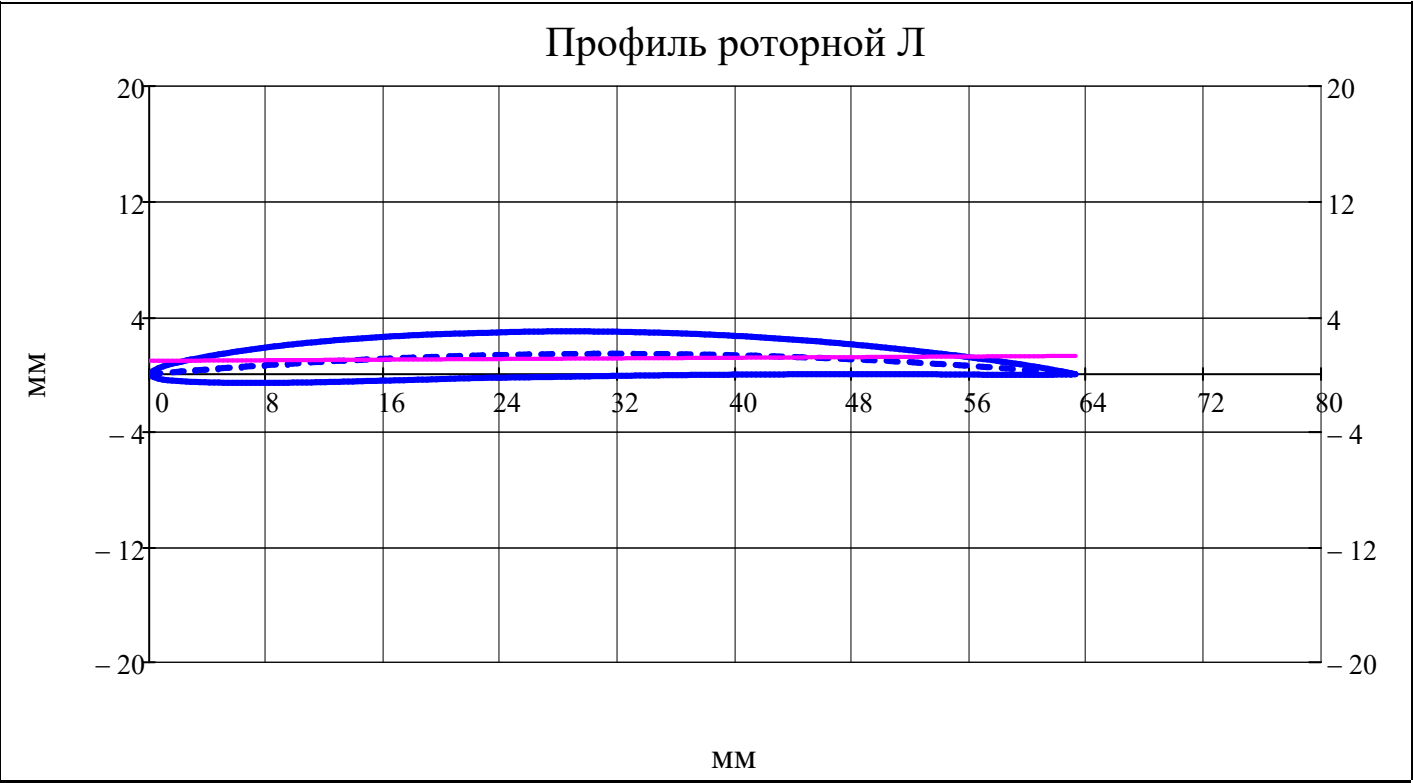
$r_w = N_r$



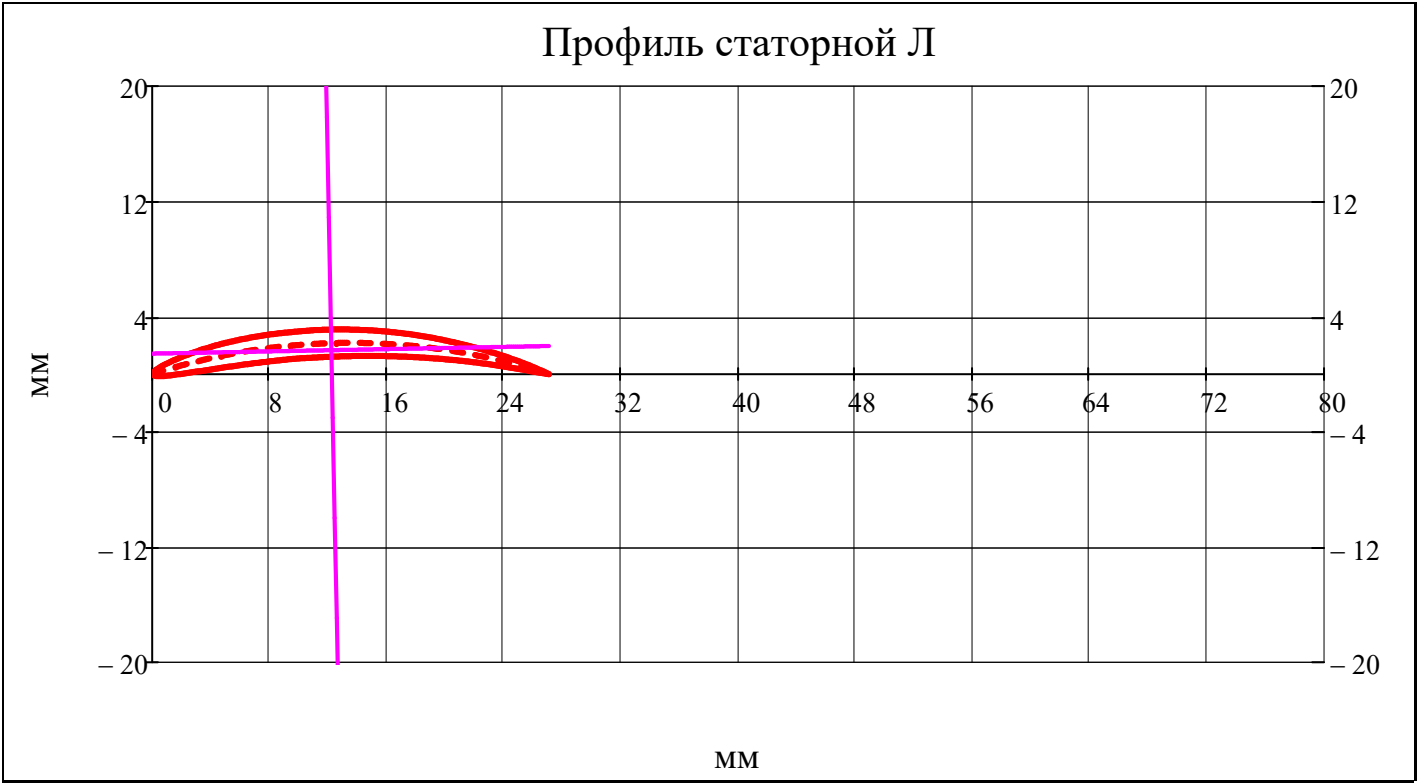
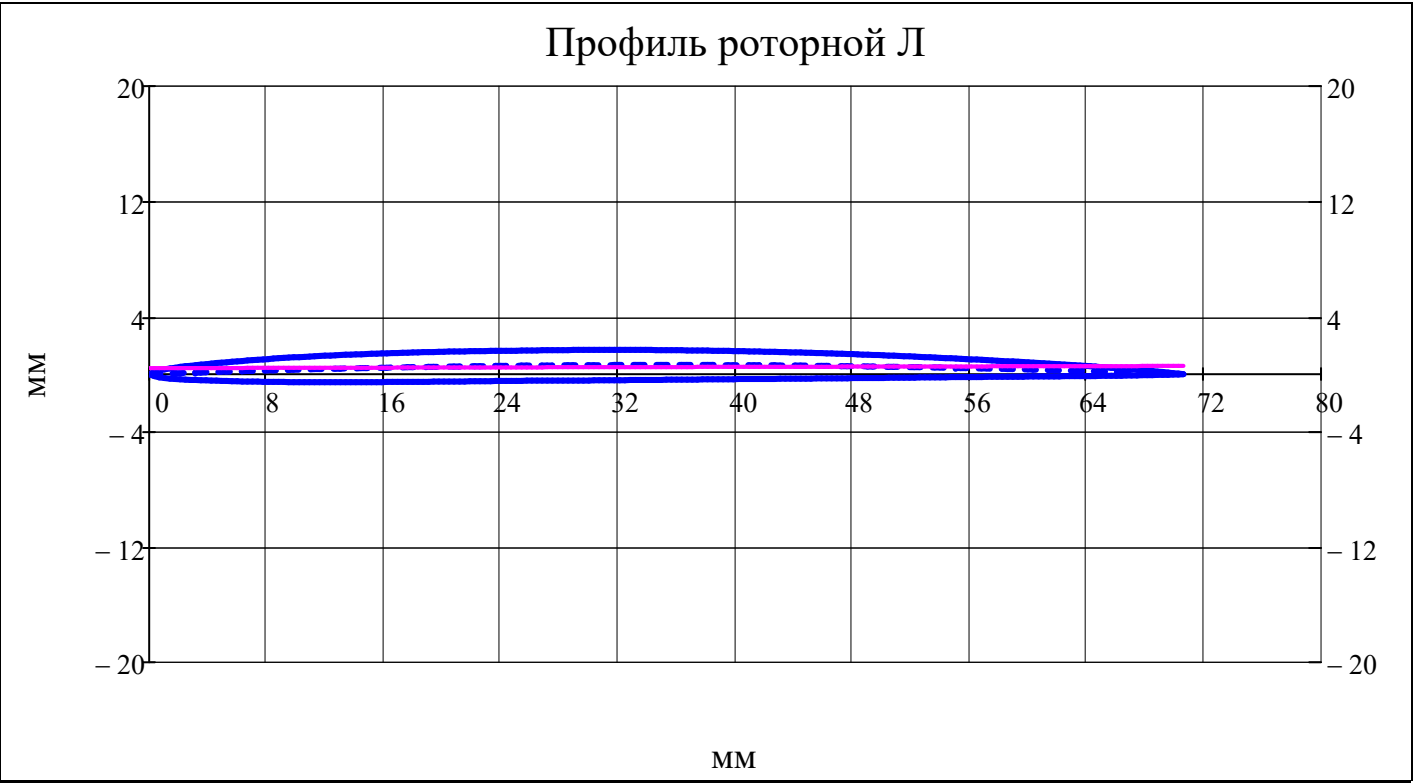
$r_w = 1$



$r_w = av(N_r)$



$r_w = N_r$





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

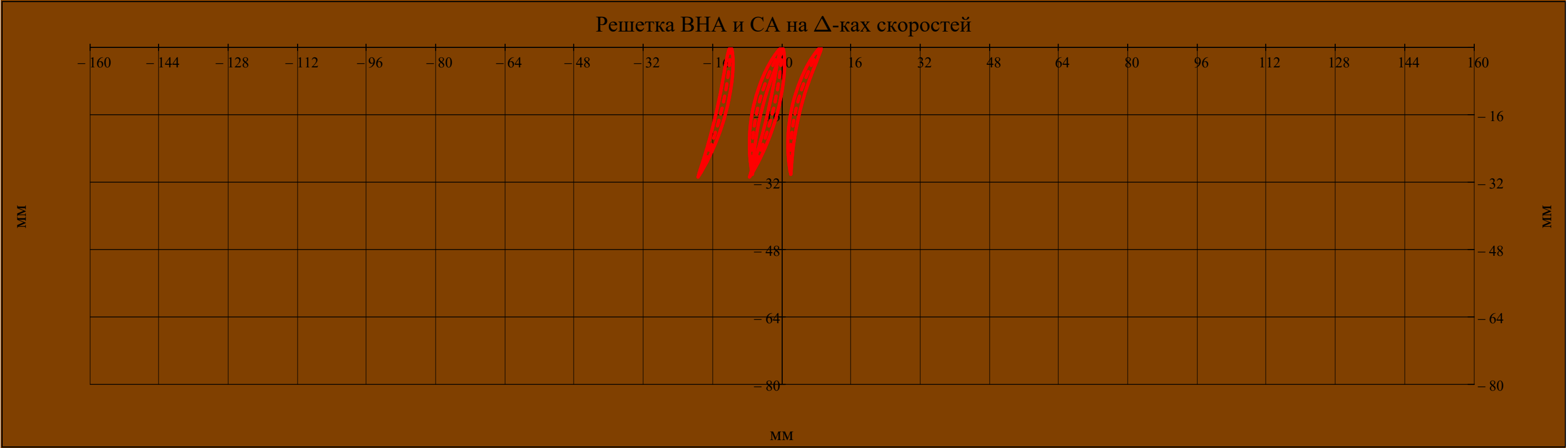
$$b_{\text{lim}} = \frac{\text{ceil}\left(\max\left(\text{chord}_{\text{rotor}_j, N_r}, \text{chord}_{\text{stator}_j, N_r}\right) \cdot 10^2\right)}{10^2} = 80 \cdot 10^{-3}$$

