Исходные данные

Коэф. запаса: $safety = 1.3$

Степень двухконтурности: $m2 = 6$

РТ: Воздух

$compressor = \text{"КВД"}$

Число Маха: $M = 0$

Геометрическая высота работы (м): $H = 0$

Массовый расход (кг/с):
$$G = \begin{cases} 35.65 + 213.93 & \text{if } compressor = \text{"Вл"} \\ 35.65 & \text{if } compressor = \text{"КНД"} \\ 34.81 & \text{if } compressor = \text{"КВД"} \end{cases} = 34.81$$

Полная температура на входе в К (К):
$$T^*_{K1} = \begin{cases} 418.2 & \text{if } compressor = \text{"КВД"} \\ 288.2 & \text{otherwise} \end{cases} = 418.2$$

Полное давление на входе в К (Па):
$$P^*_{K1} = \begin{cases} 316.2 \cdot 10^3 & \text{if } compressor = \text{"КВД"} \\ 101325 & \text{otherwise} \end{cases} = 316.2 \cdot 10^3$$

Степень повышения давления КВД:
$$\pi^*_K = \begin{cases} 1.6 & \text{if } compressor = \text{"Вл"} \\ \frac{3.2}{1.6} & \text{if } compressor = \text{"КНД"} \\ 9 & \text{if } compressor = \text{"КВД"} \end{cases} = 9.000$$

Ожидаемый адиабатический КПД ОК: $\eta^*_K = \begin{vmatrix} 0.86 \text{ if compressor = "Вл"} \\ 0.87 \text{ if compressor = "КНД"} \\ 0.88 \text{ if compressor = "КВД"} \end{vmatrix} = 88.00\cdot\%$

Частота вращения ротора (с$^{-1}$): $\omega = \begin{vmatrix} 1570.8 \text{ if compressor = "КВД"} \\ 555 \text{ otherwise} \end{vmatrix} = 1570.8$

Относ. диаметр корня 1ой ступени [14, с.7]: $\overline{d}_1 = \begin{vmatrix} 0.40 \text{ if compressor = "Вл"} \\ 0.75 \text{ if compressor = "КНД"} \\ 0.65 \text{ if compressor = "КВД"} \end{vmatrix} = 0.65$

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

Частота вращения ротора (об/мин): $n = \frac{60\cdot\omega}{2\cdot\pi} = 15000$

Закон профилирования проточной части (ЗППЧ):

$$ЗППЧ = \left(\begin{vmatrix} \text{"пер" if compressor = "Вл"} \\ \text{"пер" if compressor = "КНД"} \\ \text{"ср" if compressor = "КВД"} \end{vmatrix} \; \begin{vmatrix} \text{"пер" if compressor = "Вл"} \\ \text{"0.96" if compressor = "КНД"} \\ \text{"ср" if compressor = "КВД"} \end{vmatrix} \; \begin{vmatrix} \text{"пер" if compressor = "Вл"} \\ \text{"0.92" if compressor = "КНД"} \\ \text{"кор" if compressor = "КВД"} \end{vmatrix} \; \text{"кор" "кор" "кор" "кор" "кор" "кор" "пер" "пер" "пер" "пер" "пер" "пер"} \right)^T$$

Относ. параметры по относительным ступеням:

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

Тип компрессора	Номер ступени и $\overline{L}_{CT.i}$							
	I	II	III	IV	z_{CP}	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:

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

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

увеличение несущественно увеличивает π

понижение существенно увеличивает π

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

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

[16, с. 234]

увеличение несущественно увеличивает π

увеличение существенно увеличивает π

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

	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

$0.15 \le \bar{c}_{\sim a1}^{T} = (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1)$

$\bar{c}_{\sim a1}^{T} \le 0.65 = (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1)$

$0.18 \le \bar{H}_{\sim T}^{T} = (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1)$

$\bar{H}_{\sim T}^{T} \le 0.35 = (1\ 1\ 1\ 1\ 0\ 1\ 1\ 1)$

Коэф. теор. напора "средней" ступени [14, с. 11]:
$$\bar{H}_{Tcp} := \frac{\sum_{i=1}^{rows(z_{\sim})} \bar{H}_{\sim T_i}}{rows(z_{\sim})} = 0.3198$$

$0.25 \le \bar{H}_{Tcp} \le 0.32 = 1$

Исходные данные

Распределение основных параметров ОК по ступеням

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

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

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

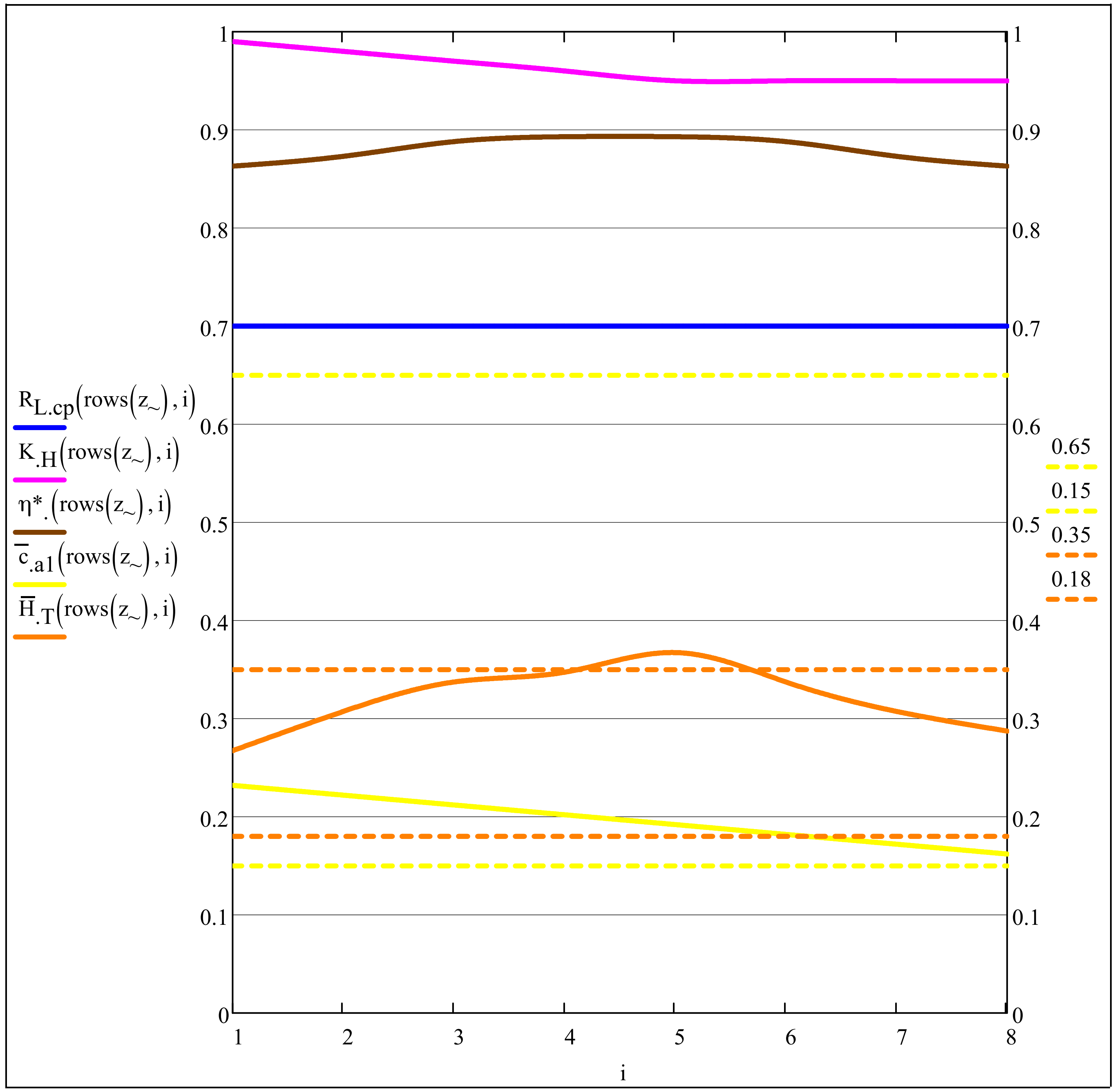
Коэф. расхода: $\overline{c}_{\sim a1}(i) = \mathrm{interp}\left(\mathrm{lspline}\left(\frac{z_{\sim}}{\mathrm{rows}(z_{\sim})}, \overline{c}_{\sim a1}\right), \frac{z_{\sim}}{\mathrm{rows}(z_{\sim})}, \overline{c}_{\sim a1}, i\right)$

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

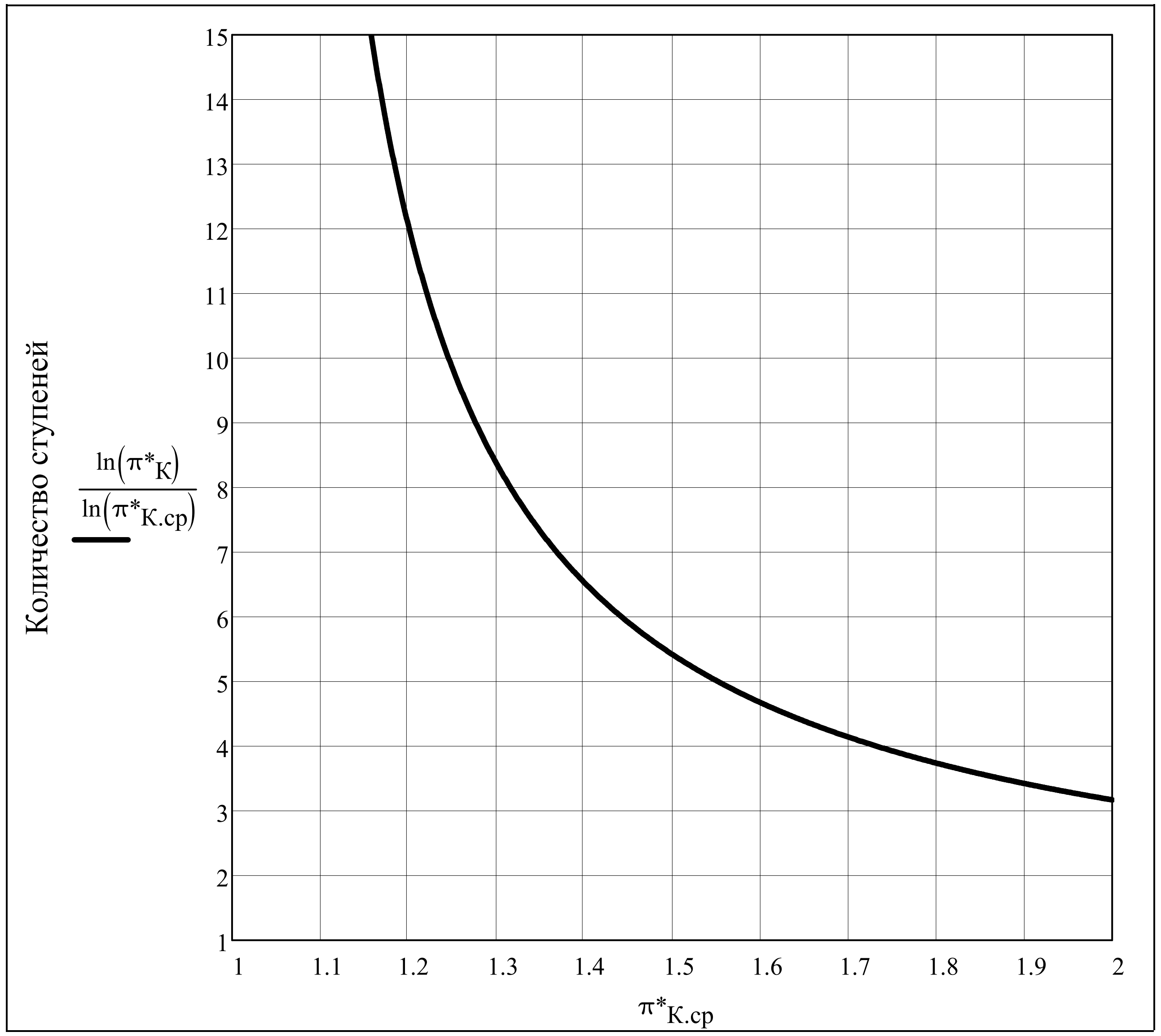
$$\begin{pmatrix} R_{L.cp} \\ K_{.H} \\ \eta^*_{.} \\ \bar{c}_{.a1} \\ \bar{H}_{.T} \end{pmatrix} = \left| \begin{array}{l} R_{L.cp}(Z,i) = \left| \begin{array}{ll} R_{L\sim cp}\left(\frac{1}{rows(z_\sim)}\right) & \text{if } i < 1 \\ R_{L\sim cp}(1) & \text{if } i > Z \\ R_{L\sim cp}\left(\frac{i}{Z}\right)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

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

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



Распределение основных параметров ОК по ступеням



Количество ступеней
$\frac{\ln(\pi^*_K)}{\ln(\pi^*_{K.cp})}$
$\pi^*_{K.cp}$
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2

Нулевые приближения

Показатель адиаьаты перед К []: $k_{К1} = k_{ад}\left(Cp_{воздух}\left(P^*_{К1}, T^*_{К1}\right), R_в\right) = 1.394$

Полное давление после К [Па]: $P^*_{К3} = \pi^*_К \cdot P^*_{К1} = 2846 \cdot 10^3$

$$\begin{pmatrix} iteration_3 \\ T^*_{К3} \\ k_{К3} \end{pmatrix} = \left| \begin{array}{l} iteration_3 = 0 \\ k_{К3} = k_{К1} \\ \text{while } 0 < 1 \\ \quad \left| \begin{array}{l} iteration_3 = iteration_3 + 1 \\ trace\left(\text{"iteration.3 = "}, num2str\left(iteration_3\right)\right) \\ k_{ср} = mean\left(k_{К1}, k_{К3}\right) \\ T^*_{К3} = T^*_{К1} \cdot \left(1 + \dfrac{\pi^{*\ \frac{k_{ср}-1}{k_{ср}}}_{К} - 1}{\eta^*_К}\right) \\ Cp_{К3} = Cp_{воздух}\left(P^*_{К3}, T^*_{К3}\right) \\ k'_{К3} = k_{ад}\left(Cp_{К3}, R_в\right) \\ \text{if } \left|eps\left(\text{"rel"}, k_{К3}, k'_{К3}\right)\right| \le epsilon \\ \quad \left| \begin{array}{l} k_{К3} = k'_{К3} \\ \text{break} \end{array} \right. \\ k_{К3} = k'_{К3} \end{array} \right. \\ \begin{pmatrix} iteration_3 \\ T^*_{К3} \\ k_{К3} \end{pmatrix} \end{array} \right.$$

Количество итераций []: $iteration_3 = 2$

Полная температура после К [К]: $T^*_{К3} = 805.9$

Показатель адиаьаты после К []: $k_{К3} = 1.354$

Полная плотность перед и после К [кг/м³]: $\begin{pmatrix} \rho^*_{К1} \\ \rho^*_{К3} \end{pmatrix} = \dfrac{1}{R_в} \cdot \begin{pmatrix} \dfrac{P^*_{К1}}{T^*_{К1}} \\ \dfrac{P^*_{К3}}{T^*_{К3}} \end{pmatrix} = \begin{pmatrix} 2.633 \\ 12.297 \end{pmatrix}$

Критические скорости перед и после К [м/с]: $\begin{pmatrix} a^*_{с.вх} \\ a^*_{с.вых} \end{pmatrix} = \begin{pmatrix} a_{кр}\left(k_{К1}, R_в, T^*_{К1}\right) \\ a_{кр}\left(k_{К3}, R_в, T^*_{К3}\right) \end{pmatrix} = \begin{pmatrix} 373.9 \\ 515.9 \end{pmatrix}$

Ср. показатель адиабаты К []: $k_{ср} = k_{ад}\left(Cp_{воздух.ср}\left(P^*_{К1}, P^*_{К3}, T^*_{К1}, T^*_{К3}\right), R_в\right) = 1.374$

Теоретический напор [Дж/кг]: $H_{ТК} = \dfrac{Cp_{воздух.ср}\left(P^*_{К1}, P^*_{К3}, T^*_{К1}, T^*_{К3}\right) \cdot T^*_{К1} \cdot \left(\pi^{*\ \frac{k_{ср}-1}{k_{ср}}}_{К} - 1\right)}{\eta^*_К} = 410.3 \cdot 10^3$

$$\begin{pmatrix} iteration_u \\ u_{1пер} \\ Z_{recomend} \\ c_{вх} \\ \lambda_{вх} \\ \rho_{K1} \end{pmatrix} = \left| \begin{array}{l} iteration_u \leftarrow 0 \\ \rho_{K1} \leftarrow \rho^*_{K1} \\ \text{while } 0 < 1 \\ \quad \left| \begin{array}{l} iteration_u \leftarrow iteration_u + 1 \\ trace(concat(\text{"iteration.u = "}, num2str(iteration_u))) \\ u_{1пер} \leftarrow \sqrt[3]{\dfrac{\pi \cdot G \cdot n^2}{900 \cdot \overline{c}_{.a1}(1,0) \cdot \rho_{K1} \cdot \left[1 - (\overline{d}_1)^2\right]}} \\ Z_{recomend} \leftarrow \max\left(round\left(\dfrac{H_{TK}}{\overline{H}_{Tср} \cdot u_{1пер}^2}\right), 1\right) \\ c_{вх} \leftarrow \overline{c}_{.a1}(Z_{recomend}, 0) \cdot u_{1пер} \\ \lambda_{вх} \leftarrow \dfrac{c_{вх}}{a^*_{c.вх}} \\ \rho'_{K1} \leftarrow \rho^*_{K1} \cdot ГДФ(\text{"ρ"}, \lambda_{вх}, k_{K1}) \\ \text{if } \left|eps(\text{"rel"}, \rho'_{K1}, \rho_{K1})\right| \le epsilon \\ \quad \left| \begin{array}{l} \rho_{K1} \leftarrow \rho'_{K1} \\ break \end{array} \right. \\ \rho_{K1} \leftarrow \rho'_{K1} \end{array} \right. \\ \begin{pmatrix} iteration_u \\ u_{1пер} \\ Z_{recomend} \\ c_{вх} \\ \lambda_{вх} \\ \rho_{K1} \end{pmatrix} \end{array} \right.$$

Количество итераций []: $iteration_u = 2$

Окружная скорость на перифкрии перед К [м/с]: $u_{1пер} = 430.5$

Рекомендуемое количество ступеней []: $Z_{recomend} = 7$

Абс. скорость перед К [м/с]: $c_{вх} = 99.9$

Приведенная скорость перед К []: $\lambda_{вх} = 0.2671$

Плотность перед К [кг/м^3]: $\rho_{K1} = 2.555$

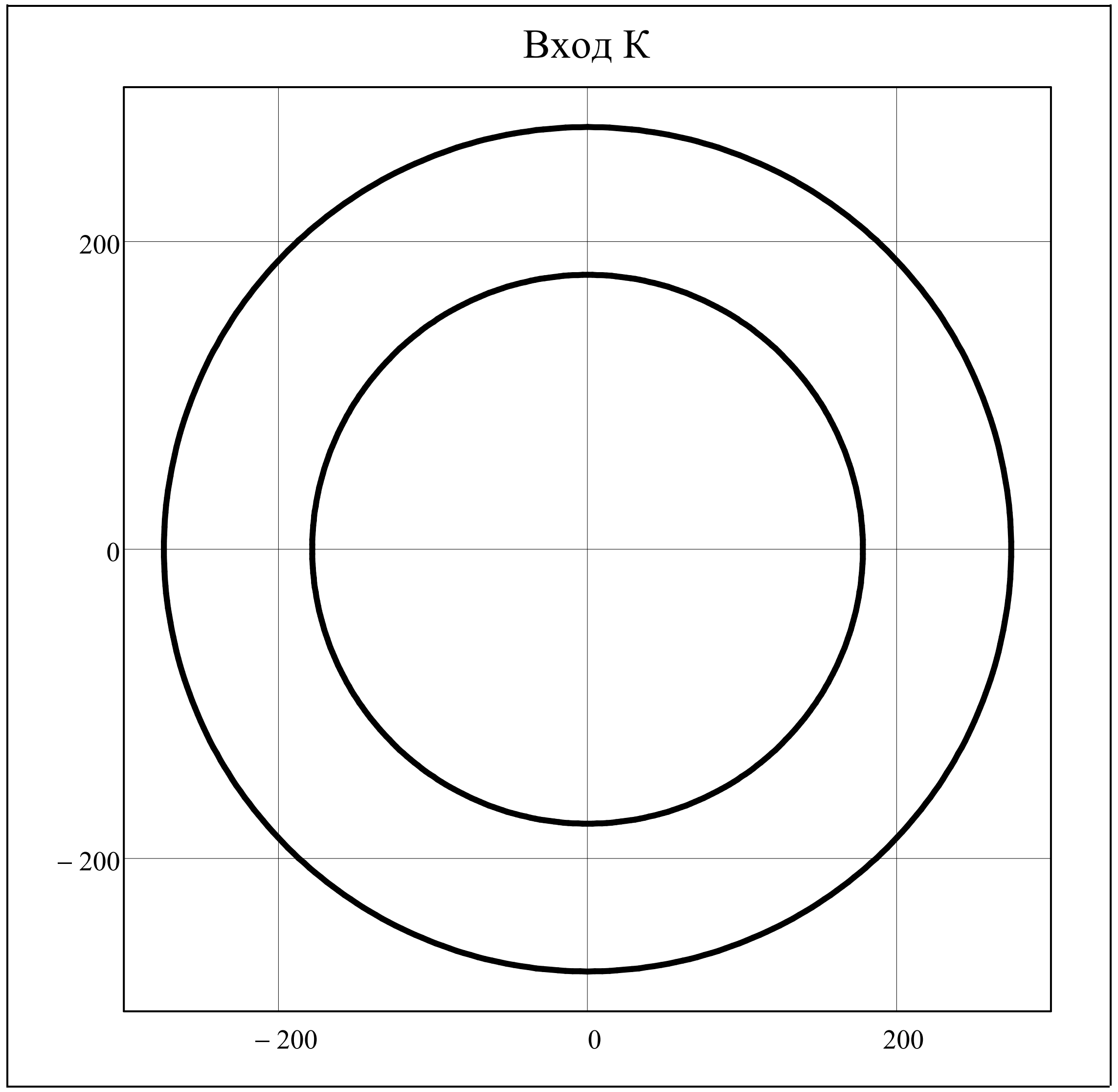
Кольцевая площадь перед К [м^2]: $F_{вх} = \dfrac{G \cdot \sqrt{R_в \cdot T^*_{K1}}}{m_q(k_{K1}) \cdot P^*_{K1} \cdot ГДФ(\text{"G"}, \lambda_{вх}, k_{K1})} = 0.1364$

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

Диамтеры перед К [м]: $D'_{ср1} = \overline{r}_{ср}(\overline{d}_1) \cdot D'_{пер1} = 462.3 \cdot 10^{-3}$

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

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



Рекомендуемое количество ступеней []: $Z_{recomend} = 7$

Количество ступеней []: $Z = \left| \begin{array}{l} 1 \ \text{if compressor} = \text{"Вл"} \\ 3 \ \text{if compressor} = \text{"КНД"} \\ 9 \ \text{if compressor} = \text{"КВД"} \end{array} \right. = 9$

Нулевые приближения

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

Расчет ВНА:

$$\begin{pmatrix} \alpha_{1BHA} & \alpha_{3BHA} \\ \sigma_{BHA} & \sigma_{BHA} \\ \overline{d}_{1BHA} & \overline{d}_{3BHA} \\ T^*_{1BHA} & T^*_{3BHA} \\ P^*_{1BHA} & P^*_{3BHA} \\ \rho^*_{1BHA} & \rho^*_{3BHA} \\ k_{1BHA} & k_{3BHA} \\ a_{кр1BHA} & a_{кр3BHA} \\ \overline{c}_{a1BHA} & \overline{c}_{a3BHA} \\ \overline{c}_{u1BHA} & \overline{c}_{u3BHA} \\ c_{a1BHA} & c_{a3BHA} \\ c_{u1BHA} & c_{u3BHA} \\ c_{1BHA} & c_{3BHA} \\ \lambda_{c1BHA} & \lambda_{c3BHA} \\ F_{1BHA} & F_{3BHA} \\ \varepsilon_{BHA} & \varepsilon_{BHA} \end{pmatrix} = \left| \begin{array}{l} \text{for } r \in av(N_r) \\ \quad \alpha_{1BHA_r} = 90° \\ \quad \overline{d}_{1BHA} = \overline{d}_1 \\ \quad \overline{d}_{3BHA} = \overline{d}_{1BHA} \\ \quad T^*_{1BHA_r} = T^*_{K1} \\ \quad T^*_{3BHA_r} = T^*_{1BHA_r} \\ \quad P^*_{1BHA_r} = P^*_{K1} \\ \quad \rho^*_{1BHA_r} = \dfrac{P^*_{1BHA_r}}{R_в \cdot T^*_{1BHA_r}} \\ \quad k_{1BHA_r} = k_{ад}\left(Cp_{воздух}\left(P^*_{1BHA_r}, T^*_{1BHA_r}\right), R_в\right) \\ \quad a_{кр1BHA_r} = a_{кр}\left(k_{1BHA_r}, R_в, T^*_{1BHA_r}\right) \\ \quad \overline{c}_{a1BHA_r} = \overline{c}_{.a1}(Z,0) \\ \quad \overline{c}_{u1BHA_r} = \begin{cases} \overline{r}_{cp}(\overline{d}_{1BHA}) \cdot \left(1 - R_{L.cp}(Z,0)\right) - \dfrac{\overline{H}_{.T}(Z,0)}{2 \cdot \overline{r}_{cp}(\overline{d}_{1BHA})} & \text{if } BHA = 1 \\ 0 & \text{otherwise} \end{cases} \\ \quad c_{a1BHA_r} = \overline{c}_{a1BHA_r} \cdot u_{1пер} \end{array} \right.$$

$\sigma_{BHA} = 0.9982$

$\text{submatrix}\left(\varepsilon_{BHA}, av(N_r), av(N_r), 1, 1\right) = (22.17) \cdot deg$

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

$\text{submatrix}\left(\alpha_{3BHA}, av(N_r), av(N_r), 1, 1\right) = (67.83) \cdot deg$

$\begin{pmatrix} \overline{d}_{1BHA} \\ \overline{d}_{3BHA} \end{pmatrix} = \begin{pmatrix} 0.6500 \\ 0.6500 \end{pmatrix}$ $\quad \begin{pmatrix} F_{1BHA} \\ F_{3BHA} \end{pmatrix} = \begin{pmatrix} 0.1364 \\ 0.1373 \end{pmatrix}$

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

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

$$\lambda_{c1BHA_r} = \frac{c_{1BHA_r}}{a_{кр1BHA_r}}$$

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

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

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

$$k_{3BHA_r} = k_{ад}\left(Cp_{воздух}\left(P^*_{3BHA_r}, T^*_{3BHA_r}\right), R_в\right)$$

$$a_{кр3BHA_r} = a_{кр}\left(k_{3BHA_r}, R_в, T^*_{3BHA_r}\right)$$

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

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

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

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

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

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

$$\lambda_{c3BHA_r} = \frac{c_{3BHA_r}}{a_{кр3BHA}}$$

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

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

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

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

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

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

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

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

$\text{submatrix}\left(a_{кр1BHA}, av(N_r), av(N_r), 1, 1\right) = (373.9)$

$\text{submatrix}\left(a_{кр3BHA}, av(N_r), av(N_r), 1, 1\right) = (373.9)$

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

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

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

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

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

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

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

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

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

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

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

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

$$\begin{pmatrix} F_{1ВНА} \\ F_{3ВНА} \end{pmatrix} = G\cdot\sqrt{R_В}\cdot\begin{pmatrix} \dfrac{\sqrt{T^*_{1ВНА_r}}}{m_q\left(k_{1ВНА_r}\right)\cdot P^*_{1ВНА_r}\cdot ГДФ\left("G", \lambda_{c1ВНА_r}, k_{1ВНА_r}\right)\cdot\sin\left(\alpha_{1ВНА_r}\right)} \\ \dfrac{\sqrt{T^*_{3ВНА_r}}}{m_q\left(k_{3ВНА_r}\right)\cdot P^*_{3ВНА_r}\cdot ГДФ\left("G", \lambda_{c3ВНА_r}, k_{3ВНА_r}\right)\cdot\sin\left(\alpha_{3ВНА_r}\right)} \end{pmatrix}$$

$$\varepsilon_{ВНА_r} = -1\cdot\left(\alpha_{3ВНА_r} - \alpha_{1ВНА_r}\right)$$

$$\begin{pmatrix} \alpha_{1ВНА} & \alpha_{3ВНА} \\ \sigma_{ВНА} & \sigma_{ВНА} \\ \bar{d}_{1ВНА} & \bar{d}_{3ВНА} \\ T^*_{1ВНА} & T^*_{3ВНА} \\ P^*_{1ВНА} & P^*_{3ВНА} \\ \rho^*_{1ВНА} & \rho^*_{3ВНА} \\ k_{1ВНА} & k_{3ВНА} \\ a_{кр1ВНА} & a_{кр3ВНА} \\ \bar{c}_{a1ВНА} & \bar{c}_{a3ВНА} \\ \bar{c}_{u1ВНА} & \bar{c}_{u3ВНА} \\ c_{a1ВНА} & c_{a3ВНА} \\ c_{u1ВНА} & c_{u3ВНА} \\ c_{1ВНА} & c_{3ВНА} \\ \lambda_{c1ВНА} & \lambda_{c3ВНА} \\ F_{1ВНА} & F_{3ВНА} \\ \varepsilon_{ВНА} & \varepsilon_{ВНА} \end{pmatrix}$$

Расчет ВНА:

Поступенчатый расчет ОК по ср. ЛТ

$$
\begin{pmatrix}
R_L & \pi^* \\
K_H & \eta^* \\
Cp & k \\
\overline{H}_T & H_T \\
L^* & L \\
T^* & T \\
P^* & P \\
\rho^* & \rho \\
a^*_c & a_{зв} \\
\lambda_c & \lambda_c \\
F & F \\
D & R \\
\overline{d} & h \\
\overline{c}_a & \overline{c}_u \\
c_a & c_u \\
u & w_u \\
c & w \\
M_c & M_w \\
\alpha & \beta \\
\varepsilon_{rotor} & \varepsilon_{stator}
\end{pmatrix}
=
\left|
\begin{array}{l}
r = av(N_r) \\
T^*_{st(1,1),r} = T^*_{3ВНА_r} \\
P^*_{st(1,1),r} = P^*_{3ВНА_r} \\
\rho^*_{st(1,1),r} = \rho^*_{3ВНА_r} \\
Cp_{st(1,1),r} = Cp_{воздух}\left(P^*_{st(1,1),r}, T^*_{st(1,1),r}\right) \\
k_{st(1,1),r} = k_{ад}\left(Cp_{st(1,1),r}, R_В\right) \\
a^*_{c_{st(1,1),r}} = a_{кр}\left(k_{st(1,1),r}, R_В, T^*_{st(1,1),r}\right) \\
\overline{c}_{a_{st(1,1),r}} = \overline{c}_{a3ВНА_r} \\
\overline{c}_{u_{st(1,1),r}} = \overline{c}_{u3ВНА_r} \\
c_{a_{st(1,1),r}} = c_{a3ВНА_r} \\
u_{st(1,1),N_r} = u_{1пер} \\
\alpha_{st(1,1),r} = \alpha_{3ВНА_r} \\
c_{st(1,1),r} = \dfrac{c_{a_{st(1,1),r}}}{\sin\left(\alpha_{st(1,1),r}\right)} \\
\lambda_{c_{st(1,1),r}} = \dfrac{c_{st(1,1),r}}{a^*_{c_{st(1,1),r}}} \\
F_{st(1,1)} = \dfrac{G\cdot\sqrt{R_В\cdot T^*_{st(1,1),r}}}{m_q\left(k_{st(1,1),r}\right)\cdot ГДФ\left("G", \lambda_{c_{st(1,1),r}}, k_{st(1,1),r}\right)\cdot\sin\left(\alpha_{st(1,1),r}\right)\cdot P^*_{st(1,1),r}}
\end{array}
\right.
$$

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

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

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

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

for $i \in 1..Z$

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 $0 < 1$

$$iteration_{12} = iteration_{12} + 1$$

trace(concat("   iteration.12 = ", num2str(iteration$_{12}$)))

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

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

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

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

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

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

$$k'_2 = k_{ад}\left(Cp_{st(i,2),r}, R_в\right)$$

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

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

break

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

$$a^*_{c_{st(i,2),r}} = a_{кр}\left(k_{st(i,2),r}, R_в, T^*_{st(i,2),r}\right)$$

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

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

$$Cp_{st(i,3),r} = Cp_{воздух}\left(P^*_{st(i,3),r}, T^*_{st(i,3),r}\right)$$

$$k_{st(i,3),r} = k_{ад}\left(Cp_{st(i,3),r}, R_в\right)$$

$$a^*_{c_{st(i,3),r}} = a_{кр}\left(k_{st(i,3),r}, R_в, T^*_{st(i,3),r}\right)$$

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

$$iteration_3 = 0$$

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

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

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

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

$$F_{st(i,3)} = \frac{F_{st(i,1)} \cdot m_q\left(k_{st(i,1),r}\right) \cdot ГДФ\left(\text{"G"}, \lambda_{c_{st(i,1),r}}, k_{st(i,1),r}\right) \cdot \sin\left(\alpha_{st(i,1),r}\right) \cdot P^*_{st(i,1),r} \cdot \sqrt{T^*_{st(i,3),r}}}{m_q\left(k_{st(i,3),r}\right) \cdot ГДФ\left(\text{"G"}, \lambda_{c_{st(i,3),r}}, k_{st(i,3),r}\right) \cdot \sin\left(\alpha_{st(i,3),r}\right) \cdot P^*_{st(i,3),r} \sqrt{T^*_{st(i,1),r}}}$$

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

$$iteration_3 = iteration_3 + 1$$

$$trace\left(concat\left(\text{"   iteration.3 = "}, num2str\left(iteration_3\right)\right)\right)$$

$$\text{if } \left(ЗППЧ_i \neq \text{"пер"}\right) \wedge \left(ЗППЧ_i \neq \text{"кор"}\right) \wedge \left(ЗППЧ_i \neq \text{"ср"}\right)$$

$$D_{st(i,3),N_r} = D_{st(i,1),N_r} \cdot str2num\left(ЗППЧ_i\right)$$

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

$$\text{if } ЗППЧ_i = \text{"пер"}$$

$$D_{st(i,3),N_r} = D_{st(i,1),N_r}$$

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

if $ЗППЧ_i$ = "кор"

$$D_{st(i,3),1} = D_{st(i,1),1}$$

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

if $ЗППЧ_i$ = "ср"

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

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

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

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

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

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

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

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

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

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

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

break if $\left(\left|eps\left("rel", F'_3, F_{st(i,3)}\right)\right| < epsilon\right) \wedge \left(iteration_3 = 0\right)$

$iteration_3 = -1$ if $\left(\left|eps\left("rel", F'_3, F_{st(i,3)}\right)\right| < epsilon\right)$

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

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

$\mathrm{iteration}_2 = 0$

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

while $0 < 1$

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

trace(concat("   iteration.2 = ", num2str(iteration$_2$)))

if $(\text{ЗППЧ}_i \ne \text{"пер"}) \wedge (\text{ЗППЧ}_i \ne \text{"кор"}) \wedge (\text{ЗППЧ}_i \ne \text{"ср"})$

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

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

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

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

if $\text{ЗППЧ}_i = \text{"пер"}$

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

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

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

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

if $\text{ЗППЧ}_i = \text{"кор"}$

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

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

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

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

if $\text{ЗППЧ}_i = \text{"ср"}$

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

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

$D_{st(i,2),N_r} = \dfrac{D_{st(i,2),r}}{\overline{r}_{cp}(\overline{d}_{st(i,2)})}$

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

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

$$\alpha_{st(i,2),r} = \mathrm{triangle}\left(\bar{c}_{a_{st(i,2),r}}, \bar{c}_{u_{st(i,2),r}}\right)$$

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

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

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

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

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

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

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

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

for $a \in 1..3$

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

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

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

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

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

$$\beta_{st(i,a),r} = \mathrm{triangle}\left(\bar{c}_{a_{st(i,a),r}}, \bar{r}_{cp}(\bar{d}_{st(i,a)}) - \bar{c}_{u_{st(i,a),r}}\right)$$

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

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

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

$$M_{w_{st(i,a),r}} = \frac{w_{st(i,a),r}}{a_{\text{зв}_{st(i,a),r}}}$$

$$M \ldots = \frac{c_{st(i,a),r}}{\ldots}$$

$$M_{c_{st(i,a),r}} = \frac{\quad}{a_{зв_{st(i,a),r}}}$$

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

for radius $\in 1..N_r$

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

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

for $i \in 1..Z$

for $a \in 1..3$

for $r \in 1..N_r$

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

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

$$\begin{pmatrix} H_T \\ R_L \end{pmatrix} = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \left| \begin{array}{l} H_{T.}(r) = \text{interp}\left[\text{pspline}\left[\begin{pmatrix} 1 \\ av(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} H_{T_{i,av(N_r)}} - \dfrac{\Delta H_T(\overline{d}_{st(i,2)})}{2} \\ H_{T_{i,av(N_r)}} \\ H_{T_{i,av(N_r)}} + \dfrac{\Delta H_T(\overline{d}_{st(i,2)})}{2} \end{pmatrix}\right], \begin{pmatrix} 1 \\ av(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} H_{T_{i,av(N_r)}} - \dfrac{\Delta H_T(\overline{d}_{st(i,2)})}{2} \\ H_{T_{i,av(N_r)}} \\ H_{T_{i,av(N_r)}} + \dfrac{\Delta H_T(\overline{d}_{st(i,2)})}{2} \end{pmatrix}, r\right] \\ R_{L.}(r) = \text{interp}\left[\text{pspline}\left[\begin{pmatrix} 1 \\ av(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} R_{L_{i,av(N_r)}} - \dfrac{\Delta R_L(\overline{d}_{st(i,2)})}{2} \\ R_{L_{i,av(N_r)}} \\ R_{L_{i,av(N_r)}} + \dfrac{\Delta R_L(\overline{d}_{st(i,2)})}{2} \end{pmatrix}\right], \begin{pmatrix} 1 \\ av(N_r) \\ N_r \end{pmatrix}, \begin{pmatrix} R_{L_{i,av(N_r)}} - \dfrac{\Delta R_L(\overline{d}_{st(i,2)})}{2} \\ R_{L_{i,av(N_r)}} \\ R_{L_{i,av(N_r)}} + \dfrac{\Delta R_L(\overline{d}_{st(i,2)})}{2} \end{pmatrix}, r\right] \\ \text{for } r \in 1..N_r \\ \quad \left| \begin{array}{l} H_{T_{i,r}} = H_{T.}(r) \\ R_{L_{i,r}} = R_{L.}(r) \end{array} \right. \end{array} \right. \\ \begin{pmatrix} H_T \\ R_L \end{pmatrix} \end{array} \right.$$