$$\mathbf{r}_w = \mathbf{1}$$


$r_w = av(N_r)$



$r_w = N_r$

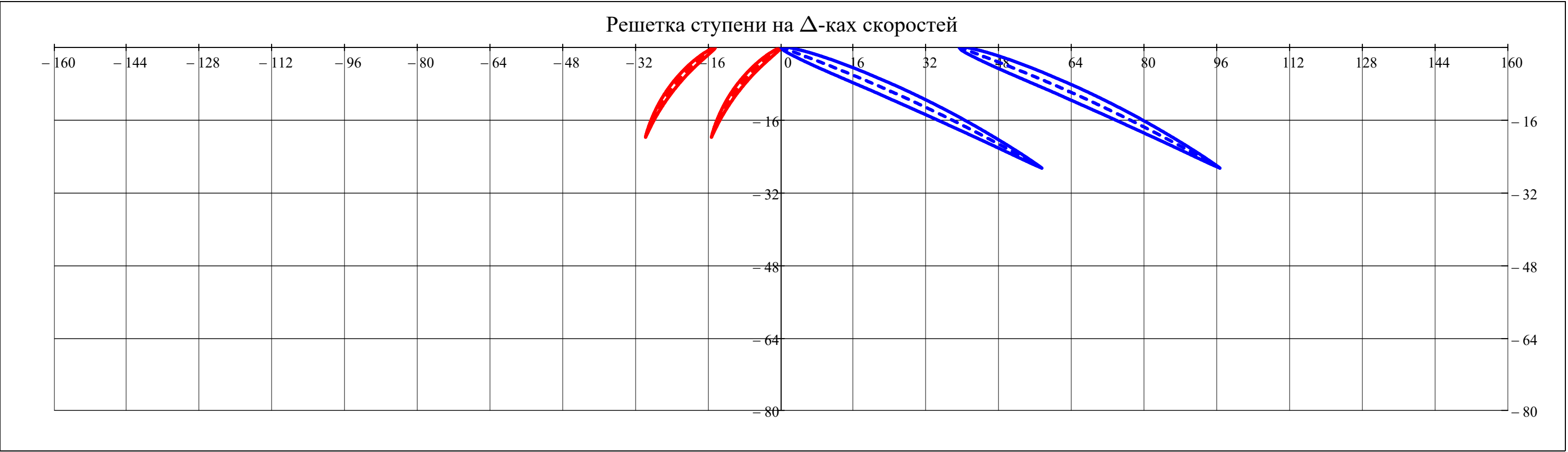




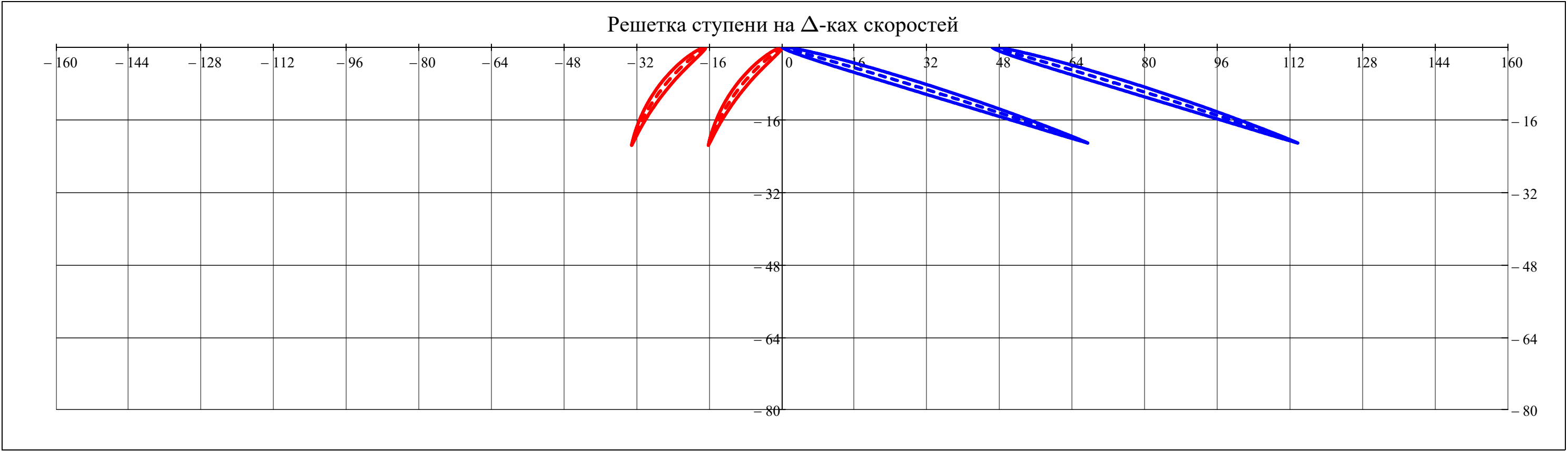
$r_w = 1$



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



$r_w = N_r$





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

0.0015 ≤ Δ<sub>r</sub> ≤ 0.0035 = 1

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

$\Delta_r^T = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 1 & 1.35 & 1.33 & 1.29 & 1.25 & 1.23 & 1.20 & 1.19 & 1.18 & 1.16 \end{bmatrix} \cdot 10^{-3}$

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

0.1 ≤ Δ<sub>a</sub> ≤ 0.2 = 1

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

$\Delta a^T = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 1 & 10.75 & 9.67 & 8.56 & 7.81 & 7.27 & 6.85 & 6.58 & 6.46 & 6.39 \end{bmatrix} \cdot 10^{-3}$

Односторонний осевой зазор (м):

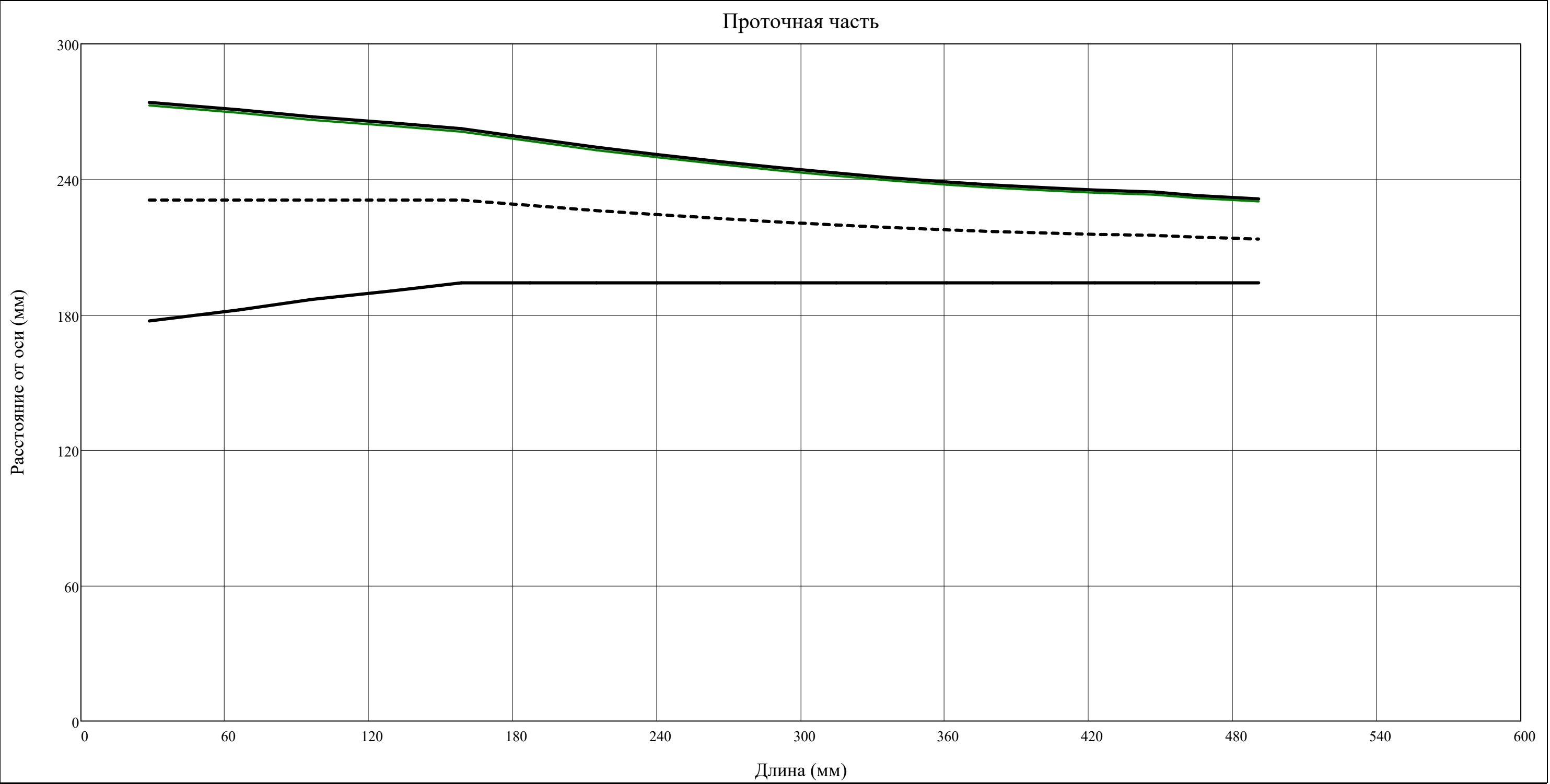
$\frac{\Delta a^T}{2} = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 1 & 5.37 & 4.83 & 4.28 & 3.91 & 3.63 & 3.43 & 3.29 & 3.23 & 3.20 \end{bmatrix} \cdot 10^{-3}$

Длина ОК (м):

$$\text{Length} = \left[ \Delta a_1 + \begin{cases} \text{chord}_{\text{BHA}_{av}(N_r)} \cdot \sin\left(v_{\text{BHA}_{av}(N_r)}\right) & \text{if BHA} = 1 \quad \dots \\ 0 & \text{otherwise} \end{cases} + \sum_{i=1}^Z \left( \text{chord}_{\text{rotor}_{i, av}(N_r)} \cdot \sin\left(v_{\text{rotor}_{i, av}(N_r)}\right) \right) + 2 \cdot \sum_{i=1}^Z \Delta a_i + \sum_{i=1}^Z \left( \text{chord}_{\text{stator}_{i, av}(N_r)} \cdot \sin\left(v_{\text{stator}_{i, av}(N_r)}\right) \right) \dots + \begin{cases} \text{chord}_{\text{CA}_{av}(N_r)} \cdot \sin\left(v_{\text{CA}_{av}(N_r)}\right) & \text{if CA} = 1 \quad + \Delta a_Z \\ 0 & \text{otherwise} \end{cases} \right] = 535.6 \cdot 10^{-3}$$

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

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



Рассматриваемая ступень:

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

⌵ Поперечная часть ступени

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

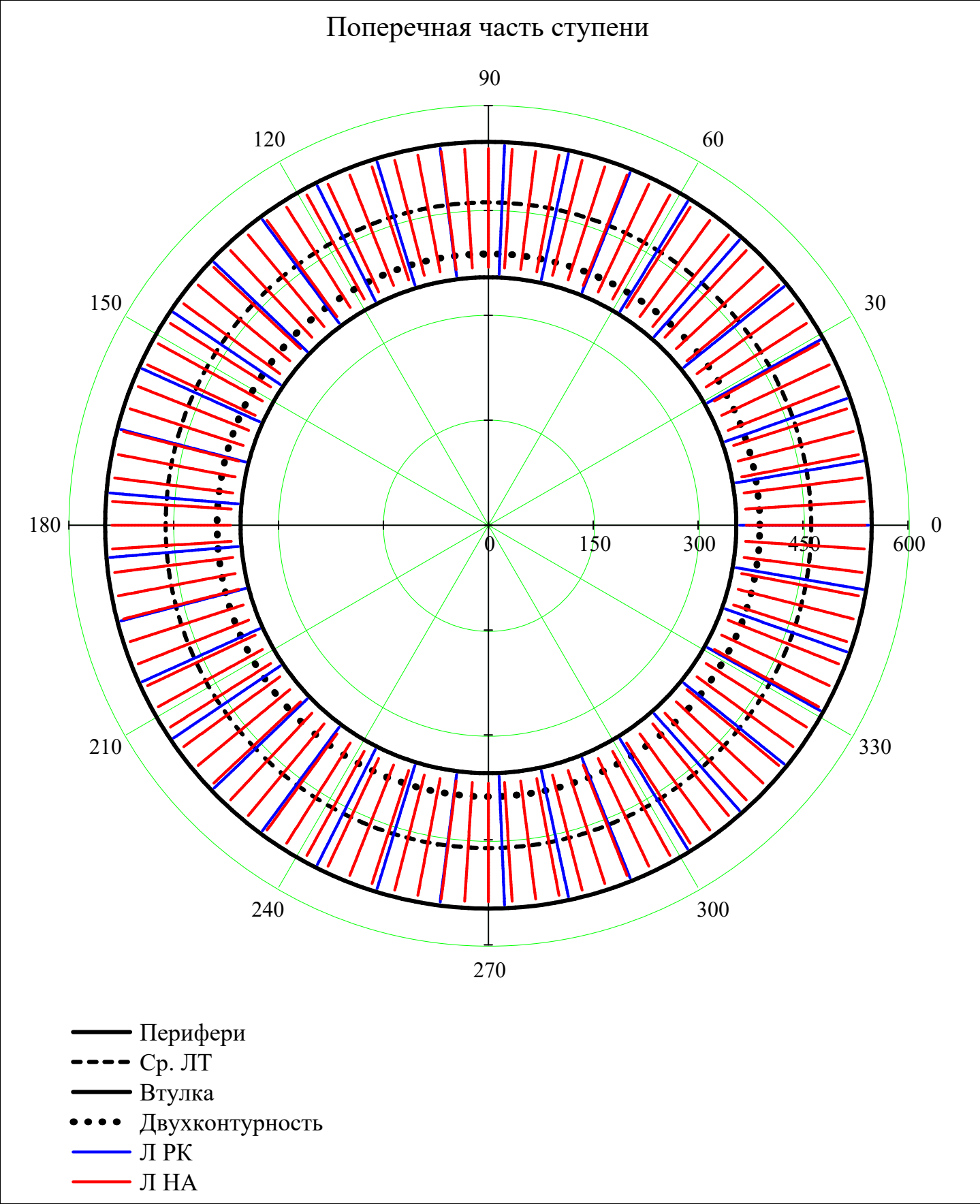
$$i_{\text{rotor}} = 1 \dots Z_{\text{rotor}_j}$$

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

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

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





Запас по температуре (K):

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

Выбранный материал Л:

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

"ЖС-6К" if 1123 ≤ T<sup>\*</sup><sub>st(i, 2), av(N<sub>r</sub>) + ΔT<sub>safety</sub></sub>

"BT41" if 873 ≤ T<sup>\*</sup><sub>st(i, 2), av(N<sub>r</sub>) + ΔT<sub>safety</sub> < 1123</sub>

"BT25" if 753 ≤ T<sup>\*</sup><sub>st(i, 2), av(N<sub>r</sub>) + ΔT<sub>safety</sub> < 873</sub>

"BT9" otherwise

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

"BT23" if compressor = "Бл"

"BT6" if compressor = "КНД"

material\_blade<sub>i</sub> otherwise

Плотность материала Л (кг/м^3):

ρ<sub>blade<sub>i</sub></sub> =

8393 if material\_blade<sub>i</sub> = "ЖС-6К"

7900 if material\_blade<sub>i</sub> = "BT41"

4500 if material\_blade<sub>i</sub> = "BT25"

4570 if material\_blade<sub>i</sub> = "BT23"

4510 if material\_blade<sub>i</sub> = "BT9"

4430 if material\_blade<sub>i</sub> = "BT6"

NaN otherwise

Предел длительной прочности Л РК (Па):

σ<sub>blade\_long<sub>i</sub></sub> = 10<sup>6</sup> ·

125 if material\_blade<sub>i</sub> = "ЖС-6К"

123 if material\_blade<sub>i</sub> = "BT41"

150 if material\_blade<sub>i</sub> = "BT25"

230 if material\_blade<sub>i</sub> = "BT23"

200 if material\_blade<sub>i</sub> = "BT9"

210 if material\_blade<sub>i</sub> = "BT6"

NaN otherwise

Коэф. формы:

$k_n = 6.8$

Модуль Юнга I рода материала Л (Па):

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

Коэф. Пуассона материала Л():

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

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

	1	2	3	4	5	6	7	8	9
1	"BT9"	"BT9"	"BT9"	"BT9"	"BT9"	"BT25"	"BT25"	"BT25"	"BT41"

ρ<sub>blade</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	4510	4510	4510	4510	4510	4500	4500	4500	7900

σ<sub>blade\_long</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	200.0	200.0	200.0	200.0	200.0	150.0	150.0	150.0	123.0

· 10<sup>6</sup>

$\nu_{0\text{изГ.stator}}$  $\nu_{0\text{изГ.rotor}}$

$\nu_{0\text{угЛ.stator}}$  $\nu_{0\text{угЛ.rotor}}$

$\nu_{0\text{угЛ.stator\_bondage}}$  $\nu_{0\text{угЛ.rotor\_bondage}}$

=

for i ∈ 1..Z

for r ∈ av(N<sub>r</sub>)

for mode ∈ 1..6

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

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

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

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

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

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

$\nu_{0\text{изГ.stator}}$  $\nu_{0\text{изГ.rotor}}$

$\nu_{0\text{угЛ.stator}}$  $\nu_{0\text{угЛ.rotor}}$

$\nu_{0\text{угЛ.stator\_bondage}}$  $\nu_{0\text{угЛ.rotor\_bondage}}$

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	1283	1523	1748	1962	2173	2377	2548	2678	2165	1176	1405	1648	1866	2079	2291	2480	2627	2089
2	3849	4568	5245	5887	6519	7131	7643	8034	6495	3529	4214	4945	5597	6238	6872	7439	7881	6267
3	6416	7614	8741	9811	10866	11886	12739	13390	10826	5882	7024	8241	9328	10396	11454	12399	13135	10445
4	8982	10659	12238	13736	15212	16640	17834	18746	15156	8235	9833	11537	13059	14555	16036	17358	18389	14624
5	11548	13705	15734	17661	19558	21394	22930	24102	19486	10588	12643	14834	16791	18713	20617	22318	23643	18802
6	14114	16751	19230	21585	23904	26149	28025	29458	23817	12941	15452	18130	20522	22872	25199	27277	28897	22980

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	302	454	632	777	974	1171	1249	1367	1237	376	485	599	696	803	909	998	1083	894
2	1892	2843	3959	4870	6103	7336	7831	8569	7754	2355	3043	3754	4365	5032	5697	6254	6789	5601
3	5297	7961	11087	13637	17089	20544	21929	23995	21713	6595	8520	10513	12222	14090	15953	17513	19011	15684
4	10388	15611	21743	26744	33513	40287	43004	47056	42581	12934	16709	20617	23968	27631	31286	34344	37281	30757
5	17164	25796	35927	44191	55377	66570	71059	77755	70360	21372	27610	34067	39605	45657	51697	56749	61603	50823
6	25634	38525	53656	65996	82703	99419	106123	116122	105079	31918	41234	50877	59148	68187	77206	84752	92000	75901

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	2566	3046	3496	3925	4346	4754	5096	5356	4330	2353	2809	3296	3731	4159	4582	4960	5254	4178
2	5132	6091	6993	7849	8692	9509	10191	10712	8661	4706	5619	6593	7462	8317	9163	9919	10508	8356
3	7699	9137	10489	11774	13039	14263	15287	16068	12991	7059	8428	9889	11194	12476	13745	14879	15762	12535
4	10265	12182	13986	15698	17385	19017	20382	21424	17321	9411	11238	13186	14925	16634	18327	19838	21016	16713
5	12831	15228	17482	19623	21731	23771	25478	26780	21652	11764	14047	16482	18656	20793	22908	24798	26270	20891
6	15397	18273	20979	23547	26077	28526	30573	32136	25982	14117	16857	19778	22387	24951	27490	29757	31525	25069



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	$\left( \rho_{\text{blade}_i} \cdot \omega^2 \quad R0_{\text{rotor}}(i,z) \right)$

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

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



[illegible]

$$\begin{aligned}
W_{p_{\text{rotor.}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{rotor.}}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{rotor.}}}, i, i, 1, N_r\right)^T, z\right) \\
W_{p_{\text{stator.}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{stator.}}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(W_{p_{\text{stator.}}}, i, i, 1, N_r\right)^T, z\right) \\
M\tau_{\text{rotor}}(i,z) &= \int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,1), N_r}, R_{\text{st}(i,2), N_r}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,2), N_r}, R_{\text{st}(i,3), N_r}\right) & \text{if type="turbine"} \end{cases} \left(q_{x_{\text{rotor}}}(i,z1) \cdot CP_{y_{\text{rotor.axis}}}(i,z1) - q_{y_{\text{rotor}}}(i,z1) \cdot CP_{x_{\text{rotor.axis}}}(i,z1)\right) dz1 \\
M\tau_{\text{stator}}(i,z) &= \int_z \begin{cases} \text{mean}\left(R_{\text{st}(i,2), 1}, R_{\text{st}(i,3), 1}\right) & \text{if type="compressor"} \\ \text{mean}\left(R_{\text{st}(i,1), 1}, R_{\text{st}(i,2), 1}\right) & \text{if type="turbine"} \end{cases} \left(q_{x_{\text{stator}}}(i,z1) \cdot CP_{y_{\text{stator.axis}}}(i,z1) - q_{y_{\text{stator}}}(i,z1) \cdot CP_{x_{\text{stator.axis}}}(i,z1)\right) dz1 \\
\tau_{\text{rotor}}(i,z) &= \frac{M\tau_{\text{rotor}}(i,z)}{W_{p_{\text{rotor.}}}(i,z)} \\
\tau_{\text{stator}}(i,z) &= \frac{M\tau_{\text{stator}}(i,z)}{W_{p_{\text{stator.}}}(i,z)} \\
\varphi_{uv_{\text{rotor}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{rotor}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{rotor}}, i, i, 1, N_r\right)^T, z\right) \\
\varphi_{uv_{\text{stator}}}(i,z) &= \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{stator}}, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, \text{st}(i,2), \text{st}(i,2), 1, N_r\right)^T, \text{submatrix}\left(\frac{\pi}{2} - v_{\text{stator}}, i, i, 1, N_r\right)^T, z\right) \\
Mu_{\text{rotor}}(i,z) &= \text{axis}_x\left(Mx_{\text{rotor}}(i,z), My_{\text{rotor}}(i,z), 0, 0, \varphi_{uv_{\text{rotor}}}(i,z), 1\right) \\
Mu_{\text{stator}}(i,z) &= \text{axis}_x\left(Mx_{\text{stator}}(i,z), My_{\text{stator}}(i,z), 0, 0, \varphi_{uv_{\text{stator}}}(i,z), 1\right) \\
Mv_{\text{rotor}}(i,z) &= \text{axis}_y\left(Mx_{\text{rotor}}(i,z), My_{\text{rotor}}(i,z), 0, 0, \varphi_{uv_{\text{rotor}}}(i,z), 1\right) \\
Mv_{\text{stator}}(i,z) &= \text{axis}_y\left(Mx_{\text{stator}}(i,z), My_{\text{stator}}(i,z), 0, 0, \varphi_{uv_{\text{stator}}}(i,z), 1\right) \\
\varphi_{\text{neutral}_{\text{rotor}}}(i,z) &= \begin{cases} \text{atan}\left(\frac{Mv_{\text{rotor}}(i,z) \cdot Ju_{\text{rotor.}}(i,z)}{Mu_{\text{rotor}}(i,z) \cdot Jv_{\text{rotor.}}(i,z)}\right) & \text{if } Mu_{\text{rotor}}(i,z) \cdot Jv_{\text{rotor.}}(i,z) \neq 0 \\ \frac{\pi}{2} & \text{otherwise} \end{cases} \\
\varphi_{\text{neutral}_{\text{stator}}}(i,z) &= \begin{cases} \text{atan}\left(\frac{Mv_{\text{stator}}(i,z) \cdot Ju_{\text{stator.}}(i,z)}{Mu_{\text{stator}}(i,z) \cdot Jv_{\text{stator.}}(i,z)}\right) & \text{if } Mu_{\text{stator}}(i,z) \cdot Jv_{\text{stator.}}(i,z) \neq 0 \\ \frac{\pi}{2} & \text{otherwise} \end{cases} \\
\left( \begin{array}{cc} R0_{\text{rotor}} & \text{area}0_{\text{rotor}} \\ N0_{\text{rotor}} & \sigma0\_z_{\text{rotor}} \\ \text{area}_{\text{rotor.}} & \text{area}_{\text{stator.}} \\ N_{\text{rotor}} & \sigma\_Z_{\text{rotor}} \end{array} \right)
\end{aligned}$$

	$P_1$	$\rho_1$
	$P_2$	$\rho_2$
	$P_3$	$\rho_3$
	$c_{a1}$	$c_{u1}$
	$c_{a2}$	$c_{u2}$
	$c_{a3}$	$c_{u3}$
	$q_{x_{rotor}}$	$q_{x_{stator}}$
	$q_{y_{rotor}}$	$q_{y_{stator}}$
	$M_{x_{rotor}}$	$M_{x_{stator}}$
	$M_{y_{rotor}}$	$M_{y_{stator}}$
	$shift\_x_{rotor}$	$shift\_y_{rotor}$
	$x0_{rotor.}$	$x0_{stator.}$
	$y0_{rotor.}$	$y0_{stator.}$
	$\alpha\_major_{rotor.}$	$\alpha\_major_{stator.}$
	$J_{u_{rotor.}}$	$J_{u_{stator.}}$
	$J_{v_{rotor.}}$	$J_{v_{stator.}}$
	$CP_{x_{rotor.}}$	$CP_{x_{stator.}}$
	$CP_{y_{rotor.}}$	$CP_{y_{stator.}}$
	$CP_{x_{rotor.axis}}$	$CP_{x_{stator.axis}}$
	$CP_{y_{rotor.axis}}$	$CP_{y_{stator.axis}}$
	$W_{p_{rotor.}}$	$W_{p_{stator.}}$
	$M\tau_{rotor}$	$M\tau_{stator}$
	$\tau_{rotor}$	$\tau_{stator}$
	$\varphi_{uv_{rotor}}$	$\varphi_{uv_{stator}}$
	$M_u_{rotor}$	$M_u_{stator}$
	$M_v_{rotor}$	$M_v_{stator}$
	$\varphi\_neutral_{rotor}$	$\varphi\_neutral_{stator}$

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

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



Наиболее удаленные точки от НЛ (мм):

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	1	2	3	4	5	6	7	8	9
1	-2.510	-2.054	-2.085	-2.115	-2.132	-1.606	-2.172	-2.185	-2.192
2	-1.351	-1.351	-1.350	-1.351	-1.351	-1.353	-1.355	-1.357	-1.358
3	-1.523	-1.522	-0.815	-0.815	-0.815	-0.815	-1.522	-1.523	-1.523

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	1	2	3	4	5	6	7	8	9
1	29.481	29.600	29.637	28.585	27.516	-14.296	-9.934	-9.382	-8.834
2	-19.718	-20.351	-20.984	-20.984	-20.983	-20.350	-18.451	-17.185	-16.552
3	-18.470	-22.001	-23.413	-23.413	-23.413	-23.413	-21.295	-19.883	-19.882

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	1	2	3	4	5	6	7	8	9
1	0.206	0.209	-1.564	-1.570	-1.618	-1.584	-1.326	-1.146	-1.070
2	-0.017	-0.012	-0.005	-0.005	-0.002	-0.003	-0.012	-0.018	-0.020
3	-0.012	-0.006	0.003	0.004	0.007	0.007	-0.004	-0.011	-0.015

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	1	2	3	4	5	6	7	8	9
1	12.342	12.334	-2.137	-2.146	-2.210	-2.164	-1.812	-1.567	-1.464
2	13.698	13.687	13.670	13.669	13.663	13.665	13.687	13.700	13.705
3	14.813	14.801	14.782	14.780	14.774	14.775	14.798	14.811	14.817