Поступенчатый расчет ОК по ср. ЛТ

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

Расчет CA:

$$\begin{pmatrix} \alpha_{1CA} & \alpha_{3CA} \\ \sigma_{CA} & \sigma_{CA} \\ \bar{d}_{1CA} & \bar{d}_{3CA} \\ T^*_{1CA} & T^*_{3CA} \\ P^*_{1CA} & P^*_{3CA} \\ \rho^*_{1CA} & \rho^*_{3CA} \\ k_{1CA} & k_{3CA} \\ a_{кр1CA} & a_{кр3CA} \\ \bar{c}_{a1CA} & \bar{c}_{a3CA} \\ \bar{c}_{u1CA} & \bar{c}_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ c_{u1CA} & c_{u3CA} \\ c_{1CA} & c_{3CA} \\ \lambda_{1CA} & \lambda_{3CA} \\ F_{1CA} & F_{3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{pmatrix} := \left| \begin{array}{l} \text{for } r \in av(N_r) \\ \quad \alpha_{1CA_r} \leftarrow \alpha_{st(Z,3),r} \\ \quad \alpha_{3CA_r} \leftarrow \begin{cases} 90\cdot° & \text{if } CA = 1 \\ \alpha_{1CA_r} & \text{otherwise} \end{cases} \\ \quad \bar{d}_{1CA} \leftarrow \bar{d}_{st(Z,3)} \\ \quad \bar{d}_{3CA} \leftarrow \bar{d}_{1CA} \\ \quad T^*_{1CA_r} \leftarrow T^*_{st(Z,3),r} \\ \quad T^*_{3CA_r} \leftarrow T^*_{1CA_r} \\ \quad P^*_{1CA_r} \leftarrow P^*_{st(Z,3),r} \\ \quad iterarion_{CA} \leftarrow 0 \\ \quad \sigma_{CA} \leftarrow 1 \\ \quad \text{while } 0 < 1 \\ \quad\quad iterarion_{CA} \leftarrow iterarion_{CA} + 1 \\ \quad\quad trace\left(concat\left(\text{"iterarion.CA = "}, num2str\left(iterarion_{CA}\right)\right)\right) \\ \quad\quad P^*_{3CA_r} \leftarrow P^*_{1CA_r}\cdot\sigma_{CA} \\ \quad\quad \begin{pmatrix} \rho^*_{1CA_r} \\ \ldots \end{pmatrix} \leftarrow \ldots \begin{pmatrix} \dfrac{P^*_{1CA_r}}{T^*_{1CA_r}} \\ \ldots \end{pmatrix} \end{array} \right.$$

$$\sigma_{CA} = 0.9981$$

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

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

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

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

$$\rho^*_{3CA_r} = \frac{1}{R_в} \cdot \frac{P^*_{3CA_r}}{T^*_{3CA_r}}$$

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

$$\begin{pmatrix} a_{кр1CA_r} \\ a_{кр3CA_r} \end{pmatrix} = \begin{pmatrix} a_{кр}\left(k_{1CA_r}, R_в, T^*_{1CA_r}\right) \\ a_{кр}\left(k_{3CA_r}, R_в, T^*_{3CA_r}\right) \end{pmatrix}$$

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

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

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

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

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

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

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

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

$$\begin{pmatrix} \lambda_{1CA_r} \\ \lambda_{3CA_r} \end{pmatrix} = \begin{pmatrix} \dfrac{c_{1CA_r}}{a_{кр1CA_r}} \\ \dfrac{c_{3CA_r}}{a_{кр3CA_r}} \end{pmatrix}$$

$$\sigma'_{CA} = \Big| 1 - \mathrm{mean}(0.25, 0.5) \cdot ГДФ\left(\text{"}\rho\text{"}, \lambda_{3CA_r}, k_{3CA_r}\right) \cdot \frac{k_{3CA_r}}{k_{3CA_r} + 1} \cdot \left(\lambda_{3CA_r}\right)^2 \ \text{if } CA = 1$$

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

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

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

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

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

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

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

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

$\mathrm{submatrix}\left(a_{кр1CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (522.4)$

$\mathrm{submatrix}\left(a_{кр3CA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (522.4)$

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

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

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

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

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

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

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

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

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

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

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

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

$$1 \quad \text{otherwise}$$

$$\text{break if } \left(\left|\text{eps}\left(\text{"rel"}, \sigma'_{CA}, \sigma_{CA}\right)\right| < \text{epsilon}\right) \wedge \left(\text{iterarion}_{CA} = 0\right)$$

$$\text{iterarion}_{CA} \leftarrow -1 \text{ if } \left(\left|\text{eps}\left(\text{"rel"}, \sigma'_{CA}, \sigma_{CA}\right)\right| < \text{epsilon}\right)$$

$$\sigma_{CA} \leftarrow \sigma'_{CA}$$

$$\begin{pmatrix} F_{1CA} \\ F_{3CA} \end{pmatrix} \leftarrow \left(\frac{\dfrac{F_{st(Z,3)}}{G \cdot \sqrt{R_B \cdot T^*_{3CA_r}}}}{m_q\left(k_{3CA_r}\right) \cdot P^*_{3CA_r} \cdot \text{ГДФ}\left(\text{"G"}, \lambda_{3CA_r}, k_{3CA_r}\right) \cdot \sin\left(\alpha_{3CA_r}\right)} \right)$$

$$\varepsilon_{CA_r} \leftarrow \alpha_{3CA_r} - \alpha_{1CA_r}$$

$$\begin{pmatrix} \alpha_{1CA} & \alpha_{3CA} \\ \sigma_{CA} & \sigma_{CA} \\ \overline{d}_{1CA} & \overline{d}_{3CA} \\ T^*_{1CA} & T^*_{3CA} \\ P^*_{1CA} & P^*_{3CA} \\ \rho^*_{1CA} & \rho^*_{3CA} \\ k_{1CA} & k_{3CA} \\ a_{кр1CA} & a_{кр3CA} \\ \overline{c}_{a1CA} & \overline{c}_{a3CA} \\ \overline{c}_{u1CA} & \overline{c}_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ c_{u1CA} & c_{u3CA} \\ c_{1CA} & c_{3CA} \\ \lambda_{1CA} & \lambda_{3CA} \\ F_{1CA} & F_{3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{pmatrix}$$

Расчет СА:

Результаты поступенчатого расчета по ср. ЛТ

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

$$\overline{\Delta}G = \begin{array}{|l} \text{for } i \in 1..Z \\ \quad \text{for } a \in 1..3 \\ \quad\quad \overline{\Delta}G_{st(i,a)} = \left| \text{eps}\left(\text{"rel"}, G, \rho_{st(i,a),av(N_r)} \cdot c_{a_{st(i,a),av(N_r)}} \cdot F_{st(i,a)}\right) \right| \\ \overline{\Delta}G \end{array}$$

$\overline{\Delta}G^T =$ … $\cdot \%$

	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: $Z = 9$

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

Дискритизация ступеней: $i = 1..Z$

$\pi^{*T} =$

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

[16, с 114] $\pi^{*T} \le 1.9 =$

	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: $\pi^*_{ЛА} = \dfrac{P^*_{3CA_{av(N_r)}}}{P^*_{1BHA_{av(N_r)}}} = 8.970$ $\quad \pi^*_{ЛА} \ge \pi^*_K = 0$

$H_T{}^T =$

	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 []: $\eta^*_K = \frac{L^*_K}{L_K} = 88.00 \cdot \%$

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

$\mathrm{submatrix}\left(R_L, 1, Z, av(N_r), av(N_r)\right)^T =$

	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						

${K_H}^T =$

	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						

${\eta^*}^T =$

	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						

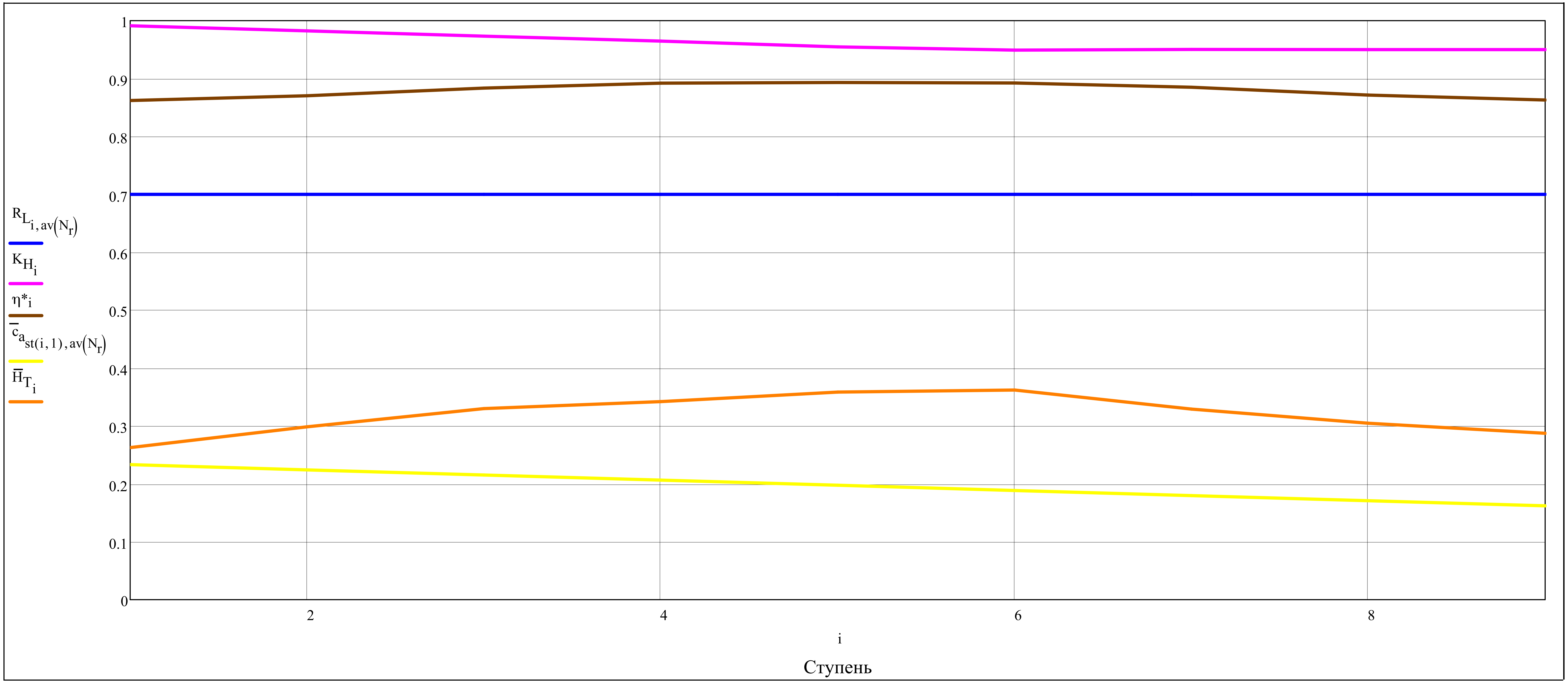
$\cdot\%$

$\mathrm{submatrix}\left(\overline{c}_a, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

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

${\overline{H}_T}^T =$

	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						



$\text{submatrix}\left(Cp, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$\text{submatrix}\left(k, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$\text{submatrix}\left(T^*, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$\text{submatrix}\left(T, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$\text{submatrix}\left(P^*, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$\cdot 10^3$

$\text{submatrix}\left(P, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$\cdot 10^3$

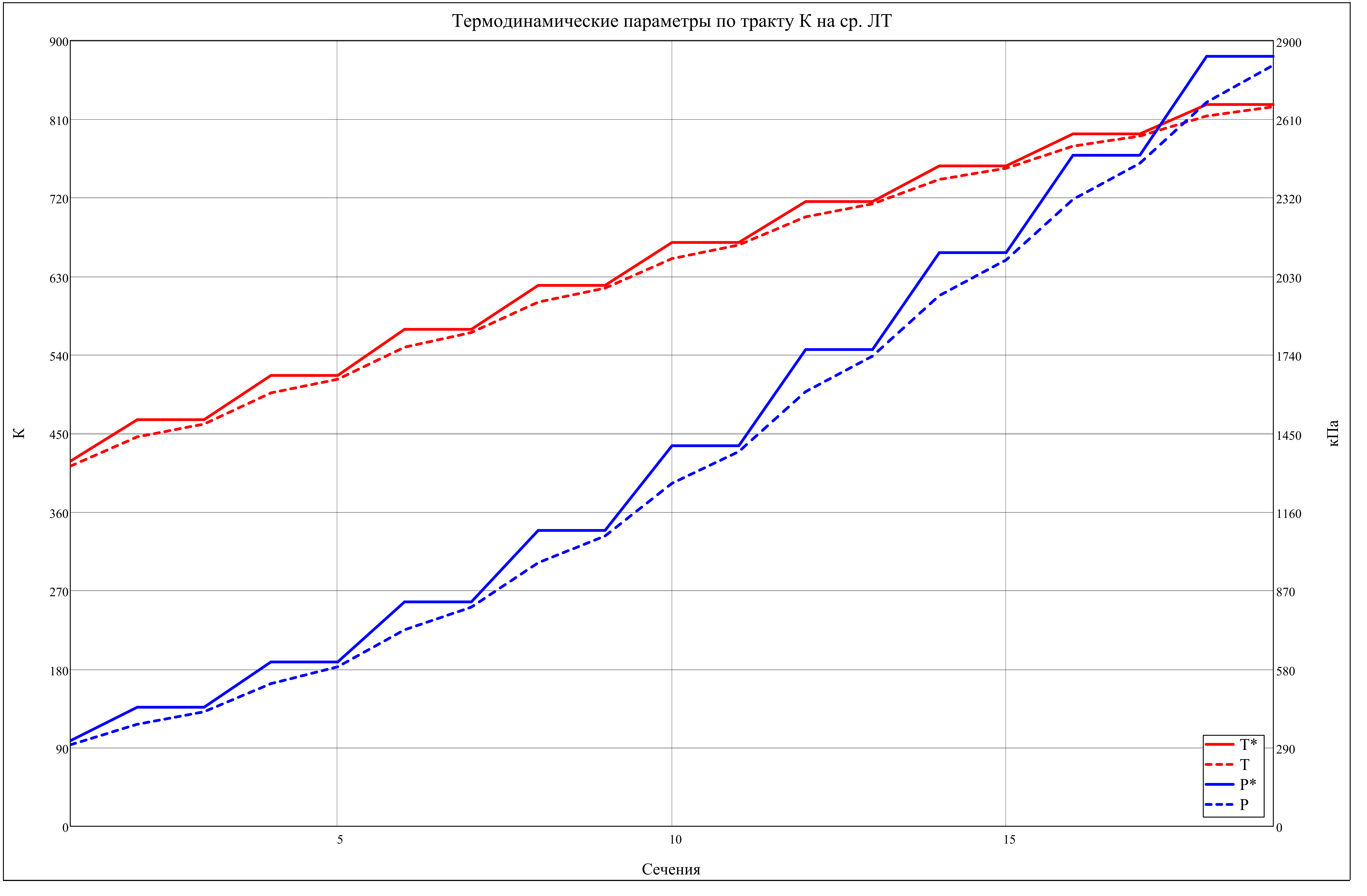
$\text{submatrix}\left(\rho^*, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$\text{submatrix}\left(\rho, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

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

$$k_{ср} = k_{ад}\left(Cp_{воздух.ср}\left(P^*_{st(1,1), av\left(N_r\right)}, P^*_{st(Z,3), av\left(N_r\right)}, T^*_{st(1,1), av\left(N_r\right)}, T^*_{st(Z,3), av\left(N_r\right)}\right), R_в\right) = 1.373$$


Термодинамические параметры по тракту К на ср. ЛТ
К
кПа
Сечения
900
810
720
630
540
450
360
270
180
90
0
2900
2610
2320
2030
1740
1450
1160
870
580
290
0
5
10
15
T*
T
P*
P

$F^T =$

	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		

$\bar{d}^T =$

	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				

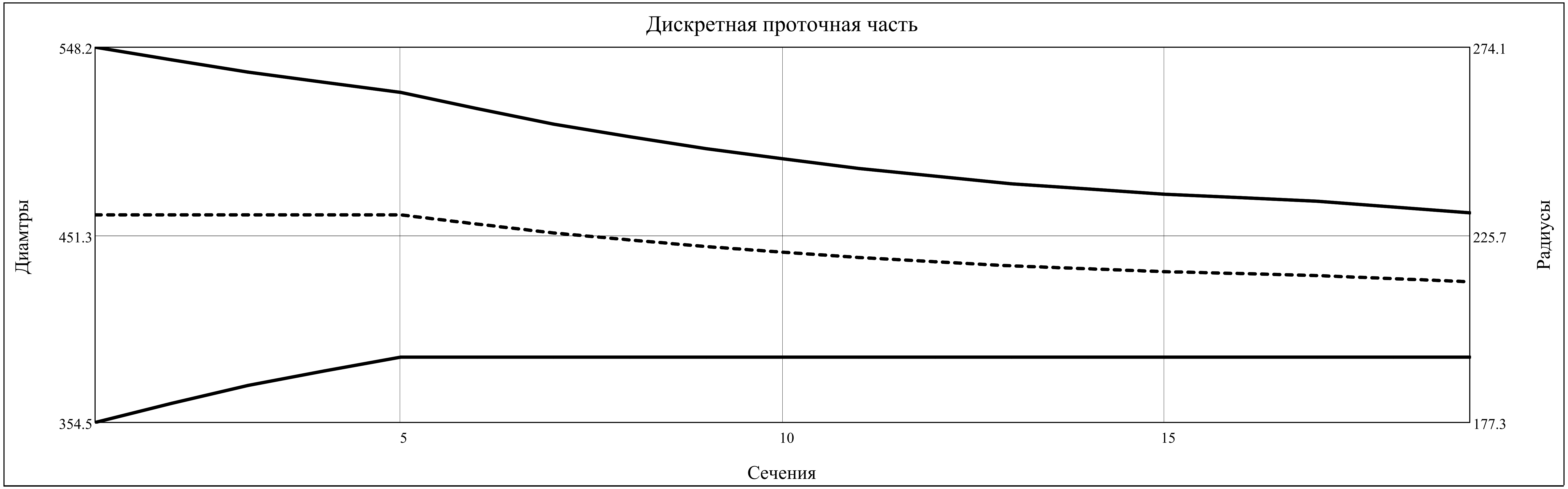
$\bar{d}_{st(Z,3)} = 0.839$ $\bar{d}_{st(Z,3)} \le 0.9 = 1$

$D^T = \cdot 10^{-3}$

	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		

$R^T = \cdot 10^{-3}$

	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						



$h^T = \cdot 10^{-3}$

	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						

$\mathrm{submatrix}\left(a^*_c, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

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

$\mathrm{submatrix}\left(a_{зв}, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

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

$\mathrm{submatrix}\left(c, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

	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		

$\mathrm{submatrix}\left(w, 1, 2Z, av(N_r), av(N_r)\right)^T =$

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

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

$\mathrm{submatrix}\left(c_a, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

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

$\mathrm{submatrix}\left(c_u, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

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

$\mathrm{submatrix}\left(w_u, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

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

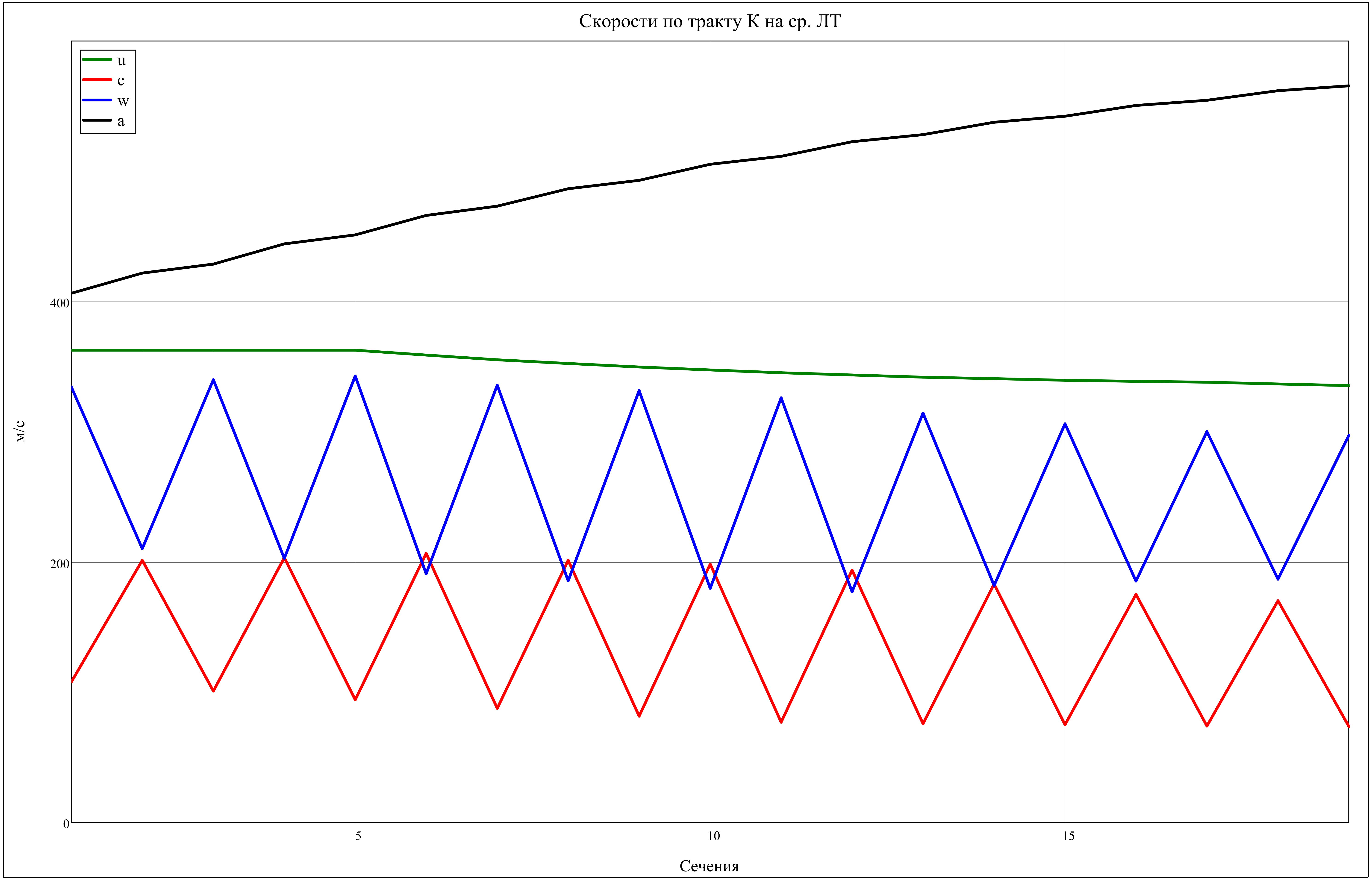
$$\Delta c_{a_{i,av(N_r)}} = \left(c_{a_{st(i,2),av(N_r)}} - c_{a_{st(i,1),av(N_r)}}\right)$$

$\mathrm{submatrix}\left(\Delta c_a, 1, Z, av(N_r), av(N_r)\right)^T =$

	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			

$\mathrm{submatrix}\left(\Delta c_a, 1, Z, av(N_r), av(N_r)\right)^T \ge -12 =$

	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	26	27	28	29	30
1	1	1	1	1	1	1	1	1	1																					


Скорости по тракту К на ср. ЛТ
u
c
w
a
м/с
400
200
0
5
10
15
Сечения

$\mathrm{submatrix}\left(\alpha,1,2\cdot Z+1,\mathrm{av}\left(N_r\right),\mathrm{av}\left(N_r\right)\right)^T =$

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

$\cdot°$

$\mathrm{submatrix}\left(\beta,1,2\cdot Z+1,\mathrm{av}\left(N_r\right),\mathrm{av}\left(N_r\right)\right)^T =$

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

$\cdot°$

$\mathrm{submatrix}\left(\varepsilon_{rotor},1,Z,\mathrm{av}\left(N_r\right),\mathrm{av}\left(N_r\right)\right)^T =$

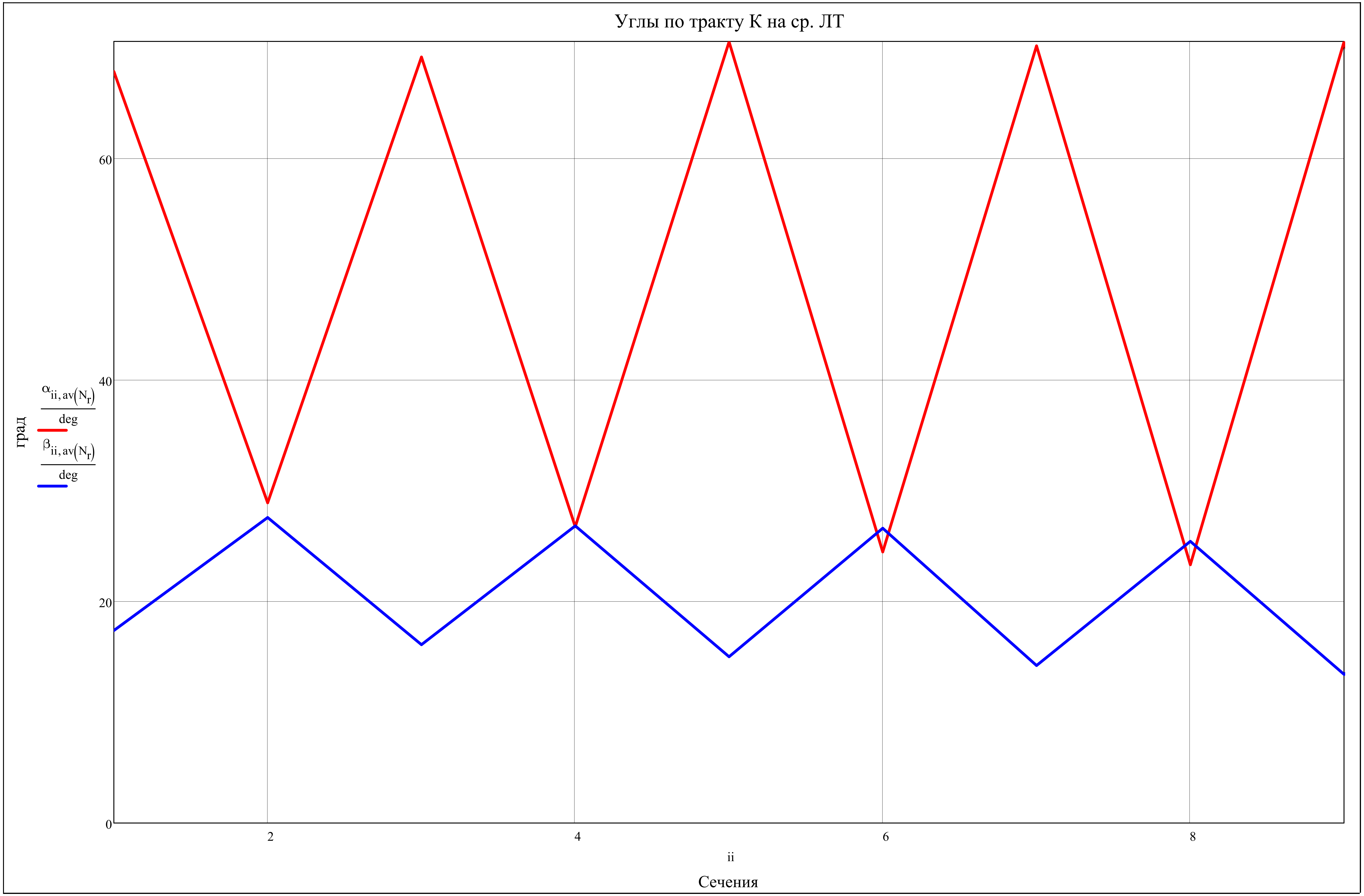
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	10.19	10.72	11.6	11.21	11.04	10.42	8.68	7.44	7.04												

$\cdot°$

$\mathrm{submatrix}\left(\varepsilon_{stator},1,Z,\mathrm{av}\left(N_r\right),\mathrm{av}\left(N_r\right)\right)^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	40.23	43.76	45.67	47.23	47.16	41.64	36.74	33.14	32.81												

$\cdot°$



Углы по тракту К на ср. ЛТ
60
40
20
0
2
4
6
8
ii
Сечения
град
$\frac{\alpha_{ii,av(N_r)}}{deg}$
$\frac{\beta_{ii,av(N_r)}}{deg}$

$\text{submatrix}\left(\lambda_c, 1, 2Z+1, \text{av}(N_r), \text{av}(N_r)\right)^T =$

	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] $\text{submatrix}\left(\lambda_c, 1, 2Z+1, \text{av}(N_r), \text{av}(N_r)\right)^T \le 0.85 =$

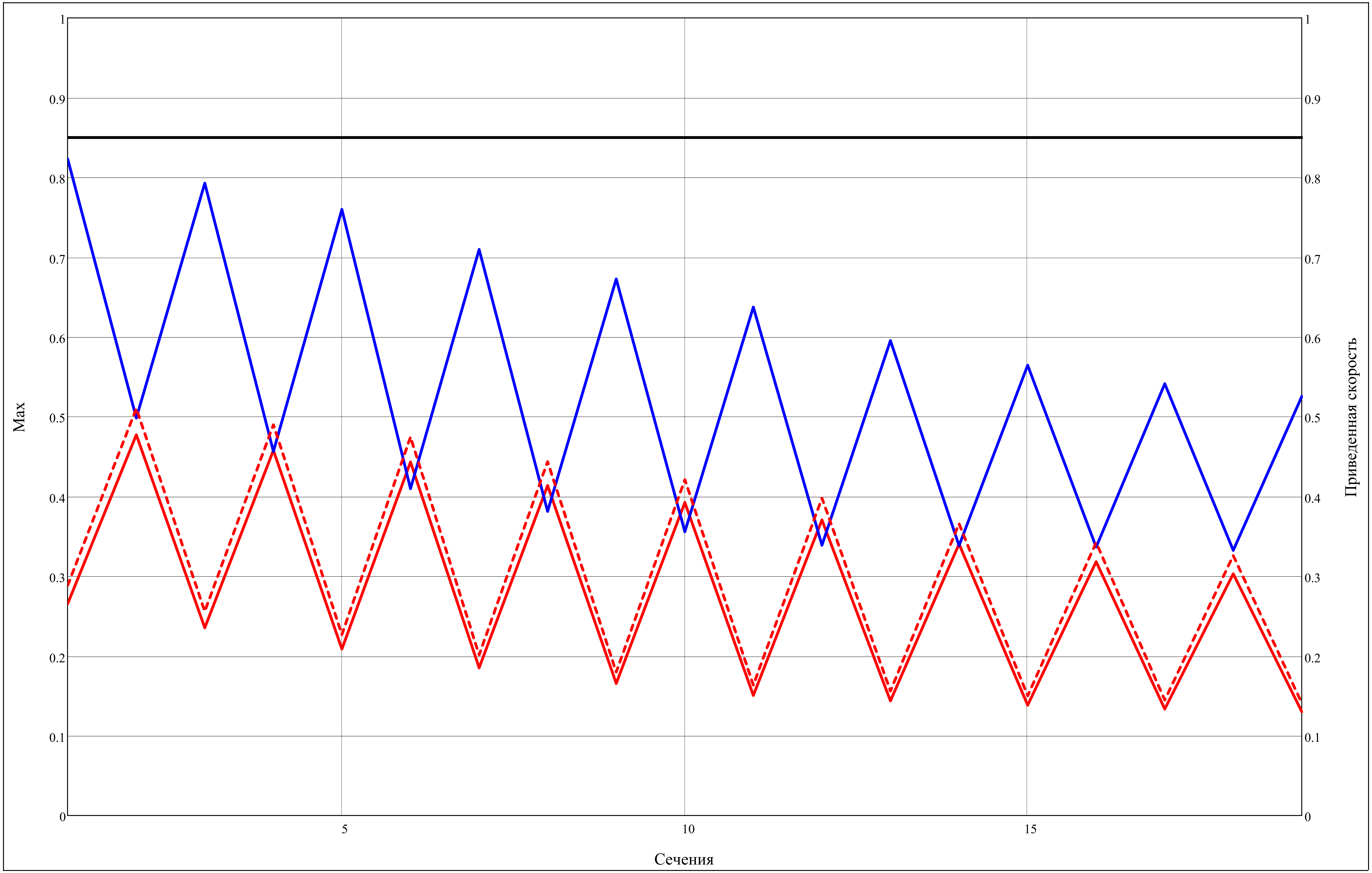
	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	...

$\text{submatrix}\left(M_w, 1, 2Z, \text{av}(N_r), \text{av}(N_r)\right)^T =$

	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	

$\text{submatrix}\left(M_c, 1, 2Z+1, \text{av}(N_r), \text{av}(N_r)\right)^T =$

	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



Max
Приведенная скорость
Сечения
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
5
10
15

Расчет параметров потока по высоте Л

Относ. диаметр корня при увеличении которого меняется з-н профилирования Л
с промежуточного на Ц = const:
с R = const на промежуточный:
[16, с.94-99]

$$\begin{pmatrix} \bar{d}_{m2Ц} \\ \bar{d}_{R2m} \end{pmatrix} = \begin{pmatrix} 0.7 \\ 0.3 \end{pmatrix}$$

$$m := \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad m_i \leftarrow \left| \begin{array}{ll} -1 & \text{if } \bar{d}_{st(i,1)} \le \bar{d}_{R2m} \\ 1 & \text{if } \bar{d}_{st(i,1)} \ge \bar{d}_{m2Ц} \\ -1 + \dfrac{1-(-1)}{\bar{d}_{m2Ц} - \bar{d}_{R2m}} \cdot \left(\bar{d}_{st(i,1)} - \bar{d}_{R2m}\right) & \text{otherwise} \end{array} \right. \\ m \end{array} \right.$$

$$m_i := \left| \begin{array}{ll} 0.73 & \text{if } compressor = \text{"Вл"} \\ m_i & \text{otherwise} \end{array} \right.$$

$m^T =$

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.733	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000			

$$\begin{pmatrix} T^*_{1BHA} & T^*_{3BHA} \\ P^*_{1BHA} & P^*_{3BHA} \\ \rho^*_{1BHA} & \rho^*_{3BHA} \\ Cp_{1BHA} & Cp_{3BHA} \\ k_{1BHA} & k_{3BHA} \\ a^*_{c1BHA} & a^*_{c3BHA} \\ c_{u1BHA} & c_{u3BHA} \\ c_{a1BHA} & c_{a3BHA} \\ \alpha_{1BHA} & \alpha_{3BHA} \\ c_{1BHA} & c_{3BHA} \\ \lambda_{c1BHA} & \lambda_{c3BHA} \\ \varepsilon_{BHA} & \varepsilon_{BHA} \end{pmatrix} =$$

for $i \in 1$

for $r \in 1 .. N_r$

$$\begin{pmatrix} T^*_{1BHA_r} \\ T^*_{3BHA_r} \end{pmatrix} = \begin{pmatrix} T^*_{1BHA_{av(N_r)}} \\ T^*_{3BHA_{av(N_r)}} \end{pmatrix}$$

$$\begin{pmatrix} P^*_{1BHA_r} \\ P^*_{3BHA_r} \end{pmatrix} = \begin{pmatrix} P^*_{1BHA_{av(N_r)}} \\ P^*_{3BHA_{av(N_r)}} \end{pmatrix}$$

$$\begin{pmatrix} \rho^*_{1BHA_r} \\ \rho^*_{3BHA_r} \end{pmatrix} = \begin{pmatrix} \rho^*_{1BHA_{av(N_r)}} \\ \rho^*_{3BHA_{av(N_r)}} \end{pmatrix}$$

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

$$\begin{pmatrix} k_{1BHA_r} \\ k_{3BHA_r} \end{pmatrix} = \begin{pmatrix} k_{ад}\left(Cp_{1BHA_r}, R_в\right) \\ k_{ад}\left(Cp_{3BHA_r}, R_в\right) \end{pmatrix}$$

$$\begin{pmatrix} a^*_{c1BHA_r} \\ a^*_{c3BHA_r} \end{pmatrix} = \begin{pmatrix} \sqrt{\dfrac{2 \cdot k_{1BHA_r}}{k_{1BHA_r}+1} \cdot R_в \cdot T^*_{1BHA_r}} \\ \sqrt{\dfrac{2 \cdot k_{3BHA_r}}{k_{3BHA_r}+1} \cdot R_в \cdot T^*_{3BHA_r}} \end{pmatrix}$$