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	1	2	3	4	5	6	7	8	9
1	4.237	4.076	4.019	3.929	3.875	3.807	3.694	3.622	3.587
2	1.901	1.915	1.939	1.928	1.923	1.904	1.851	1.812	1.799
3	1.203	1.260	1.288	1.289	1.293	1.287	1.254	1.229	1.225

10<sup>-3</sup>

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	1	2	3	4	5	6	7	8	9
1	-5.196	-4.168	-3.793	-3.326	-3.071	-2.850	-2.880	-2.923	-2.948
2	-1.511	-1.528	-1.556	-1.547	-1.544	-1.528	-1.489	-1.471	-1.468
3	-0.990	-1.025	-1.053	-1.055	-1.060	-1.054	-1.023	-1.005	-1.004

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	1	2	3	4	5	6	7	8	9
1	0.766	0.804	10.237	10.237	10.240	10.238	10.225	10.217	10.214
2	1.085	1.133	1.203	1.208	1.227	1.218	1.132	1.070	1.041
3	1.433	1.483	1.559	1.568	1.590	1.583	1.497	1.433	1.403

10<sup>-3</sup>

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	1	2	3	4	5	6	7	8	9
1	-1.735	-1.904	-12.327	-12.327	-12.324	-12.326	-12.341	-12.351	-12.354
2	-1.873	-2.090	-2.405	-2.428	-2.513	-2.477	-2.087	-1.814	-1.692
3	-1.994	-2.222	-2.567	-2.607	-2.708	-2.684	-2.287	-2.005	-1.872

10<sup>-3</sup>

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

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

$$\sigma_{\text{protor}}^{\text{T}}$$

$\cdot 10^6 \text{ } \sigma \text{ p}_e$

$\sigma_{\text{piston}}^T$

$\sigma_{\text{Detected}}$

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

$$\sigma_{n_{\text{stator}}}$$

$\sigma_{\text{hydro}}^T$

$\sigma_{\text{net},\text{tot}} = \sigma_{\text{net},\text{tot}}^{\text{net}} + \sigma_{\text{net},\text{tot}}^{\text{ext}}$



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

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

$\sigma_{\text{rotor}}^T =$		1	2	3	4	5	6	7	8	9
	1	178.23	171.81	180.85	187.05	195.55	171.43	171.26	178.96	217.93
	2	131.00	127.56	139.70	149.69	161.90	172.59	160.88	163.99	190.73
	3	5.03	4.08	6.73	5.17	4.15	3.19	2.04	1.34	3.80

$\cdot 10^6$

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

	1	2	3	4	5	6	7	8	9
1	0.81	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	144.85	123.76	125.98	125.75	114.43	97.76	86.81	69.34	52.57
3	268.55	238.86	243.74	245.49	226.20	193.19	165.56	128.17	96.05

$\cdot 10^6$



Рассматриваемая ступень:

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

$$b_{lim} = \frac{ceil\left(\max\left(chord_{rotor_{j,N_r}}, chord_{stator_{j,N_r}}\right) \cdot 10^2\right)}{10^2} = 80 \cdot 10^{-3}$$

Расстояния от оси ЛМ до рассматриваемой ступени (м):

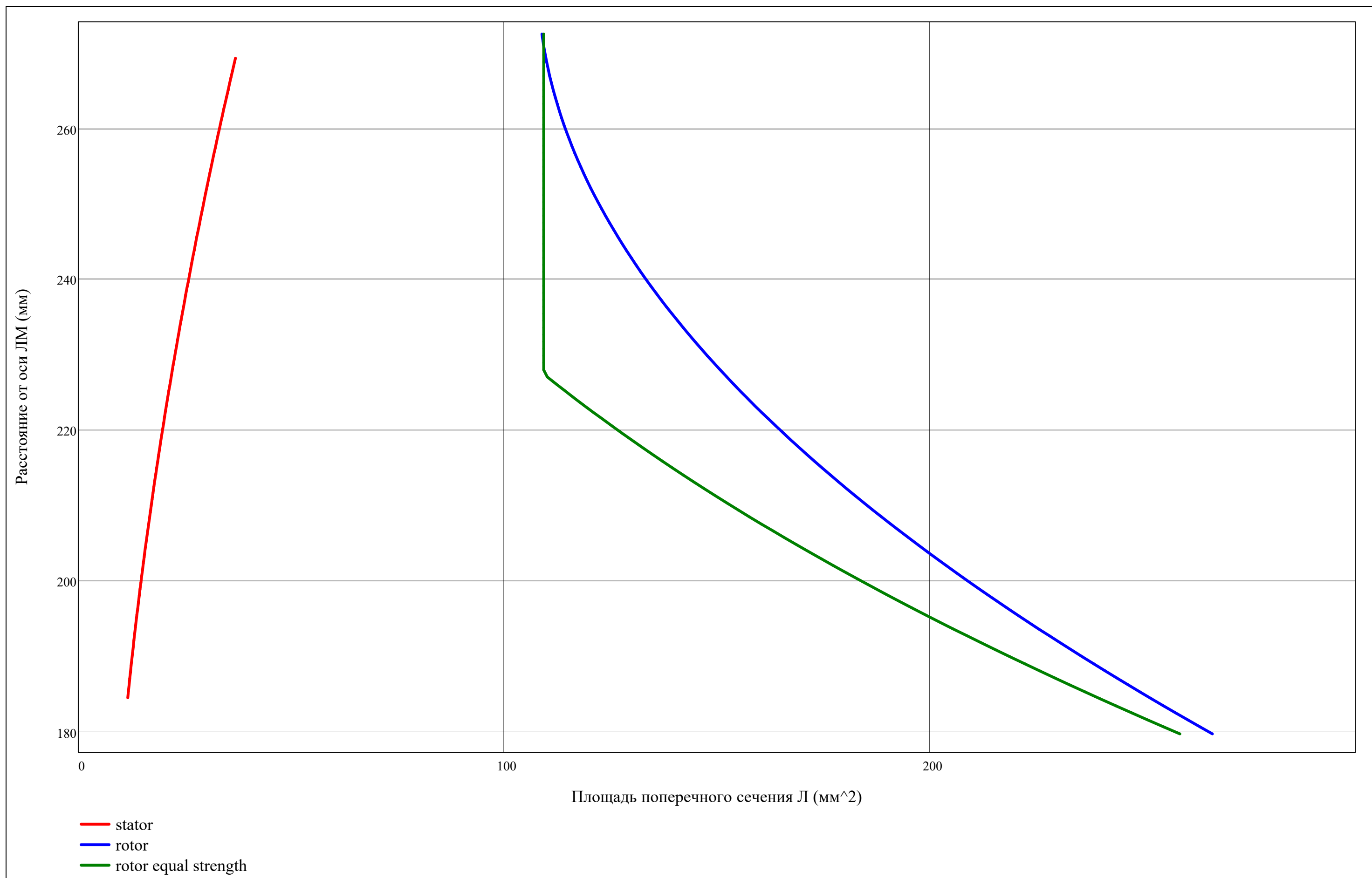
$$R_j = submatrix\left(R, 2 \cdot j - 1, 2 \cdot j + 1, 1, N_r\right) = \begin{array}{|c|c|c|c|} \hline & 1 & 2 & 3 \\ \hline 1 & 177.3 & 230.8 & 274.1 \\ \hline 2 & 182.2 & 230.8 & 270.8 \\ \hline 3 & 186.8 & 230.8 & 267.7 \\ \hline \end{array} \cdot 10^{-3}$$

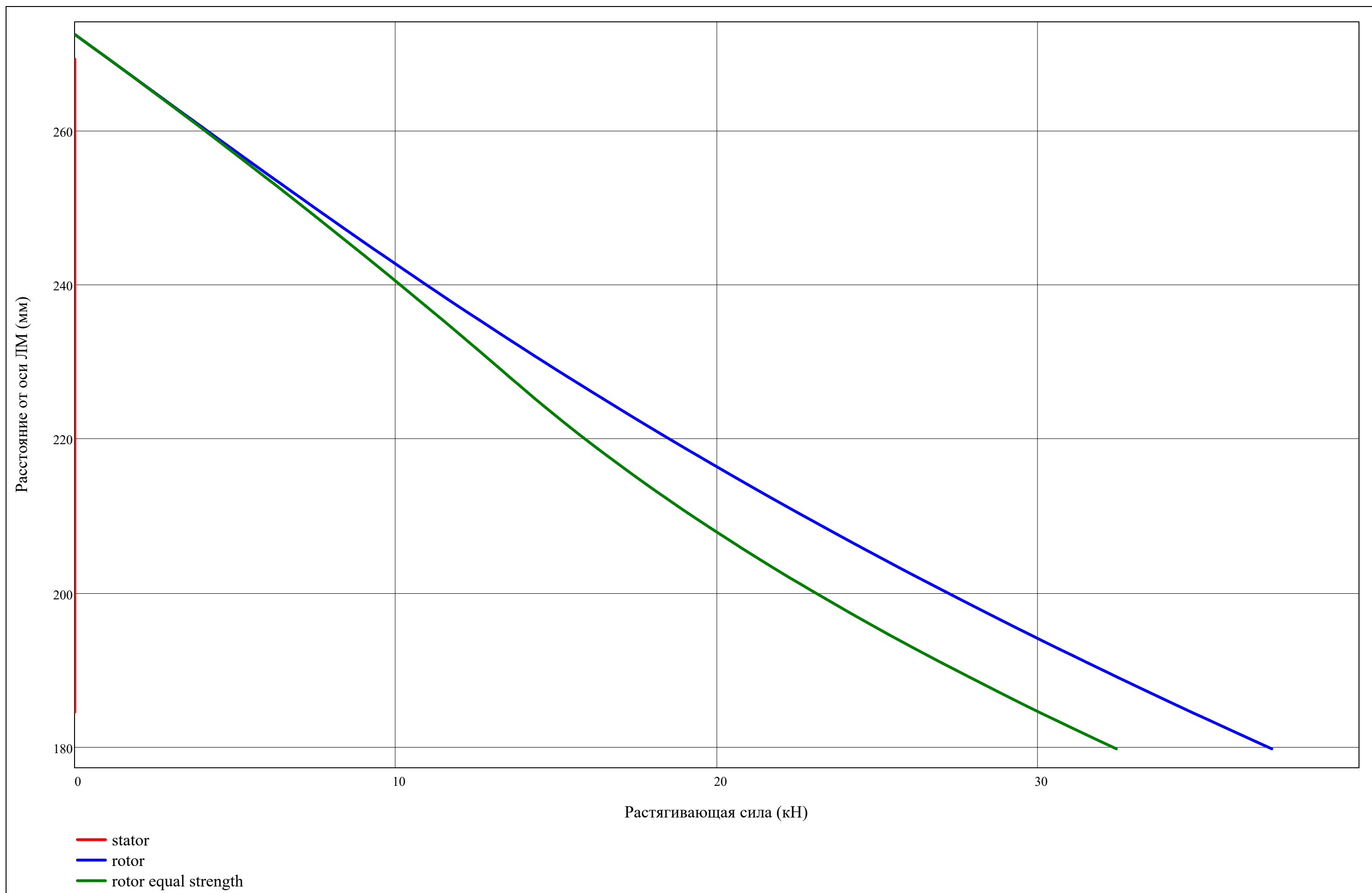
Дискретизация по высоте Л:

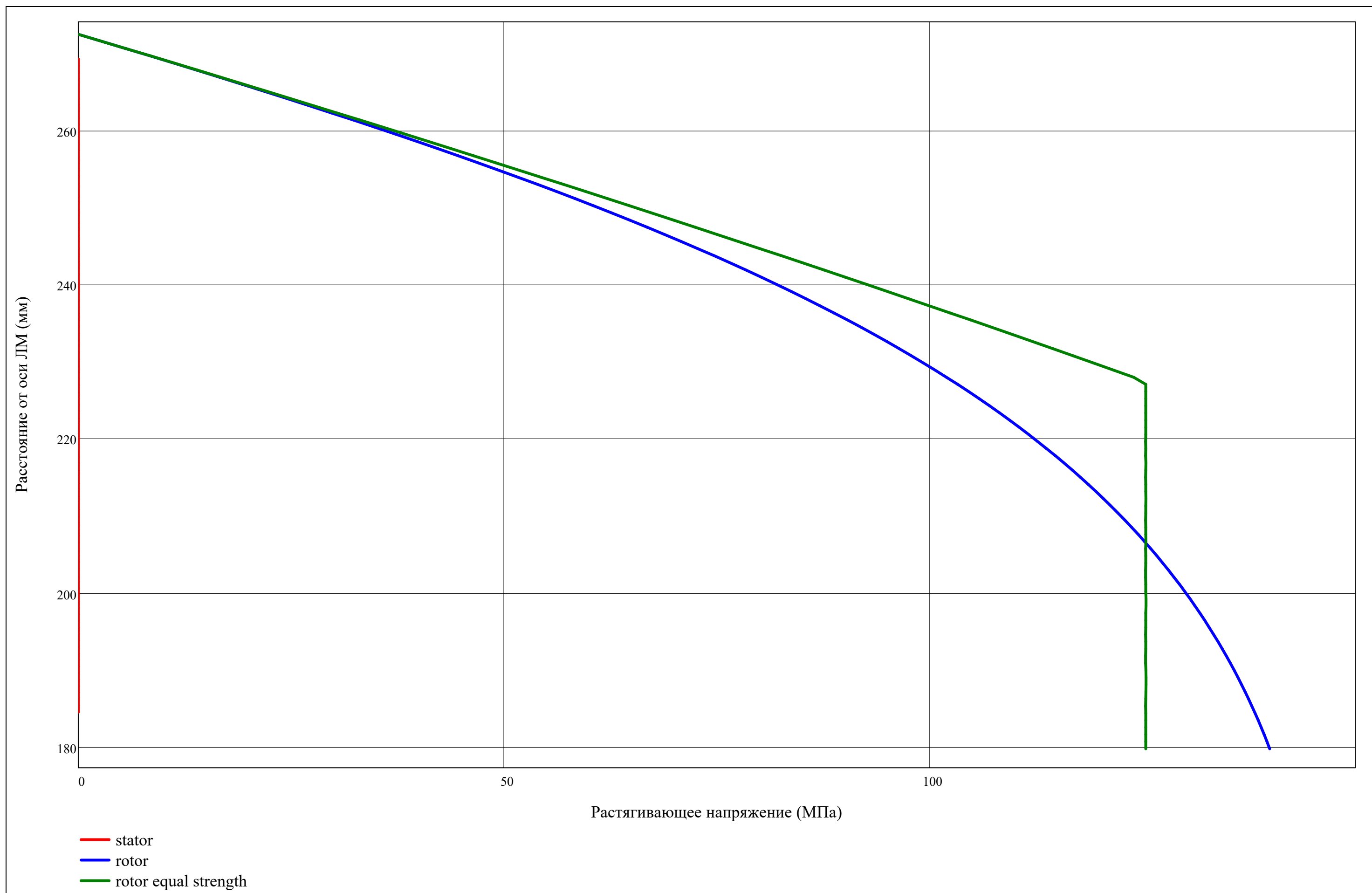
$$z = \min(R_j), \min(R_j) + \frac{\max(R_j) - \min(R_j)}{100} .. \max(R_j)$$

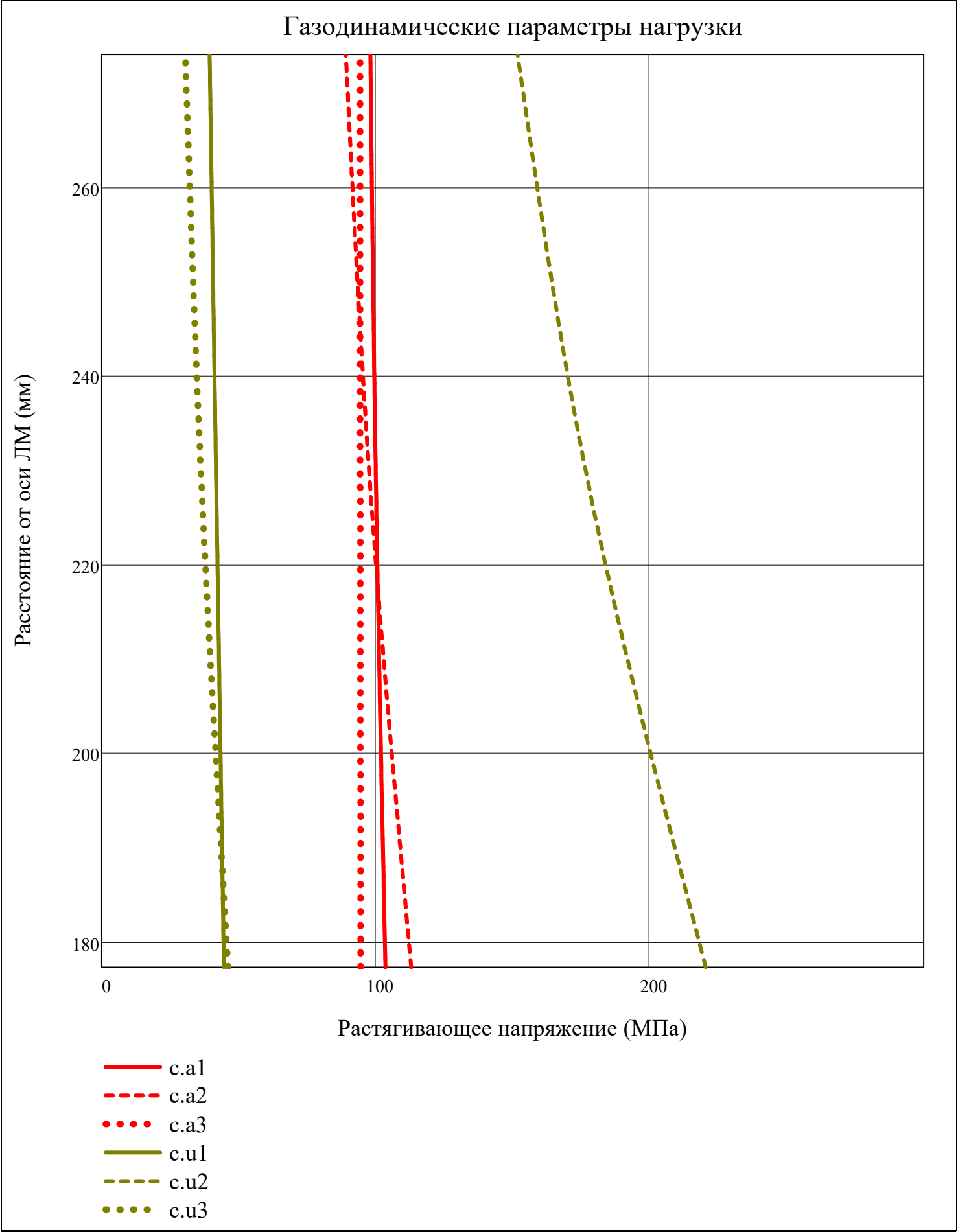
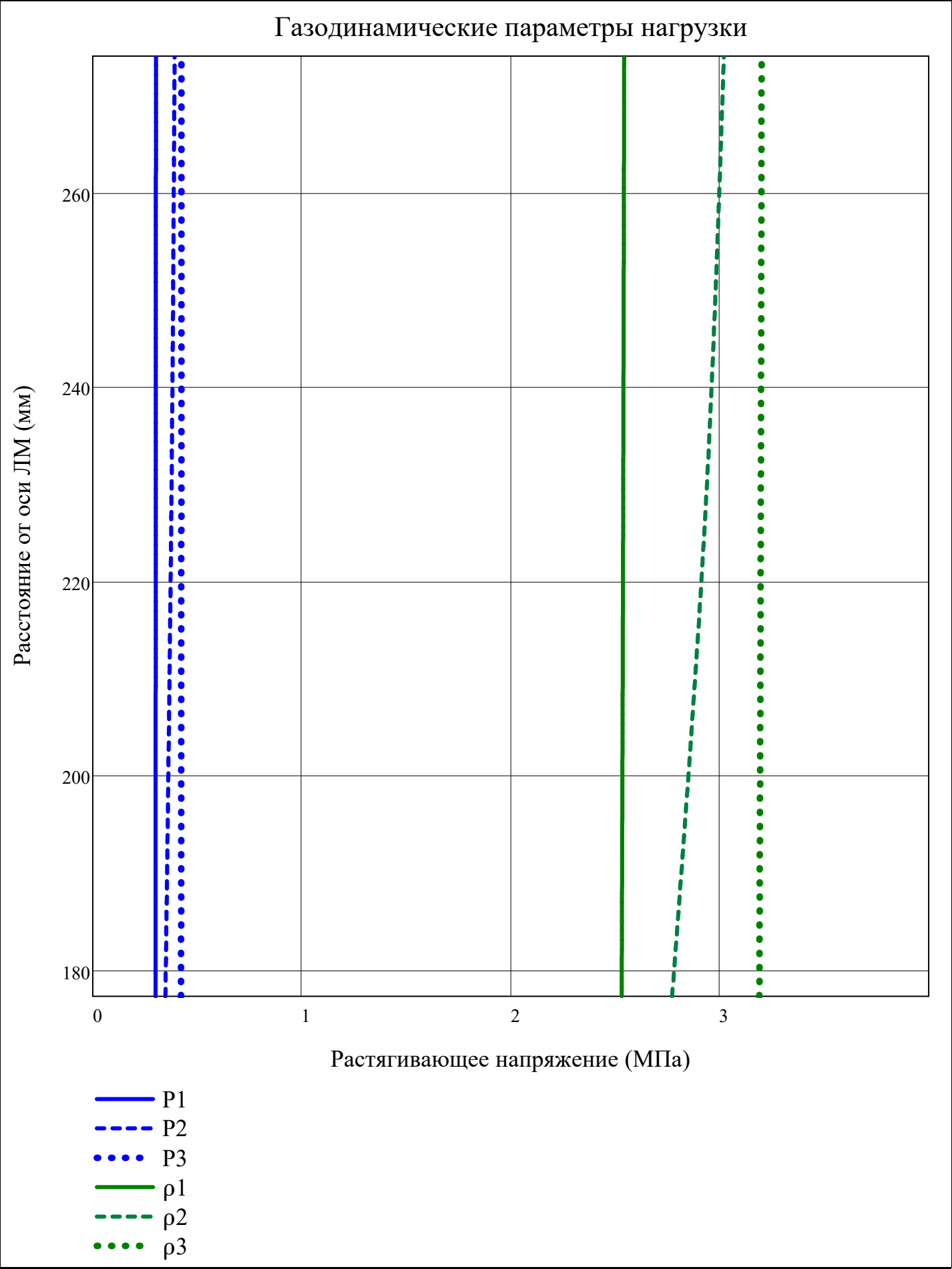
$$z_{rotor} = \left\{ \begin{array}{l} \text{mean}\left(R_{j1,1}, R_{j2,1}\right), \text{mean}\left(R_{j1,1}, R_{j2,1}\right) + \frac{\text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) - \text{mean}\left(R_{j1,1}, R_{j2,1}\right)}{100} .. \text{mean}\left(R_{j1,N_r}, R_{j2,N_r}\right) \text{ if type = "compressor"}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

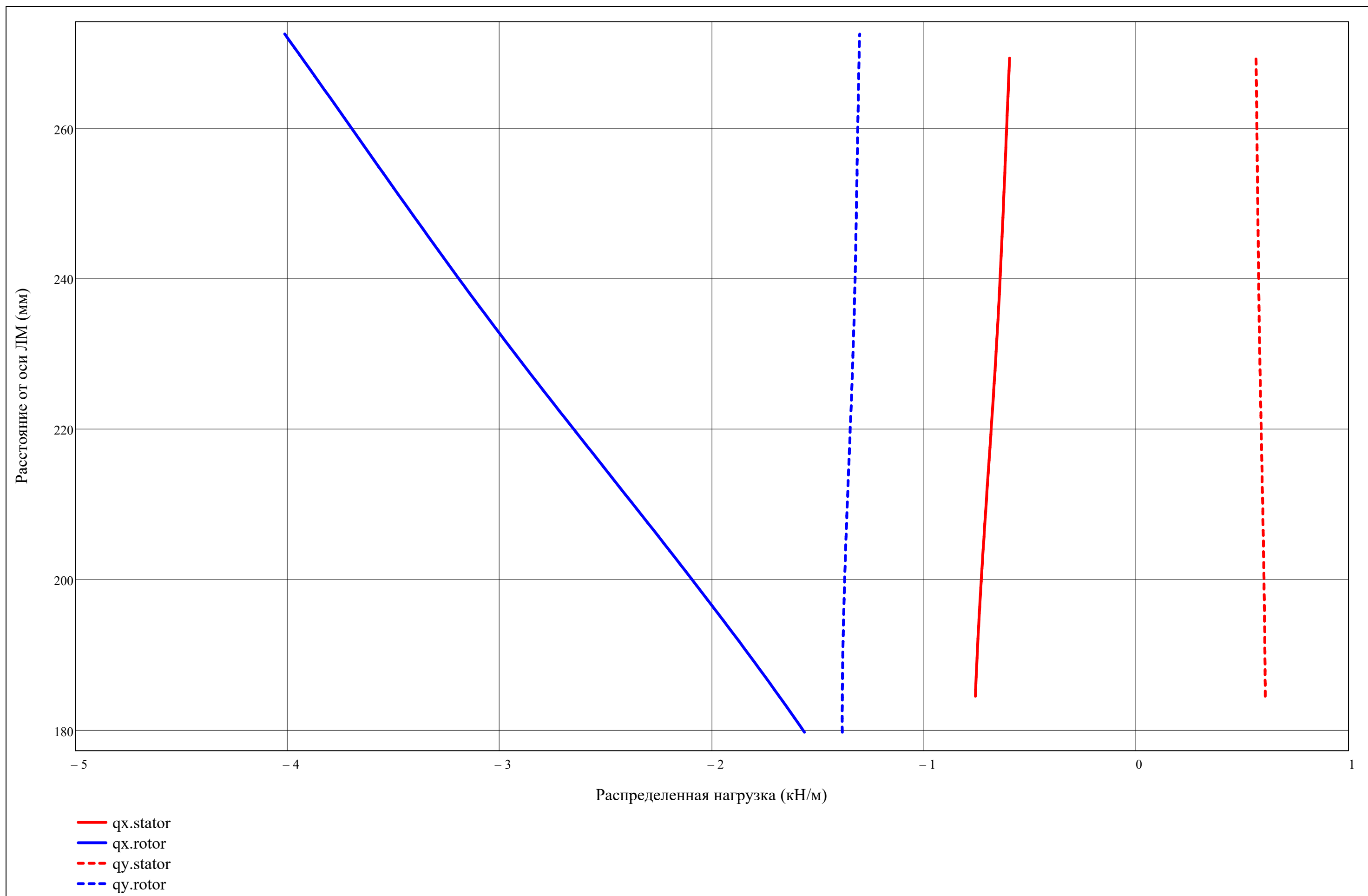
$$z_{stator} = \left\{ \begin{array}{l} \text{mean}\left(R_{j2,1}, R_{j3,1}\right), \text{mean}\left(R_{j2,1}, R_{j3,1}\right) + \frac{\text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) - \text{mean}\left(R_{j2,1}, R_{j3,1}\right)}{100} .. \text{mean}\left(R_{j2,N_r}, R_{j3,N_r}\right) \text{ if type = "compressor"}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