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

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

$$\begin{pmatrix} c_{u1BHA} \end{pmatrix} \quad \left[\; c_{u1BHA_{av(N_r)}} \quad A \quad B \right.$$

$$\begin{pmatrix} c_{u1BHA_r} \\ c_{u3BHA_r} \end{pmatrix} = \begin{bmatrix} \dfrac{A}{\left(R_{st(i,1),r}\right)^{m_i}} - \dfrac{B}{\left(R_{st(i,1),r}\right)} & \text{if } BHA = 1 \\ c_{u1BHA_{av(N_r)}} & \text{otherwise} \end{bmatrix}$$

$$\begin{pmatrix} c_{a1BHA_r} \\ c_{a3BHA_r} \end{pmatrix} = \begin{bmatrix} c_{a1BHA_{av(N_r)}} \\ \left| \begin{array}{l} \text{if } BHA = 1 \\ \quad \left| \begin{array}{ll} \sqrt{\left(c_{a3BHA_{av(N_r)}}\right)^2 - 2\cdot A^2\cdot\left[\left(R_{st(i,1),r}\right)^2 - \left(R_{st(i,1),av(N_r)}\right)^2\right] + 4\cdot A\cdot B\cdot \ln\left(\dfrac{R_{st(i,1),r}}{R_{st(i,1),av(N_r)}}\right)} & \text{if } m_i = -1 \\ \sqrt{\left(c_{a3BHA_{av(N_r)}}\right)^2 - 2\cdot A^2\cdot \ln\left(\dfrac{R_{st(i,1),r}}{R_{st(i,1),av(N_r)}}\right) - 2\cdot A\cdot B\cdot\left(\dfrac{1}{R_{st(i,1),r}} - \dfrac{1}{R_{st(i,1),av(N_r)}}\right)} & \text{if } m_i = 0 \\ \sqrt{\left(c_{a3BHA_{av(N_r)}}\right)^2 + \dfrac{A\cdot(m_i - 1)\cdot\left[\begin{array}{l} -A\cdot(m_i+1)\cdot\left[\dfrac{1}{\left(R_{st(i,1),r}\right)^{2\cdot m_i}} - \dfrac{1}{\left(R_{st(i,1),av(N_r)}\right)^{2\cdot m_i}}\right] \ldots \\ + 2\cdot B\cdot m_i\cdot\left[\dfrac{1}{\left(R_{st(i,1),r}\right)^{m_i+1}} - \dfrac{1}{\left(R_{st(i,1),av(N_r)}\right)^{m_i+1}}\right] \end{array}\right]}{m_i\cdot(m_i+1)}} & \text{otherwise} \end{array}\right. \\ c_{a1BHA_{av(N_r)}} \quad \text{otherwise} \end{array}\right. \end{bmatrix}$$

$$\begin{pmatrix} \alpha_{1BHA_r} \\ \alpha_{3BHA_r} \end{pmatrix} = \begin{pmatrix} \text{triangle}\left(c_{a1BHA_r}, c_{u1BHA_r}\right) \\ \text{triangle}\left(c_{a3BHA_r}, c_{u3BHA_r}\right) \end{pmatrix}$$

$$\begin{pmatrix} c_{1BHA_r} \\ c_{3BHA_r} \end{pmatrix} = \begin{pmatrix} \dfrac{c_{a1BHA_r}}{\sin\left(\alpha_{1BHA_r}\right)} \\ \dfrac{c_{a3BHA_r}}{\sin\left(\alpha_{3BHA_r}\right)} \end{pmatrix}$$

$$\begin{pmatrix} \lambda_{c1BHA_r} \\ \lambda_{c3BHA_r} \end{pmatrix} = \begin{pmatrix} \dfrac{c_{1BHA_r}}{a^*_{c1BHA_r}} \\ \dfrac{c_{3BHA_r}}{a^*_{c3BHA_r}} \end{pmatrix}$$

$$\varepsilon_{BHA_r} = -1\cdot\left(\alpha_{3BHA_r} - \alpha_{1BHA_r}\right)$$

$$\begin{pmatrix} T^*_{1BHA} & P^*_{1BHA} & \rho^*_{1BHA} & Cp_{1BHA} & k_{1BHA} & a^*_{c1BHA} & c_{u1BHA} & c_{a1BHA} & \alpha_{1BHA} & c_{1BHA} & \lambda_{c1BHA} & \varepsilon_{BHA} \\ T^*_{3BHA} & P^*_{3BHA} & \rho^*_{3BHA} & Cp_{3BHA} & k_{3BHA} & a^*_{c3BHA} & c_{u3BHA} & c_{a3BHA} & \alpha_{3BHA} & c_{3BHA} & \lambda_{c3BHA} & \varepsilon_{BHA} \end{pmatrix}^T$$

$$
\begin{pmatrix}
T^* & T \\
P^* & P \\
\rho^* & \rho \\
Cp & k \\
a^*_c & a_{зв} \\
c_u & c_a \\
\alpha & \beta \\
c & w \\
\lambda_c & w_u \\
M_w & M_c \\
R_L & R_L \\
\varepsilon_{rotor} & \varepsilon_{stator}
\end{pmatrix}
=
\left|
\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 Cp_{st(i,a),r} = Cp_{воздух}\left(P^*_{st(i,a),r}, T^*_{st(i,a),r}\right) \\
\quad\quad\quad k_{st(i,a),r} = k_{ад}\left(Cp_{st(i,a),r}, R_в\right) \\
\quad\quad\quad a^*_{c_{st(i,a),r}} = \sqrt{\dfrac{2\cdot k_{st(i,a),r}}{k_{st(i,a),r}+1}\cdot R_в \cdot T^*_{st(i,a),r}} \\
\quad\quad\quad \text{if } \Delta H_{Tmax} = 0 \\
\quad\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\quad B_{st(i,a)} = \dfrac{H_{T_{i,av(N_r)}}}{2\cdot\omega} \\
\quad\quad\quad\quad c_{u_{st(i,a),r}} = \left|
\begin{array}{l}
c_{u_{st(i,a-1),r}}\cdot\dfrac{R_{st(i,a),r}}{R_{st(i,a-1),r}} + \dfrac{H_{T_{i,av(N_r)}}}{\omega\cdot R_{st(i,a),r}} \quad \text{if } a = 2 \\
\text{otherwise} \\
\quad \left|
\begin{array}{l}
0 \quad \text{if } (a = 1) \wedge (i = 1) \wedge (BHA = 0) \\
\dfrac{A_{st(i,a)}}{\left(R_{st(i,a),r}\right)^{m_i}} - \dfrac{B_{st(i,a)}}{\left(R_{st(i,a),r}\right)} \quad \text{otherwise}
\end{array}
\right.
\end{array}
\right. \\
\quad\quad\quad\quad c_{a_{st(i,a),r}} = \left|
\begin{array}{l}
c_{a3BHA_r} \quad \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(\dfrac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right)}\cdot\left|\begin{array}{l}-1 \quad \text{if } a = 2 \\ 1 \quad \text{otherwise}\end{array}\right. \quad \text{if } m_i = -1 \\
\sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 - 2\cdot\left(A_{st(i,a)}\right)^2\cdot\ln\left(\dfrac{R_{st(i,a),r}}{R\ldots}\right) - 2\cdot A_{st(i,a)}\cdot B_{st(i,a)}\cdot\left(\dfrac{1}{R\ldots} - \dfrac{1}{R\ldots}\right)}\cdot\left|-1 \quad \text{if } a = 2\right. \quad \text{if } m_i = 0
\end{array}
\right.
\end{array}
\right.
$$

$$\ldots \quad \begin{cases} \ldots \\ 1 & \text{otherwise} \end{cases}$$

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

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

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

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

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

$$k_{HT} = \frac{H_{T_{i,av(N_r)}} - H_{T_{i,1}}}{R_{st(i,a),av(N_r)} - R_{st(i,a),1}}$$

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

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

$$\alpha_{st(i,a)} \ldots = \text{triangle}(c \ldots, c \ldots)$$

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

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

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

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

$$a_{зв_{st(i,a),r}} = \sqrt{k_{st(i,a),r} \cdot R_{в} \cdot T_{st(i,a),r}}$$

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

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

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

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

for $r \in 1 .. N_r$

$$R_{L_{i,r}} = 1 - \frac{c_{u_{st(i,1),r}} + c_{u_{st(i,2),r}}}{u_{st(i,1),r} + u_{st(i,2),r}}$$

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

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

$$\begin{pmatrix} T^*_{1CA} & T^*_{3CA} \\ P^*_{1CA} & P^*_{3CA} \\ \rho^*_{1CA} & \rho^*_{3CA} \\ Cp_{1CA} & Cp_{3CA} \\ k_{1CA} & k_{3CA} \\ a^*_{c1CA} & a^*_{c3CA} \\ c_{u1CA} & c_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ \alpha_{1CA} & \alpha_{3CA} \\ c_{1CA} & c_{3CA} \\ \lambda_{c1CA} & \lambda_{c3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{pmatrix} = \quad \text{for } i \in Z$$

$$\text{for } r \in 1..N_r$$

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

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

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

$$\begin{pmatrix} Cp{1CA}_r \\ Cp{3CA}_r \end{pmatrix} = \begin{pmatrix} Cp_{воздух}\left(P^*{1CA}_r, T^*{1CA}_r\right) \\ Cp_{воздух}\left(P^*{3CA}_r, T^*{3CA}_r\right) \end{pmatrix}$$

$$\begin{pmatrix} k{1CA}_r \\ k{3CA}_r \end{pmatrix} = \begin{pmatrix} k_{ад}\left(Cp{1CA}_r, R_в\right) \\ k_{ад}\left(Cp{3CA}_r, R_в\right) \end{pmatrix}$$

$$\begin{pmatrix} a^*{c1CA}_r \\ a^*{c3CA}_r \end{pmatrix} = \begin{pmatrix} \sqrt{\dfrac{2 \cdot k{1CA}_r}{k{1CA}_r + 1} \cdot R_в \cdot T^*{1CA}_r} \\ \sqrt{\dfrac{2 \cdot k{3CA}_r}{k{3CA}_r + 1} \cdot R_в \cdot T^*{3CA}_r} \end{pmatrix}$$

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

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

$$\begin{pmatrix} c_{u1CA_r} \\ c_{u3CA} \ldots \end{pmatrix} = \begin{pmatrix} c_{u_{st(i,3),r}} \\ c_{u3CA_{av(N_r)}} \quad \text{if } CA = 1 \\ \ldots \end{pmatrix}$$

$$c_{u3CA_r} \quad \left| \; c_{u_{st(i,3),r}} \quad \text{otherwise} \right)$$

$$\begin{pmatrix} c_{a1CA_r} \\ c_{a3CA_r} \end{pmatrix} = \left[\begin{array}{l} c_{a_{st(i,3),r}} \\ \left| \begin{array}{l} \text{if } CA = 1 \\ \quad \left| \begin{array}{ll} \sqrt{\left(c_{a3CA_{av(N_r)}}\right)^2 - 2\cdot A^2\cdot\left[\left(R_{st(i,3),r}\right)^2 - \left(R_{st(i,3),av(N_r)}\right)^2\right] + 4\cdot A\cdot B\cdot \ln\left(\dfrac{R_{st(i,3),r}}{R_{st(i,3),av(N_r)}}\right)} & \text{if } m_i = -1 \\ \sqrt{\left(c_{a3CA_{av(N_r)}}\right)^2 - 2\cdot A^2\cdot \ln\left(\dfrac{R_{st(i,3),r}}{R_{st(i,3),av(N_r)}}\right) - 2\cdot A\cdot B\cdot\left(\dfrac{1}{R_{st(i,3),r}} - \dfrac{1}{R_{st(i,3),av(N_r)}}\right)} & \text{if } m_i = 0 \\ \sqrt{\left(c_{a3CA_{av(N_r)}}\right)^2 + \dfrac{A\cdot(m_i - 1)\cdot\left[-A\cdot(m_i+1)\cdot\left[\dfrac{1}{\left(R_{st(i,3),r}\right)^{2\cdot m_i}} - \dfrac{1}{\left(R_{st(i,3),av(N_r)}\right)^{2\cdot m_i}}\right] \ldots + 2\cdot B\cdot m_i\cdot\left[\dfrac{1}{\left(R_{st(i,3),r}\right)^{m_i+1}} - \dfrac{1}{\left(R_{st(i,3),av(N_r)}\right)^{m_i+1}}\right]\right]}{m_i\cdot(m_i+1)}} & \text{otherwise} \end{array} \right. \\ c_{a_{st(i,3),r}} \quad \text{otherwise} \end{array} \right. \end{array}\right]$$

$$\begin{pmatrix} \alpha_{1CA_r} \\ \alpha_{3CA_r} \end{pmatrix} = \begin{pmatrix} \text{triangle}\left(c_{a1CA_r}, c_{u1CA_r}\right) \\ \text{triangle}\left(c_{a3CA_r}, c_{u3CA_r}\right) \end{pmatrix}$$

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

$$\begin{pmatrix} \lambda_{c1CA_r} \\ \lambda_{c3CA_r} \end{pmatrix} = \begin{pmatrix} \dfrac{c_{1CA_r}}{a^*_{c1CA_r}} \\ \dfrac{c_{3CA_r}}{a^*_{c3CA_r}} \end{pmatrix}$$

$$\varepsilon_{CA_r} = \left(\alpha_{3CA_r} - \alpha_{1CA_r}\right)$$

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

Расчет параметров потока по высоте Л

Результаты расчета параметров потока по высоте Л

$$T^*_{1ВНА} = \begin{pmatrix} 418.2 \\ 418.2 \\ 418.2 \end{pmatrix} \quad T^*_{3ВНА} = \begin{pmatrix} 418.2 \\ 418.2 \\ 418.2 \end{pmatrix} \quad a^*_{c1ВНА} = \begin{pmatrix} 373.95 \\ 373.95 \\ 373.95 \end{pmatrix} \quad a^*_{c3ВНА} = \begin{pmatrix} 373.95 \\ 373.95 \\ 373.95 \end{pmatrix} \quad \alpha_{1ВНА} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ° \quad \alpha_{3ВНА} = \begin{pmatrix} 66.71 \\ 67.39 \\ 68.13 \end{pmatrix} \cdot °$$

$$P^*_{1ВНА} = \begin{pmatrix} 316.2 \\ 316.2 \\ 316.2 \end{pmatrix} \cdot 10^3 \quad P^*_{3ВНА} = \begin{pmatrix} 315.6 \\ 315.6 \\ 315.6 \end{pmatrix} \cdot 10^3 \quad c_{1ВНА} = \begin{pmatrix} 99.9 \\ 99.9 \\ 99.9 \end{pmatrix} \quad c_{3ВНА} = \begin{pmatrix} 112.6 \\ 108.2 \\ 105.6 \end{pmatrix} \quad \varepsilon_{ВНА} = \begin{pmatrix} 23.29 \\ 22.61 \\ 21.87 \end{pmatrix} \cdot °$$

$$\rho^*_{1ВНА} = \begin{pmatrix} 2.633 \\ 2.633 \\ 2.633 \end{pmatrix} \quad \rho^*_{3ВНА} = \begin{pmatrix} 2.628 \\ 2.628 \\ 2.628 \end{pmatrix} \quad c_{u1ВНА} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix} \quad c_{u3ВНА} = \begin{pmatrix} 44.5 \\ 41.6 \\ 39.3 \end{pmatrix}$$

$$Cp_{1ВНА} = \begin{pmatrix} 1016.2 \\ 1016.2 \\ 1016.2 \end{pmatrix} \quad Cp_{3ВНА} = \begin{pmatrix} 1016.2 \\ 1016.2 \\ 1016.2 \end{pmatrix} \quad c_{a1ВНА} = \begin{pmatrix} 99.9 \\ 99.9 \\ 99.9 \end{pmatrix} \quad c_{a3ВНА} = \begin{pmatrix} 103.5 \\ 99.9 \\ 98.0 \end{pmatrix} \quad \lambda_{c1ВНА} = \begin{pmatrix} 0.267 \\ 0.267 \\ 0.267 \end{pmatrix} \quad \lambda_{c3ВНА} = \begin{pmatrix} 0.301 \\ 0.289 \\ 0.282 \end{pmatrix}$$

$$k_{1ВНА} = \begin{pmatrix} 1.394 \\ 1.394 \\ 1.394 \end{pmatrix} \quad k_{3ВНА} = \begin{pmatrix} 1.394 \\ 1.394 \\ 1.394 \end{pmatrix}$$

$T^{*T} =$

	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						

$T^{T} =$

	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						

$P^{*T} =$

	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		

$\cdot 10^3$

$P^{T} =$

	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		

$\cdot 10^3$

$\rho^{*T} =$

	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		

$\rho^{T} =$

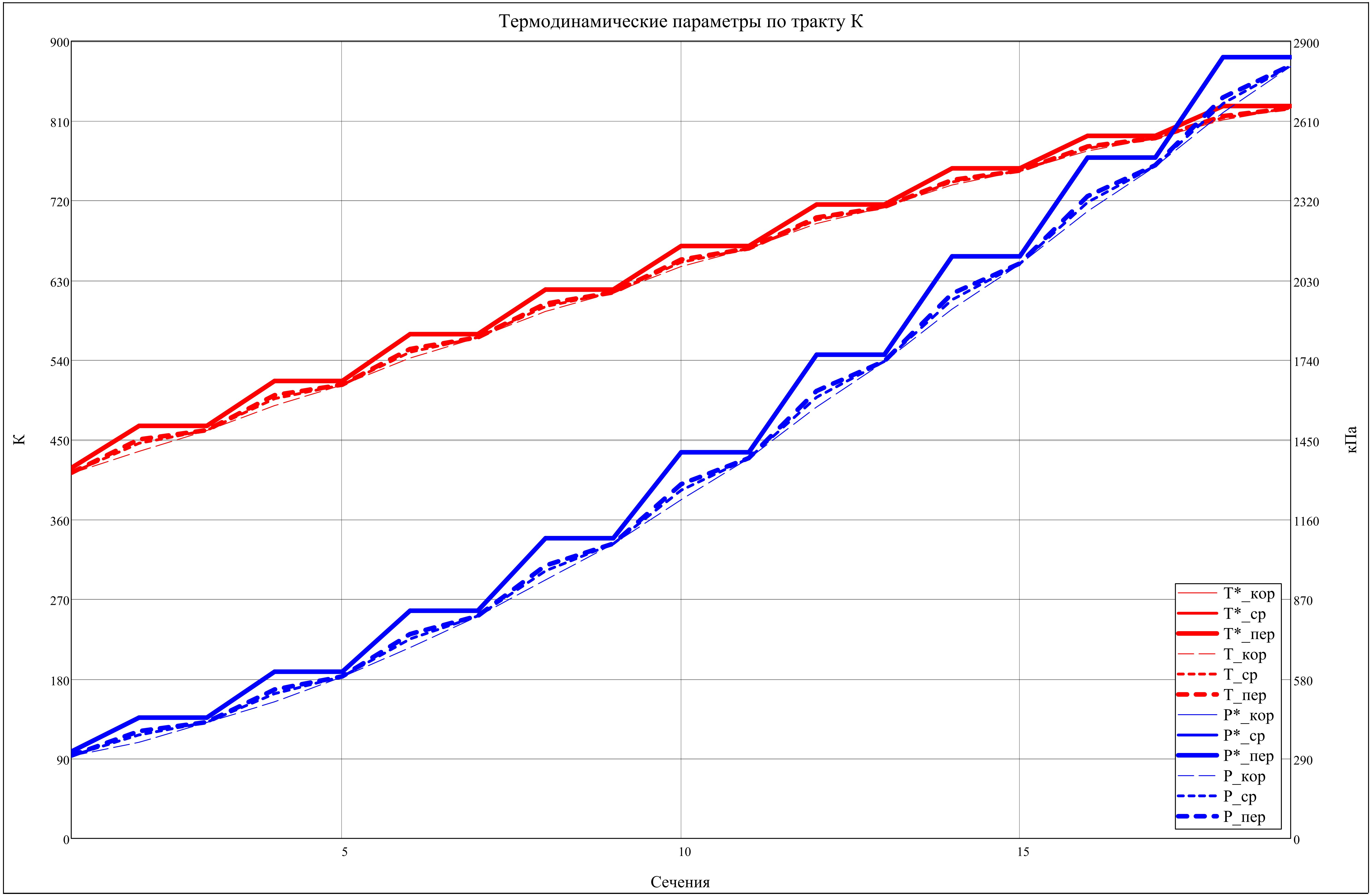
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	2.530	2.788	3.190	3.542	3.999	4.458	4.977	5.506	6.052	6.648	7.230	7.875	8.472	9.091	9.651	10.236	10.772	11.338	11.866		
2	2.537	2.940	3.196	3.691	4.003	4.604	4.981	5.644	6.055	6.782	7.233	8.004	8.477	9.207	9.657	10.345	10.780	11.441	11.873		
3	2.542	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		

$Cp^{T} =$

	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						

$k^{T} =$

	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
900
810
720
630
540
450
360
270
180
90
0
К
2900
2610
2320
2030
1740
1450
1160
870
580
290
0
кПа
5
10
15
Сечения
T*_кор
T*_ср
T*_пер
T_кор
T_ср
T_пер
P*_кор
P*_ср
P*_пер
P_кор
P_ср
P_пер

$a^*{}_c^T =$

	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						

$a_{зв}^T =$

	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						

$c^T =$

	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					

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

$\Delta c_a{}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.00	7.83	-16.91	-2.36	-3.28	-3.22	-3.10	-2.80	-2.72	-2.51	-2.46	-2.27	-2.23	-2.04	-2.02	-1.89	-1.87	-0.38	-0.38		
2	0.00	-2.60	-3.01	-2.79	-2.73	-3.22	-3.10	-2.80	-2.72	-2.51	-2.46	-2.27	-2.23	-2.04	-2.02	-1.89	-1.87	-0.38	-0.38		
3	0.00	-8.41	4.66	-3.01	-2.45	-3.22	-3.10	-2.80	-2.72	-2.51	-2.46	-2.27	-2.23	-2.04	-2.02	-1.89	-1.87	-0.38	-0.38		

[16, c. 81] $\Delta c_a{}^T \geq -25 =$

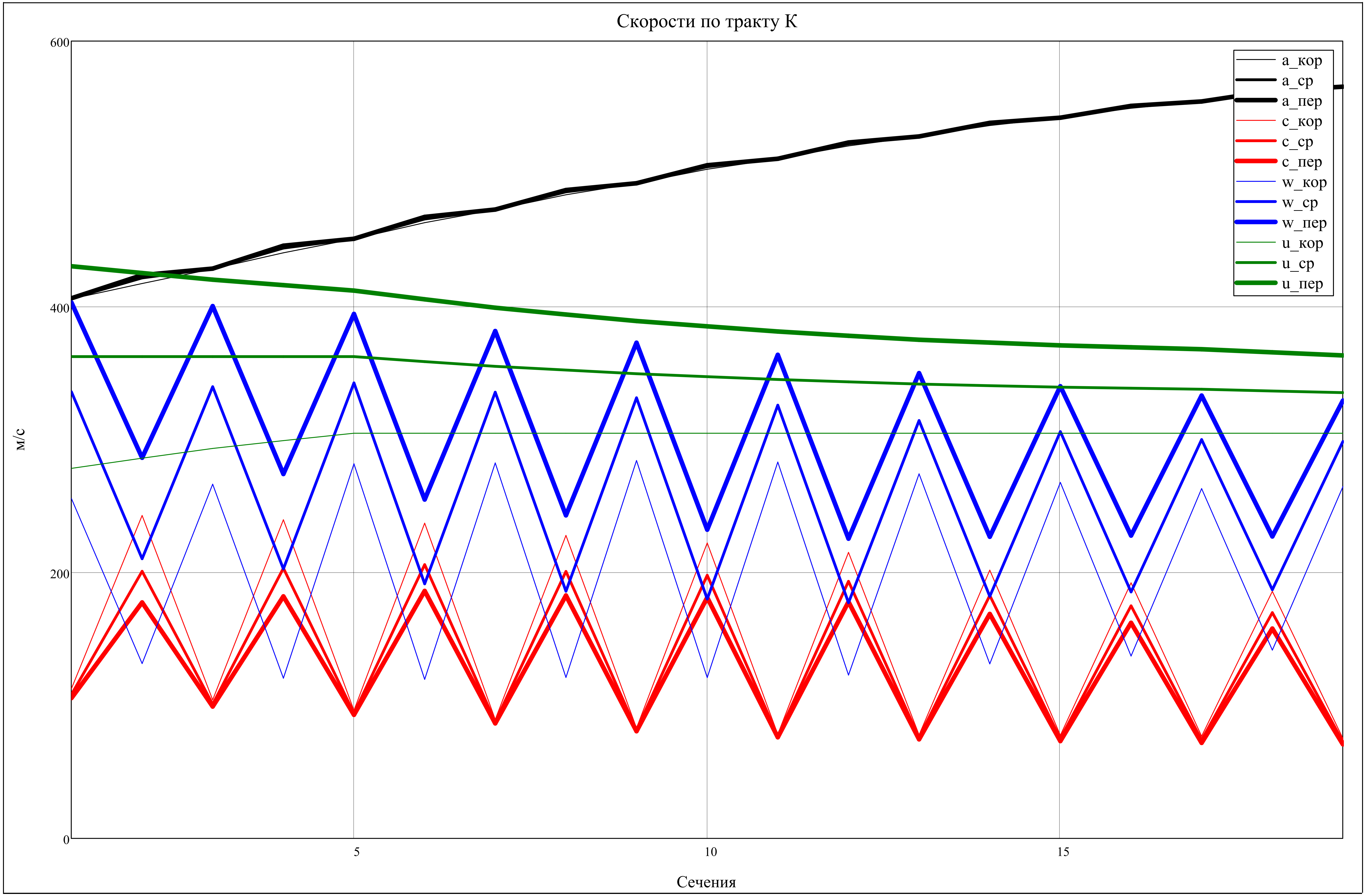
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						

$R_L{}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.5386	0.5520	0.5759	0.5927	0.6054	0.6153	0.6229	0.6280	0.6314			
2	0.7000	0.7000	0.6967	0.6974	0.6978	0.6983	0.6990	0.6994	0.6990			
3	0.7749	0.7743	0.7639	0.7592	0.7552	0.7519	0.7495	0.7478	0.7457			

$R_L{}^T \geq 0 =$

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



Скорости по тракту К
600
400
200
0
м/с
5
10
15
Сечения
a_кор
a_ср
a_пер
c_кор
c_ср
c_пер
w_кор
w_ср
w_пер
u_кор
u_ср
u_пер

$\alpha^T =$ $\cdot°$

	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						

$\beta^T =$ $\cdot°$

	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		

$\beta^T \le 91\cdot° =$

	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		

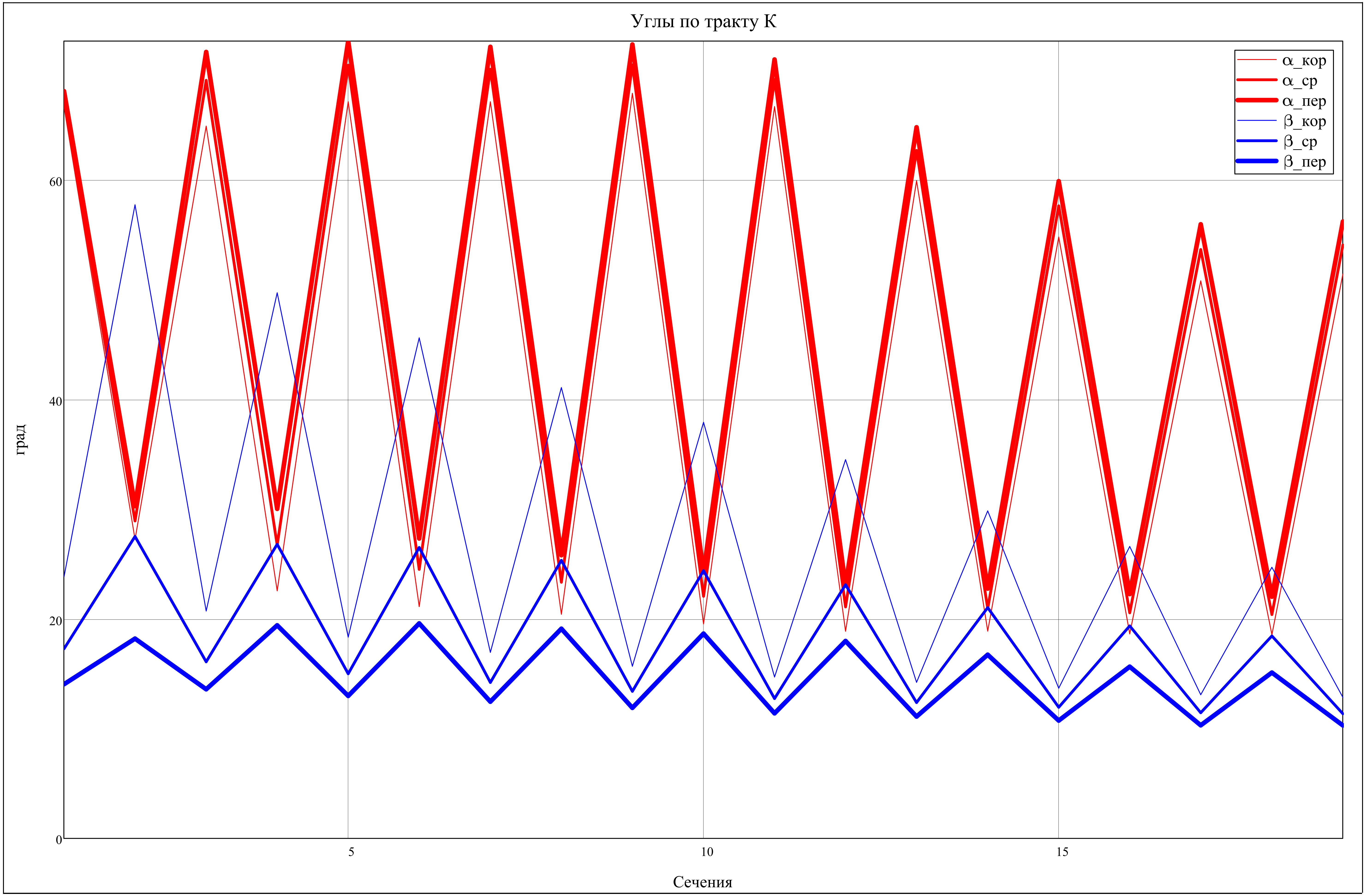
β.2 > 91 => поменять з-н профилирования

$\varepsilon_{rotor}{}^T =$ $\cdot°$

	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						

$\varepsilon_{stator}{}^T =$ $\cdot°$

	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						


Углы по тракту К
α_кор
α_ср
α_пер
β_кор
β_ср
β_пер
град
0
20
40
60
5
10
15
Сечения

$\lambda_c^T =$

	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] $\lambda_c^T \le 0.85 =$

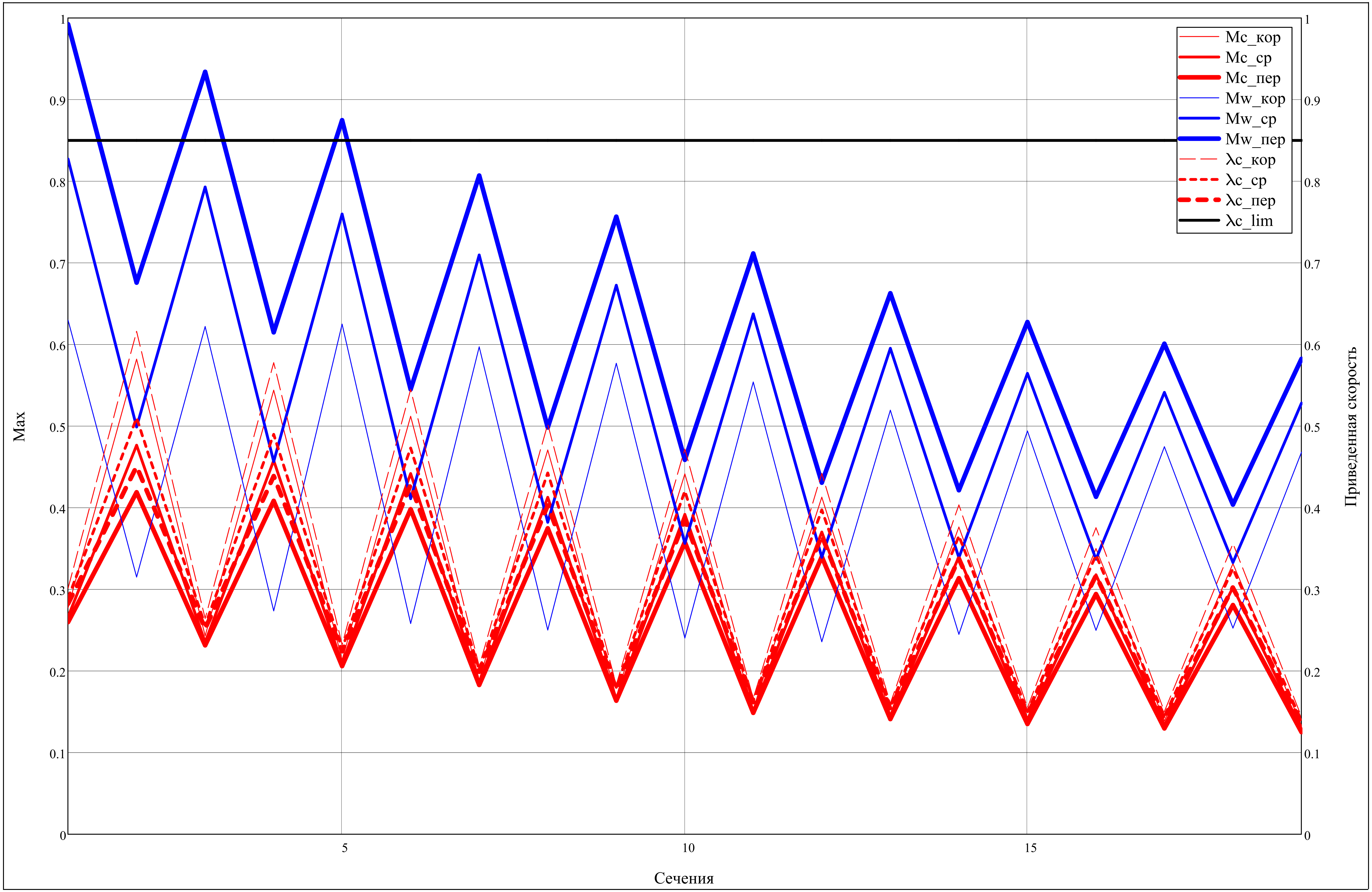
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

$M_c^T =$

	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				



Мс_кор
Мс_ср
Мс_пер
Мw_кор
Мw_ср
Мw_пер
λс_кор
λс_ср
λс_пер
λс_lim
Max
Приведенная скорость
Сечения

$$T^*_{1CA} = \begin{pmatrix} 826.7 \\ 826.7 \\ 826.7 \end{pmatrix} \qquad T^*_{3CA} = \begin{pmatrix} 826.7 \\ 826.7 \\ 826.7 \end{pmatrix} \qquad a^*_{c1CA} = \begin{pmatrix} 522.4 \\ 522.4 \\ 522.4 \end{pmatrix} \qquad a^*_{c3CA} = \begin{pmatrix} 522.4 \\ 522.4 \\ 522.4 \end{pmatrix} \qquad \alpha_{1CA} = \begin{pmatrix} 51.47 \\ 54.10 \\ 56.25 \end{pmatrix} \cdot ° \qquad \alpha_{3CA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot °$$

$$P^*_{1CA} = \begin{pmatrix} 2841.7 \\ 2841.7 \\ 2841.7 \end{pmatrix} \cdot 10^3 \qquad P^*_{3CA} = \begin{pmatrix} 2836.3 \\ 2836.3 \\ 2836.3 \end{pmatrix} \cdot 10^3 \qquad c_{1CA} = \begin{pmatrix} 75.3 \\ 72.7 \\ 70.8 \end{pmatrix} \qquad c_{3CA} = \begin{pmatrix} 48.9 \\ 48.9 \\ 48.9 \end{pmatrix} \qquad \varepsilon_{CA} = \begin{pmatrix} 38.53 \\ 35.90 \\ 33.75 \end{pmatrix} \cdot °$$

$$\rho^*_{1CA} = \begin{pmatrix} 11.972 \\ 11.972 \\ 11.972 \end{pmatrix} \qquad \rho^*_{3CA} = \begin{pmatrix} 11.949 \\ 11.949 \\ 11.949 \end{pmatrix} \qquad c_{u1CA} = \begin{pmatrix} 46.9 \\ 42.6 \\ 39.3 \end{pmatrix} \qquad c_{u3CA} = \begin{pmatrix} 0.0 \\ 0.0 \\ 0.0 \end{pmatrix}$$

$$Cp_{1CA} = \begin{pmatrix} 1103.8 \\ 1103.8 \\ 1103.8 \end{pmatrix} \qquad Cp_{3CA} = \begin{pmatrix} 1103.8 \\ 1103.8 \\ 1103.8 \end{pmatrix} \qquad c_{a1CA} = \begin{pmatrix} 58.9 \\ 58.9 \\ 58.9 \end{pmatrix} \qquad c_{a3CA} = \begin{pmatrix} 48.9 \\ 48.9 \\ 48.9 \end{pmatrix} \qquad \lambda_{c1CA} = \begin{pmatrix} 0.144 \\ 0.139 \\ 0.136 \end{pmatrix} \qquad \lambda_{c3CA} = \begin{pmatrix} 0.094 \\ 0.094 \\ 0.094 \end{pmatrix}$$

$$k_{1CA} = \begin{pmatrix} 1.352 \\ 1.352 \\ 1.352 \end{pmatrix} \qquad k_{3CA} = \begin{pmatrix} 1.352 \\ 1.352 \\ 1.352 \end{pmatrix}$$

Результаты расчета параметров потока по высоте Л

Рассматриваемая ступень: $j = \left| \begin{array}{l} j = 1 \\ j = \left| \begin{array}{ll} \text{"Такой ступени не существует!"} & \text{if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{array} \right. \end{array} \right. = 1$

Построение треугольников скоростей в 3х сечениях

$$\Delta_c(v,i,j,r) = \left| \begin{array}{ll} \tan\left(\alpha_{st(i,j),r}\right)\cdot v & \text{if } \left(\tan\left(\alpha_{st(i,j),r}\right) \ge 0 \wedge -\left|c_{st(i,j),r}\cdot\cos\left(\alpha_{st(i,j),r}\right)\right| \le v \le 0\right) \\ \tan\left(\alpha_{st(i,j),r}\right)\cdot v & \text{if } \left(\tan\left(\alpha_{st(i,j),r}\right) < 0 \wedge 0 \le v \le \left|c_{st(i,j),r}\cdot\cos\left(\alpha_{st(i,j),r}\right)\right|\right) \end{array} \right.$$