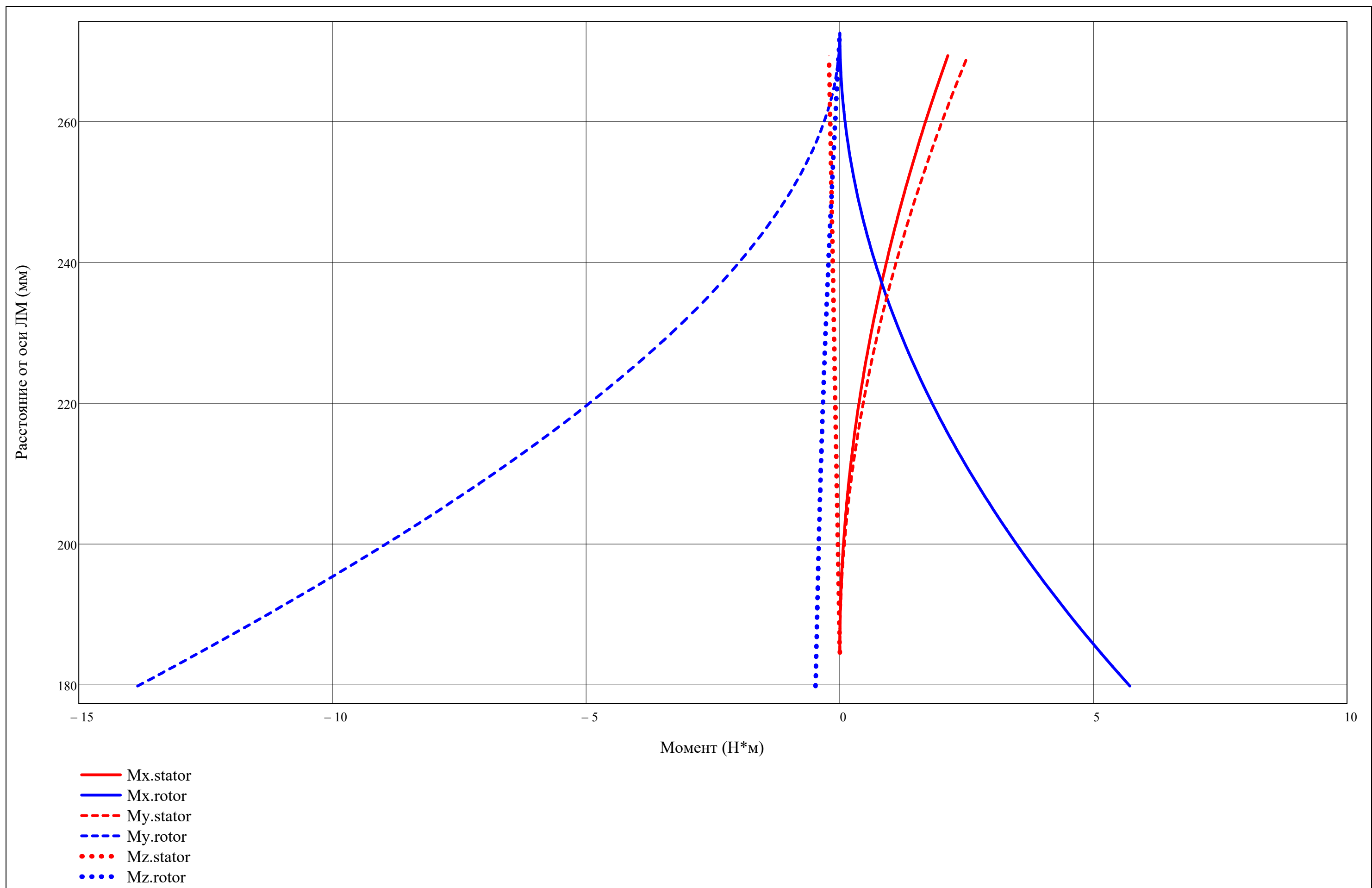


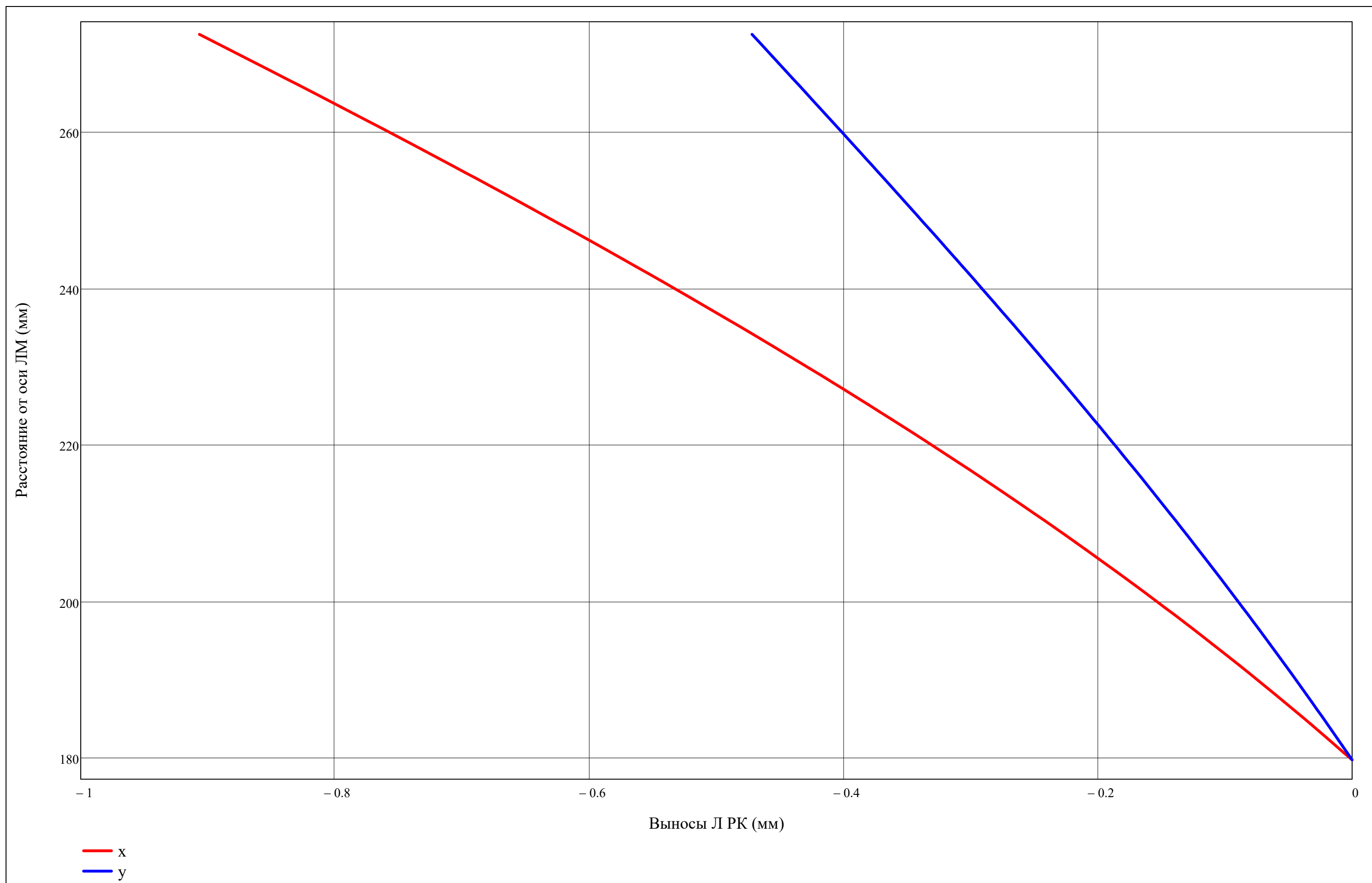


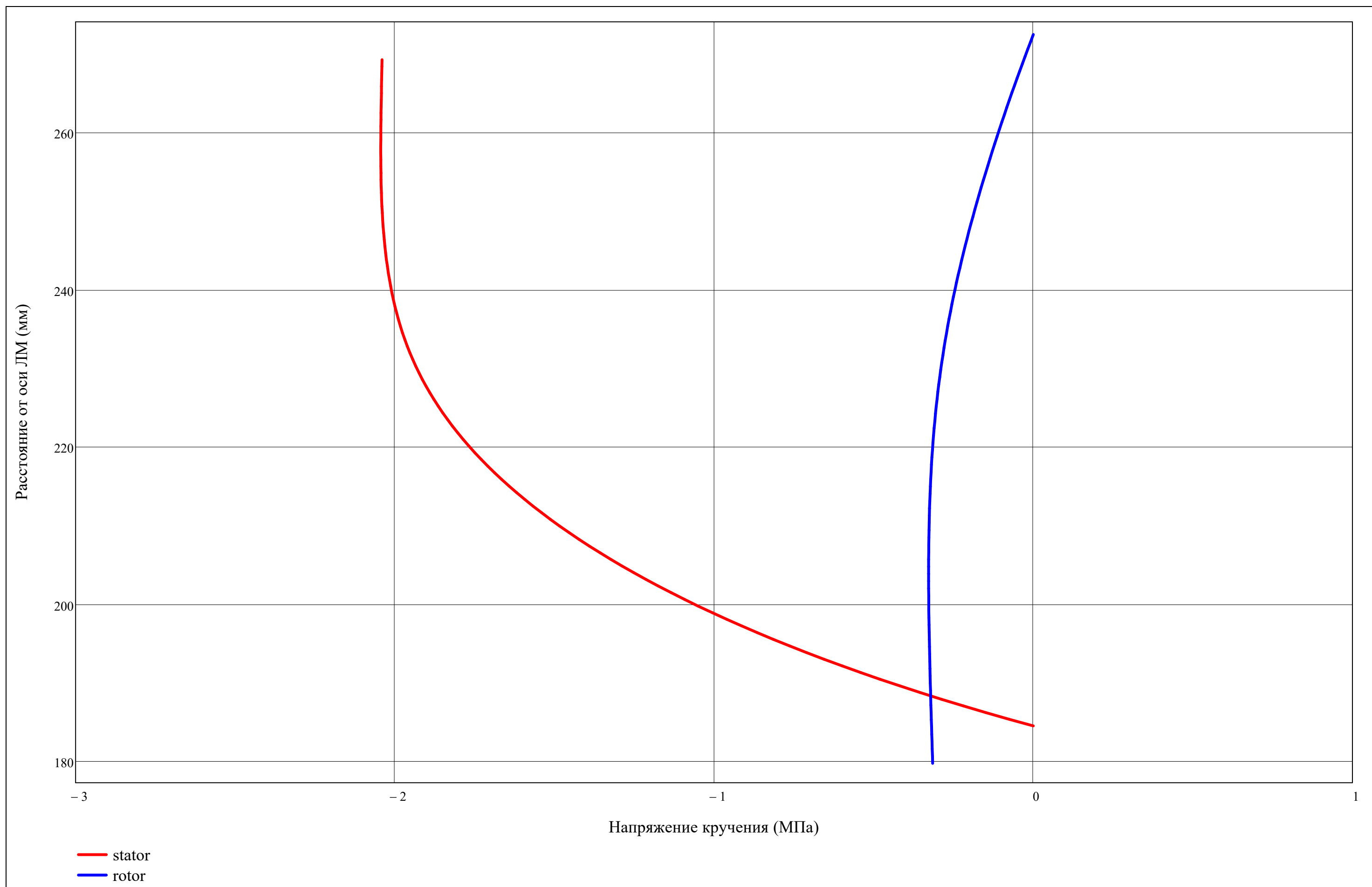


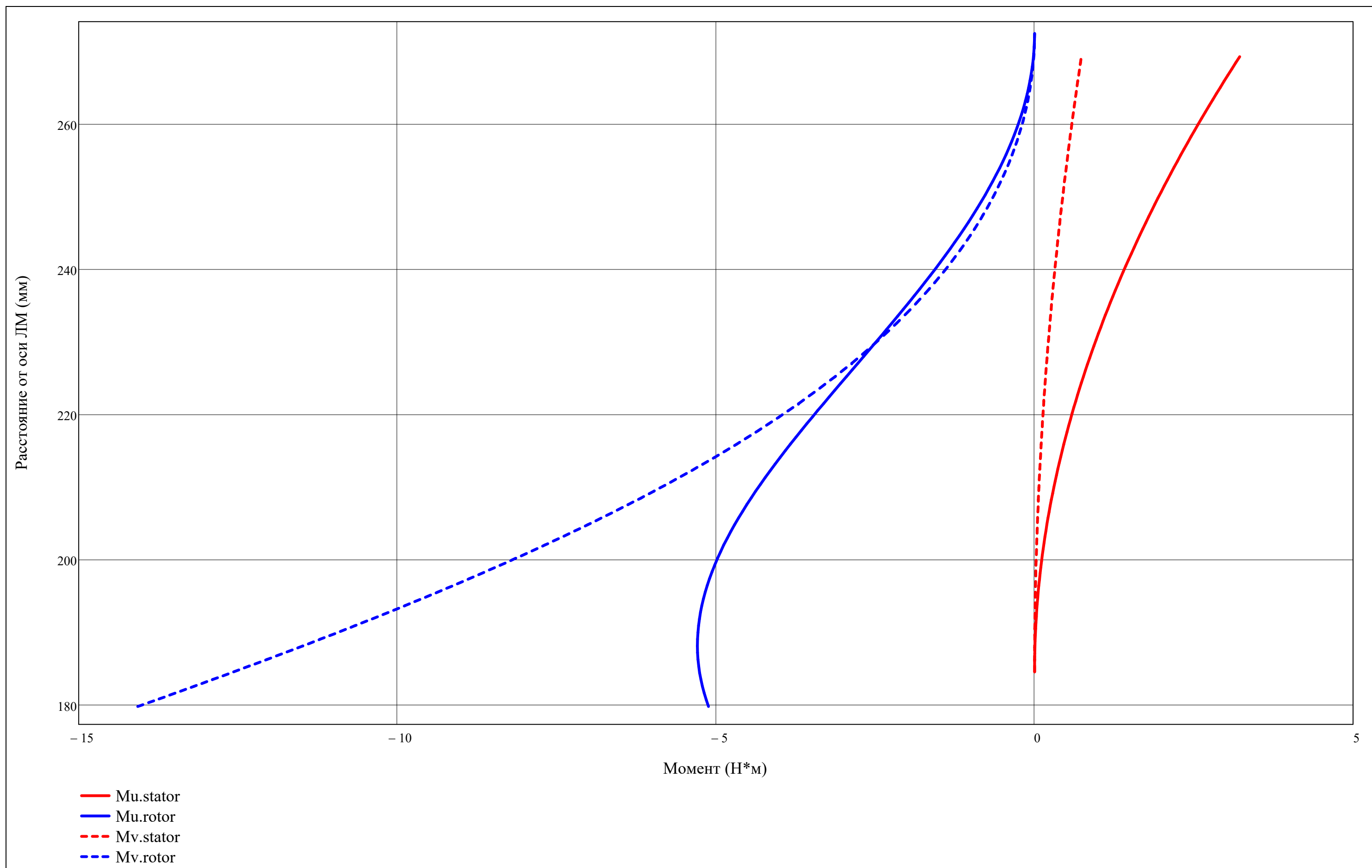


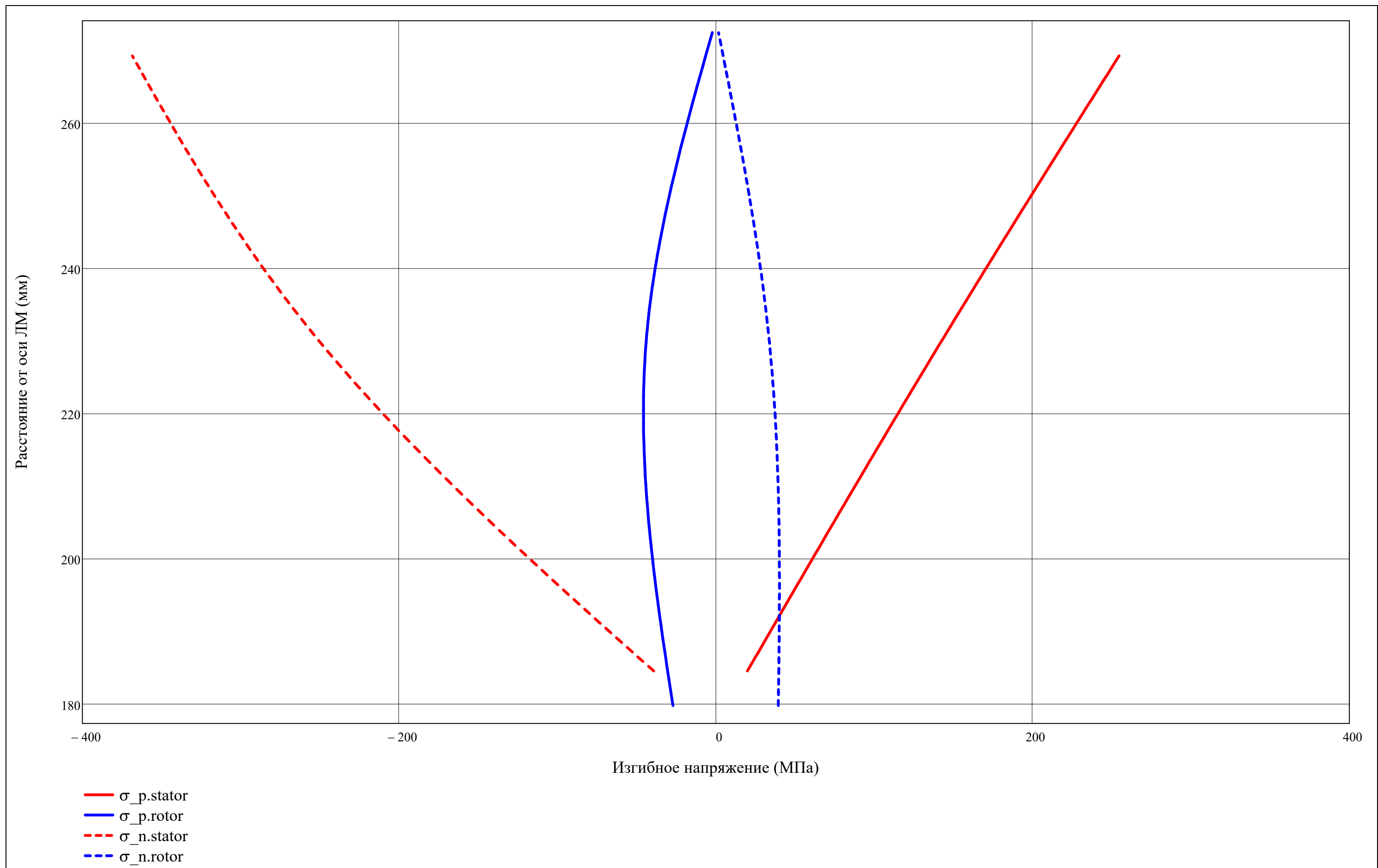


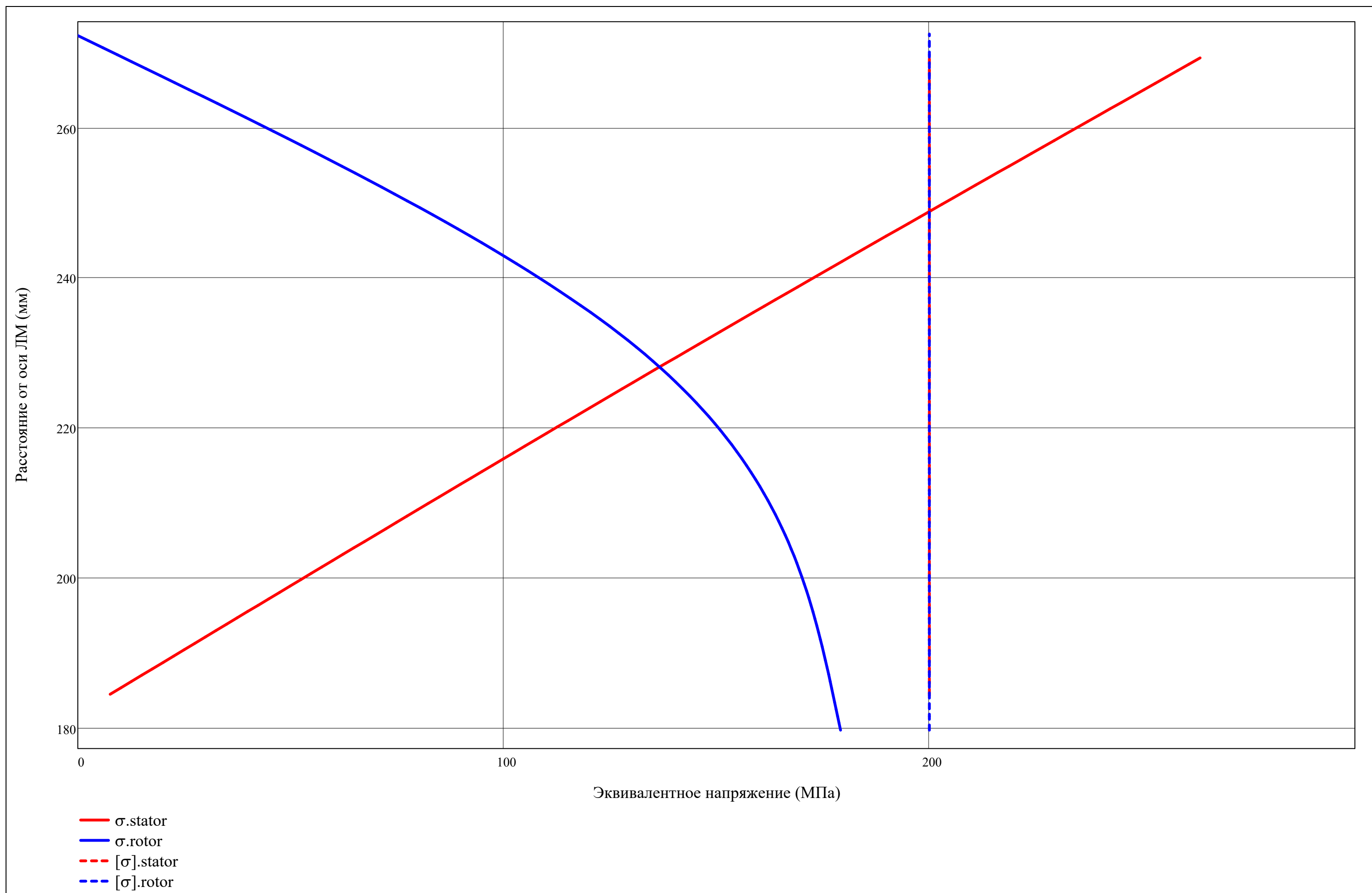










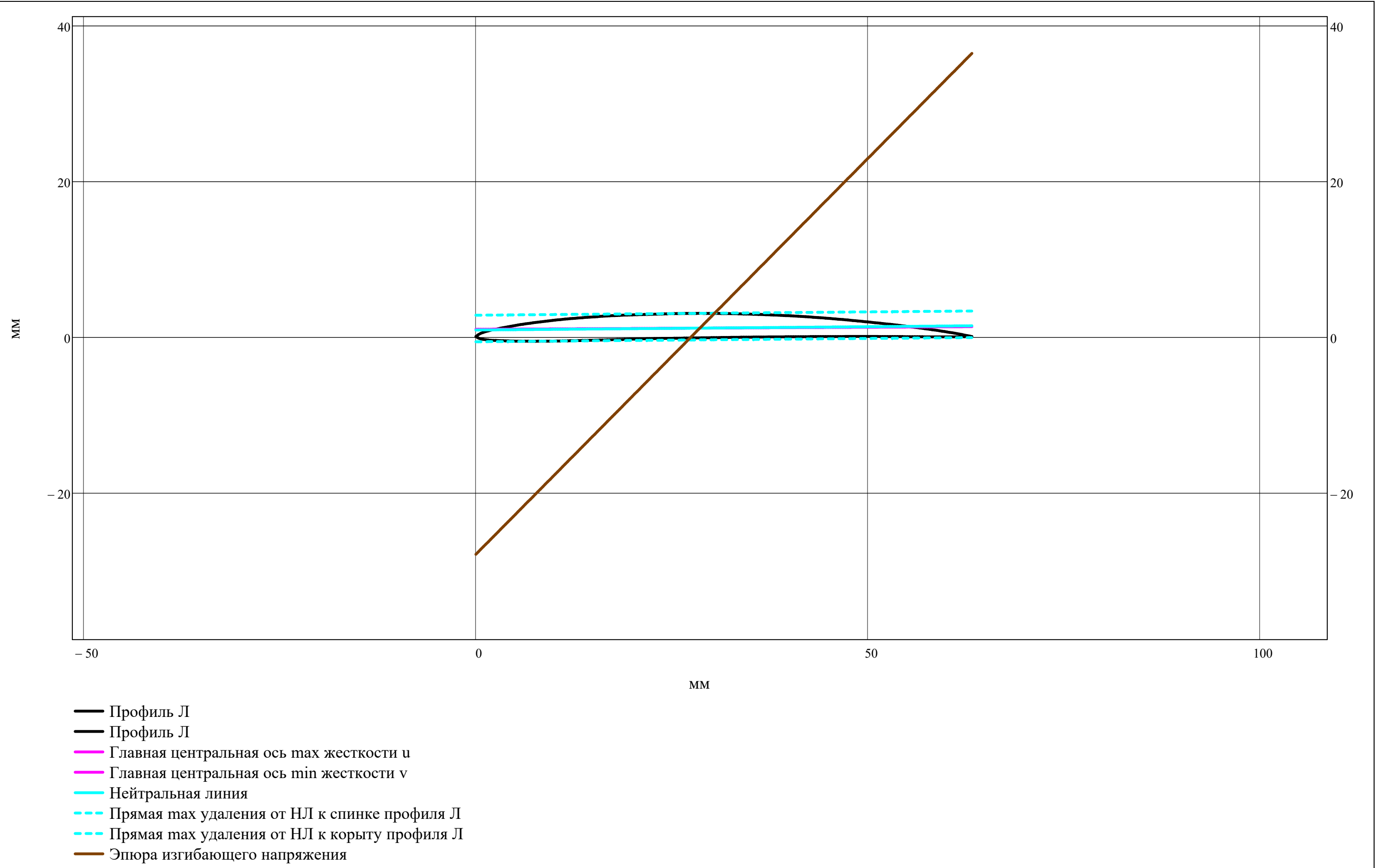


$$\begin{pmatrix} \text{blade} \\ \text{r} \end{pmatrix} = \begin{pmatrix} \text{"rotor"} \\ 2 \end{pmatrix}$$

$$\begin{pmatrix} \text{v\_p} \\ \text{v\_n} \end{pmatrix} = \begin{cases} \begin{pmatrix} \text{v\_u}_{\text{rotor}_{\text{j},\text{r}}} \\ \text{v\_l}_{\text{rotor}_{\text{j},\text{r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} \text{v\_u}_{\text{stator}_{\text{j},\text{r}}} \\ \text{v\_l}_{\text{stator}_{\text{j},\text{r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.901 \\ \hline 2 & -1.511 \\ \hline \end{array} \cdot 10^{-3}$$

$$\begin{pmatrix} \text{x0} \\ \text{y0} \end{pmatrix} = \begin{cases} \begin{pmatrix} \text{x0}_{\text{rotor}_{\text{j},\text{r}}} \\ \text{y0}_{\text{rotor}_{\text{j},\text{r}}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} \text{x0}_{\text{stator}_{\text{j},\text{r}}} \\ \text{y0}_{\text{stator}_{\text{j},\text{r}}} \end{pmatrix} & \text{otherwise} \end{cases} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 28.557 \\ \hline 2 & 1.079 \\ \hline \end{array} \cdot 10^{-3}$$

$$\text{chord} = \begin{cases} \text{chord}_{\text{rotor}_{\text{j},\text{r}}} & \text{if blade = "rotor"} \\ \text{chord}_{\text{stator}_{\text{j},\text{r}}} & \text{if blade = "stator"} \end{cases} = 63 \cdot 10^{-3}$$





Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u_{-u_{\text{rotor}_{j,r}}} & v_{-u_{\text{rotor}_{j,r}}} \\ u_{-l_{\text{rotor}_{j,r}}} & v_{-l_{\text{rotor}_{j,r}}} \\ u_{-u_{\text{stator}_{j,r}}} & v_{-u_{\text{stator}_{j,r}}} \\ u_{-l_{\text{stator}_{j,r}}} & v_{-l_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{array}{|c|c|c|} \hline & 1 & 2 \\ \hline 1 & -1.35 & 1.90 \\ \hline 2 & -19.72 & -1.51 \\ \hline 3 & -0.02 & 1.08 \\ \hline 4 & 13.70 & -1.87 \\ \hline \end{array} \cdot 10^{-3}$$

$$\begin{pmatrix} \sigma_{-p_{\text{rotor}_{j,r}}} & \sigma_{-p_{\text{stator}_{j,r}}} \\ \sigma_{-n_{\text{rotor}_{j,r}}} & \sigma_{-n_{\text{stator}_{j,r}}} \end{pmatrix} = \begin{pmatrix} -43.70 & 144.83 \\ 33.26 & -253.77 \end{pmatrix} \cdot 10^6$$

$$\begin{pmatrix} \sigma_{\text{stator}_{j,r}} \\ \sigma_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{pmatrix} 144.85 \\ 131.00 \end{pmatrix} \cdot 10^6$$

$$\begin{pmatrix} \text{safety}_{\text{stator}_{j,r}} \\ \text{safety}_{\text{rotor}_{j,r}} \end{pmatrix} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.381 \\ \hline 2 & 1.527 \\ \hline \end{array}$$



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):  

ρ<sub>disk<sub>i</sub></sub> = 

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):  

σ<sub>disk\_long<sub>i</sub></sub> = 10<sup>6</sup> · 

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	"BT9"	"BT9"	"BT9"	"BT9"	"BT9"	"BT9"	"BT9"	"BT9"	"BT9"

ρ<sub>disk</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	4510	4510	4510	4510	4510	4510	4510	4510	4510

σ<sub>disk\_long</sub><sup>T</sup> =

	1	2	3	4	5	6	7	8	9
1	200	200	200	200	200	200	200	200	200

· 10<sup>6</sup>

▲ Выбор материала Д

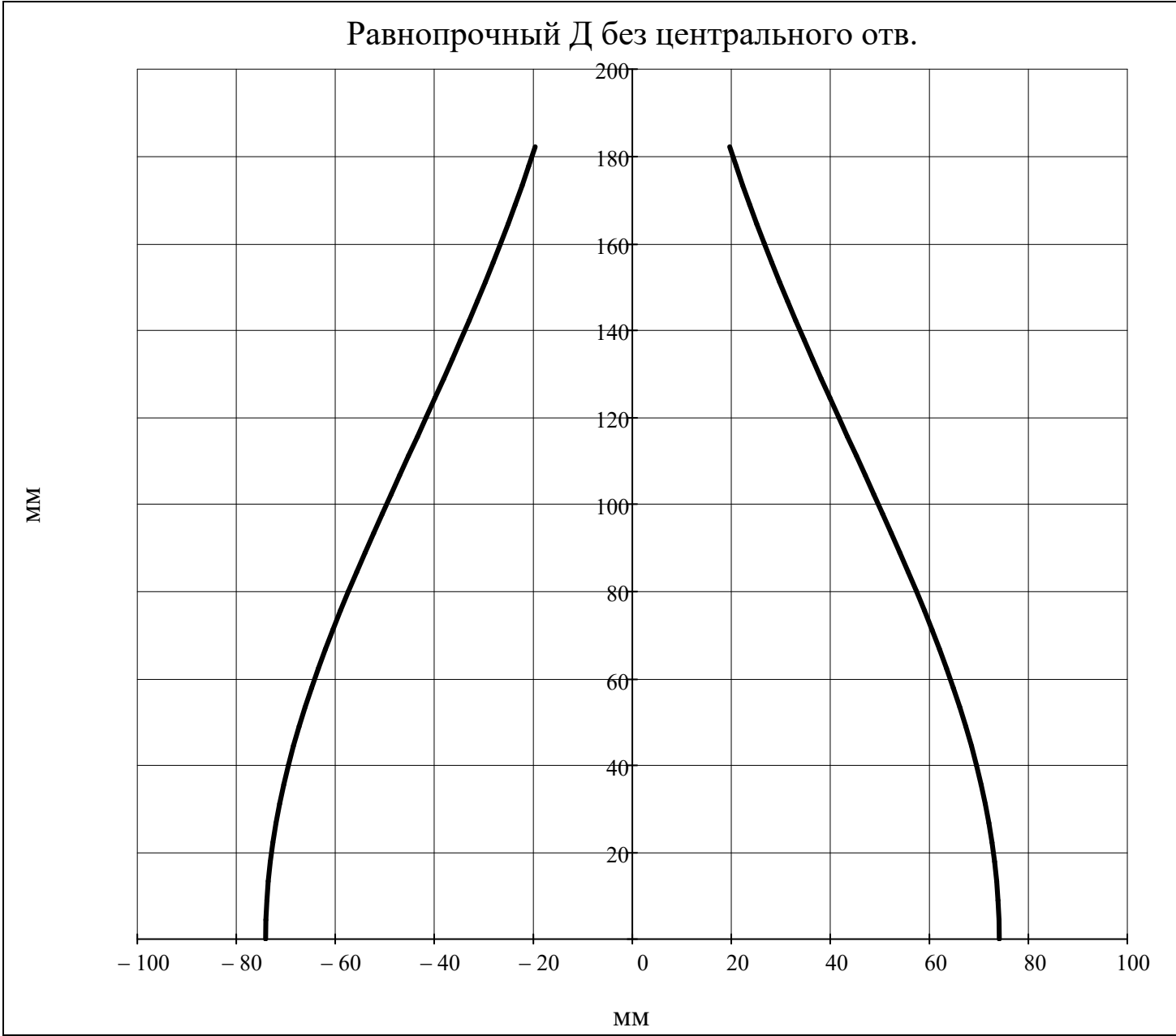
Рассматриваемая ступень:

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

▼ Профилирование равнопрочного Д без центрального отв.

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

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



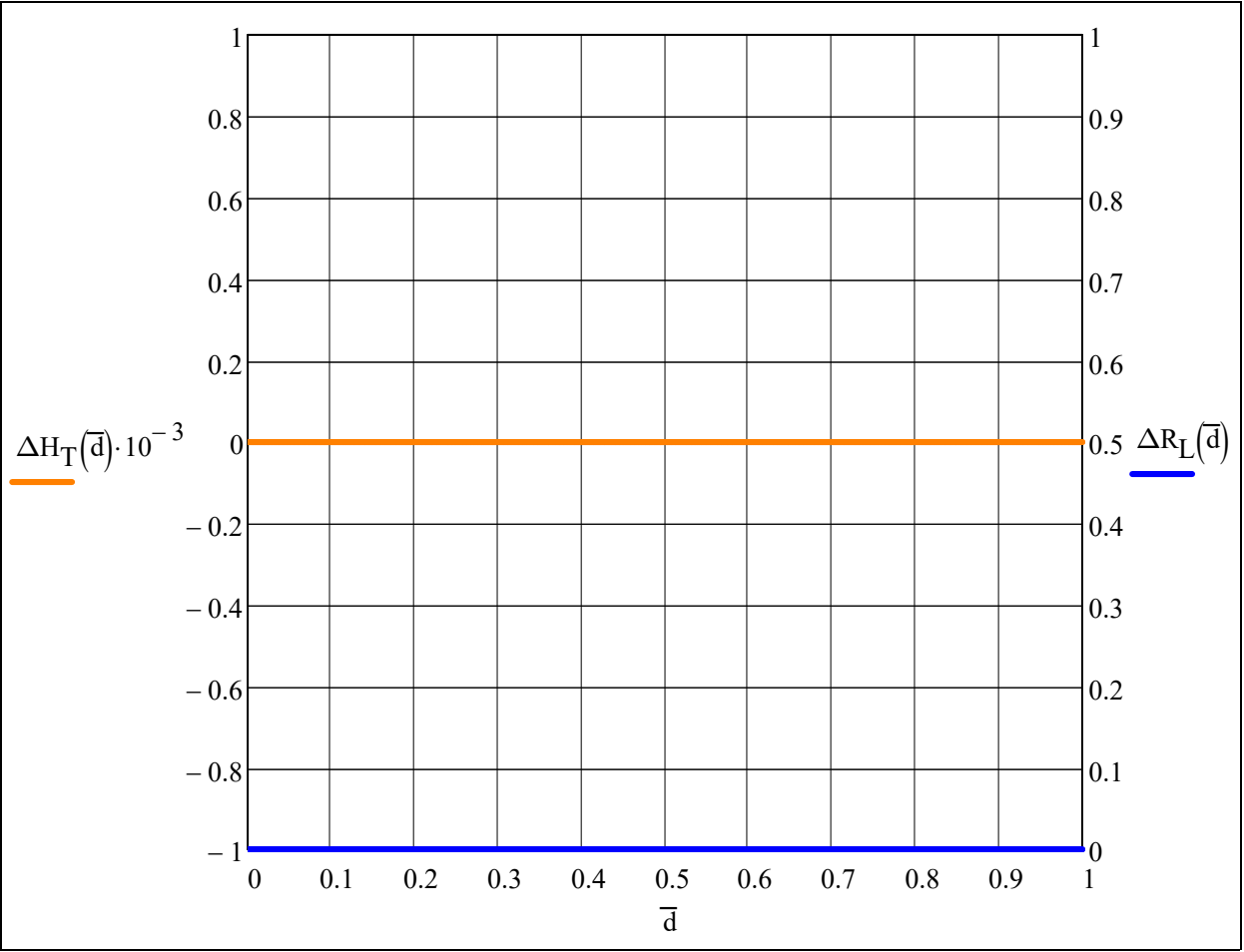
▲ Профилирование равнопрочного Д без центрального отв.

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

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

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

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





$$\begin{pmatrix} c_{\text{st}(\text{j},1),\text{r}} \\ c_{\text{st}(\text{j},2),\text{r}} \\ c_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 112.65 \\ 242.98 \\ 104.19 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{\text{st}(\text{j},1),\text{r}} \\ \alpha_{\text{st}(\text{j},2),\text{r}} \\ \alpha_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 66.71 \\ 27.26 \\ 64.95 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{\text{stator}_{\text{j},\text{r}}} = 38.38 \cdot ^\circ$$

$$\begin{pmatrix} c_{\text{a}_{\text{st}(\text{j},1),\text{r}}} \\ c_{\text{a}_{\text{st}(\text{j},2),\text{r}}} \\ c_{\text{a}_{\text{st}(\text{j},3),\text{r}}} \end{pmatrix} = \begin{pmatrix} 103.47 \\ 111.3 \\ 94.4 \end{pmatrix}$$

$$\begin{pmatrix} u_{\text{st}(\text{j},1),\text{r}} \\ u_{\text{st}(\text{j},2),\text{r}} \\ u_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 278.42 \\ 286.15 \\ 293.41 \end{pmatrix}$$

$$\begin{pmatrix} w_{\text{st}(\text{j},1),\text{r}} \\ w_{\text{st}(\text{j},2),\text{r}} \\ w_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 255.76 \\ 131.57 \\ 266.58 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{\text{st}(\text{j},1),\text{r}} \\ \beta_{\text{st}(\text{j},2),\text{r}} \\ \beta_{\text{st}(\text{j},3),\text{r}} \end{pmatrix} = \begin{pmatrix} 23.86 \\ 57.77 \\ 20.74 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{\text{rotor}_{\text{j},\text{r}}} = 33.91 \cdot ^\circ$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 108.2 \\ 201.04 \\ 100.9 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 67.39 \\ 28.94 \\ 69.13 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{stator_{j,r}} = 37.26 \cdot ^\circ$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 99.89 \\ 97.28 \\ 94.28 \end{pmatrix}$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 362.55 \\ 362.55 \\ 362.55 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 336.14 \\ 210.45 \\ 339.94 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 17.29 \\ 27.53 \\ 16.1 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{rotor_{j,r}} = 10.25 \cdot ^\circ$$



$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 105.56 \\ 177.58 \\ 99.23 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 97.97 \\ 89.56 \\ 94.22 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 403.30 \\ 286.46 \\ 400.56 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 68.13 \\ 30.29 \\ 71.71 \end{pmatrix} \cdot ^\circ$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 430.54 \\ 425.44 \\ 420.47 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 14.06 \\ 18.22 \\ 13.6 \end{pmatrix} \cdot ^\circ$$

$$\epsilon_{stator_{j,r}} = 36.52 \cdot ^\circ$$

$$\epsilon_{rotor_{j,r}} = 4.16 \cdot ^\circ$$

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$$,z)$$

$$)^T,z)$$





$$0^{-3}$$