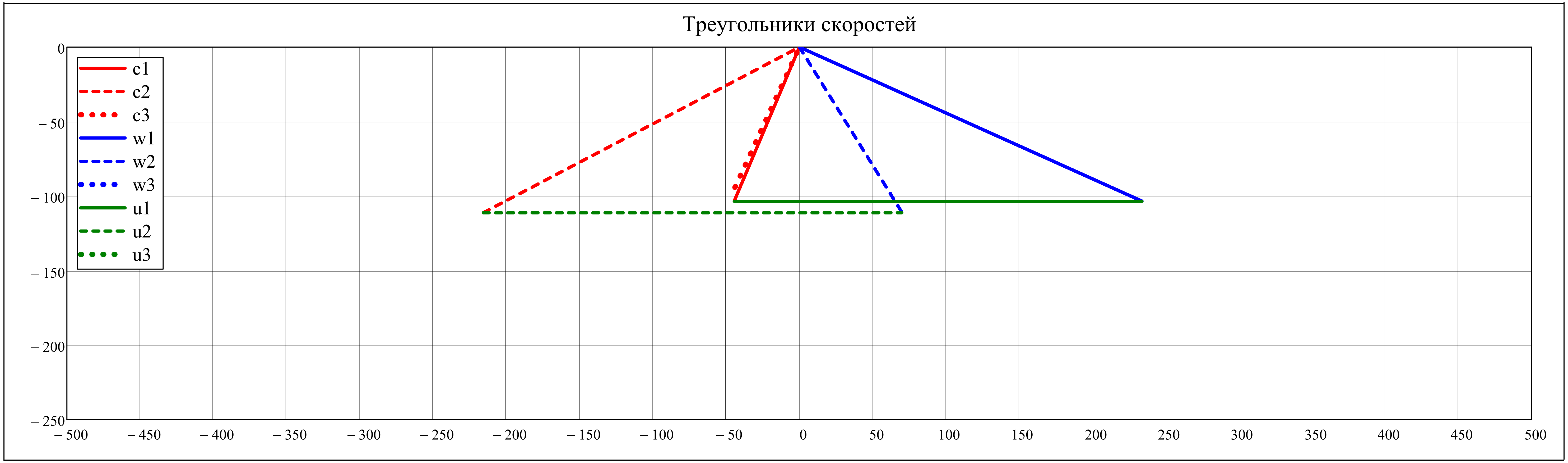
$$\Delta_w(v,i,j,r) = \left| \begin{array}{ll} -\tan\left(\beta_{st(i,j),r}\right)\cdot v & \text{if } \left(-\tan\left(\beta_{st(i,j),r}\right) \ge 0\right) \wedge \left(-\left|w_{st(i,j),r}\cdot\cos\left(\beta_{st(i,j),r}\right)\right| \le v \le 0\right) \wedge (j \ne 3) \\ -\tan\left(\beta_{st(i,j),r}\right)\cdot v & \text{if } \left(-\tan\left(\beta_{st(i,j),r}\right) < 0\right) \wedge \left(0 \le v \le \left|w_{st(i,j),r}\cdot\cos\left(\beta_{st(i,j),r}\right)\right|\right) \wedge (j \ne 3) \end{array} \right.$$

$$\Delta_u(v,i,j,r) = \left| \begin{array}{ll} -c_{a_{st(i,j),r}} & \text{if } \left(-c_{st(i,j),r}\cdot\cos\left(\alpha_{st(i,j),r}\right) \le v \le w_{st(i,j),r}\cdot\cos\left(\beta_{st(i,j),r}\right)\right) \wedge (j \ne 3) \\ \text{NaN} & \text{otherwise} \end{array} \right.$$

$$v_{lim} = \text{ceil}\left(\frac{\max(c,w,u)}{10^2}\right)\cdot 10^2 = 500$$

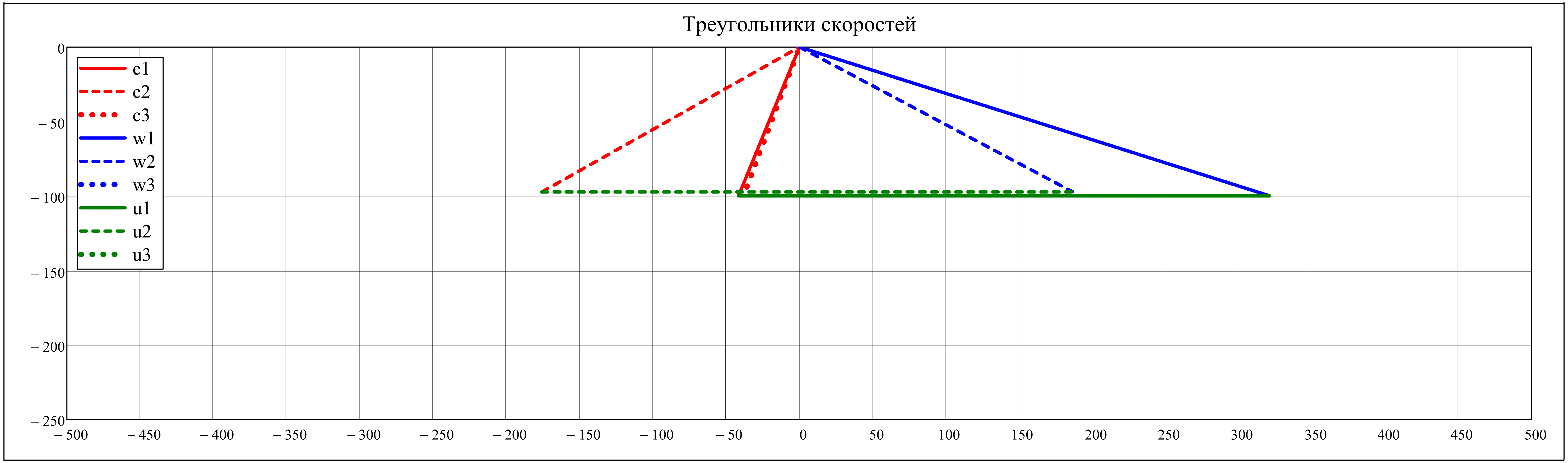
Дискретизация скорости: $v = -v_{lim}, -v_{lim} + \frac{v_{lim}}{3000} .. v_{lim}$

r = 1



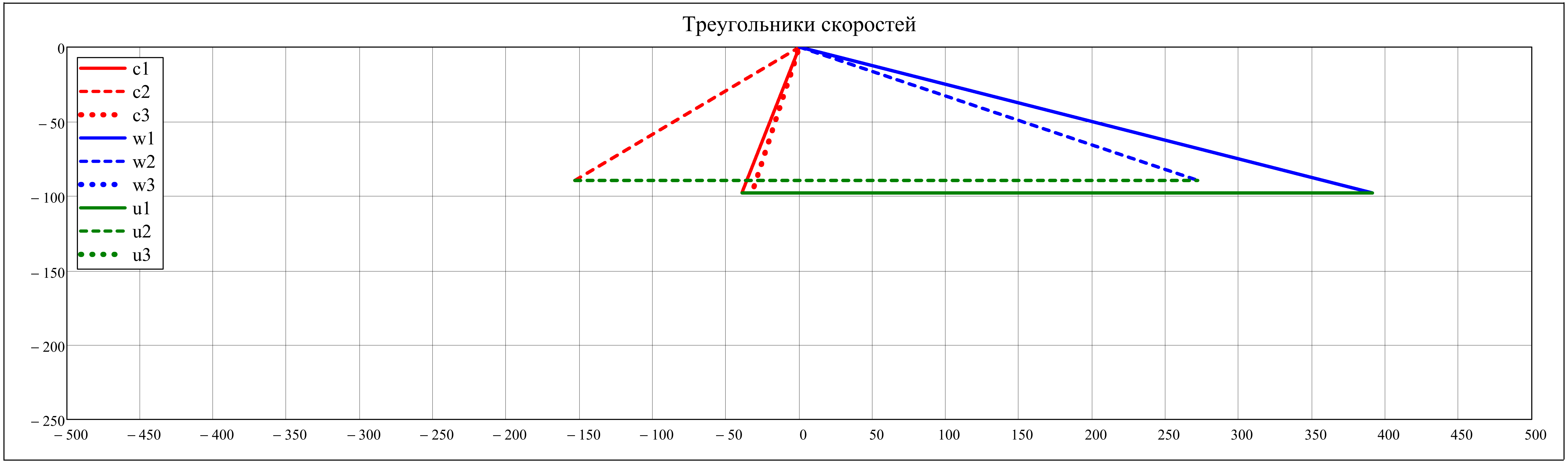
Треугольники скоростей
c1
c2
c3
w1
w2
w3
u1
u2
u3
0
− 50
− 100
− 150
− 200
− 250
− 500
− 450
− 400
− 350
− 300
− 250
− 200
− 150
− 100
− 50
0
50
100
150
200
250
300
350
400
450
500

$r := av(N_r)$



Треугольники скоростей
c1
c2
c3
w1
w2
w3
u1
u2
u3
0
− 50
− 100
− 150
− 200
− 250
− 500
− 450
− 400
− 350
− 300
− 250
− 200
− 150
− 100
− 50
0
50
100
150
200
250
300
350
400
450
500

$r = N_r$



Построение треугольников скоростей в 3х сечениях

Определение степени повышения полного давлеия по 2ум контурам

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

Кольцевые площади (м^2):

$\text{stack}\left(F_I^T, F_{II}^T, F^T\right) =$

	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):

$\text{stack}\left(R2^T, D2^T\right) =$

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

$\cdot 10^{-3}$

$$\begin{pmatrix}\pi^*_{II}\\ \pi^*_{I}\end{pmatrix} = \left| \begin{array}{l} \text{for } i\in 1..Z \\ \quad \text{for } a\in 1 \\ \qquad Cp(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(Cp,st(i,a),st(i,a),1,N_r)^T\right), \text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(Cp,st(i,a),st(i,a),1,N_r)^T, z\right) \\ \qquad k(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(k,st(i,a),st(i,a),1,N_r)^T\right), \text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(k,st(i,a),st(i,a),1,N_r)^T, z\right) \\ \qquad T^*(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(T^*,st(i,a),st(i,a),1,N_r)^T\right), \text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(T^*,st(i,a),st(i,a),1,N_r)^T, z\right) \\ \qquad H_T(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(H_T,i,i,1,N_r)^T\right), \text{submatrix}(R,st(i,a),st(i,a),1,N_r)^T, \text{submatrix}(H_T,i,i,1,N_r)^T, z\right) \\ \qquad \pi^*_{II_i} = \left| \begin{array}{l} 1 \ \text{ if } m2 = 0 \\ \dfrac{2\cdot\pi}{F_{II_{st(i,a)}}}\cdot\displaystyle\int_{R2_{st(i,a)}}^{R_{st(i,a),N_r}} \left(1+\frac{K_{H_i}\cdot\eta^*_i\cdot H_T(r)}{Cp(r)\cdot T^*(r)}\right)^{\frac{k(r)}{k(r)-1}}\cdot r\,dr \ \text{ otherwise} \end{array}\right. \\ \qquad \pi^*_{I_i} = \dfrac{2\cdot\pi}{F_{I_{st(i,a)}}}\cdot\displaystyle\int_{R_{st(i,a),1}}^{R2_{st(i,a)}} \left(1+\frac{K_{H_i}\cdot\eta^*_i\cdot H_T(r)}{Cp(r)\cdot T^*(r)}\right)^{\frac{k(r)}{k(r)-1}}\cdot r\,dr \\ \begin{pmatrix}\pi^*_{II}\\ \pi^*_{I}\end{pmatrix} \end{array}\right.$$

$\text{stack}\left(\pi^{*T}_{I}, \pi^{*T}_{II}\right) =$

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

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

Определение степени повышения полного давлеия по 2ум контурам

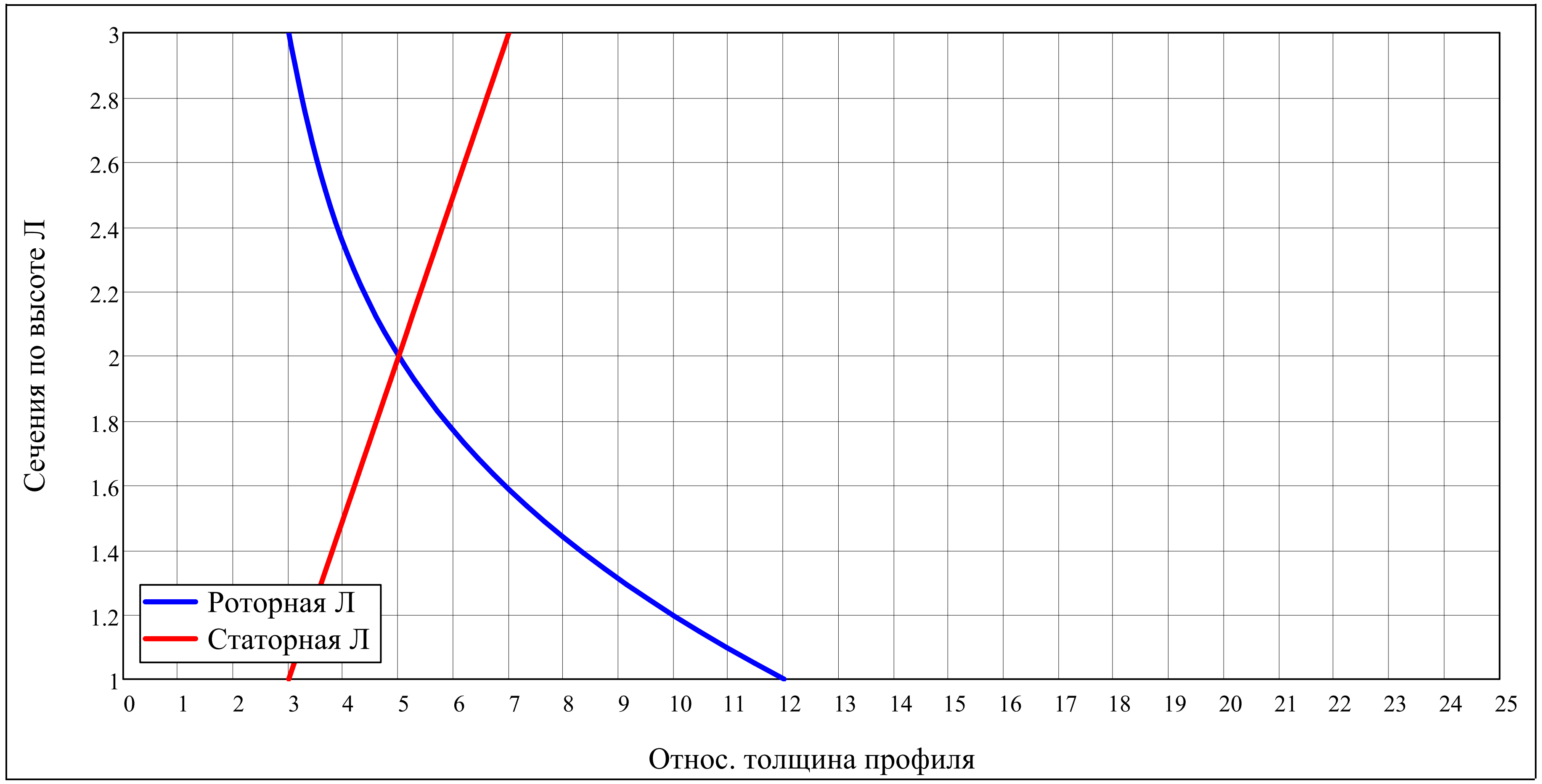
Относ. толщины и радиусы профилей

Относ. толщины Л РК и СА:

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

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

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



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

$\overline{c}_{BHA} =$

	1
1	3.00
2	5.00
3	7.00

$\cdot\%$

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

$\overline{c}_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
2	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
3	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00

$\cdot\%$

$\overline{c}_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
2	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
3	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

$\cdot\%$

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

$\overline{c}_{CA} =$

	1
1	3.00
2	5.00
3	7.00

$\cdot\%$

$$\begin{pmatrix} \overline{r\_inlet}_{BHA} \\ \overline{r\_outlet}_{BHA} \end{pmatrix} = \left| \begin{array}{l} \text{for } r \in 1..N_r \\ \quad \begin{pmatrix} \overline{r\_inlet}_{BHA_r} \\ \overline{r\_outlet}_{BHA_r} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{stator.}(r) \\ \begin{pmatrix} \overline{r\_inlet}_{BHA} \\ \overline{r\_outlet}_{BHA} \end{pmatrix} \end{array} \right. \quad \text{if } BHA = 1$$

$$\begin{pmatrix} \overline{r\_inlet}_{CA} \\ \overline{r\_outlet}_{CA} \end{pmatrix} = \left| \begin{array}{l} \text{for } r \in 1..N_r \\ \quad \begin{pmatrix} \overline{r\_inlet}_{CA_r} \\ \overline{r\_outlet}_{CA_r} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{stator.}(r) \\ \begin{pmatrix} \overline{r\_inlet}_{CA} \\ \overline{r\_outlet}_{CA} \end{pmatrix} \end{array} \right. \quad \text{if } CA = 1$$

$$\begin{pmatrix} \overline{r\_inlet}_{rotor} & \overline{r\_inlet}_{stator} \\ \overline{r\_outlet}_{rotor} & \overline{r\_outlet}_{stator} \end{pmatrix} = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } r \in 1..N_r \\ \quad\quad \begin{pmatrix} \overline{r\_inlet}_{stator_{i,r}} \\ \overline{r\_outlet}_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{stator.}(r) \\ \quad\quad \begin{pmatrix} \overline{r\_inlet}_{rotor_{i,r}} \\ \overline{r\_outlet}_{rotor_{i,r}} \end{pmatrix} = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} \cdot \overline{c}_{rotor.}(r) \\ \begin{pmatrix} \overline{r\_inlet}_{rotor} & \overline{r\_inlet}_{stator} \\ \overline{r\_outlet}_{rotor} & \overline{r\_outlet}_{stator} \end{pmatrix} \end{array} \right.$$

$\overline{r\_inlet}_{BHA} =$ $\cdot\%$

	1
1	0.600
2	1.000
3	1.400

$\overline{r\_inlet}_{CA} =$ $\cdot\%$

	1
1	0.600
2	1.000
3	1.400

$\overline{r\_inlet}_{stator}{}^{T} =$ $\cdot\%$

	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

$\overline{r\_inlet}_{rotor}{}^{T} =$ $\cdot\%$

	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

$\overline{r\_outlet}_{stator}{}^{T} =$ $\cdot\%$

	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

$\overline{r\_outlet}_{rotor}{}^{T} =$ $\cdot\%$

	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

$\overline{r\_outlet}_{BHA} =$ $\cdot\%$

	1
1	0.300
2	0.500
3	0.700

$\overline{r\_outlet}_{CA} =$ $\cdot\%$

	1
1	0.300
2	0.500
3	0.700

Относ. толщины и радиусы профилей

Распределение параметров по высоте Л

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

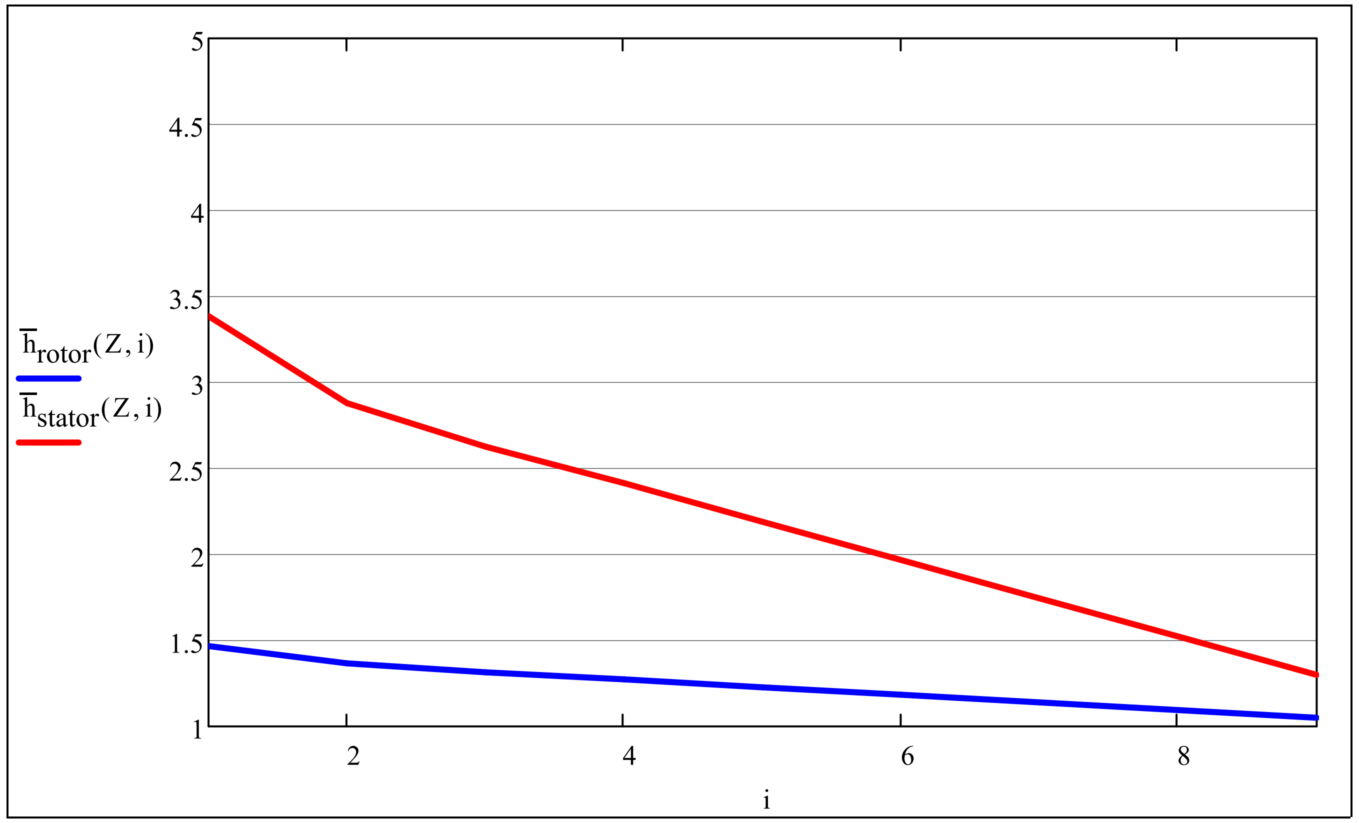
$$\overline{h}_{\sim rotor} = (2\ \ 1.9\ \ 1.85\ \ 1.8\ \ 1.75\ \ 1.7\ \ 1.65\ \ 1.6)^T + \begin{cases} 1.1 & \text{if compressor = "Вл"} \\ -0.1 & \text{if compressor = "КНД"} \\ -0.55 & \text{if compressor = "КВД"} \end{cases}$$

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

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

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

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



Для компрессора газогенератора

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

$\frac{h_{РК}}{S_{РК}}$=2,0…3,5 – для первой околозвуковой ступени;

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

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

[16, с. 83-84]

Распределение параметров по высоте Л

Парусность: $\begin{pmatrix} sail_{rotor} \\ sail_{stator} \end{pmatrix} = \begin{pmatrix} 1.3 \\ 1.2 \end{pmatrix}$

Расчет длин хорд по высоте Л

$$chord_{BHA} := \left| \begin{array}{l} \text{for } i \in 1 \\ \quad \left| \begin{array}{l} chord_{BHA_{av(N_r)}} \leftarrow \dfrac{h_{st(i,1)}}{\overline{h}_{stator}(Z,0)} \\ sail \leftarrow \dfrac{R_{st(1,1),N_r} - R_{st(1,1),1}}{R_{st(1,1),av(N_r)} - R_{st(1,1),1}} \\ \text{for } r \in 1..N_r \\ \quad \left| \begin{array}{l} b_{BHAкор} \leftarrow \dfrac{chord_{BHA_{av(N_r)}} \cdot sail}{sail_{stator} - 1 + sail} \\ b_{BHAпер} \leftarrow b_{BHAкор} \cdot sail_{stator} \\ b_{BHA.}(z) \leftarrow interp\left[cspline\left[\begin{pmatrix} R_{st(i,1),1} \\ R_{st(i,1),av(N_r)} \\ R_{st(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{BHAкор} \\ chord_{BHA_{av(N_r)}} \\ b_{BHAпер} \end{pmatrix}\right], \begin{pmatrix} R_{st(i,1),1} \\ R_{st(i,1),av(N_r)} \\ R_{st(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{BHAкор} \\ chord_{BHA_{av(N_r)}} \\ b_{BHAпер} \end{pmatrix}, z\right] \\ chord_{BHA_r} \leftarrow b_{BHA.}\left(R_{st(i,1),r}\right) \end{array} \right. \end{array} \right. \\ chord_{BHA} \end{array} \right. \quad \text{if } BHA = 1$$

$$
\begin{pmatrix} chord_{rotor} & chord_{stator} \end{pmatrix} = \left|
\begin{array}{l}
\text{for } i \in 1..Z \\
\quad \left|
\begin{array}{l}
\begin{pmatrix} chord_{rotor_{i,av(N_r)}} \\ chord_{stator_{i,av(N_r)}} \end{pmatrix} \leftarrow \begin{pmatrix} \dfrac{mean\left(h_{st(i,1)}, h_{st(i,2)}\right)}{\overline{h}_{rotor}(Z,i)} \\ \dfrac{mean\left(h_{st(i,2)}, h_{st(i,3)}\right)}{\overline{h}_{stator}(Z,i)} \end{pmatrix} \\
sail \leftarrow \dfrac{R_{st(i,2),N_r} - R_{st(i,2),1}}{R_{st(i,2),av(N_r)} - R_{st(i,2),1}} \\
\text{for } r \in 1..N_r \\
\quad \left|
\begin{array}{l}
b_{РКкор} \leftarrow \dfrac{chord_{rotor_{i,av(N_r)}} \cdot sail}{sail_{rotor} - 1 + sail} \\
b_{НАкор} \leftarrow \dfrac{chord_{stator_{i,av(N_r)}} \cdot sail}{sail_{stator} - 1 + sail} \\
\begin{pmatrix} b_{РКпер} \\ b_{НАпер} \end{pmatrix} \leftarrow \begin{pmatrix} b_{РКкор} \cdot sail_{rotor} \\ b_{НАкор} \cdot sail_{stator} \end{pmatrix} \\
chord_{rotor.}(z) \leftarrow interp\left[cspline\left[\begin{pmatrix} R_{st(i,2),1} \\ R_{st(i,2),av(N_r)} \\ R_{st(i,2),N_r} \end{pmatrix}, \begin{pmatrix} b_{РКкор} \\ chord_{rotor_{i,av(N_r)}} \\ b_{РКпер} \end{pmatrix}\right], \begin{pmatrix} R_{st(i,2),1} \\ R_{st(i,2),av(N_r)} \\ R_{st(i,2),N_r} \end{pmatrix}, \begin{pmatrix} b_{РКкор} \\ chord_{rotor_{i,av(N_r)}} \\ b_{РКпер} \end{pmatrix}, z\right] \\
chord_{stator.}(z) \leftarrow interp\left[cspline\left[\begin{pmatrix} R_{st(i,2),1} \\ R_{st(i,2),av(N_r)} \\ R_{st(i,2),N_r} \end{pmatrix}, \begin{pmatrix} b_{НАкор} \\ chord_{stator_{i,av(N_r)}} \\ b_{НАпер} \end{pmatrix}\right], \begin{pmatrix} R_{st(i,2),1} \\ R_{st(i,2),av(N_r)} \\ R_{st(i,2),N_r} \end{pmatrix}, \begin{pmatrix} b_{НАкор} \\ chord_{stator_{i,av(N_r)}} \\ b_{НАпер} \end{pmatrix}, z\right] \\
chord_{rotor_{i,r}} \leftarrow chord_{rotor.}\left(R_{st(i,2),r}\right) \\
chord_{stator_{i,r}} \leftarrow chord_{stator.}\left(R_{st(i,2),r}\right)
\end{array}\right.
\end{array}\right. \\
\begin{pmatrix} chord_{rotor} & chord_{stator} \end{pmatrix}
\end{array}\right.
$$

$$chord_{CA} = \left| \begin{array}{l} \text{for } i \in Z \\ \quad \left| \begin{array}{l} chord_{CA_{av(N_r)}} \leftarrow \dfrac{h_{st(i,3)}}{\overline{h}_{stator}(Z, Z+1)} \\ sail \leftarrow \dfrac{R_{st(1,1),N_r} - R_{st(1,1),1}}{R_{st(1,1),av(N_r)} - R_{st(1,1),1}} \\ \text{for } r \in 1..N_r \\ \quad \left| \begin{array}{l} b_{CAкор} \leftarrow \dfrac{chord_{CA_{av(N_r)}} \cdot sail}{sail_{stator} - 1 + sail} \\ b_{CAпер} \leftarrow b_{CAкор} \cdot sail_{stator} \\ b_{CA.}(z) \leftarrow interp\left[cspline\left[\begin{pmatrix} R_{st(i,1),1} \\ R_{st(i,1),av(N_r)} \\ R_{st(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{CAкор} \\ chord_{CA_{av(N_r)}} \\ b_{CAпер} \end{pmatrix}\right], \begin{pmatrix} R_{st(i,1),1} \\ R_{st(i,1),av(N_r)} \\ R_{st(i,1),N_r} \end{pmatrix}, \begin{pmatrix} b_{CAкор} \\ chord_{CA_{av(N_r)}} \\ b_{CAпер} \end{pmatrix}, z\right] \\ chord_{CA_r} \leftarrow b_{CA.}\left(R_{st(i,1),r}\right) \end{array} \right. \end{array} \right. \\ chord_{CA} \end{array} \right. \quad \text{if } CA = 1$$

Расчет длин хорд по высоте Л

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

$\overline{x}_f = 0.5$

Определение количества Л РК и НА

$$\begin{pmatrix} \varepsilon_{BHA(b/t)=1} \\ Z_{BHA} \\ r\_inlet_{BHA} \\ r\_outlet_{BHA} \\ t_{BHA} \\ i_{BHA} \\ m_{BHA} \\ \theta_{BHA} \\ \delta_{BHA} \\ \chi_{BHA} \\ \upsilon_{BHA} \\ R_{СЛ.BHA} \\ K_{BHA} \\ D_{BHA} \end{pmatrix} = \left| \begin{array}{l} \text{if } BHA = 1 \\ \quad \left| \begin{array}{l} \text{for } r \in av(N_r) \\ \quad \left| \begin{array}{l} \varepsilon_{BHA(b/t)=1_r} = \varepsilon_{(b/t)=1}(\alpha_{3BHA_r}) \\ b/t_{BHA_r} = b/t{=}1\left(\dfrac{\varepsilon_{BHA_r}}{\varepsilon_{BHA(b/t)=1_r}}\right) \\ t_{BHA_r} = \dfrac{chord_{BHA_r}}{b/t_{BHA_r}} \\ Z_{BHA} = \left| \begin{array}{l} round\left(\dfrac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right) \text{ if } mod\left(round\left(\dfrac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right), 2\right) = 0 \\ round\left(\dfrac{\pi \cdot D_{st(1,1),r}}{t_{BHA_r}}\right) + 1 \text{ otherwise} \end{array} \right. \end{array} \right. \\ \text{for } r \in 1..N_r \\ \quad \left| \begin{array}{l} \left(r\_inlet_{BHA_r}\ \ r\_outlet_{BHA_r}\right) = chord_{BHA_r} \cdot \left(\overline{r\_inlet}_{BHA_r}\ \ \overline{r\_outlet}_{BHA_r}\right) \\ t_{BHA_r} = \dfrac{D_{st(1,1),r}}{Z_{BHA}} \\ i_{BHA_r} = 2.5 \cdot \left(\dfrac{chord_{BHA_r}}{t_{BHA_r}} - 2\right) \cdot {}^\circ \\ m_{BHA_r} = 0.23 \cdot \left(2 \cdot \overline{x}_f\right)^2 + 0.18 - \dfrac{0.002}{deg} \cdot \left(\alpha_{3BHA_r}\right) \end{array} \right. \end{array} \right. \end{array} \right.$$

$$\theta_{BHA_r} = \frac{\varepsilon_{BHA_r} - i_{BHA_r}}{1 - m_{BHA_r}\cdot\sqrt{\dfrac{t_{BHA_r}}{chord_{BHA_r}}}}$$

$$\delta_{BHA_r} = m_{BHA_r}\cdot\theta_{BHA_r}\cdot\sqrt{\frac{t_{BHA_r}}{chord_{BHA_r}}}$$

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

$$\upsilon_{BHA_r} = \chi_{BHA_r} + \alpha_{1BHA_r} + i_{BHA_r}$$

$$R_{СЛ.BHA_r} = \frac{chord_{BHA_r}}{2\cdot\sin\left(0.5\cdot\theta_{BHA_r}\right)}$$

$$K_{BHA_r} = \frac{c_{a3BHA_r}}{c_{a1BHA_r}}$$

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

$$\left(\varepsilon_{BHA(b/t)=1}\ \ Z_{BHA}\ \ r\_inlet_{BHA}\ \ r\_outlet_{BHA}\ \ t_{BHA}\ \ i_{BHA}\ \ m_{BHA}\ \ \theta_{BHA}\ \ \delta_{BHA}\ \ \chi_{BHA}\ \ \upsilon_{BHA}\ \ R_{СЛ.BHA}\ \ K_{BHA}\ \ D_{BHA}\right)^T$$

$$
\begin{pmatrix}
\varepsilon_{PK(b/t)=1} & \varepsilon_{HA(b/t)=1} \\
Z_{rotor} & Z_{stator} \\
r\_inlet_{rotor} & r\_inlet_{stator} \\
r\_outlet_{rotor} & r\_outlet_{stator} \\
t_{rotor} & t_{stator} \\
i_{rotor} & i_{stator} \\
m_{rotor} & m_{stator} \\
\theta_{rotor} & \theta_{stator} \\
\delta_{rotor} & \delta_{stator} \\
\chi_{rotor} & \chi_{stator} \\
\upsilon_{rotor} & \upsilon_{stator} \\
R_{СЛ.rotor} & R_{СЛ.stator} \\
K_{rotor} & K_{stator} \\
D_{rotor} & D_{stator} \\
\zeta_{rotor} & \zeta_{stator} \\
quality_{rotor} & quality_{stator} \\
\eta_{stage} & \eta_{stage}
\end{pmatrix}
=
$$

$$\text{for } i \in 1..Z$$

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

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

$$\quad\quad \begin{pmatrix} b/t_{PK_{i,r}} \\ b/t_{HA_{i,r}} \end{pmatrix} = \begin{pmatrix} b/t{=}1\left(\dfrac{\varepsilon_{rotor_{i,r}}}{\varepsilon_{PK(b/t)=1_{i,r}}}\right) \\ b/t{=}1\left(\dfrac{\varepsilon_{stator_{i,r}}}{\varepsilon_{HA(b/t)=1_{i,r}}}\right) \end{pmatrix}$$

$$\quad\quad \begin{pmatrix} t_{rotor_{i,r}} \\ t_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \dfrac{chord_{rotor_{i,r}}}{b/t_{PK_{i,r}}} \\ \dfrac{chord_{stator_{i,r}}}{b/t_{HA_{i,r}}} \end{pmatrix}$$

$$\quad\quad \begin{pmatrix} t_{rotor_{i,r}} \\ t_{stator_{i,r}} \end{pmatrix} = \frac{2}{3}\begin{pmatrix} chord_{rotor_{i,r}} \cdot \cos\left(\beta_{st(i,1),r}\right) \\ chord_{stator_{i,r}} \cdot \cos\left(\alpha_{st(i,2),r}\right) \end{pmatrix}$$

$$\quad\quad Z_{stator_i} = \begin{cases} round\left(\dfrac{\pi \cdot mean\left(D_{st(i,2),r}, D_{st(i,3),r}\right)}{t_{stator_{i,r}}}\right) & \text{if } mod\left(round\left(\dfrac{\pi \cdot mean\left(D_{st(i,2),r}, D_{st(i,3),r}\right)}{t_{stator_{i,r}}}\right), 2\right) = 0 \\ round\left(\dfrac{\pi \cdot mean\left(D_{st(i,2),r}, D_{st(i,3),r}\right)}{t_{stator_{i,r}}}\right) + 1 & \text{otherwise} \end{cases}$$

$$\quad\quad Z_{rotor_i} = \Big|\; Z_{rotor_i} = round\left(\frac{\pi \cdot mean\left(D_{st(i,1),r}, D_{st(i,2),r}\right)}{t_{rotor_{i,r}}}\right)$$

$$\text{while } \gcd\left(Z_{rotor_i}, Z_{stator_i}\right) \neq 1$$

$$Z_{rotor_i} = Z_{rotor_i} + 1$$

$$\text{for } r \in 1..N_r$$

$$\begin{pmatrix} r\_inlet_{stator_{i,r}} & r\_outlet_{stator_{i,r}} \\ r\_inlet_{rotor_{i,r}} & r\_outlet_{rotor_{i,r}} \end{pmatrix} = \begin{pmatrix} \overline{r\_inlet}_{stator_{i,r}} \cdot chord_{stator_{i,r}} & \overline{r\_outlet}_{stator_{i,r}} \cdot chord_{stator_{i,r}} \\ \overline{r\_inlet}_{rotor_{i,r}} \cdot chord_{rotor_{i,r}} & \overline{r\_outlet}_{rotor_{i,r}} \cdot chord_{rotor_{i,r}} \end{pmatrix}$$

$$\begin{pmatrix} t_{rotor_{i,r}} \\ t_{stator_{i,r}} \end{pmatrix} = \pi \cdot \begin{pmatrix} \dfrac{\text{mean}\left(D_{st(i,1),r}, D_{st(i,2),r}\right)}{Z_{rotor_i}} \\ \dfrac{\text{mean}\left(D_{st(i,2),r}, D_{st(i,3),r}\right)}{Z_{stator_i}} \end{pmatrix}$$

$$\begin{pmatrix} i_{rotor_{i,r}} \\ i_{stator_{i,r}} \end{pmatrix} = 2.5 \cdot \begin{pmatrix} \dfrac{chord_{rotor_{i,r}}}{t_{rotor_{i,r}}} - 1 \\ \dfrac{chord_{stator_{i,r}}}{t_{stator_{i,r}}} - 2 \end{pmatrix} \cdot {}^\circ$$

$$\begin{pmatrix} m_{rotor_{i,r}} \\ m_{stator_{i,r}} \end{pmatrix} = 0.23 \cdot \left(2 \cdot \overline{x}_f\right)^2 + 0.18 - \frac{0.002}{deg} \cdot \begin{pmatrix} \beta_{st(i,2),r} \\ \alpha_{st(i,3),r} \end{pmatrix}$$

$$\begin{pmatrix} \theta_{rotor_{i,r}} \\ \theta_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \dfrac{\varepsilon_{rotor_{i,r}} - i_{rotor_{i,r}}}{1 - m_{rotor_{i,r}} \cdot \sqrt{\dfrac{t_{rotor_{i,r}}}{chord_{rotor_{i,r}}}}} \\ \dfrac{\varepsilon_{stator_{i,r}} - i_{stator_{i,r}}}{1 - m_{stator_{i,r}} \cdot \sqrt{\dfrac{t_{stator_{i,r}}}{chord_{stator_{i,r}}}}} \end{pmatrix}$$

$$\begin{pmatrix} \delta_{rotor_{i,r}} \\ \delta_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} m_{rotor_{i,r}} \cdot \theta_{rotor_{i,r}} \cdot \sqrt{\dfrac{t_{rotor_{i,r}}}{chord_{rotor_{i,r}}}} \\ m_{stator_{i,r}} \cdot \theta_{stator_{i,r}} \cdot \sqrt{\dfrac{t_{stator_{i,r}}}{chord_{stator_{i,r}}}} \end{pmatrix}$$

$$\begin{pmatrix} \chi_{rotor_{i,r}} \\ \chi_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \theta_{rotor_{i,r}} \\ \theta_{stator_{i,r}} \end{pmatrix} \cdot \frac{1 + 2 \cdot \left(1 - 2 \cdot \overline{x}_f\right)}{2}$$

$$\begin{pmatrix} \upsilon_{rotor_{i,r}} \end{pmatrix} \quad \begin{pmatrix} \chi_{rotor_{i,r}} + \beta_{st(i,1),r} + i_{rotor_{i,r}} \end{pmatrix}$$

$$\begin{pmatrix} \\ \upsilon_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \\ \chi_{stator_{i,r}} + \alpha_{st(i,2),r} + i_{stator_{i,r}} \end{pmatrix}$$

$$\begin{pmatrix} R_{СЛ.rotor_{i,r}} \\ R_{СЛ.stator_{i,r}} \end{pmatrix} = \frac{1}{2} \cdot \begin{pmatrix} \dfrac{chord_{rotor_{i,r}}}{\sin\left(0.5 \cdot \theta_{rotor_{i,r}}\right)} \\ \dfrac{chord_{stator_{i,r}}}{\sin\left(0.5 \cdot \theta_{stator_{i,r}}\right)} \end{pmatrix}$$

$$\begin{pmatrix} K_{rotor_{i,r}} \\ K_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \dfrac{c_{a_{st(i,2),r}}}{c_{a_{st(i,1),r}}} \\ \dfrac{c_{a_{st(i,3),r}}}{c_{a_{st(i,2),r}}} \end{pmatrix}$$

$$\begin{pmatrix} D_{rotor_{i,r}} \\ D_{stator_{i,r}} \end{pmatrix} = \begin{bmatrix} \left(1 - K_{rotor_{i,r}} \cdot \dfrac{\sin\left(\beta_{st(i,1),r}\right)}{\sin\left(\left|\beta_{st(i,2),r}\right|\right)}\right) + \left(\dfrac{1}{\tan\left(\beta_{st(i,1),r}\right)} - K_{rotor_{i,r}} \cdot \dfrac{1}{\tan\left(\beta_{st(i,2),r}\right)}\right) \cdot \dfrac{\sin\left(\beta_{st(i,1),r}\right)}{2 \cdot \dfrac{chord_{rotor_{i,r}}}{t_{rotor_{i,r}}}} \\ \left(1 - K_{stator_{i,r}} \cdot \dfrac{\sin\left(\alpha_{st(i,2),r}\right)}{\sin\left(\alpha_{st(i,3),r}\right)}\right) + \left(\dfrac{1}{\tan\left(\alpha_{st(i,2),r}\right)} - K_{stator_{i,r}} \cdot \dfrac{1}{\tan\left(\alpha_{st(i,3),r}\right)}\right) \cdot \dfrac{\sin\left(\alpha_{st(i,2),r}\right)}{2 \cdot \dfrac{chord_{stator_{i,r}}}{t_{stator_{i,r}}}} \end{bmatrix}$$

$$\begin{pmatrix} \zeta_{rotor_{i,r}} \\ \zeta_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \dfrac{\text{ζ•sin(β3)/(2b/t)} \left(D_{rotor_{i,r}}\right) \cdot 2 \cdot \dfrac{chord_{rotor_{i,r}}}{t_{rotor_{i,r}}}}{\sin\left(\beta_{st(i,2),r}\right)} \\ \dfrac{\text{ζ•sin(β3)/(2b/t)} \left(D_{stator_{i,r}}\right) \cdot 2 \cdot \dfrac{chord_{stator_{i,r}}}{t_{stator_{i,r}}}}{\sin\left(\alpha_{st(i,3),r}\right)} \end{pmatrix}$$

$$\begin{pmatrix} \beta_{cp_{i,r}} \\ \alpha_{cp_{i,r}} \end{pmatrix} = \begin{pmatrix} \operatorname{atan}\left(\dfrac{c_{a_{st(i,1),r}}}{\operatorname{mean}\left(w_{u_{st(i,1),r}}, w_{u_{st(i,2),r}}\right)}\right) \\ \operatorname{atan}\left(\dfrac{c_{a_{st(i,2),r}}}{\operatorname{mean}\left(c_{u_{st(i,2),r}}, c_{u_{st(i,3),r}}\right)}\right) \end{pmatrix}$$

$$\begin{pmatrix} quality_{rotor_{i,r}} \\ quality_{stator_{i,r}} \end{pmatrix} = \begin{bmatrix} \dfrac{2}{\zeta_{rotor_{i,r}}} \cdot \left(\dfrac{1}{\tan\left(\beta_{st(i,1),r}\right)} - \dfrac{1}{\tan\left(\beta_{st(i,2),r}\right)}\right) \cdot \left(\dfrac{\sin\left(\beta_{st(i,1),r}\right)}{\sin\left(\beta_{cp_{i,r}}\right)}\right)^2 - \dfrac{1}{\tan\left(\beta_{cp_{i,r}}\right)} \\ \dfrac{2}{\zeta_{stator_{i,r}}} \cdot \left(\dfrac{1}{\tan\left(\alpha_{st(i,2),r}\right)} - \dfrac{1}{\tan\left(\alpha_{st(i,3),r}\right)}\right) \cdot \left(\dfrac{\sin\left(\alpha_{st(i,2),r}\right)}{\sin\left(\alpha_{cp_{i,r}}\right)}\right)^2 - \dfrac{1}{\tan\left(\alpha_{cp_{i,r}}\right)} \end{bmatrix}$$

$$\eta_{stage_{i,r}} = 1 - \left[\frac{\left(\frac{c_{a_{st(i,1),r}}}{u_{st(i,1),r}}\right)^2 + \left(R_{L_{i,r}}\right)^2}{quality_{rotor_{i,r}} \cdot \frac{c_{a_{st(i,1),r}}}{u_{st(i,1),r}} + R_{L_{i,r}}} + \frac{\left(\frac{c_{a_{st(i,2),r}}}{u_{st(i,2),r}}\right)^2 + \left(1 - R_{L_{i,r}}\right)^2}{quality_{stator_{i,r}} \cdot \frac{c_{a_{st(i,2),r}}}{u_{st(i,2),r}} + \left(1 - R_{L_{i,r}}\right)} \right]$$

$$\begin{pmatrix} \varepsilon_{РК(b/t)=1} & Z_{rotor} & r\_inlet_{rotor} & r\_outlet_{rotor} & t_{rotor} & i_{rotor} & m_{rotor} & \theta_{rotor} & \delta_{rotor} & \chi_{rotor} & \upsilon_{rotor} & R_{СЛ.rotor} & K_{rotor} & D_{rotor} & \zeta_{rotor} & quality_{rotor} & \eta_{stage} \\ \varepsilon_{НА(b/t)=1} & Z_{stator} & r\_inlet_{stator} & r\_outlet_{stator} & t_{stator} & i_{stator} & m_{stator} & \theta_{stator} & \delta_{stator} & \chi_{stator} & \upsilon_{stator} & R_{СЛ.stator} & K_{stator} & D_{stator} & \zeta_{stator} & quality_{stator} & \eta_{stage} \end{pmatrix}^T$$

$$
\begin{pmatrix} \varepsilon_{CA(b/t)=1} \\ Z_{CA} \\ r\_inlet_{CA} \\ r\_outlet_{CA} \\ t_{CA} \\ i_{CA} \\ m_{CA} \\ \theta_{CA} \\ \delta_{CA} \\ \chi_{CA} \\ \upsilon_{CA} \\ R_{СЛ.CA} \\ K_{CA} \\ D_{CA} \end{pmatrix} =
$$

$\text{if } CA = 1$

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

$$\varepsilon_{CA(b/t)=1_r} \leftarrow \varepsilon_{(b/t)=1}\left(\alpha_{3CA_r}\right)$$

$$b/t_{CA_r} \leftarrow b/t{=}1\left(\frac{\varepsilon_{CA_r}}{\varepsilon_{CA(b/t)=1_r}}\right)$$

$$t_{CA_r} \leftarrow \frac{chord_{CA_r}}{b/t_{CA_r}}$$

$$Z_{CA} \leftarrow \begin{cases} \mathrm{round}\left(\dfrac{\pi \cdot D_{st(Z,3),r}}{t_{CA_r}}\right) & \text{if } \mathrm{mod}\left(\mathrm{round}\left(\dfrac{\pi \cdot D_{st(Z,3),r}}{t_{CA_r}}\right), 2\right) = 0 \\ \mathrm{round}\left(\dfrac{\pi \cdot D_{st(Z,3),r}}{t_{CA_r}}\right) + 1 & \text{otherwise} \end{cases}$$

$\quad \text{for } r \in 1 .. N_r$

$$\left(r\_inlet_{CA_r} \;\; r\_outlet_{CA_r}\right) \leftarrow chord_{CA_r} \cdot \left(\overline{r\_inlet}_{CA_r} \;\; \overline{r\_outlet}_{CA_r}\right)$$

$$t_{CA_r} \leftarrow \frac{D_{st(Z,3),r}}{Z_{CA}}$$

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

$$m_{CA_r} \leftarrow 0.23 \cdot \left(2 \cdot \overline{x}_f\right)^2 + 0.18 - \frac{0.002}{deg} \cdot \left(\alpha_{3CA_r}\right)$$

$$\theta_{CA_r} \leftarrow \frac{\varepsilon_{CA_r} - i_{CA_r}}{1 - m_{CA_r} \cdot \sqrt{\dfrac{t_{CA_r}}{chord_{CA_r}}}}$$

$$\delta_{CA_r} = m_{CA_r} \cdot \theta_{CA_r} \cdot \sqrt{\frac{t_{CA_r}}{chord_{CA_r}}}$$

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

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

$$R_{СЛ.CA_r} = \frac{chord_{CA_r}}{2 \cdot \sin\left(0.5 \cdot \theta_{CA_r}\right)}$$

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

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

$$\left(\varepsilon_{CA(b/t)=1} \ \ Z_{CA} \ \ r\_inlet_{CA} \ \ r\_outlet_{CA} \ \ t_{CA} \ \ i_{CA} \ \ m_{CA} \ \ \theta_{CA} \ \ \delta_{CA} \ \ \chi_{CA} \ \ \upsilon_{CA} \ \ R_{СЛ.CA} \ \ K_{CA} \ \ D_{CA}\right)^T$$

Определение количества Л РК и НА

Результаты расчета количества Л и параметров решеток РК и НА

Длина хорды Л (м):

$chord_{BHA} =$

	1
1	26.42
2	29.35
3	31.71

$\cdot 10^{-3}$

$chord_{rotor}{}^{T} =$

	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						

$\cdot 10^{-3}$

$chord_{stator}{}^{T} =$

	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						

$\cdot 10^{-3}$

$chord_{CA} =$

	1
1	25.80
2	28.65
3	30.96

$\cdot 10^{-3}$

Радисы входных и выходных кромок профилей Л (мм):

$r\_inlet_{BHA} =$

	1
1	0.16
2	0.29
3	0.44

$\cdot 10^{-3}$

$r\_outlet_{BHA} =$

	1
1	0.08
2	0.15
3	0.22

$\cdot 10^{-3}$

$r\_inlet_{rotor}{}^{T} =$

	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

$\cdot 10^{-3}$

$r\_outlet_{rotor}{}^{T} =$

	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

$\cdot 10^{-3}$

$r\_inlet_{stator}{}^{T} =$

	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

$\cdot 10^{-3}$

$r\_outlet_{stator}{}^{T} =$

	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

$\cdot 10^{-3}$

$r\_inlet_{CA} =$

	1
1	0.15
2	0.29
3	0.43

$\cdot 10^{-3}$

$r\_outlet_{CA} =$

	1
1	0.08
2	0.14
3	0.22

$\cdot 10^{-3}$

$$\varepsilon_{BHA(b/t)=1_{av(N_r)}} = 23.47\cdot{}^\circ$$

Угол поворота потока:

$$submatrix\left(\varepsilon_{PK(b/t)=1}, 1, Z, av(N_r), av(N_r)\right)^T = \cdot{}^\circ$$

	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						

$$submatrix\left(\varepsilon_{HA(b/t)=1}, 1, Z, av(N_r), av(N_r)\right)^T = \cdot{}^\circ$$

	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						

$$\varepsilon_{CA(b/t)=1_{av(N_r)}} = 33.67\cdot{}^\circ$$

$$\frac{chord_{BHA}}{t_{BHA}} =$$

	1
1	3.429
2	2.924
3	2.661

Густота решетки:

$$\left(\frac{chord_{rotor}}{t_{rotor}}\right)^T =$$

	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						

$$\left(\frac{chord_{stator}}{t_{stator}}\right)^T =$$

	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

$$\frac{chord_{CA}}{t_{CA}} =$$

	1
1	3.455
2	3.488
3	3.479

$$Z_{BHA} = 46$$

Количество Л:

$$Z_{rotor}^T =$$

	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						

$$Z_{stator}^T =$$

	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						

$$Z_{CA} = 52$$

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

$t_{BHA} =$

	1
1	7.71
2	10.04
3	11.92

$\cdot 10^{-3}$

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

	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						

$\cdot 10^{-3}$

Шаг решетки (м):

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

	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						

$\cdot 10^{-3}$

$t_{CA} =$

	1
1	7.47
2	8.21
3	8.90

$\cdot 10^{-3}$

$i_{BHA} =$

	1
1	3.572
2	2.311
3	1.652

$\cdot \circ$

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

	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						

$\cdot \circ$

Угол атаки:

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

	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						

$\cdot \circ$

$i_{CA} =$

	1
1	3.639
2	3.721
3	3.698

$\cdot \circ$

$m_{BHA} =$

	1
1	0.2766
2	0.2752
3	0.2737

Коэф. формы ср. линии профиля по Ховеллу:

$m_{rotor}^{T} =$

	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						

$m_{stator}^{T} =$

	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						

$m_{CA} =$

	1
1	0.2300
2	0.2300
3	0.2300

$\theta_{BHA} =$

	1
1	23.18
2	24.19
3	24.29

$\cdot°$

Угол изгиба ср. линии профиля:

$\theta_{rotor}^{T} =$

	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						

$\cdot°$

$\theta_{stator}^{T} =$

	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						

$\cdot°$

$\theta_{CA} =$

	1
1	39.82
2	36.69
3	34.27

$\cdot°$

$\delta_{BHA} =$

	1
1	3.462
2	3.893
3	4.076

$\cdot°$

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

	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

$\cdot°$

Угол отставания:

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

	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	...

$\cdot°$

$\delta_{CA} =$

	1
1	4.926
2	4.519
3	4.226

$\cdot°$

$\upsilon_{BHA} =$

	1
1	105.16
2	104.40
3	103.80

$\cdot°$

$\upsilon_{rotor}^{T} =$

	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

$\cdot°$

Угол установки Л:

$\upsilon_{stator}^{T} =$

	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

$\cdot°$

$\upsilon_{CA} =$

	1
1	75.02
2	76.17
3	77.09

$\cdot°$

$R_{СЛ.ВНА} =$

	1
1	65.77
2	70.03
3	75.35

$\cdot 10^{-3}$

$R_{СЛ.rotor}{}^{T} =$

	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						

$\cdot 10^{-3}$

Радиус дуги ср. линии (м):

$R_{СЛ.stator}{}^{T} =$

	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						

$\cdot 10^{-3}$

$R_{СЛ.СА} =$

	1
1	37.88
2	45.51
3	52.53

$\cdot 10^{-3}$

$K_{ВНА} =$

	1
1	1.0359
2	1.0000
3	0.9808

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

	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						

Фактор диффузорности решетки:

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

	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						

$K_{СА} =$

	1
1	0.8302
2	0.8302
3	0.8302

$D_{BHA} =$

	1
1	-0.1928
2	-0.1544
3	-0.1308

Диффузорность решетки:

$D_{rotor}^{T} =$

	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						

$D_{stator}^{T} =$

	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						

$D_{CA} =$

	1
1	0.4407
2	0.4115
3	0.3896

$D_{BHA} \le 0.6 =$

	1
1	1
2	1
3	1

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

	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

[18, с. 71]

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

	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

$D_{CA} \le 0.6 =$

	1
1	1
2	1
3	1

$\zeta_{rotor}{}^{T} =$

	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						

Коэф. потерь полного давления:

$\zeta_{stator}{}^{T} =$

	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						

$quality_{rotor}{}^{T} =$

	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						

Качество профилей решеток РК и НА:

$quality_{stator}{}^{T} =$

	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: $\eta_{stage}{}^{T} =$

	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						

$\cdot\%$

Результаты расчета количества Л и параметров решеток РК и НА

Подключение симметричного профиля

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

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

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

$EXCEL_{AIRFOIL.supersonic} =$ ...\Емин сверхзв ой профиль.xlsx

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

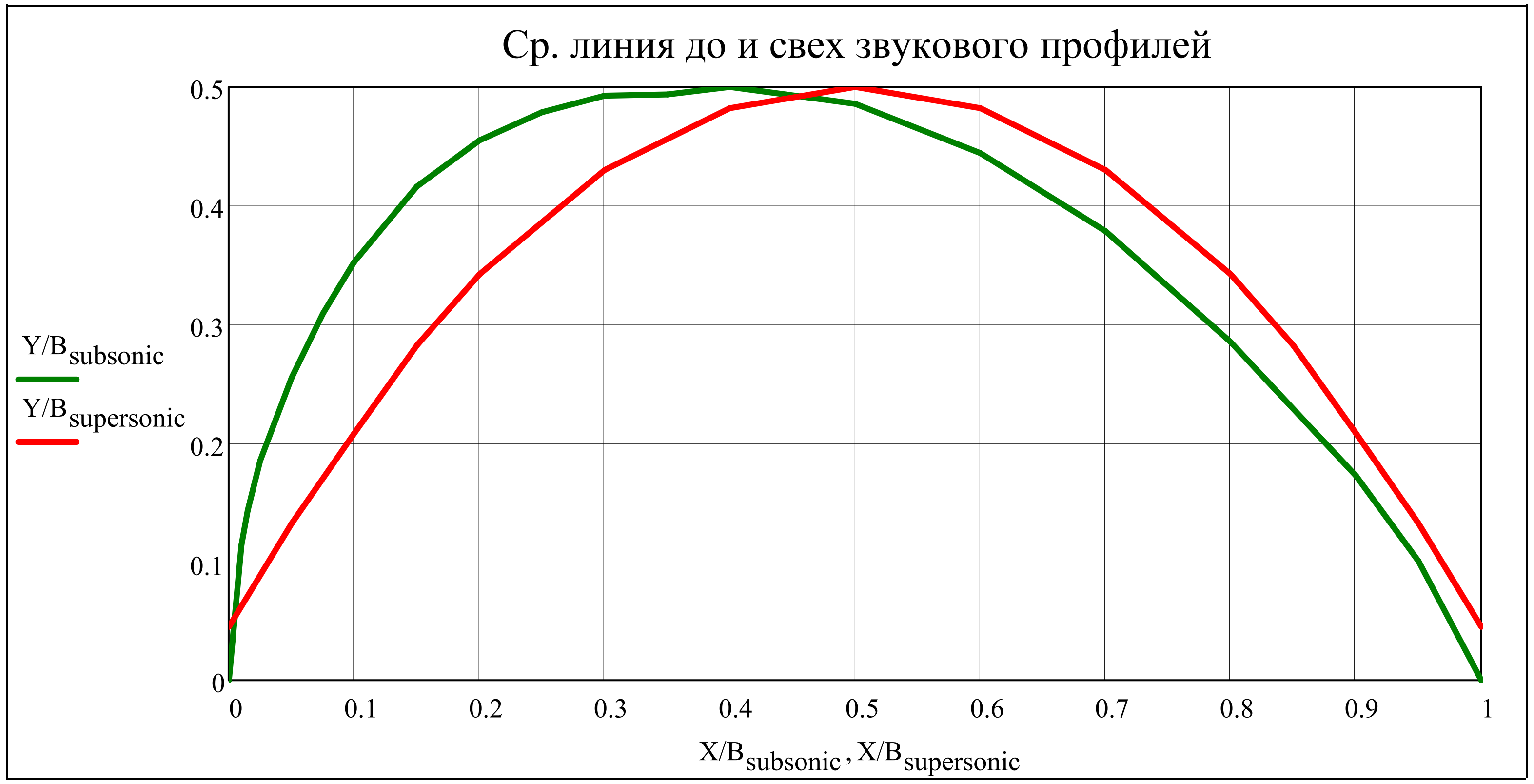
$Y/B_{supersonic} = submatrix(EXCEL_{AIRFOIL.supersonic}, 2, rows(EXCEL_{AIRFOIL.supersonic}), ORIGIN + 1, ORIGIN + 1)$

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

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

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

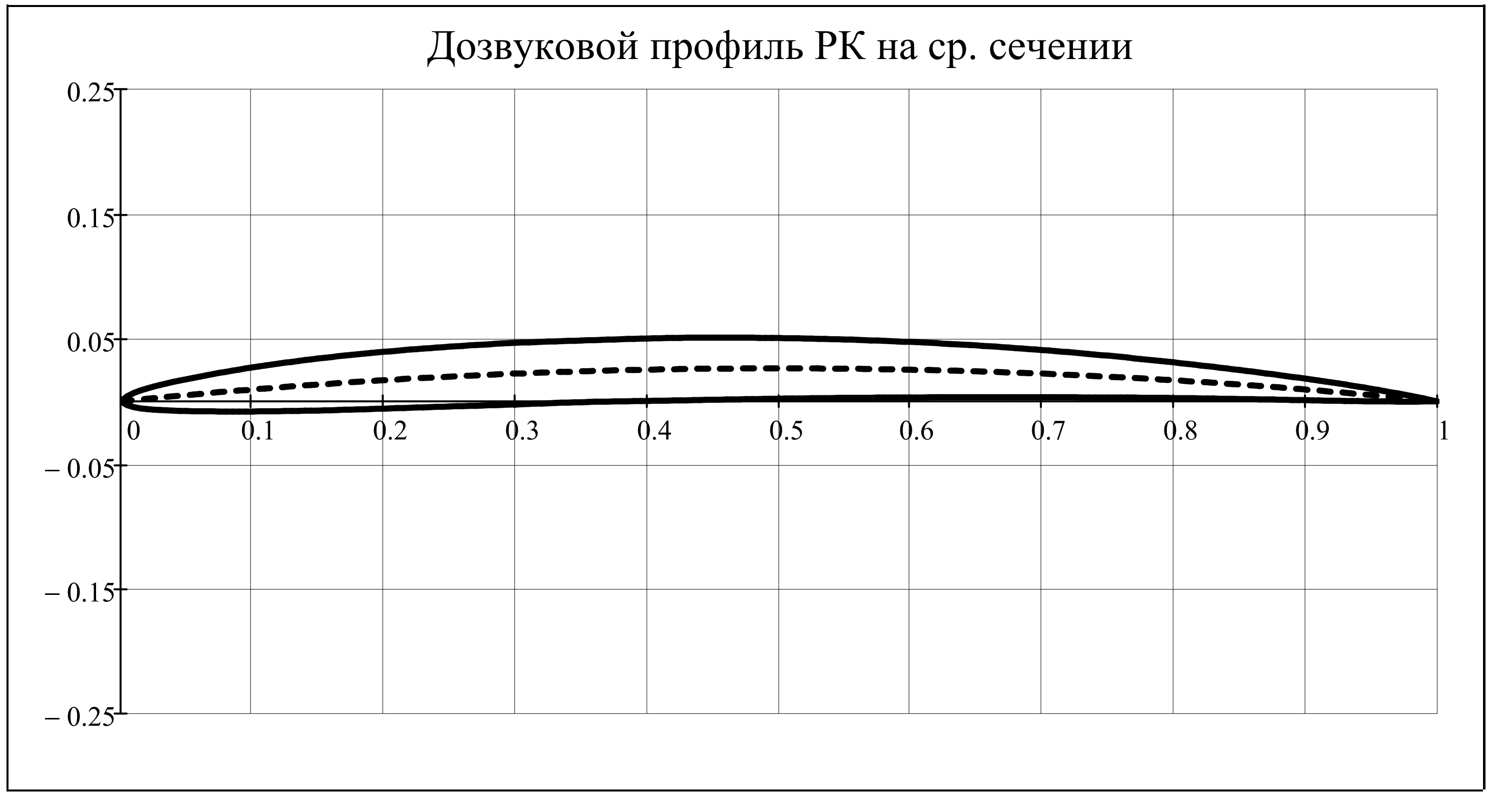
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.000	0.050	0.100	0.150	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.850	0.900	0.950	1.000
2	0.045	0.132	0.208	0.282	0.342	0.430	0.482	0.500	0.482	0.430	0.342	0.282	0.208	0.132	0.045

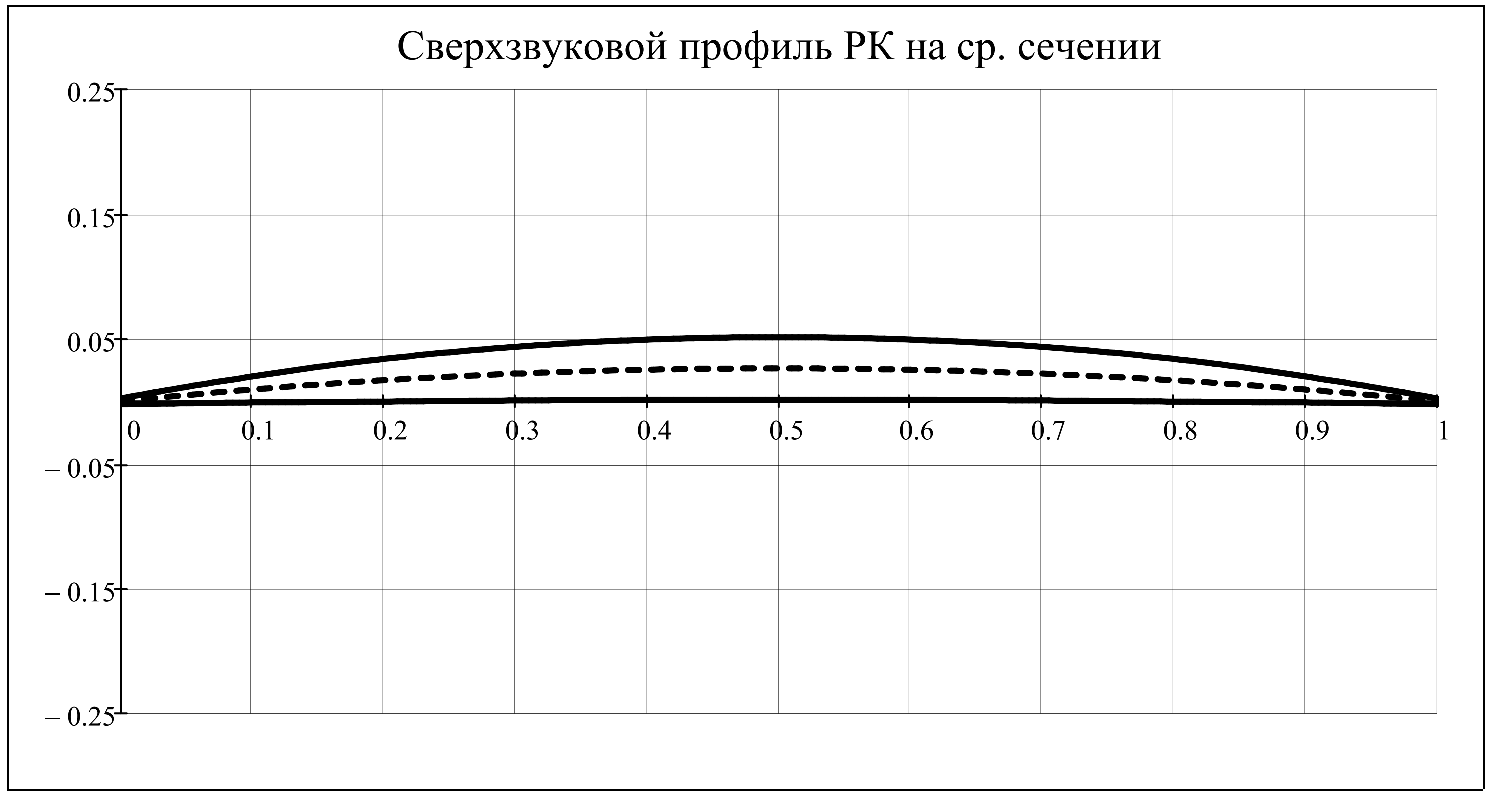


$$
AIRFOIL_{subsonic}(x, line, \overline{c}, \theta) = \begin{cases} \begin{cases} interp\left(cspline\left(X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right) + Y/B_{subsonic} \cdot \overline{c}\right), X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right) + Y/B_{subsonic} \cdot \overline{c}, x\right) & \text{if } line = "+" \\ interp\left(cspline\left(X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right)\right), X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right), x\right) & \text{if } line = "0" \\ interp\left(cspline\left(X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right) - Y/B_{subsonic} \cdot \overline{c}\right), X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right) - Y/B_{subsonic} \cdot \overline{c}, x\right) & \text{if } line = "-" \end{cases} & \text{if } 0 \le x \le 1 \\ NaN & \text{otherwise} \end{cases}
$$

$$
AIRFOIL_{supersonic}(x, line, \overline{c}, \theta) = \begin{cases} \begin{cases} interp\left(cspline\left(X/B_{supersonic}, y/b_{ср.л}\left(X/B_{supersonic}, \theta\right) + Y/B_{supersonic} \cdot \overline{c}\right), X/B_{supersonic}, y/b_{ср.л}\left(X/B_{supersonic}, \theta\right) + Y/B_{supersonic} \cdot \overline{c}, x\right) & \text{if } line = "+" \\ interp\left(cspline\left(X/B_{supersonic}, y/b_{ср.л}\left(X/B_{supersonic}, \theta\right)\right), X/B_{supersonic}, y/b_{ср.л}\left(X/B_{supersonic}, \theta\right), x\right) & \text{if } line = "0" \\ interp\left(cspline\left(X/B_{supersonic}, y/b_{ср.л}\left(X/B_{supersonic}, \theta\right) - Y/B_{supersonic} \cdot \overline{c}\right), X/B_{supersonic}, y/b_{ср.л}\left(X/B_{supersonic}, \theta\right) - Y/B_{supersonic} \cdot \overline{c}, x\right) & \text{if } line = "-" \end{cases} & \text{if } 0 \le x \le 1 \\ NaN & \text{otherwise} \end{cases}
$$

$x = 0, 0.005 .. 1$ $\qquad$ $j = 1$





Подключение симметричного профиля

Результат расчета абсолютных геометрических характеристик сечений Л

$l\_upper_{stator}^{T} =$

	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	9
1	258.75	210.23	165.14	137.84	119.46	106.28	98.03	94.65	92.69
2	146.21	118.31	92.68	77.22	66.83	59.38	54.73	52.81	51.68
3	109.32	88.82	69.77	58.24	50.47	44.90	41.42	39.99	39.16

$\cdot 10^{-6}$

$Sx_{rotor}^{T} =$

	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

$\cdot 10^{-3}$

$Jx_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	27	31	33	29	31	32	28	29	37
2	65	76	82	73	77	80	72	78	98
3	123	143	155	141	149	157	145	162	205

$\cdot 10^{-12}$

$Jy_{stator}^{T} =$

	1	2	3	4	5	6	7	8
1	1486	1437	1194	1054	1039	1119	1381	1959
2	3756	3610	2989	2633	2589	2784	3431	4865
3	7191	6951	5777	5101	5028	5413	6680	...

$\cdot 10^{-12}$

$Jxy_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	173	183	173	154	156	165	170	209	279
2	424	453	429	381	387	410	429	531	709
3	796	850	812	728	744	793	840	1049	1405

$\cdot 10^{-12}$

$Jx0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	2.64	2.98	3.12	2.77	2.88	2.99	2.70	2.98	3.81
2	7.73	8.62	8.74	7.82	8.09	8.49	8.16	9.53	12.44
3	18.39	19.91	19.60	17.66	18.25	19.38	19.75	24.24	32.36

$\cdot 10^{-12}$

$Jy0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	325	314	261	230	227	244	301	428	612
2	820	788	653	575	565	608	749	1062	1519
3	1571	1518	1262	1114	1098	1182	1459	2070	2963

$\cdot 10^{-12}$

$Jxy0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	6.57	6.93	6.54	5.80	5.88	6.21	6.45	7.94	10.62
2	16.12	17.15	16.18	14.38	14.60	15.46	16.25	20.17	26.99
3	30.25	32.25	30.63	27.46	28.02	29.87	31.82	39.86	53.47

$\cdot 10^{-12}$

$\alpha\_major_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	1.17	1.28	1.45	1.46	1.50	1.47	1.24	1.07	1.00
2	1.14	1.26	1.44	1.45	1.50	1.48	1.26	1.10	1.03
3	1.12	1.23	1.41	1.43	1.49	1.47	1.27	1.12	1.04

$\cdot \circ$

$Jx_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	3392	1751	986	578	389	268	178	142	126
2	276	192	131	87	64	46	31	24	22
3	59	57	42	29	23	17	12	9	9

$\cdot 10^{-12}$

$Jy_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	199075	131414	81089	56493	42434	33583	28572	26635	25543
2	152550	99887	61296	42552	31870	25164	21371	19898	19057
3	142139	93830	57897	40336	30298	23978	20400	19017	18238

$\cdot 10^{-12}$

$Jxy_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	20427	11506	6672	4106	2839	1999	1340	1033	890
2	4686	3209	2116	1421	1050	783	554	442	400
3	1771	1636	1146	804	615	473	345	280	263

$\cdot 10^{-12}$

$Jx0_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	910.63	558.14	336.05	224.46	164.68	126.68	103.28	94.10	89.38
2	105.83	70.34	44.31	30.38	22.64	17.53	14.15	12.75	12.09
3	32.42	23.05	14.82	10.35	7.83	6.13	4.97	4.48	4.27

$\cdot 10^{-12}$

$Jy0_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	43476	28700	17709	12338	9267	7334	6240	5817	5578
2	33311	21812	13385	9292	6959	5495	4667	4345	4161
3	31038	20489	12643	8808	6616	5236	4455	4153	3982

$\cdot 10^{-12}$

$Jxy0_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	776.02	438.10	254.22	156.90	108.56	76.51	51.33	39.59	34.13
2	179.68	123.06	81.11	54.50	40.27	30.03	21.26	16.96	15.34
3	67.94	62.77	43.96	30.84	23.60	18.16	13.23	10.75	10.08

$\cdot 10^{-12}$

$\alpha\_major_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	1.04	0.89	0.84	0.74	0.68	0.61	0.48	0.40	0.36
2	0.31	0.32	0.35	0.34	0.33	0.31	0.26	0.22	0.21
3	0.13	0.18	0.20	0.20	0.20	0.20	0.17	0.15	0.15

$\cdot \circ$

$Ju_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	2.50	2.82	2.95	2.63	2.73	2.83	2.56	2.84	3.62
2	7.41	8.24	8.33	7.45	7.71	8.09	7.80	9.14	11.96
3	17.81	19.21	18.85	16.98	17.52	18.61	19.05	23.46	31.39

$\cdot 10^{-12}$

$Jv_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	325	314	261	230	227	244	302	428	613
2	821	789	653	575	566	608	750	1063	1519
3	1571	1519	1262	1115	1099	1183	1460	2071	2964

$\cdot 10^{-12}$

$Juv_{stator}^{T} =$

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

$\cdot 10^{-12}$

$Jp_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	327	317	264	233	230	247	304	431	616
2	828	797	661	583	574	616	757	1072	1531
3	1589	1538	1281	1132	1116	1202	1479	2095	2996

$\cdot 10^{-12}$

$Wp_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	26.3	25.6	22.3	20.3	20.1	21.2	24.8	32.3	42.3
2	59.9	58.1	50.5	45.9	45.3	47.8	56.0	72.7	95.1
3	106.3	103.6	90.2	82.2	81.3	85.9	100.6	130.8	171.1

$\cdot 10^{-9}$

$stiffness_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	1.25	1.21	1.00	0.88	0.87	0.94	1.16	1.64	2.35
2	8.75	8.41	6.97	6.14	6.03	6.49	8.00	11.34	16.21
3	32.85	31.75	26.39	23.30	22.96	24.73	30.51	43.30	61.97

$\cdot 10^{-12}$

$Ju_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	896.49	551.33	332.33	222.43	163.39	125.87	102.85	93.83	89.16
2	104.86	69.65	43.82	30.06	22.41	17.37	14.05	12.69	12.04
3	32.27	22.86	14.67	10.24	7.74	6.07	4.93	4.45	4.25

$\cdot 10^{-12}$

$Jv_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	43491	28707	17713	12340	9269	7335	6240	5817	5579
2	33312	21812	13385	9292	6959	5495	4667	4345	4161
3	31038	20489	12643	8808	6616	5236	4455	4153	3982

$\cdot 10^{-12}$

$Juv_{rotor}^{T} =$

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

$\cdot 10^{-12}$

$Jp_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	44387	29258	18045	12562	9432	7461	6343	5911	5668
2	33417	21882	13429	9322	6982	5512	4681	4358	4174
3	31070	20512	12657	8818	6624	5242	4460	4157	3987

$\cdot 10^{-12}$

$Wp_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	1482.7	1085.9	756.0	576.5	465.1	390.3	345.7	328.0	317.9
2	963.3	701.2	486.1	369.7	297.7	249.3	220.6	209.1	202.4
3	802.6	587.8	409.2	312.1	251.8	211.3	187.2	177.6	172.1

$\cdot 10^{-9}$

$stiffness_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	2672.12	1763.93	1088.43	758.29	569.58	450.78	383.51	357.51	342.86
2	355.50	232.78	142.84	99.16	74.27	58.64	49.80	46.37	44.41
3	119.25	78.72	48.57	33.84	25.42	20.12	17.11	15.95	15.30

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$CPx_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	7.900	7.833	7.479	7.250	7.224	7.359	7.756	8.465	9.259
2	8.767	8.680	8.280	8.021	7.988	8.134	8.570	9.352	10.227
3	9.480	9.400	8.975	8.700	8.669	8.830	9.307	10.158	11.111

$\cdot 10^{-3}$

$CPx_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	19.004	17.130	15.182	13.871	12.913	12.179	11.697	11.494	11.374
2	22.131	19.908	17.620	16.083	14.962	14.104	13.540	13.300	13.157
3	24.705	22.269	19.737	18.032	16.787	15.833	15.206	14.942	14.786

$\cdot 10^{-3}$

$CPy_{stator}^{T} =$

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

$\cdot 10^{-3}$

$CPy_{rotor}^{T} =$

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

$\cdot 10^{-3}$

Результат расчета абсолютных геометрических характеристик сечений Л

Профилирование решеток

Абс. координаты профиля:

$$
\mathrm{Airfoil}(type, x, line, i, r) = \begin{cases}
\text{if } type = \text{"BHA"} & \begin{cases} \mathrm{AIRFOIL}_{subsonic}\left(x, line, \bar{c}_{BHA_r}, \varepsilon_{BHA_r}\right) & \text{if } M_{c_{st(1,1),r}} < 1 \\ \mathrm{AIRFOIL}_{supersonic}\left(x, line, \bar{c}_{BHA_r}, \varepsilon_{BHA_r}\right) & \text{otherwise} \end{cases} \\
\text{if } type = \text{"rotor"} & \begin{cases} \mathrm{AIRFOIL}_{subsonic}\left(x, line, \bar{c}_{rotor_{i,r}}, \varepsilon_{rotor_{i,r}}\right) & \text{if } M_{w_{st(i,1),r}} < 1 \\ \mathrm{AIRFOIL}_{supersonic}\left(x, line, \bar{c}_{rotor_{i,r}}, \varepsilon_{rotor_{i,r}}\right) & \text{otherwise} \end{cases} \\
\text{if } type = \text{"stator"} & \begin{cases} \mathrm{AIRFOIL}_{subsonic}\left(x, line, \bar{c}_{stator_{i,r}}, \varepsilon_{stator_{i,r}}\right) & \text{if } M_{c_{st(i,2),r}} < 1 \\ \mathrm{AIRFOIL}_{supersonic}\left(x, line, \bar{c}_{stator_{i,r}}, \varepsilon_{stator_{i,r}}\right) & \text{otherwise} \end{cases} \\
\text{if } type = \text{"CA"} & \begin{cases} \mathrm{AIRFOIL}_{subsonic}\left(x, line, \bar{c}_{CA_r}, \varepsilon_{CA_r}\right) & \text{if } M_{c_{st(Z,3),r}} < 1 \\ \mathrm{AIRFOIL}_{supersonic}\left(x, line, \bar{c}_{CA_r}, \varepsilon_{CA_r}\right) & \text{otherwise} \end{cases}
\end{cases}
$$

Профилирование решеток

Рассматриваемая ступень: $j = \left| \begin{array}{l} j = 1 \\ j = \left| \begin{array}{ll} \text{"Такой ступени не существует!"} & \text{if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{array} \right. \end{array} \right. = 1$

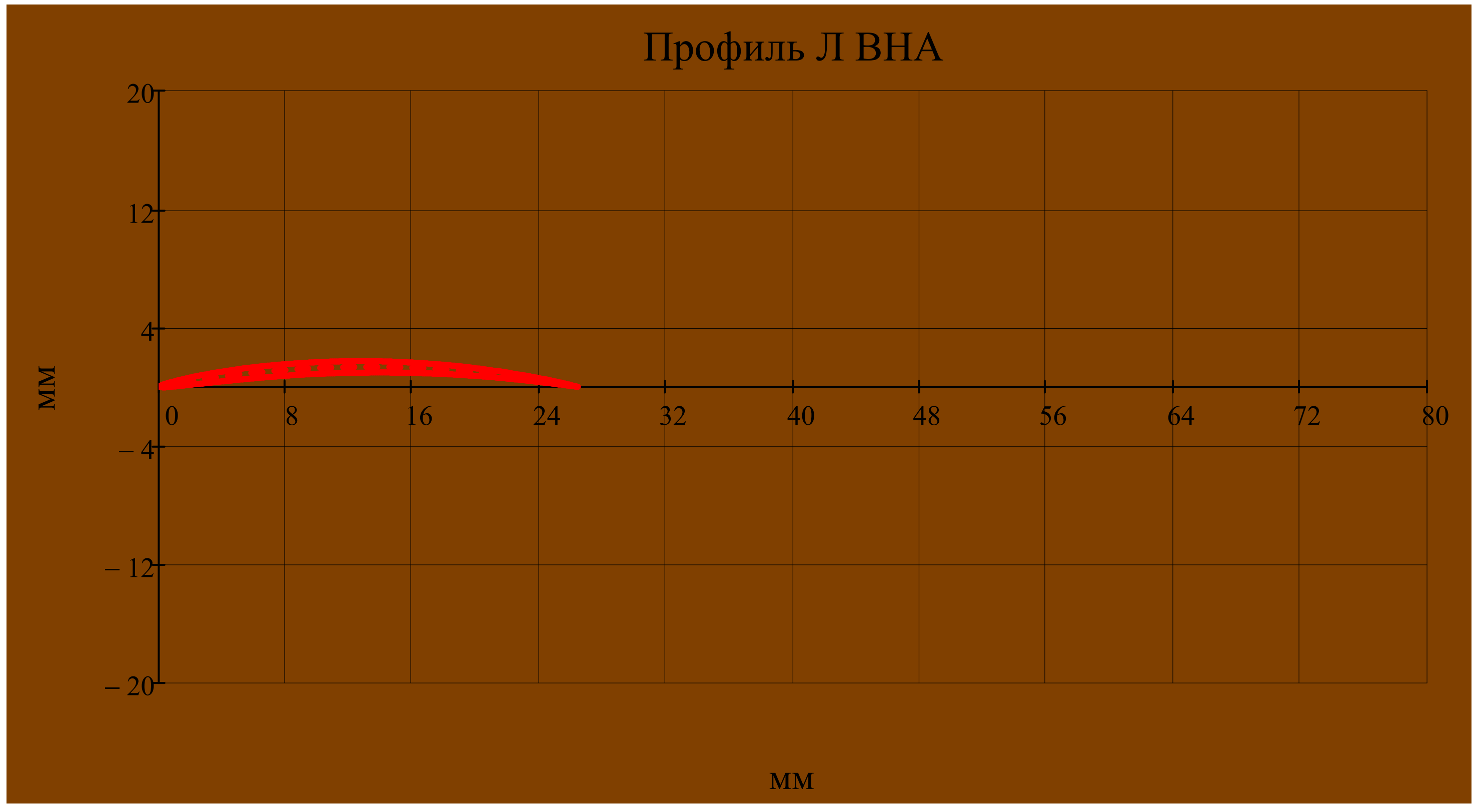
Построение профилей Л РК и НА

$$AXLE0(type, x, i, r) = \left| \begin{array}{ll} \dfrac{y0rotor_{i,r}}{chord rotor_{i,r}} + \tan\left(\alpha\_major rotor_{i,r}\right) \cdot \left(x - \dfrac{x0rotor_{i,r}}{chord rotor_{i,r}}\right) & \text{if } type = \text{"rotor"} \\ \dfrac{y0stator_{i,r}}{chord stator_{i,r}} + \tan\left(\alpha\_major stator_{i,r}\right) \cdot \left(x - \dfrac{x0stator_{i,r}}{chord stator_{i,r}}\right) & \text{if } type = \text{"stator"} \\ NaN & \text{otherwise} \end{array} \right.$$

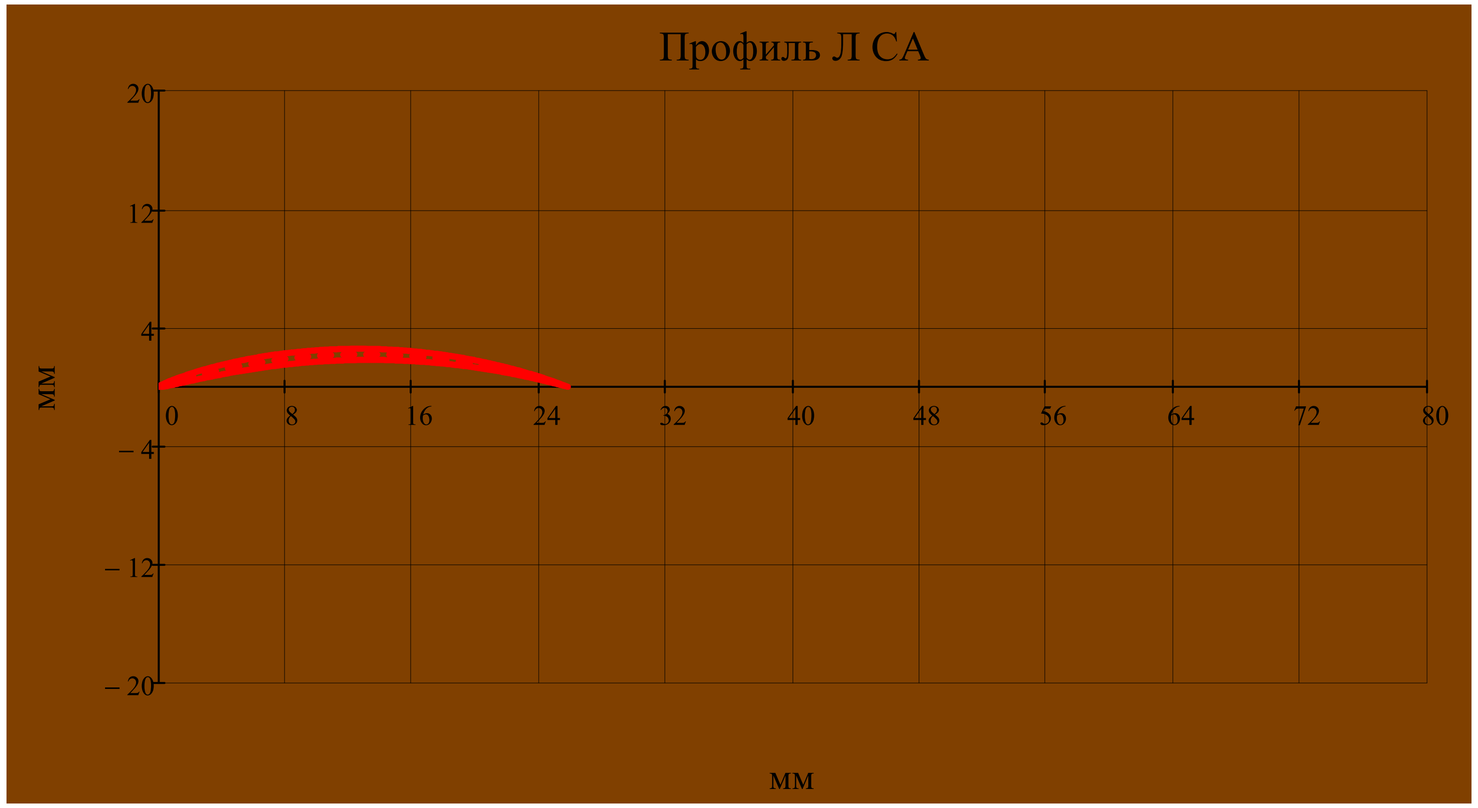
$$b_{lim} = \frac{\text{ceil}\left(\max\left(chord rotor_{j, N_r}, chord stator_{j, N_r}\right) \cdot 10^2\right)}{10^2} = 80 \cdot 10^{-3}$$

$$AXLE90(type, x, i, r) = \left| \begin{array}{ll} \dfrac{y0rotor_{i,r}}{chord rotor_{i,r}} + \tan\left(\alpha\_major rotor_{i,r} + \dfrac{\pi}{2}\right) \cdot \left(x - \dfrac{x0rotor_{i,r}}{chord rotor_{i,r}}\right) & \text{if } (type = \text{"rotor"}) \wedge \left|\alpha\_major rotor_{i,r}\right| \geq 1 \cdot ° \\ \dfrac{y0stator_{i,r}}{chord stator_{i,r}} + \tan\left(\alpha\_major stator_{i,r} + \dfrac{\pi}{2}\right) \cdot \left(x - \dfrac{x0stator_{i,r}}{chord stator_{i,r}}\right) & \text{if } (type = \text{"stator"}) \wedge \left|\alpha\_major stator_{i,r}\right| \geq 1 \cdot ° \\ NaN & \text{otherwise} \end{array} \right.$$

r = 1

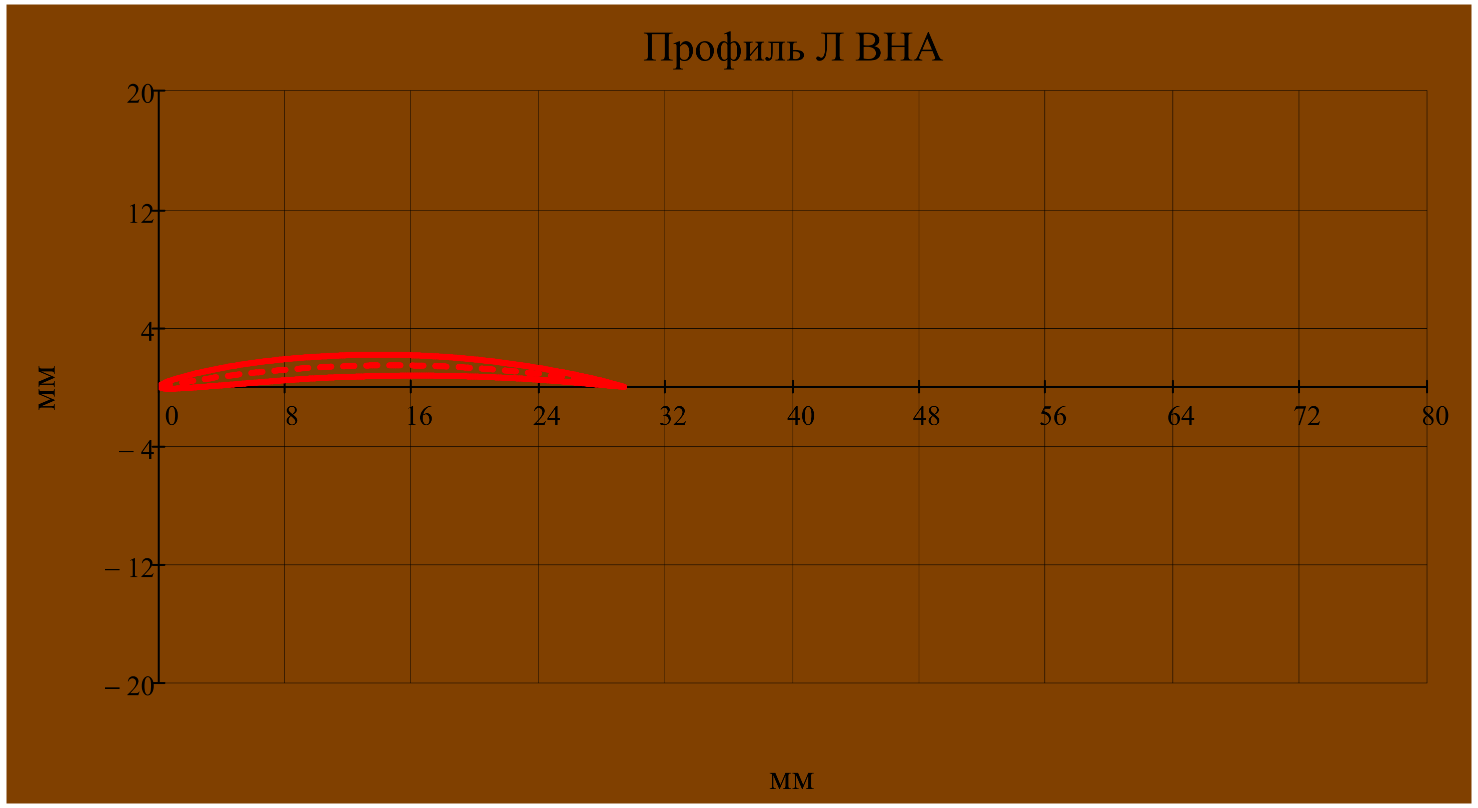


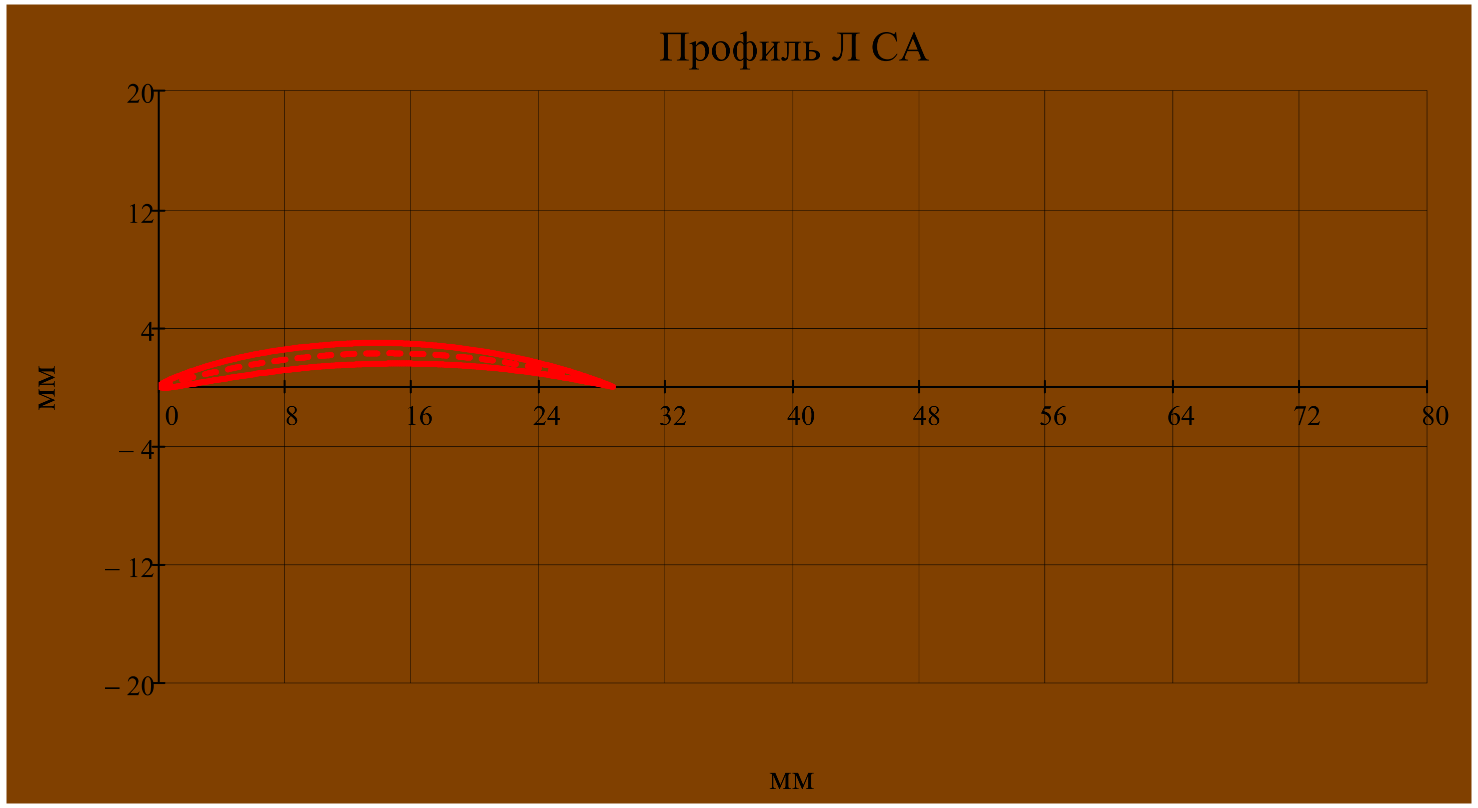
Профиль Л ВНА
мм
мм
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80



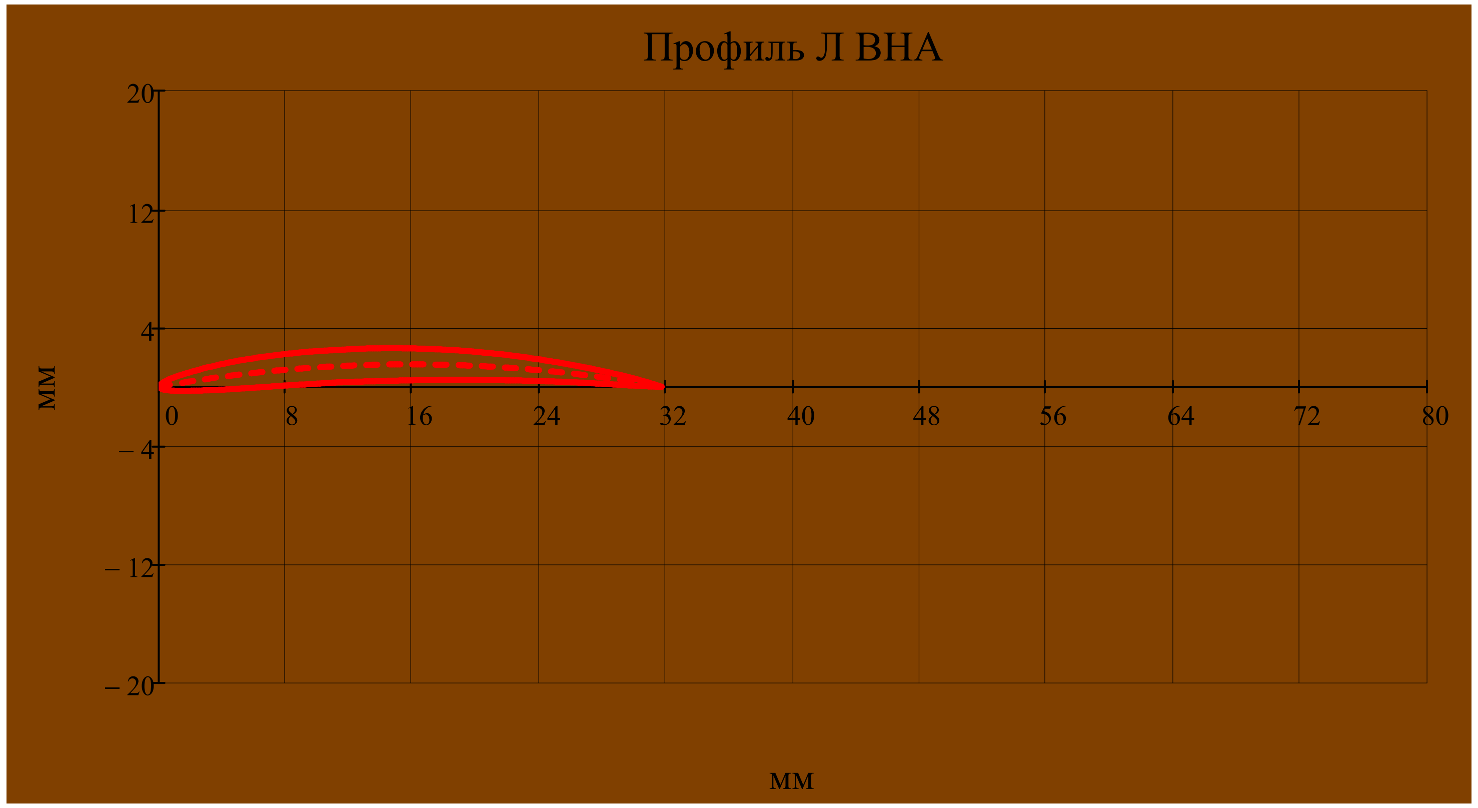
Профиль Л СА
мм
мм
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80

$r = av(N_r)$

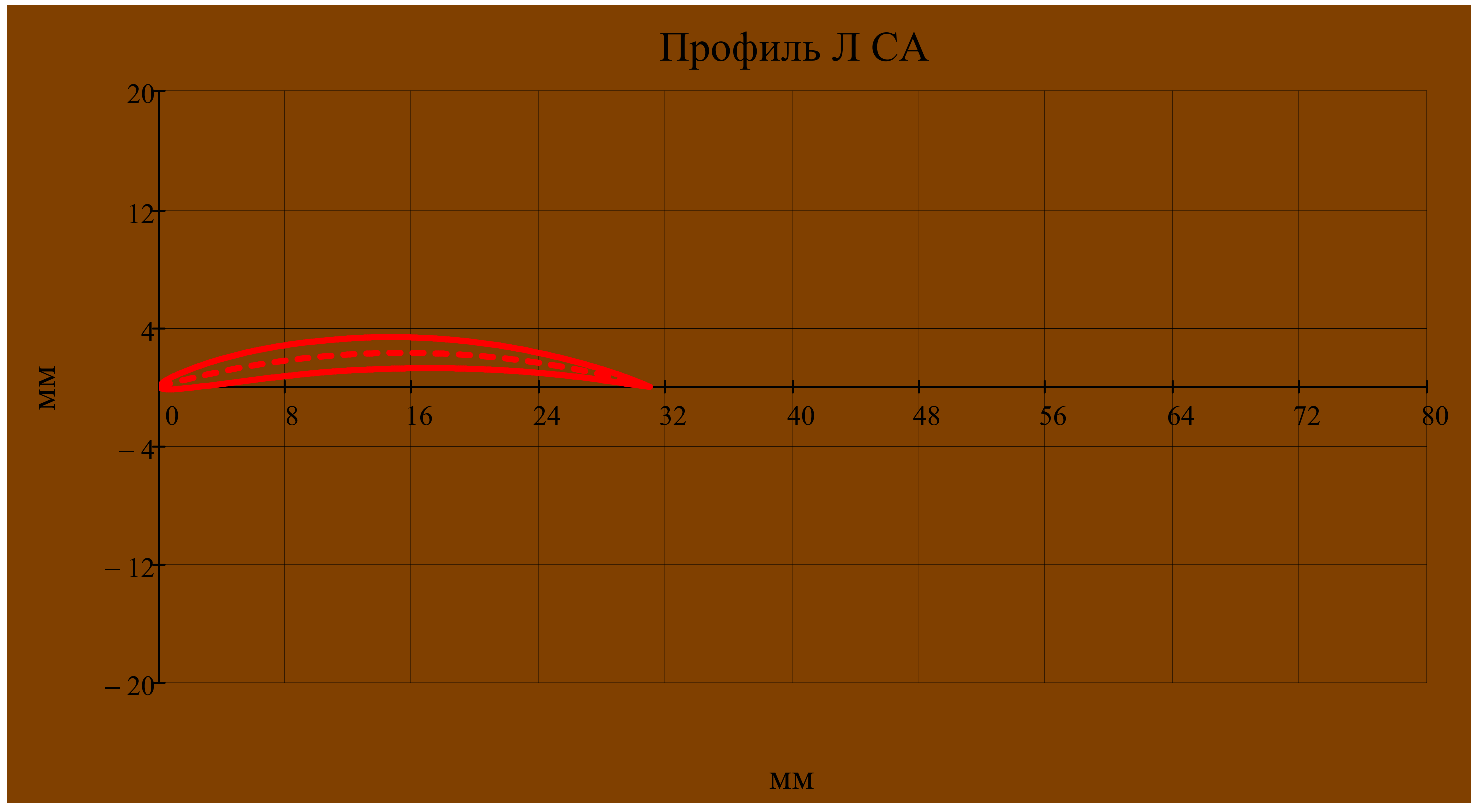

Профиль Л ВНА
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм


Профиль Л СА
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм

$r = N_r$

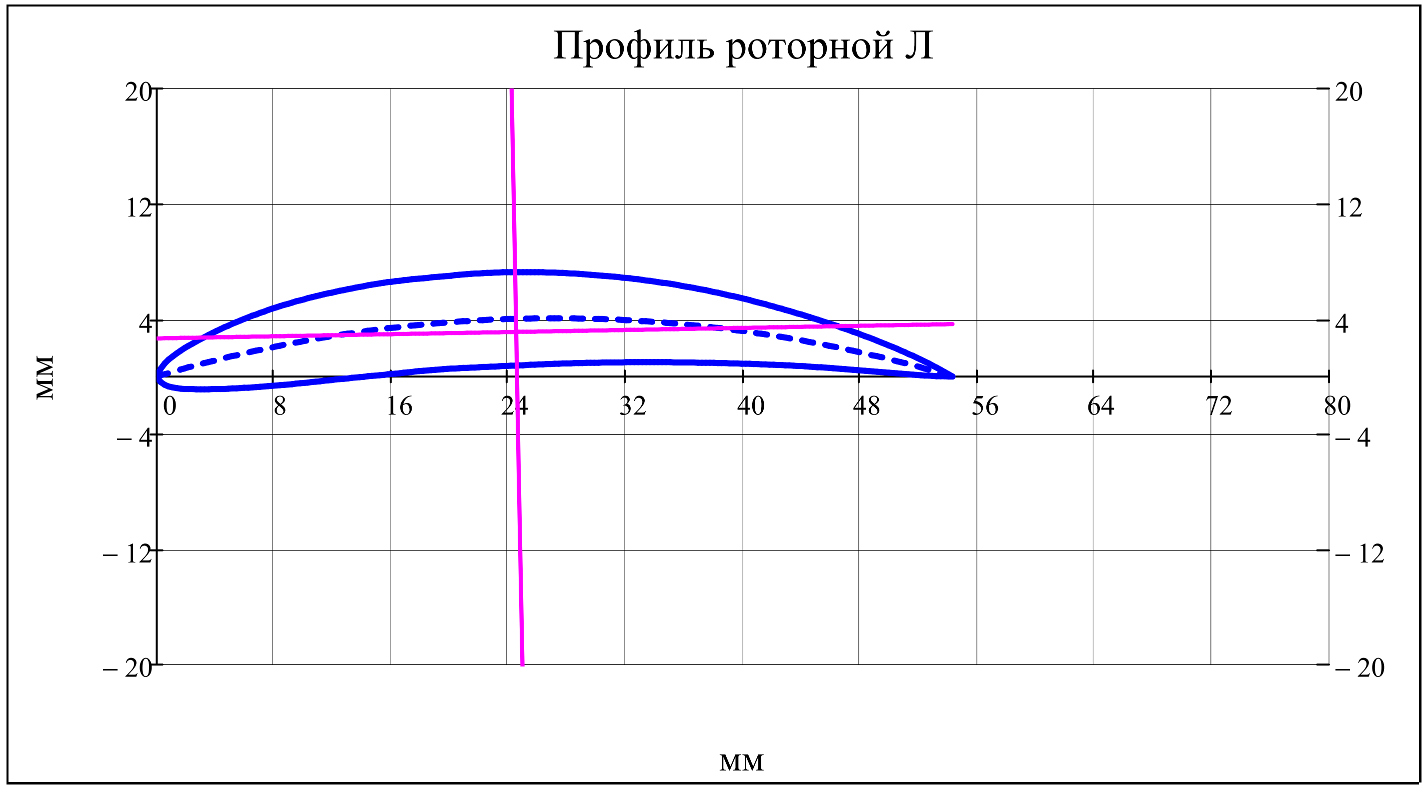


Профиль Л ВНА
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм

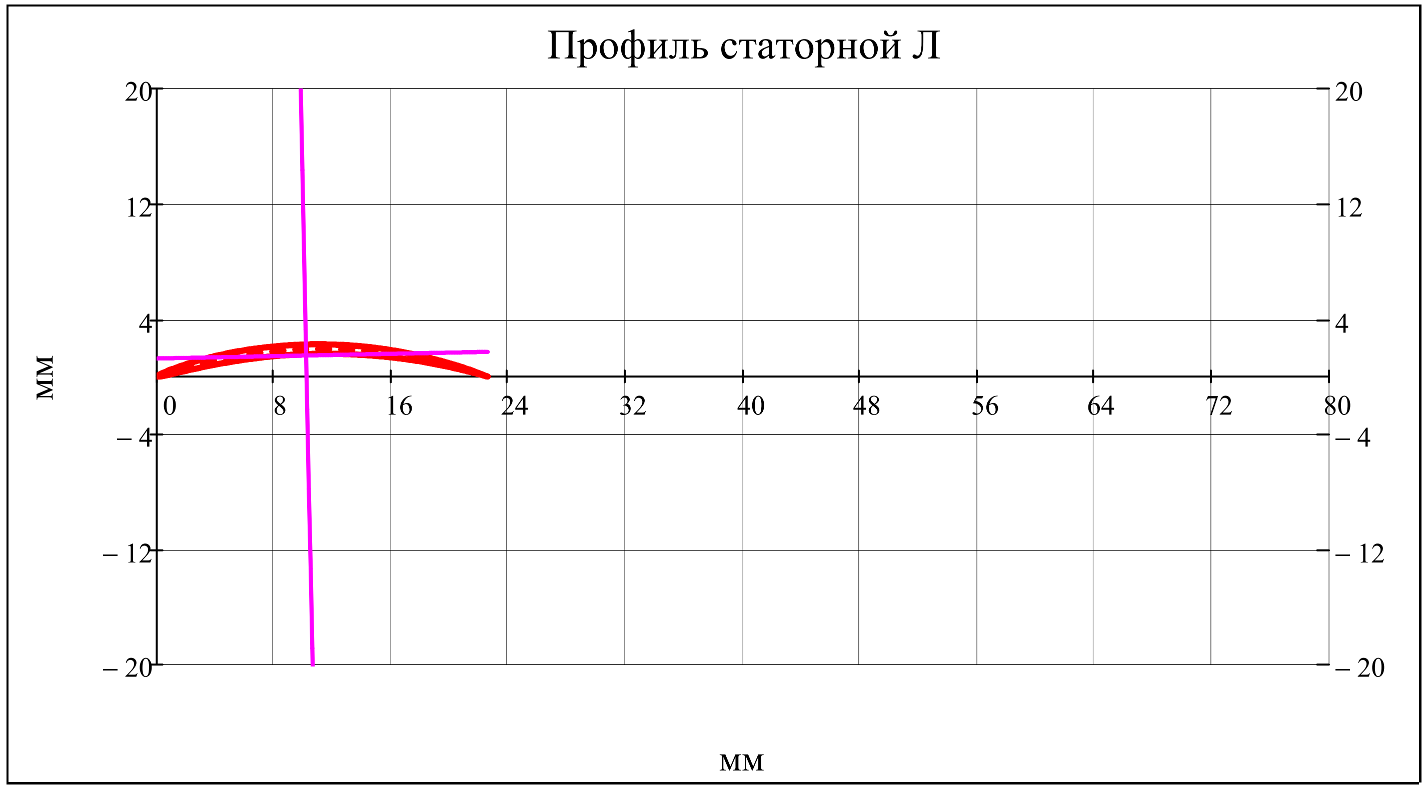


Профиль Л СА
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм

$r = 1$

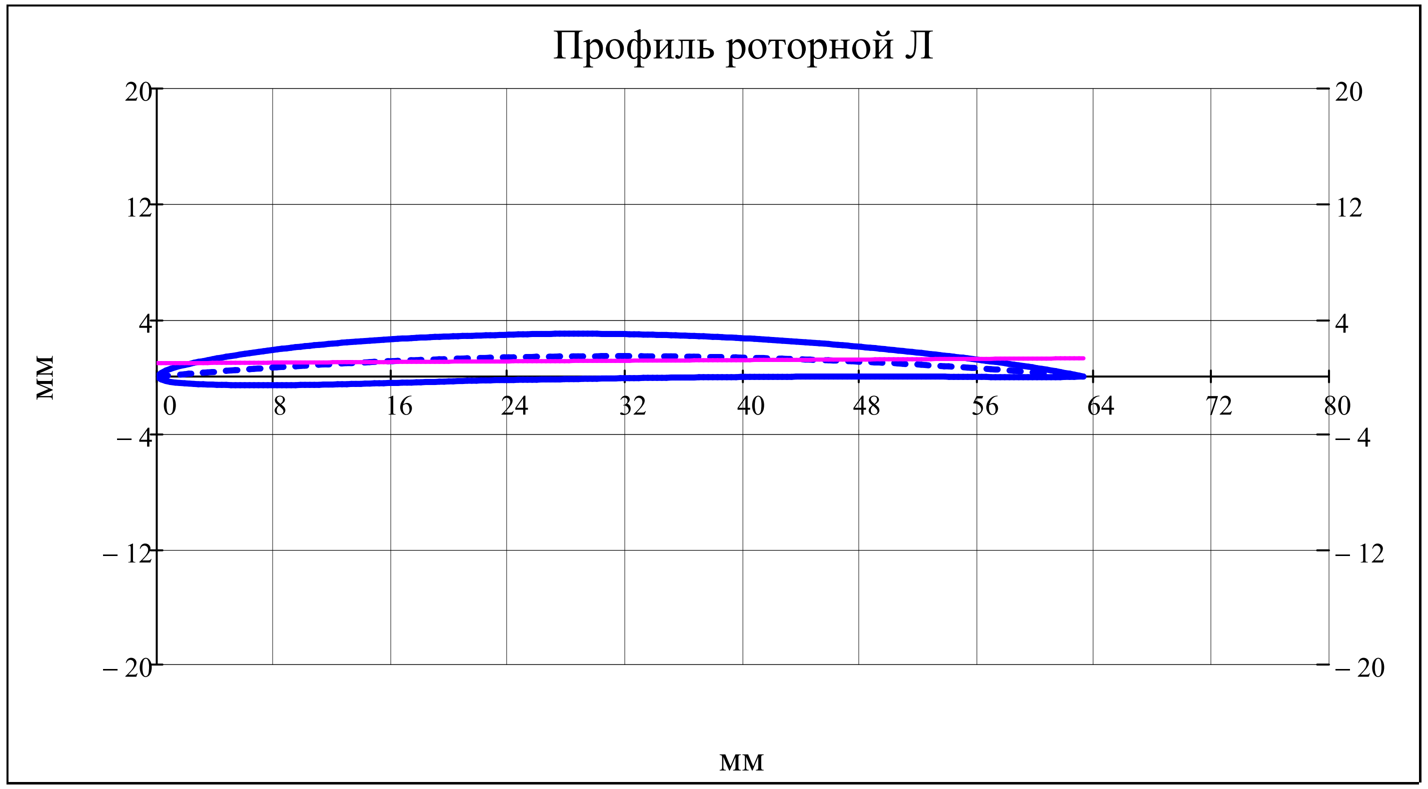


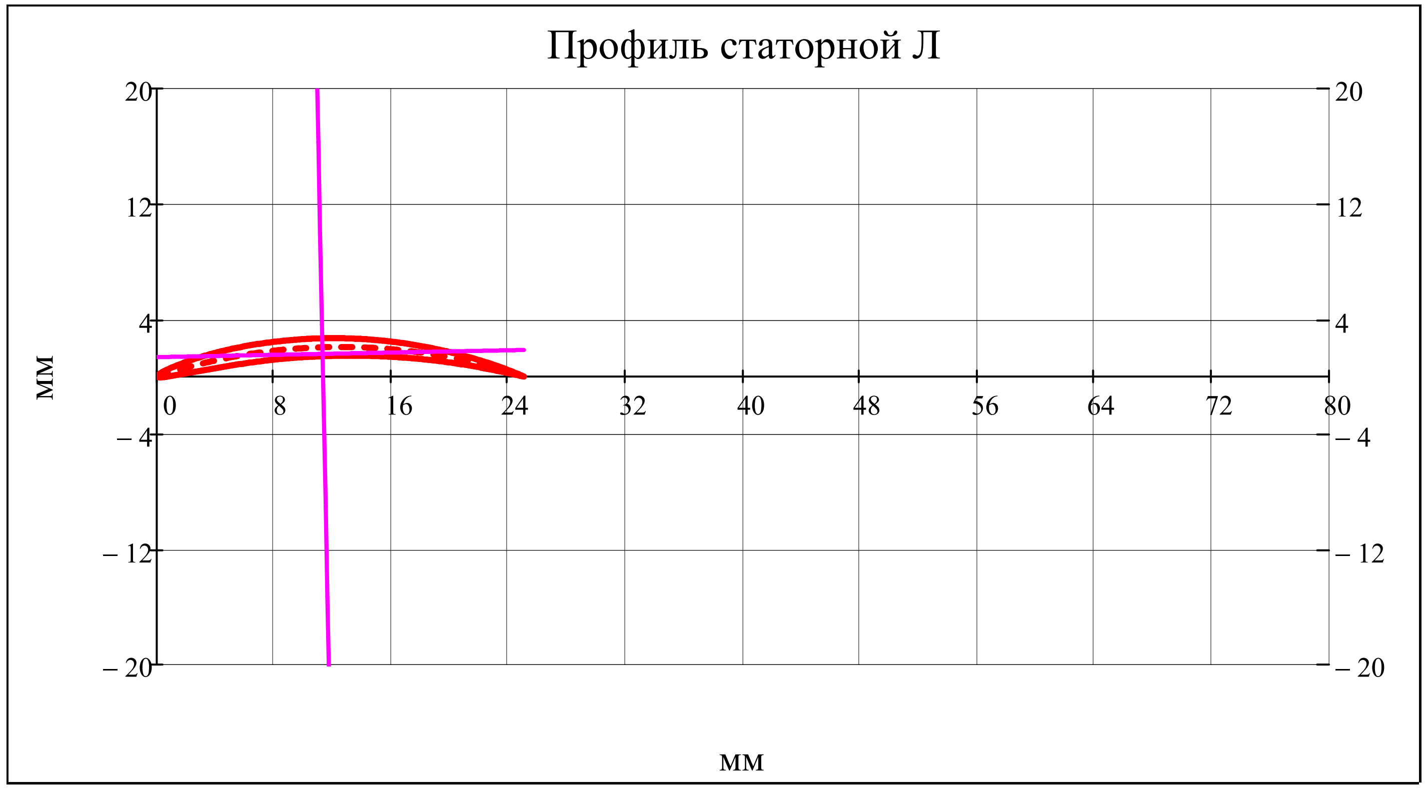
Профиль роторной Л
20
12
4
− 4
− 12
− 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм



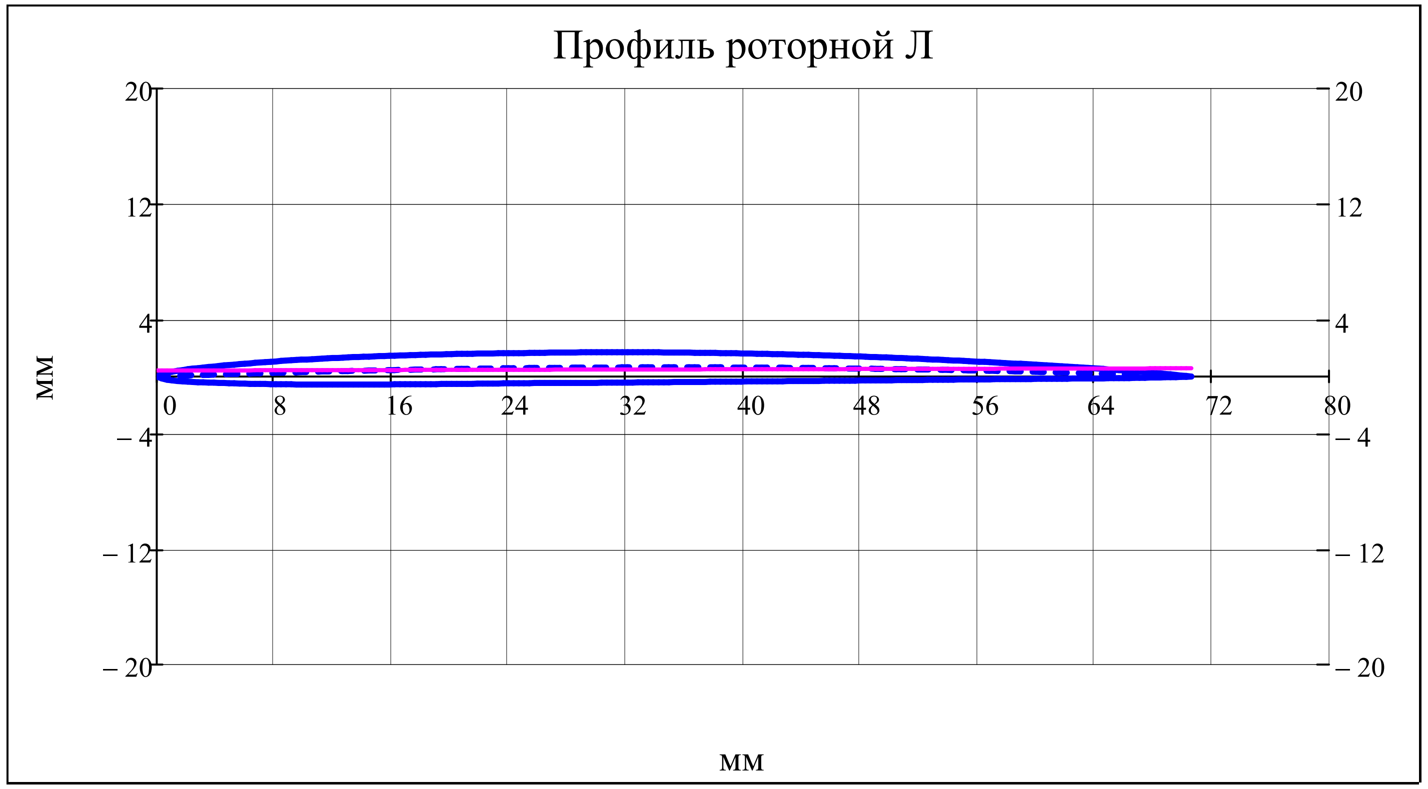
Профиль статорной Л
20
12
4
− 4
− 12
− 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм

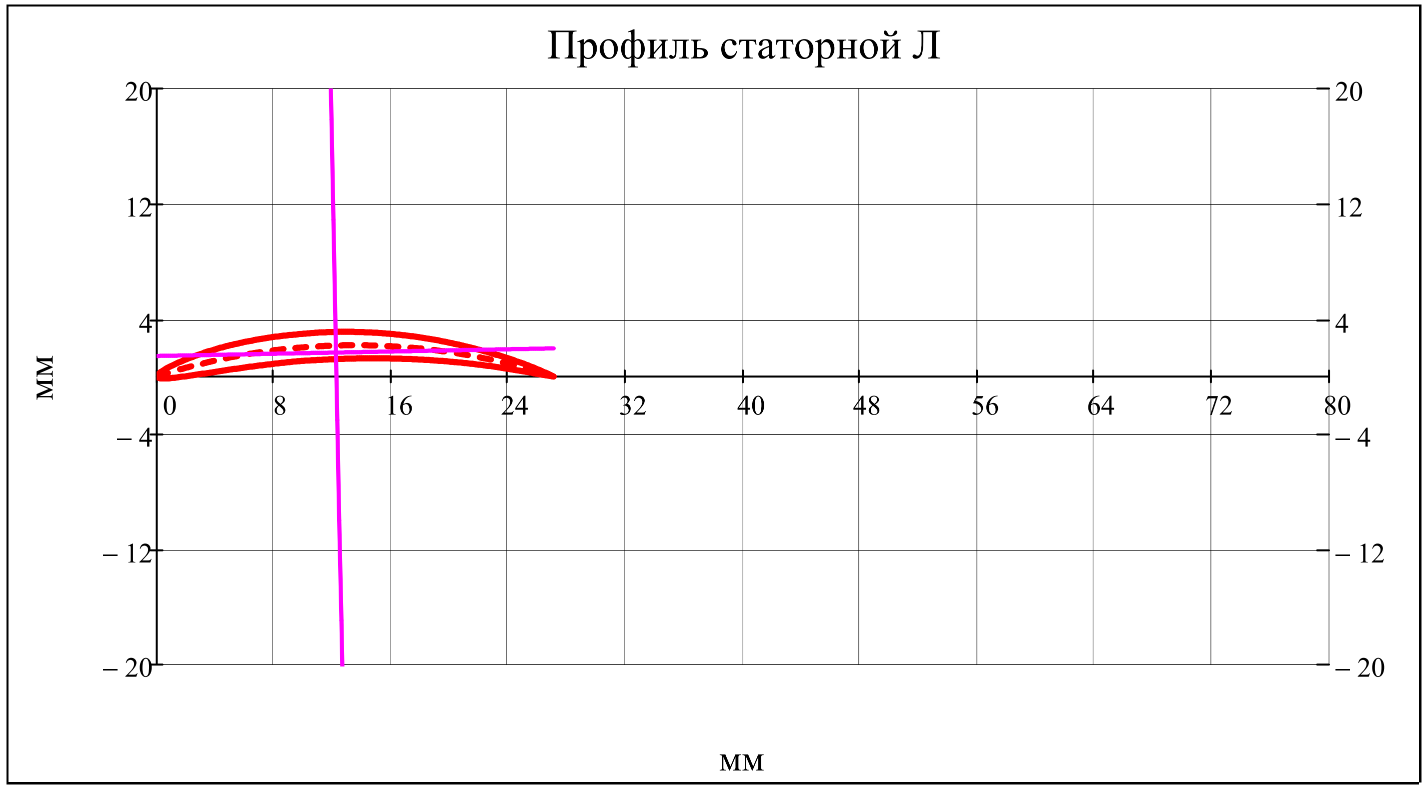
$r = av(N_r)$


Профиль роторной Л
20
12
4
0
8
16
24
32
40
48
56
64
72
80
− 4
− 12
− 20
мм
мм


Профиль статорной Л
20
12
4
0
8
16
24
32
40
48
56
64
72
80
− 4
− 12
− 20
мм
мм

$r = N_r$





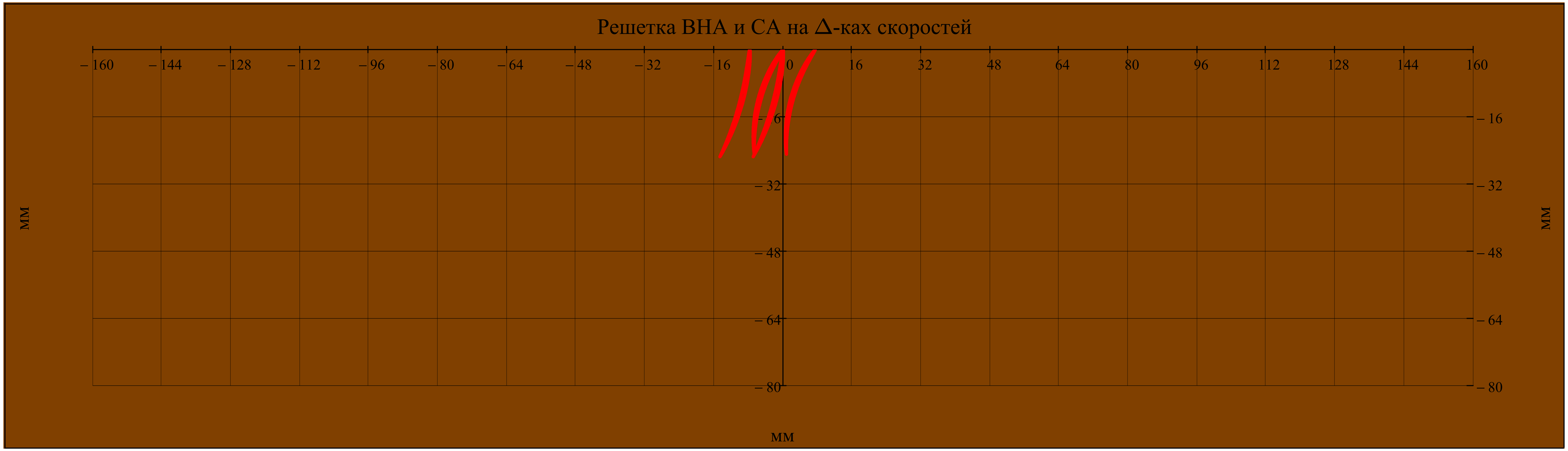
Построение профилей Л РК и НА

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

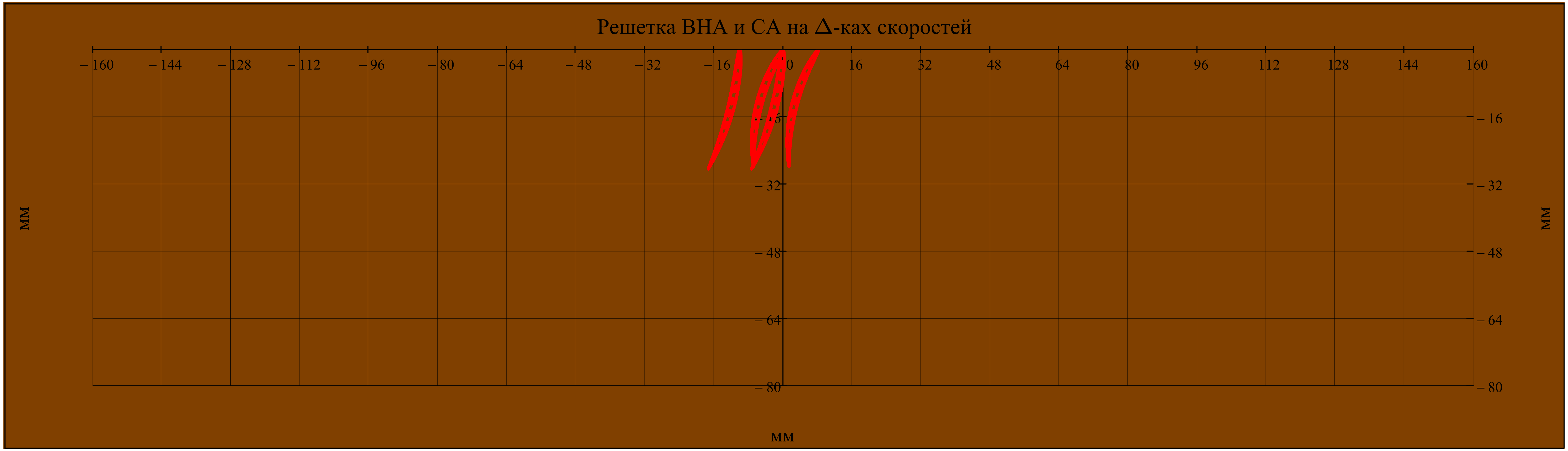
$$b_{lim} = \frac{\mathrm{ceil}\left(\max\left(chord_{rotor_{j,N_r}}, chord_{stator_{j,N_r}}\right)\cdot 10^2\right)}{10^2} = 80\cdot 10^{-3}$$

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

$r = 1$

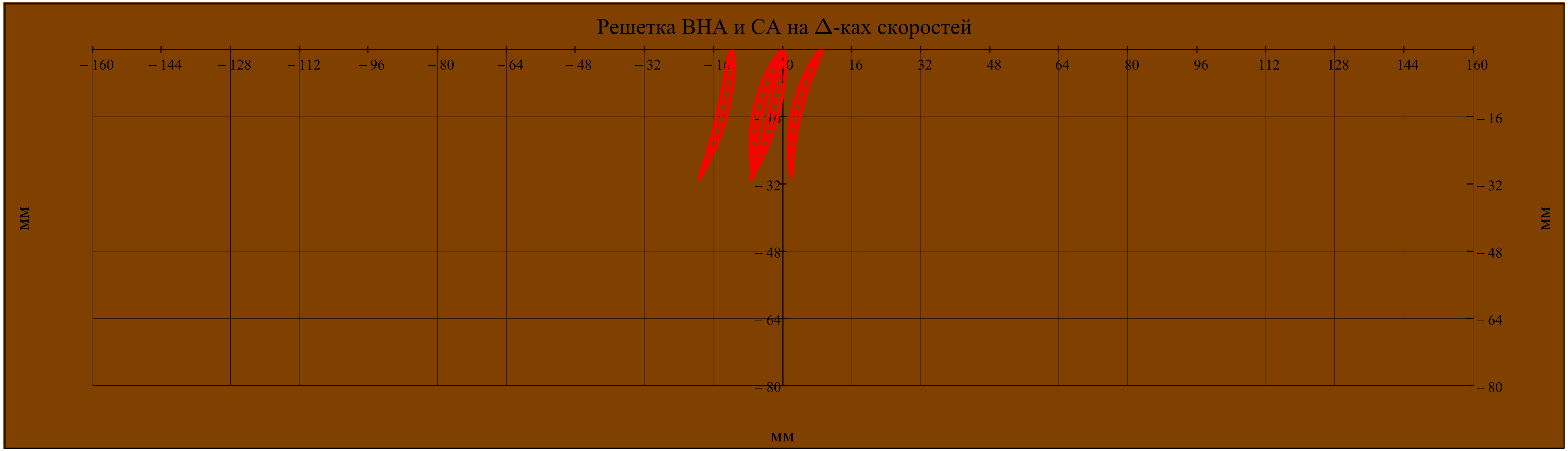


$r = av(N_r)$

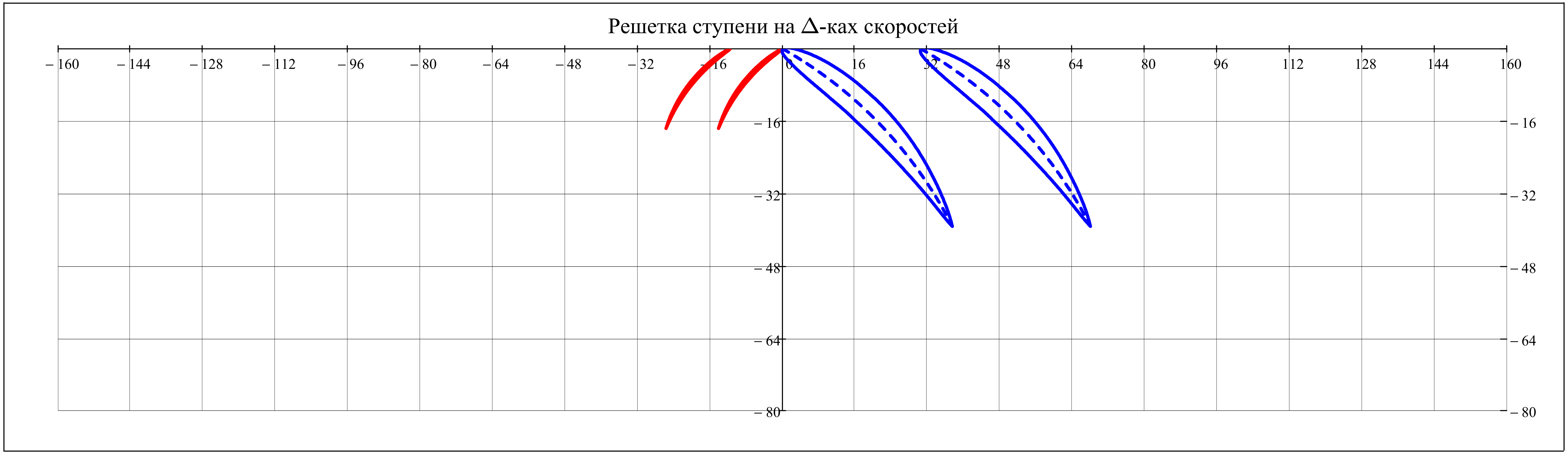


Решетка ВНА и СА на Δ-ках скоростей
– 160
– 144
– 128
– 112
– 96
– 80
– 64
– 48
– 32
– 16
0
16
32
48
64
80
96
112
128
144
160
– 16
– 32
– 48
– 64
– 80
мм
мм
мм

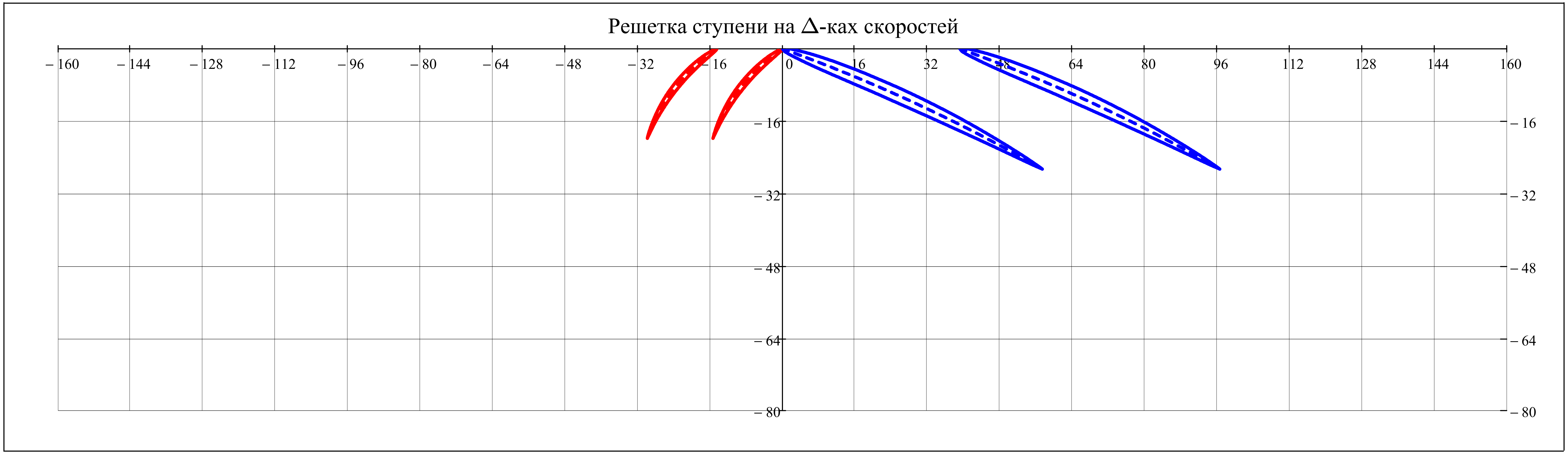
$r = N_r$


Решетка ВНА и СА на Δ-ках скоростей
– 160
– 144
– 128
– 112
– 96
– 80
– 64
– 48
– 32
0
16
32
48
64
80
96
112
128
144
160
– 16
– 32
– 48
– 64
– 80
мм
мм
мм

$r = 1$

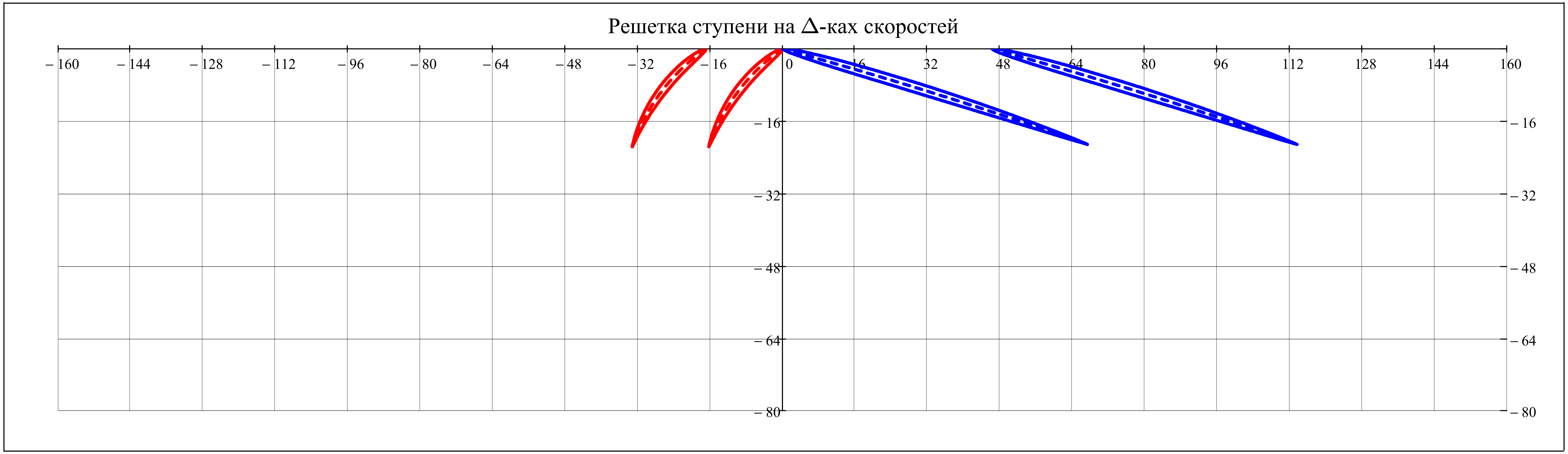

Решетка ступени на Δ-ках скоростей
– 160
– 144
– 128
– 112
– 96
– 80
– 64
– 48
– 32
– 16
0
16
32
48
64
80
96
112
128
144
160
– 16
– 32
– 48
– 64
– 80

$r = av(N_r)$



Решетка ступени на Δ-ках скоростей
– 160
– 144
– 128
– 112
– 96
– 80
– 64
– 48
– 32
– 16
0
16
32
48
64
80
96
112
128
144
160
– 16
– 32
– 48
– 64
– 80

$r = N_r$



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

Радиальные и осевые зазоры и длина К

Радиальный зазор (м)
[с.64 казаджан]:

$\bar{\Delta}r = 0.0025$

$0.0015 \le \bar{\Delta}r \le 0.0035 = 1$

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

$\Delta_r^{T} =$

	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

$\cdot 10^{-3}$

Относительный осевой зазор () [16,с. 245]: $\bar{\Delta}a = 0.17$

$0.1 \le \bar{\Delta}a \le 0.2 = 1$

Осевой зазор (м): $\Delta a_i = \bar{\Delta}a \cdot chord_{rotor_{i,av(N_r)}}$

$\Delta a^{T} =$

	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

$\cdot 10^{-3}$

Односторонний осевой зазор (м):

$\dfrac{\Delta a^{T}}{2} =$

	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

$\cdot 10^{-3}$

Длина ОК (м):

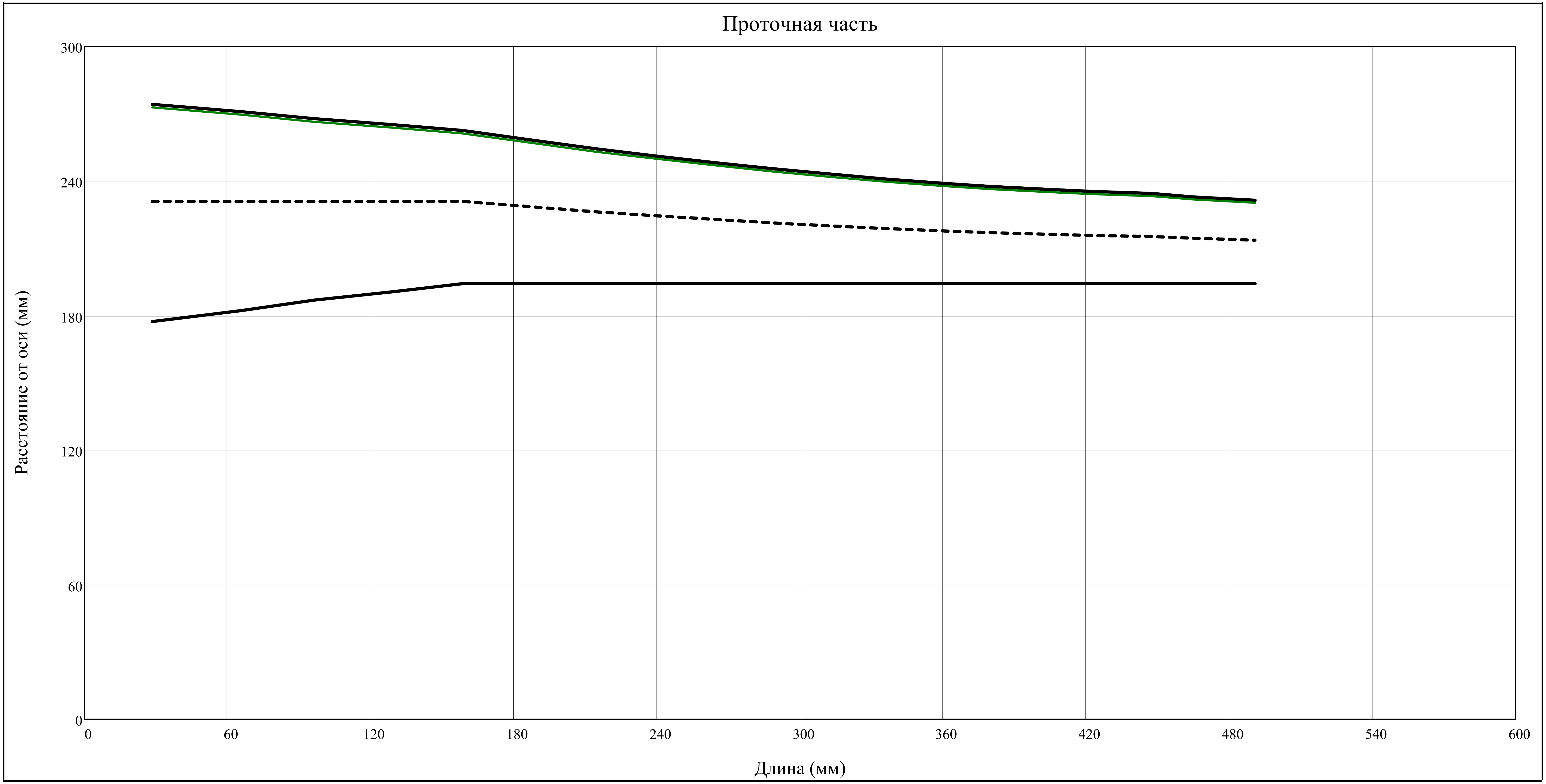
$$Length = \left[\Delta a_1 + \left|\begin{array}{l} chord_{BHA_{av(N_r)}} \cdot \sin\left(\upsilon_{BHA_{av(N_r)}}\right) \text{ if } BHA = 1 \\ 0 \text{ otherwise}\end{array}\right. \ldots \\ + \sum_{i=1}^{Z}\left(chord_{rotor_{i,av(N_r)}} \cdot \sin\left(\upsilon_{rotor_{i,av(N_r)}}\right)\right) + 2\cdot\sum_{i=1}^{Z}\Delta a_i + \sum_{i=1}^{Z}\left(chord_{stator_{i,av(N_r)}} \cdot \sin\left(\upsilon_{stator_{i,av(N_r)}}\right)\right) \ldots \\ + \left|\begin{array}{l} chord_{CA_{av(N_r)}} \cdot \sin\left(\upsilon_{CA_{av(N_r)}}\right) \text{ if } CA = 1 \\ 0 \text{ otherwise}\end{array}\right. + \Delta a_Z\right] = 535.6\cdot 10^{-3}$$

Радиальные и осевые зазоры и длина К

Проточная часть

$$\begin{pmatrix} x_{ПЧ} \\ y_{ПЧпер} \\ y_{ПЧср} \\ y_{ПЧкор} \\ y_{Лпер} \end{pmatrix} = \left| \begin{array}{l} c \leftarrow 1 \\ x_{ПЧ_c} \leftarrow \left| \begin{array}{ll} chord_{BHA_{av(N_r)}} \cdot \sin\left(\upsilon_{BHA_{av(N_r)}}\right) & \text{if } BHA = 1 \\ 0 & \text{otherwise} \end{array} \right. \\ y_{ПЧпер_c} \leftarrow R_{st(c,1),N_r} \\ y_{Лпер_c} \leftarrow y_{ПЧпер_c} - \Delta r_c \\ y_{ПЧср_c} \leftarrow R_{st(c,1),av(N_r)} \\ y_{ПЧкор_c} \leftarrow R_{st(c,1),ORIGIN} \\ \text{for } i \in 1..Z \\ \quad \left| \begin{array}{l} c \leftarrow c+1 \\ x_{ПЧ_c} \leftarrow x_{ПЧ_{c-1}} + 0.5\cdot\Delta a_i + chord_{rotor_{i,av(N_r)}} \cdot \sin\left(\upsilon_{rotor_{i,av(N_r)}}\right) + 0.5\cdot\Delta a_i \\ \begin{pmatrix} y_{ПЧпер_c} \\ y_{ПЧср_c} \\ y_{ПЧкор_c} \end{pmatrix} \leftarrow \begin{pmatrix} R_{st(i,2),N_r} \\ R_{st(i,2),av(N_r)} \\ R_{st(i,2),ORIGIN} \end{pmatrix} \\ y_{Лпер_c} \leftarrow y_{ПЧпер_c} - \Delta r_i \\ c \leftarrow c+1 \\ x_{ПЧ_c} \leftarrow x_{ПЧ_{c-1}} + 0.5\cdot\Delta a_i + chord_{stator_{i,av(N_r)}} \cdot \sin\left(\upsilon_{stator_{i,av(N_r)}}\right) + 0.5\cdot\Delta a_i \\ \begin{pmatrix} y_{ПЧпер_c} \\ y_{ПЧср_c} \\ y_{ПЧкор_c} \end{pmatrix} \leftarrow \begin{pmatrix} R_{st(i,3),N_r} \\ R_{st(i,3),av(N_r)} \\ R_{st(i,3),ORIGIN} \end{pmatrix} \\ y_{Лпер_c} \leftarrow y_{ПЧпер_c} - \Delta r_i \end{array} \right. \\ \left(x_{ПЧ} \;\; y_{ПЧпер} \;\; y_{ПЧср} \;\; y_{ПЧкор} \;\; y_{Лпер} \right)^T \end{array} \right.$$

$$y_{ПЧпер}(l) := interp\left(cspline\left(x_{ПЧ}, y_{ПЧпер}\right), x_{ПЧ}, y_{ПЧпер}, l\right)$$
$$y_{ПЧср}(l) := interp\left(cspline\left(x_{ПЧ}, y_{ПЧср}\right), x_{ПЧ}, y_{ПЧср}, l\right)$$
$$y_{ПЧкор}(l) := interp\left(cspline\left(x_{ПЧ}, y_{ПЧкор}\right), x_{ПЧ}, y_{ПЧкор}, l\right)$$
$$y_{Лпер}(l) := interp\left(cspline\left(x_{ПЧ}, y_{Лпер}\right), x_{ПЧ}, y_{Лпер}, l\right)$$



Проточная часть

Рассматриваемая ступень: $j := \left| \begin{array}{l} j \leftarrow 1 \\ j \leftarrow \left| \begin{array}{ll} \text{"Такой ступени не существует!"} & \text{if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{array} \right. \end{array} \right. = 1$

Поперечная часть ступени

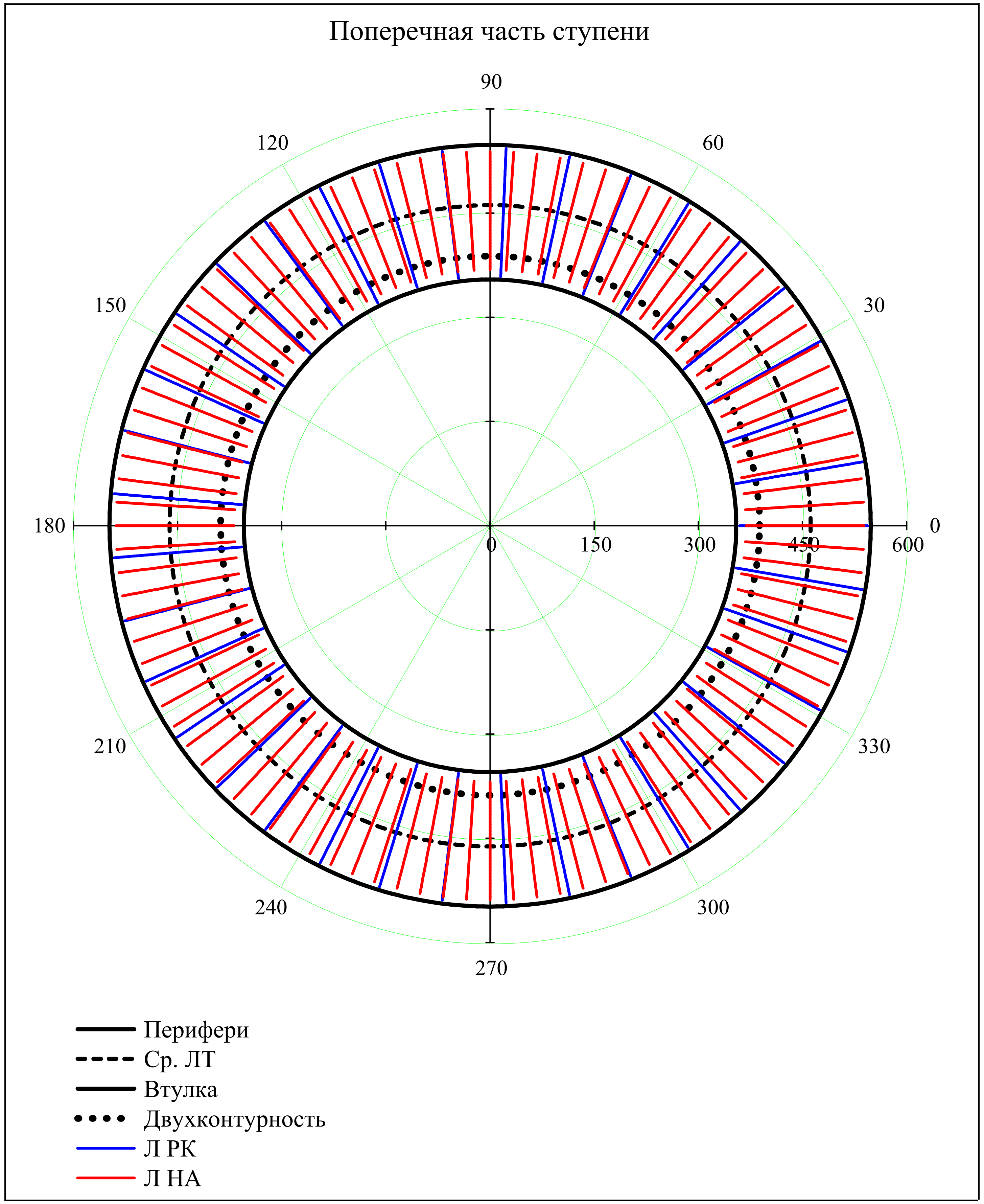
$$r := \min(D), \min(D) + \frac{\max(D) - \min(D)}{N_{dis}} .. \max(D)$$

$$i_{rotor} := 1 .. Z_{rotor_j}$$

$$i_{stator} := 1 .. Z_{stator_j}$$

$$Л_{РК}(r, j) := \left| \begin{array}{ll} \dfrac{2 \cdot \pi}{Z_{rotor_j}} & \text{if } D_{st(j,1),1} < r < D_{st(j,1),N_r} \\ \text{NaN} & \text{otherwise} \end{array} \right.$$

$$Л_{НА}(r, j) := \left| \begin{array}{ll} \dfrac{2 \cdot \pi}{Z_{stator_j}} & \text{if } D_{st(j,2),1} < r < D_{st(j,2),N_r} \\ \text{NaN} & \text{otherwise} \end{array} \right.$$



Поперечная часть ступени

Выбор материала Л

Запас по температуре (К): $\Delta T_{safety} = 50$

Выбранный материал Л:

$$material\_blade_i = \begin{cases} \text{"ЖС-6К"} & \text{if } 1123 \le T^*_{st(i,2),av(N_r)} + \Delta T_{safety} \\ \text{"ВТ41"} & \text{if } 873 \le T^*_{st(i,2),av(N_r)} + \Delta T_{safety} < 1123 \\ \text{"ВТ25"} & \text{if } 753 \le T^*_{st(i,2),av(N_r)} + \Delta T_{safety} < 873 \\ \text{"ВТ9"} & \text{otherwise} \end{cases}$$

$$material\_blade_i = \begin{cases} \text{"ВТ23"} & \text{if } compressor = \text{"Вл"} \\ \text{"ВТ6"} & \text{if } compressor = \text{"КНД"} \\ material\_blade_i & \text{otherwise} \end{cases}$$

Плотность материала Л (кг/м^3):

$$\rho\_blade_i = \begin{cases} 8393 & \text{if } material\_blade_i = \text{"ЖС-6К"} \\ 7900 & \text{if } material\_blade_i = \text{"ВТ41"} \\ 4500 & \text{if } material\_blade_i = \text{"ВТ25"} \\ 4570 & \text{if } material\_blade_i = \text{"ВТ23"} \\ 4510 & \text{if } material\_blade_i = \text{"ВТ9"} \\ 4430 & \text{if } material\_blade_i = \text{"ВТ6"} \\ NaN & \text{otherwise} \end{cases}$$

Коэф. формы: $k_n = 6.8$

Модуль Юнга I рода материала Л (Па): $E\_blade = 210 \cdot 10^9$

Коэф. Пуассона материала Л (): $\mu\_steel = 0.3$

Предел длительной прочности Л РК (Па):

$$\sigma\_blade\_long_i = 10^6 \cdot \begin{cases} 125 & \text{if } material\_blade_i = \text{"ЖС-6К"} \\ 123 & \text{if } material\_blade_i = \text{"ВТ41"} \\ 150 & \text{if } material\_blade_i = \text{"ВТ25"} \\ 230 & \text{if } material\_blade_i = \text{"ВТ23"} \\ 200 & \text{if } material\_blade_i = \text{"ВТ9"} \\ 210 & \text{if } material\_blade_i = \text{"ВТ6"} \\ NaN & \text{otherwise} \end{cases}$$

$material\_blade^T =$

	1	2	3	4	5	6	7	8	9
1	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ25"	"ВТ25"	"ВТ25"	"ВТ41"

$\rho\_blade^T =$

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

$\sigma\_blade\_long^T =$ $\cdot 10^6$

	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

Выбор материала Л

Расчет собственных частот колебаний Л

$$\begin{pmatrix} \nu 0_{изг.stator} & \nu 0_{изг.rotor} \\ \nu 0_{угл.stator} & \nu 0_{угл.rotor} \\ \nu 0_{угл.stator\_bondage} & \nu 0_{угл.rotor\_bondage} \end{pmatrix} = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } r \in av(N_r) \\ \quad\quad \text{for } mode \in 1..6 \\ \quad\quad\quad \left| \begin{array}{l} \nu 0_{изг.stator_{i,mode}} \leftarrow \nu 0_{изгиб}\left(mode, mean\left(h_{st(i,2)}, h_{st(i,3)}\right), E\_blade, \rho\_blade_i, area_{stator_{i,r}}, Ju_{stator_{i,r}}\right) \\ \nu 0_{изг.rotor_{i,mode}} \leftarrow \nu 0_{изгиб}\left(mode, mean\left(h_{st(i,1)}, h_{st(i,2)}\right), E\_blade, \rho\_blade_i, area_{rotor_{i,r}}, Ju_{rotor_{i,r}}\right) \\ \nu 0_{угл.stator_{i,mode}} \leftarrow \nu 0_{угл}\left(mode, 0, mean\left(h_{st(i,2)}, h_{st(i,3)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{stator_{i,r}}, Jp_{stator_{i,r}}\right) \\ \nu 0_{угл.rotor_{i,mode}} \leftarrow \nu 0_{угл}\left(mode, 0, mean\left(h_{st(i,1)}, h_{st(i,2)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{rotor_{i,r}}, Jp_{rotor_{i,r}}\right) \\ \nu 0_{угл.stator\_bondage_{i,mode}} \leftarrow \nu 0_{угл}\left(mode, 1, mean\left(h_{st(i,2)}, h_{st(i,3)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{stator_{i,r}}, Jp_{stator_{i,r}}\right) \\ \nu 0_{угл.rotor\_bondage_{i,mode}} \leftarrow \nu 0_{угл}\left(mode, 1, mean\left(h_{st(i,1)}, h_{st(i,2)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{rotor_{i,r}}, Jp_{rotor_{i,r}}\right) \end{array} \right. \\ \begin{pmatrix} \nu 0_{изг.stator} & \nu 0_{изг.rotor} \\ \nu 0_{угл.stator} & \nu 0_{угл.rotor} \\ \nu 0_{угл.stator\_bondage} & \nu 0_{угл.rotor\_bondage} \end{pmatrix} \end{array} \right.$$

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

$$\mathrm{stack}\left(\nu0_{\text{угл.stator}}, \nu0_{\text{угл.rotor}}\right)^{T} =$$

	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:

$$\mathrm{stack}\left(\nu0_{\text{изг.stator}}, \nu0_{\text{изг.rotor}}\right)^{T} =$$

	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

$$\mathrm{stack}\left(\nu0_{\text{угл.stator\_bondage}}, \nu0_{\text{угл.rotor\_bondage}}\right)^{T} =$$

	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

Расчет собственных частот колебаний Л

Расчетный узел: type = "compressor"

Объем бандажной полки ($м^3$): $V_{бп} = 0$

Радиус положения ЦМ бандажной полки (м): $R_{бп} = 0$

Расчет Л на прочность

$$\begin{pmatrix} R0_{rotor} & area0_{rotor} \\ N0_{rotor} & \sigma 0\_z_{rotor} \\ area_{rotor.} & area_{stator.} \\ N_{rotor} & \sigma\_z_{rotor} \\ P_1 & \rho_1 \\ P_2 & \rho_2 \\ P_3 & \rho_3 \\ c_{a1} & c_{u1} \\ c_{a2} & c_{u2} \\ c_{a3} & c_{u3} \\ qx_{rotor} & qx_{stator} \\ qy_{rotor} & qy_{stator} \\ Mx_{rotor} & Mx_{stator} \\ My_{rotor} & My_{stator} \\ shift\_x_{rotor} & shift\_y_{rotor} \\ x0_{rotor.} & x0_{stator.} \\ y0_{rotor.} & y0_{stator.} \\ \alpha\_major_{rotor.} & \alpha\_major_{stator.} \\ Ju_{rotor.} & Ju_{stator.} \\ Jv_{rotor.} & Jv_{stator.} \\ CPx_{rotor.} & CPx_{stator.} \\ CPy_{rotor.} & CPy_{stator.} \\ CPx_{rotor.axis} & CPx_{stator.axis} \\ CPy_{rotor.axis} & CPy_{stator.axis} \end{pmatrix} = \left| \begin{array}{l} \chi_{rotor}(i,z) = \dfrac{area_{rotor_{i,N_r}}}{area_{rotor_{i,1}}} \\ R0_{rotor}(i,z) = \dfrac{1}{\sqrt{1-\ln(\chi_{rotor}(i,z))}} \cdot \left| \begin{array}{ll} \sqrt{mean(R_{st(i,1),1}, R_{st(i,2),1})^2 - mean(R_{st(i,1),N_r}, R_{st(i,2),N_r})^2 \cdot \ln(\chi_{rotor}(i,z))} & \text{if type = "compressor"} \\ \sqrt{mean(R_{st(i,2),1}, R_{st(i,3),1})^2 - mean(R_{st(i,2),N_r}, R_{st(i,3),N_r})^2 \cdot \ln(\chi_{rotor}(i,z))} & \text{if type = "turbine"} \end{array} \right. \\ \sigma 0_{rotor.max}(i,z) = \dfrac{\rho\_blade_i \cdot \omega^2}{2} \cdot \left| \begin{array}{ll} \left[mean(R_{st(i,1),N_r}, R_{st(i,2),N_r})^2 - (R0_{rotor}(i,z))^2\right] & \text{if type = "compressor"} \\ \left[mean(R_{st(i,2),N_r}, R_{st(i,3),N_r})^2 - (R0_{rotor}(i,z))^2\right] & \text{if type = "turbine"} \end{array} \right. \\ \quad \left| \left(\dfrac{\rho\_blade_i \cdot \omega^2}{\ldots} \int^{R0_{rotor}(i,z)} \ldots \right) \right. \end{array} \right.$$

$$\begin{pmatrix} \varphi_{rotor.axis} & \varphi_{stator.axis} \\ Wp_{rotor.} & Wp_{stator.} \\ M\tau_{rotor} & M\tau_{stator} \\ \tau_{rotor} & \tau_{stator} \\ \varphi\_uv_{rotor} & \varphi\_uv_{stator} \\ Mu_{rotor} & Mu_{stator} \\ Mv_{rotor} & Mv_{stator} \\ \varphi\_neutral_{rotor} & \varphi\_neutral_{stator} \end{pmatrix}$$

$$area0_{rotor}(i,z) = area_{rotor_{i,N_r}} \cdot \begin{cases} e^{\left(\frac{\cdots}{\sigma0_{rotor.max}(i,z)} \cdot \int_z \cdots z\,dz\right)} & \text{if } z \le R0_{rotor}(i,z) \\ 1 & \text{otherwise} \end{cases}$$

$$N0_{rotor}(i,z) = \rho\_blade_i \cdot \omega^2 \cdot \begin{cases} \left(\int_z^{mean\left(R_{st(i,1),N_r}, R_{st(i,2),N_r}\right)} area0_{rotor}(i,z) \cdot z\,dz + V_{бп} \cdot R_{бп}\right) & \text{if type = "compressor"} \\ \left(\int_z^{mean\left(R_{st(i,2),N_r}, R_{st(i,3),N_r}\right)} area0_{rotor}(i,z) \cdot z\,dz + V_{бп} \cdot R_{бп}\right) & \text{if type = "turbine"} \end{cases}$$

$$\sigma0\_z_{rotor}(i,z) = \frac{N0_{rotor}(i,z)}{area0_{rotor}(i,z)}$$

$$area_{rotor.}(i,z) = interp\left(pspline\left(submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(area_{rotor}, i, i, 1, N_r\right)^T\right), submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(area_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$area_{stator.}(i,z) = interp\left(pspline\left(submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(area_{stator}, i, i, 1, N_r\right)^T\right), submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(area_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$N_{rotor}(i,z) = \rho\_blade_i \cdot \omega^2 \cdot \begin{cases} \left(\int_z^{mean\left(R_{st(i,1),N_r}, R_{st(i,2),N_r}\right)} area_{rotor.}(i,z) \cdot z\,dz + V_{бп} \cdot R_{бп}\right) & \text{if type = "compressor"} \\ \left(\int_z^{mean\left(R_{st(i,2),N_r}, R_{st(i,3),N_r}\right)} area_{rotor.}(i,z) \cdot z\,dz + V_{бп} \cdot R_{бп}\right) & \text{if type = "turbine"} \end{cases}$$

$$\sigma\_z_{rotor}(i,z) = \frac{N_{rotor}(i,z)}{area_{rotor.}(i,z)}$$

$$\rho_1(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(\rho, st(i,1), st(i,1), 1, N_r\right)^T\right), submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(\rho, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$$

$$\rho_2(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(\rho, st(i,2), st(i,2), 1, N_r\right)^T\right), submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(\rho, st(i,2), st(i,2), 1, N_r\right)^T, z\right)$$

$$\rho_3(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,3), st(i,3), 1, N_r\right)^T, submatrix\left(\rho, st(i,3), st(i,3), 1, N_r\right)^T\right), submatrix\left(R, st(i,3), st(i,3), 1, N_r\right)^T, submatrix\left(\rho, st(i,3), st(i,3), 1, N_r\right)^T, z\right)$$

$$P_1(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(P, st(i,1), st(i,1), 1, N_r\right)^T\right), submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(P, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$$

$$P_2(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(P, st(i,2), st(i,2), 1, N_r\right)^T\right), submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(P, st(i,2), st(i,2), 1, N_r\right)^T, z\right)$$

$$P_3(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,3), st(i,3), 1, N_r\right)^T, submatrix\left(P, st(i,3), st(i,3), 1, N_r\right)^T\right), submatrix\left(R, st(i,3), st(i,3), 1, N_r\right)^T, submatrix\left(P, st(i,3), st(i,3), 1, N_r\right)^T, z\right)$$

$$c_{a1}(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(c_a, st(i,1), st(i,1), 1, N_r\right)^T\right), submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(c_a, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$$

$$c_{a2}(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(c_a, st(i,2), st(i,2), 1, N_r\right)^T\right), submatrix\left(R, st(i,2), st(i,2), 1, N_r\right)^T, submatrix\left(c_a, st(i,2), st(i,2), 1, N_r\right)^T, z\right)$$

$$c_{a3}(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,3), st(i,3), 1, N_r\right)^T, submatrix\left(c_a, st(i,3), st(i,3), 1, N_r\right)^T\right), submatrix\left(R, st(i,3), st(i,3), 1, N_r\right)^T, submatrix\left(c_a, st(i,3), st(i,3), 1, N_r\right)^T, z\right)$$

$$c_{u1}(i,z) = interp\left(lspline\left(submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(c_u, st(i,1), st(i,1), 1, N_r\right)^T\right), submatrix\left(R, st(i,1), st(i,1), 1, N_r\right)^T, submatrix\left(c_u, st(i,1), st(i,1), 1, N_r\right)^T, z\right)$$

$$c_{u2}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^{1}, \mathrm{submatrix}\left(c_u, st(i,2), st(i,2), 1, N_r\right)^{1}\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^{1}, \mathrm{submatrix}\left(c_u, st(i,2), st(i,2), 1, N_r\right)^{1}, z\right)$$

$$c_{u3}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^{T}, \mathrm{submatrix}\left(c_u, st(i,3), st(i,3), 1, N_r\right)^{T}\right), \mathrm{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^{T}, \mathrm{submatrix}\left(c_u, st(i,3), st(i,3), 1, N_r\right)^{T}, z\right)$$

$$w_{u1}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^{T}, \mathrm{submatrix}\left(w_u, st(i,1), st(i,1), 1, N_r\right)^{T}\right), \mathrm{submatrix}\left(R, st(i,1), st(i,1), 1, N_r\right)^{T}, \mathrm{submatrix}\left(w_u, st(i,1), st(i,1), 1, N_r\right)^{T}, z\right)$$

$$w_{u2}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^{T}, \mathrm{submatrix}\left(w_u, st(i,2), st(i,2), 1, N_r\right)^{T}\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^{T}, \mathrm{submatrix}\left(w_u, st(i,2), st(i,2), 1, N_r\right)^{T}, z\right)$$

$$w_{u3}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^{T}, \mathrm{submatrix}\left(w_u, st(i,3), st(i,3), 1, N_r\right)^{T}\right), \mathrm{submatrix}\left(R, st(i,3), st(i,3), 1, N_r\right)^{T}, \mathrm{submatrix}\left(w_u, st(i,3), st(i,3), 1, N_r\right)^{T}, z\right)$$

$$qx_{rotor}(i,z) = -\frac{2\pi z}{Z_{rotor_i}} \cdot \left| \begin{array}{ll} \left[\left(P_2(i,z) - P_1(i,z)\right) + \rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(c_{a2}(i,z) - c_{a1}(i,z)\right)\right] & \text{if type = "compressor"} \\ \left[\left(P_3(i,z) - P_2(i,z)\right) + \rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(c_{a3}(i,z) - c_{a2}(i,z)\right)\right] & \text{if type = "turbine"} \end{array}\right.$$

$$qx_{stator}(i,z) = -\frac{2\pi z}{Z_{stator_i}} \cdot \left| \begin{array}{ll} \left[\left(P_3(i,z) - P_2(i,z)\right) + \rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(c_{a3}(i,z) - c_{a2}(i,z)\right)\right] & \text{if type = "compressor"} \\ \left[\left(P_2(i,z) - P_1(i,z)\right) + \rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(c_{a2}(i,z) - c_{a1}(i,z)\right)\right] & \text{if type = "turbine"} \end{array}\right.$$

$$qy_{rotor}(i,z) = \frac{2\pi z}{Z_{rotor_i}} \cdot \left| \begin{array}{ll} \left[\rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(w_{u2}(i,z) - w_{u1}(i,z)\right)\right] & \text{if type = "compressor"} \\ \left[\rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(w_{u3}(i,z) - w_{u2}(i,z)\right)\right] & \text{if type = "turbine"} \end{array}\right.$$

$$qy_{stator}(i,z) = -\frac{2\pi z}{Z_{stator_i}} \cdot \left| \begin{array}{ll} \left[\rho_2(i,z) \cdot c_{a2}(i,z) \cdot \left(c_{u3}(i,z) - c_{u2}(i,z)\right)\right] & \text{if type = "compressor"} \\ \left[\rho_1(i,z) \cdot c_{a1}(i,z) \cdot \left(c_{u2}(i,z) - c_{u1}(i,z)\right)\right] & \text{if type = "turbine"} \end{array}\right.$$

$$Mx_{rotor}(i,z) = -\int_z^{\left| \begin{array}{ll} \mathrm{mean}\left(R_{st(i,1),N_r}, R_{st(i,2),N_r}\right) & \text{if type="compressor"} \\ \mathrm{mean}\left(R_{st(i,2),N_r}, R_{st(i,3),N_r}\right) & \text{if type="turbine"} \end{array}\right.} qy_{rotor}(i,z1) \cdot (z1 - z)\, dz1$$

$$Mx_{stator}(i,z) = \int_z^{\left| \begin{array}{ll} \mathrm{mean}\left(R_{st(i,2),1}, R_{st(i,3),1}\right) & \text{if type="compressor"} \\ \mathrm{mean}\left(R_{st(i,1),1}, R_{st(i,2),1}\right) & \text{if type="turbine"} \end{array}\right.} qy_{stator}(i,z1) \cdot (z1 - z)\, dz1$$

$$My_{rotor}(i,z) = \int_z^{\left| \begin{array}{ll} \mathrm{mean}\left(R_{st(i,1),N_r}, R_{st(i,2),N_r}\right) & \text{if type="compressor"} \\ \mathrm{mean}\left(R_{st(i,2),N_r}, R_{st(i,3),N_r}\right) & \text{if type="turbine"} \end{array}\right.} qx_{rotor}(i,z1) \cdot (z1 - z)\, dz1$$

$$My_{stator}(i,z) = -\int_z^{\left| \begin{array}{ll} \mathrm{mean}\left(R_{st(i,2),1}, R_{st(i,3),1}\right) & \text{if type="compressor"} \\ \mathrm{mean}\left(R_{st(i,1),1}, R_{st(i,2),1}\right) & \text{if type="turbine"} \end{array}\right.} qx_{stator}(i,z1) \cdot (z1 - z)\, dz1$$

$$\int^{z} \int^{\left| \begin{array}{ll} \mathrm{mean}\left(R_{st(i,1),N_r}, R_{st(i,2),N_r}\right) & \text{if type="compressor"} \\ \mathrm{mean}\left(R_{st(i,2),N_r}, R_{st(i,3),N_r}\right) & \text{if type="turbine"} \end{array}\right.} qx(i,z)\, dz$$

$$\mathrm{shift\_x_{rotor}}(i,z) = \int_{\begin{cases}\mathrm{mean}\left(R_{st(i,1),1}, R_{st(i,2),1}\right) & \text{if type="compressor"}\\ \mathrm{mean}\left(R_{st(i,2),1}, R_{st(i,3),1}\right) & \text{if type="turbine"}\end{cases}} \frac{\int_z qx_{rotor}(i,z)\,dz}{N_{rotor}(i,z)}\,dz$$

$$\mathrm{shift\_y_{rotor}}(i,z) = z\cdot\int_{\begin{cases}\mathrm{mean}\left(R_{st(i,1),1}, R_{st(i,2),1}\right) & \text{if type="compressor"}\\ \mathrm{mean}\left(R_{st(i,2),1}, R_{st(i,3),1}\right) & \text{if type="turbine"}\end{cases}}^{z} \frac{\int_z^{\begin{cases}\mathrm{mean}\left(R_{st(i,1),N_r}, R_{st(i,2),N_r}\right) & \text{if type="compressor"}\\ \mathrm{mean}\left(R_{st(i,2),N_r}, R_{st(i,3),N_r}\right) & \text{if type="turbine"}\end{cases}} \left(qy_{rotor}(i,z)\cdot z\right)dz}{N_{rotor}(i,z)\cdot z^2}\,dz$$

$$x0_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(x0_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(x0_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$x0_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(x0_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(x0_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$y0_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(y0_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(y0_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$y0_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(y0_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(y0_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$\alpha\_major_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\alpha\_major_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\alpha\_major_{rotor}, i, i, 1, N_r\right)^T\right.$$

$$\alpha\_major_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\alpha\_major_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\alpha\_major_{stator}, i, i, 1, N_r\right.\right.$$

$$Ju_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Ju_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Ju_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$Ju_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Ju_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Ju_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$Jv_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Jv_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Jv_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$Jv_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Jv_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Jv_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$CPx_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPx_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPx_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$CPx_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPx_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPx_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$CPy_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPy_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPy_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$CPy_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPy_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(CPy_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$CPx_{rotor.axis}(i,z) = \mathrm{axis}_x\left(CPx_{rotor.}(i,z), CPy_{rotor.}(i,z), x0_{rotor.}(i,z), y0_{rotor.}(i,z), \alpha\_major_{rotor.}(i,z), 1\right)$$

$$CPx_{stator.axis}(i,z) = \mathrm{axis}_x\left(CPx_{stator.}(i,z), CPy_{stator.}(i,z), x0_{stator.}(i,z), y0_{stator.}(i,z), \alpha\_major_{stator.}(i,z), 1\right)$$

$$CPy_{rotor.axis}(i,z) = \mathrm{axis}_y\left(CPx_{rotor.}(i,z), CPy_{rotor.}(i,z), x0_{rotor.}(i,z), y0_{rotor.}(i,z), \alpha\_major_{rotor.}(i,z), 1\right)$$

$$CPy_{stator.axis}(i,z) = \mathrm{axis}_y\left(CPx_{stator.}(i,z), CPy_{stator.}(i,z), x0_{stator.}(i,z), y0_{stator.}(i,z), \alpha\_major_{stator.}(i,z), 1\right)$$

$$Wp_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Wp_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Wp_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$Wp_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Wp_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(Wp_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$M\tau_{rotor}(i,z) = \int_z^{\left|\begin{array}{ll} \mathrm{mean}\left(R_{st(i,1),N_r}, R_{st(i,2),N_r}\right) & \text{if type="compressor"} \\ \mathrm{mean}\left(R_{st(i,2),N_r}, R_{st(i,3),N_r}\right) & \text{if type="turbine"} \end{array}\right.} \left(qx_{rotor}(i,z1)\cdot CPy_{rotor.axis}(i,z1) - qy_{rotor}(i,z1)\cdot CPx_{rotor.axis}(i,z1)\right) dz1$$

$$M\tau_{stator}(i,z) = \int_z^{\left|\begin{array}{ll} \mathrm{mean}\left(R_{st(i,2),1}, R_{st(i,3),1}\right) & \text{if type="compressor"} \\ \mathrm{mean}\left(R_{st(i,1),1}, R_{st(i,2),1}\right) & \text{if type="turbine"} \end{array}\right.} \left(qx_{stator}(i,z1)\cdot CPy_{stator.axis}(i,z1) - qy_{stator}(i,z1)\cdot CPx_{stator.axis}(i,z1)\right) dz1$$

$$\tau_{rotor}(i,z) = \frac{M\tau_{rotor}(i,z)}{Wp_{rotor.}(i,z)}$$

$$\tau_{stator}(i,z) = \frac{M\tau_{stator}(i,z)}{Wp_{stator.}(i,z)}$$

$$\varphi\_uv_{rotor}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\frac{\pi}{2} - \upsilon_{rotor}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\frac{\pi}{2} - \upsilon_{rotor}, i, i, 1, N_r\right)^T, z\right)$$

$$\varphi\_uv_{stator}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\frac{\pi}{2} - \upsilon_{stator}, i, i, 1, N_r\right)^T\right), \mathrm{submatrix}\left(R, st(i,2), st(i,2), 1, N_r\right)^T, \mathrm{submatrix}\left(\frac{\pi}{2} - \upsilon_{stator}, i, i, 1, N_r\right)^T, z\right)$$

$$Mu_{rotor}(i,z) = \mathrm{axis}_x\left(Mx_{rotor}(i,z), My_{rotor}(i,z), 0, 0, \varphi\_uv_{rotor}(i,z), 1\right)$$

$$Mu_{stator}(i,z) = \mathrm{axis}_x\left(Mx_{stator}(i,z), My_{stator}(i,z), 0, 0, \varphi\_uv_{stator}(i,z), 1\right)$$

$$Mv_{rotor}(i,z) = \mathrm{axis}_y\left(Mx_{rotor}(i,z), My_{rotor}(i,z), 0, 0, \varphi\_uv_{rotor}(i,z), 1\right)$$

$$Mv_{stator}(i,z) = \mathrm{axis}_y\left(Mx_{stator}(i,z), My_{stator}(i,z), 0, 0, \varphi\_uv_{stator}(i,z), 1\right)$$

$$\varphi\_neutral_{rotor}(i,z) = \left|\begin{array}{ll} \mathrm{atan}\left(\dfrac{Mv_{rotor}(i,z)\cdot Ju_{rotor.}(i,z)}{Mu_{rotor}(i,z)\cdot Jv_{rotor.}(i,z)}\right) & \text{if } Mu_{rotor}(i,z)\cdot Jv_{rotor.}(i,z) \neq 0 \\ \dfrac{\pi}{2} & \text{otherwise} \end{array}\right.$$

$$\varphi\_neutral_{stator}(i,z) = \left|\begin{array}{ll} \mathrm{atan}\left(\dfrac{Mv_{stator}(i,z)\cdot Ju_{stator.}(i,z)}{Mu_{stator}(i,z)\cdot Jv_{stator.}(i,z)}\right) & \text{if } Mu_{stator}(i,z)\cdot Jv_{stator.}(i,z) \neq 0 \\ \dfrac{\pi}{2} & \text{otherwise} \end{array}\right.$$

$$\begin{pmatrix} R0_{rotor} & area0_{rotor} \\ N0_{rotor} & \sigma0\_z_{rotor} \\ area_{rotor.} & area_{stator.} \\ N_{rotor} & \sigma\_z_{rotor} \end{pmatrix}$$

$$\text{neutral\_line}(\text{type}, x, i, r) = \begin{cases} \dfrac{y0_{rotor_{i,r}}}{chord_{rotor_{i,r}}} + \tan\left(\left(\alpha\_major_{rotor_{i,r}} + \varphi\_neutral_{rotor}\left(i, R_{st(i,2),r}\right)\right)\right) \cdot \left(x - \dfrac{x0_{rotor_{i,r}}}{chord_{rotor_{i,r}}}\right) & \text{if type} = \text{"rotor"} \\ \dfrac{y0_{stator_{i,r}}}{chord_{stator_{i,r}}} + \tan\left(\left(\alpha\_major_{stator_{i,r}} + \varphi\_neutral_{stator}\left(i, R_{st(i,2),r}\right)\right)\right) \cdot \left(x - \dfrac{x0_{stator_{i,r}}}{chord_{stator_{i,r}}}\right) & \text{if type} = \text{"stator"} \end{cases}$$

$$\text{epure}(\text{type}, x, i, r) = \begin{cases} \dfrac{y0_{rotor_{i,r}}}{chord_{rotor_{i,r}}} + \dfrac{-1}{\tan\left(\alpha\_major_{rotor_{i,r}} + \varphi\_neutral_{rotor}\left(i, R_{st(i,2),r}\right) - \dfrac{\pi}{4}\right)} \cdot \left(x - \dfrac{x0_{rotor_{i,r}}}{chord_{rotor_{i,r}}}\right) & \text{if type} = \text{"rotor"} \\ \dfrac{y0_{stator_{i,r}}}{chord_{stator_{i,r}}} + \dfrac{-1}{\tan\left(\alpha\_major_{stator_{i,r}} + \varphi\_neutral_{stator}\left(i, R_{st(i,2),r}\right) - \dfrac{\pi}{4}\right)} \cdot \left(x - \dfrac{x0_{stator_{i,r}}}{chord_{stator_{i,r}}}\right) & \text{if type} = \text{"stator"} \end{cases}$$

Наиболее удаленные точки от НЛ (мм):

$u\_u_{rotor}{}^{T} =$

	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

$\cdot 10^{-3}$

$v\_u_{rotor}{}^{T} =$

	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

$\cdot 10^{-3}$

$u\_l_{rotor}{}^{T} =$

	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

$\cdot 10^{-3}$

$v\_l_{rotor}{}^{T} =$

	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

$\cdot 10^{-3}$

$u\_u_{stator}{}^{T} =$

	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

$\cdot 10^{-3}$

$v\_u_{stator}{}^{T} =$

	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

$\cdot 10^{-3}$

$u\_l_{stator}{}^{T} =$

	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

$\cdot 10^{-3}$

$v\_l_{stator}{}^{T} =$

	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

$\cdot 1$

$$\begin{pmatrix} \sigma\_p_{rotor} & \sigma\_n_{rotor} \\ \sigma\_p_{stator} & \sigma\_n_{stator} \end{pmatrix} = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } r \in 1..N_r \\ \qquad \begin{pmatrix} \sigma\_p_{rotor_{i,r}} & \sigma\_n_{rotor_{i,r}} \\ \sigma\_p_{stator_{i,r}} & \sigma\_n_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \dfrac{Mu_{rotor}(i, R_{st(i,2),r})}{Ju_{rotor_{i,r}}} \cdot v\_u_{rotor_{i,r}} - \dfrac{Mv_{rotor}(i, R_{st(i,2),r})}{Jv_{rotor_{i,r}}} \cdot u\_u_{rotor_{i,r}} & \dfrac{Mu_{rotor}(i, R_{st(i,2),r})}{Ju_{rotor_{i,r}}} \cdot v\_l_{rotor_{i,r}} - \dfrac{Mv_{rotor}(i, R_{st(i,2),r})}{Jv_{rotor_{i,r}}} \cdot u\_l_{rotor_{i,r}} \\ \dfrac{Mu_{stator}(i, R_{st(i,2),r})}{Ju_{stator_{i,r}}} \cdot v\_u_{stator_{i,r}} - \dfrac{Mv_{stator}(i, R_{st(i,2),r})}{Jv_{stator_{i,r}}} \cdot u\_u_{stator_{i,r}} & \dfrac{Mu_{stator}(i, R_{st(i,2),r})}{Ju_{stator_{i,r}}} \cdot v\_l_{stator_{i,r}} - \dfrac{Mv_{stator}(i, R_{st(i,2),r})}{Jv_{stator_{i,r}}} \cdot u\_l_{stator_{i,r}} \end{pmatrix} \\ \begin{pmatrix} \sigma\_p_{rotor} & \sigma\_n_{rotor} \\ \sigma\_p_{stator} & \sigma\_n_{stator} \end{pmatrix} \end{array} \right.$$

$$\begin{pmatrix} \sigma\_p_{rotor.} & \sigma\_p_{stator.} \\ \sigma\_n_{rotor.} & \sigma\_n_{stator.} \end{pmatrix} = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \left| \begin{array}{l} \sigma\_p_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_p_{rotor}, i, i, 1, N_r)^T\right), \mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_p_{rotor}, i, i, 1, N_r)^T, z\right) \\ \sigma\_p_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_p_{stator}, i, i, 1, N_r)^T\right), \mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_p_{stator}, i, i, 1, N_r)^T, z\right) \\ \sigma\_n_{rotor.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_n_{rotor}, i, i, 1, N_r)^T\right), \mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_n_{rotor}, i, i, 1, N_r)^T, z\right) \\ \sigma\_n_{stator.}(i,z) = \mathrm{interp}\left(\mathrm{lspline}\left(\mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_n_{stator}, i, i, 1, N_r)^T\right), \mathrm{submatrix}(R, st(i,1), st(i,1), 1, N_r)^T, \mathrm{submatrix}(\sigma\_n_{stator}, i, i, 1, N_r)^T, z\right) \end{array} \right. \\ \begin{pmatrix} \sigma\_p_{rotor.} & \sigma\_p_{stator.} \\ \sigma\_n_{rotor.} & \sigma\_n_{stator.} \end{pmatrix} \end{array} \right.$$

$\sigma\_p_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	-25.36	-43.41	-69.75	-98.16	-126.08	-151.02	-146.74	-155.42	-151.05
2	-43.70	-59.19	-87.64	-113.08	-138.10	-159.06	-148.26	-154.01	-151.15
3	-0.17	-0.20	-0.88	-0.83	-0.78	-0.65	-0.32	-0.17	-0.48

$\cdot 10^{6}$

$\sigma\_p_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	0.78	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	144.83	123.74	125.95	125.71	114.39	97.71	86.77	69.31	52.54
3	268.54	238.84	243.72	245.47	226.17	193.17	165.54	128.15	96.03

$\cdot 10^{6}$

$\sigma\_p_{rotor}^{T} \le 70 \cdot 10^{6} =$

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

$\sigma\_p_{stator}^{T} \le 70 \cdot 10^{6} =$

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

$\sigma\_n_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	39.17	54.70	79.76	99.20	117.75	101.61	107.20	118.76	118.43
2	33.26	45.23	67.36	87.13	106.69	123.25	115.91	121.96	120.57
3	0.14	0.16	0.70	0.67	0.63	0.52	0.26	0.14	0.39

$\cdot 10^{6}$

$\sigma\_n_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	-1.78	-1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	-253.77	-232.86	-258.44	-259.25	-241.04	-204.55	-163.58	-119.70	-86.72
3	-380.79	-367.69	-414.61	-421.48	-398.71	-339.21	-260.39	-183.82	-131.07

$\cdot 10^{6}$

$\sigma\_n_{rotor}^{T} \le 70 \cdot 10^{6} =$

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

$\sigma\_n_{stator}^{T} \le 70 \cdot 10^{6} =$

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

$$\begin{pmatrix} \sigma_{rotor} \\ \sigma_{stator} \end{pmatrix} = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } r \in 1..N_r \\ \quad \quad \left| \begin{array}{l} \sigma_{rotor_{i,r}} = \sqrt{\left(\sigma\_z_{rotor}\left(i, R_{st(i,2),r}\right) + \max\left(\sigma\_p_{rotor_{i,r}}, \sigma\_n_{rotor_{i,r}}\right)\right)^2 + \tau_{rotor}\left(i, R_{st(i,2),r}\right)^2} \\ \sigma_{stator_{i,r}} = \sqrt{\left(0 + \max\left(\sigma\_p_{stator_{i,r}}, \sigma\_n_{stator_{i,r}}\right)\right)^2 + \tau_{stator}\left(i, R_{st(i,2),r}\right)^2} \end{array} \right. \\ \begin{pmatrix} \sigma_{rotor} \\ \sigma_{stator} \end{pmatrix} \end{array} \right.$$

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

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

	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

$\cdot 10^6$

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

	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

$\cdot 10^6$

$$
\begin{pmatrix} safety_{rotor} \\ safety_{stator} \end{pmatrix} = \left|
\begin{array}{l}
\text{for } i \in 1..Z \\
\quad \text{for } r \in 1..N_r \\
\quad\quad \left| \begin{array}{l}
safety_{rotor_{i,r}} = \left| \begin{array}{ll} \dfrac{\sigma\_blade\_long_i}{\sigma_{rotor_{i,r}}} & \text{if } \sigma_{rotor_{i,r}} \neq 0 \\ \infty & \text{otherwise} \end{array} \right. \\
safety_{stator_{i,r}} = \left| \begin{array}{ll} \dfrac{\sigma\_blade\_long_i}{\sigma_{stator_{i,r}}} & \text{if } \sigma_{stator_{i,r}} \neq 0 \\ \infty & \text{otherwise} \end{array} \right.
\end{array} \right. \\
\begin{pmatrix} safety_{rotor} \\ safety_{stator} \end{pmatrix}
\end{array} \right.
$$

$safety_{rotor}{}^{T} =$

	1	2	3	4	5	6	7	8	9
1	1.12	1.16	1.11	1.07	1.02	0.87	0.88	0.84	0.56
2	1.53	1.57	1.43	1.34	1.24	0.87	0.93	0.91	0.64
3	39.76	48.99	29.72	38.69	48.16	46.96	73.45	112.07	32.4

$safety_{rotor}{}^{T} \geq safety =$

	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	0	0	0
3	1	1	1	1	1	1	1	1	1

$safety_{stator}{}^{T} =$

	1	2	3	4	5
1	248.08	320.97	0000000000000000000000000000000	0000000000000000000000000000000	0000000000000000000000000000000
2	1.38	1.62	1.59	1.59	1.75
3	0.74	0.84	0.82	0.81	...

$safety_{stator}{}^{T} \geq safety =$

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

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

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

Расстояния от оси ЛМ до рассматриваемой ступени (м): $Rj := \mathrm{submatrix}(R, 2\cdot j - 1, 2\cdot j + 1, 1, N_r) =$

	1	2	3
1	177.3	230.8	274.1
2	182.2	230.8	270.8
3	186.8	230.8	267.7

$\cdot 10^{-3}$

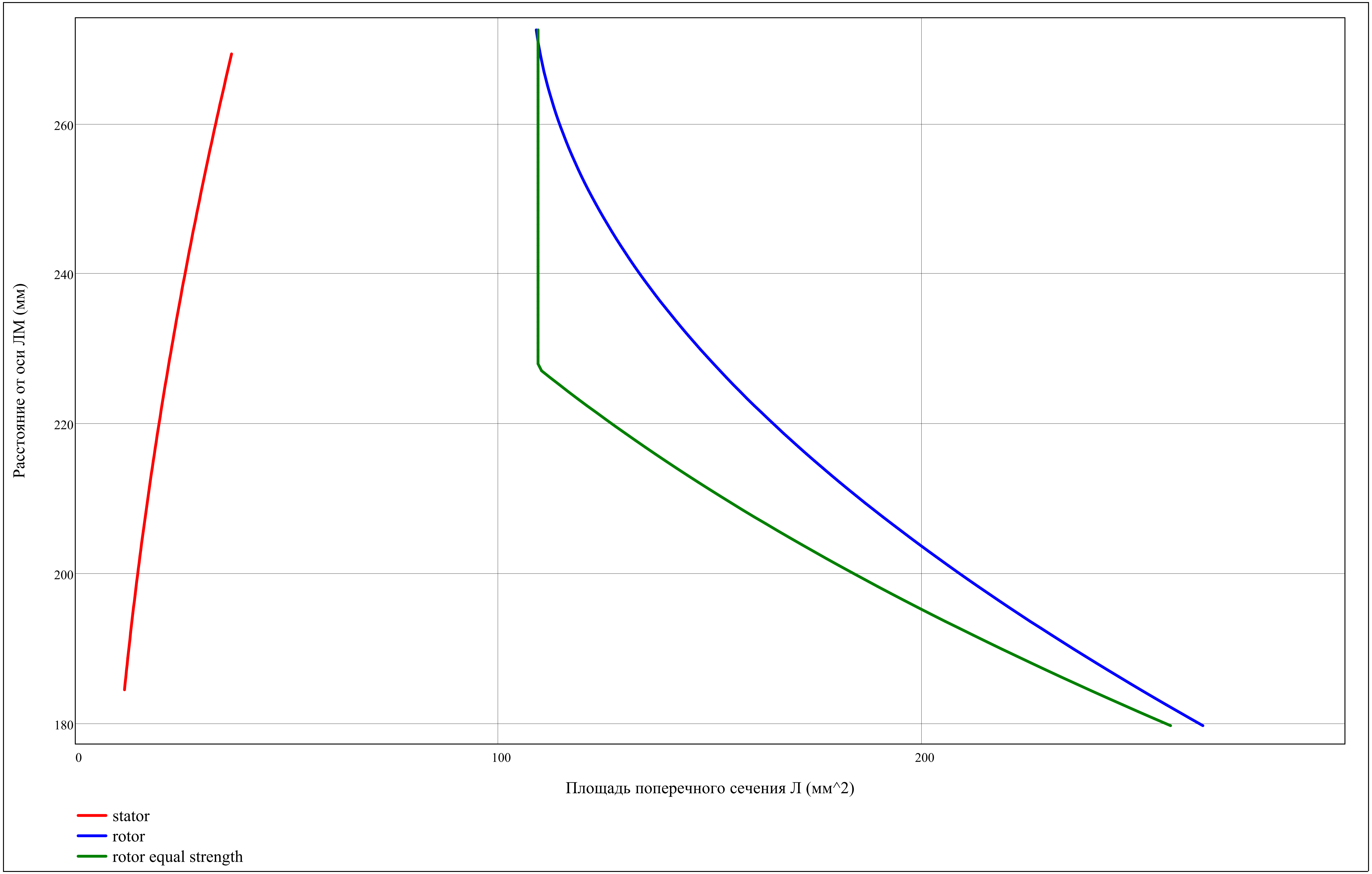
Дискретизация по высоте Л:

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

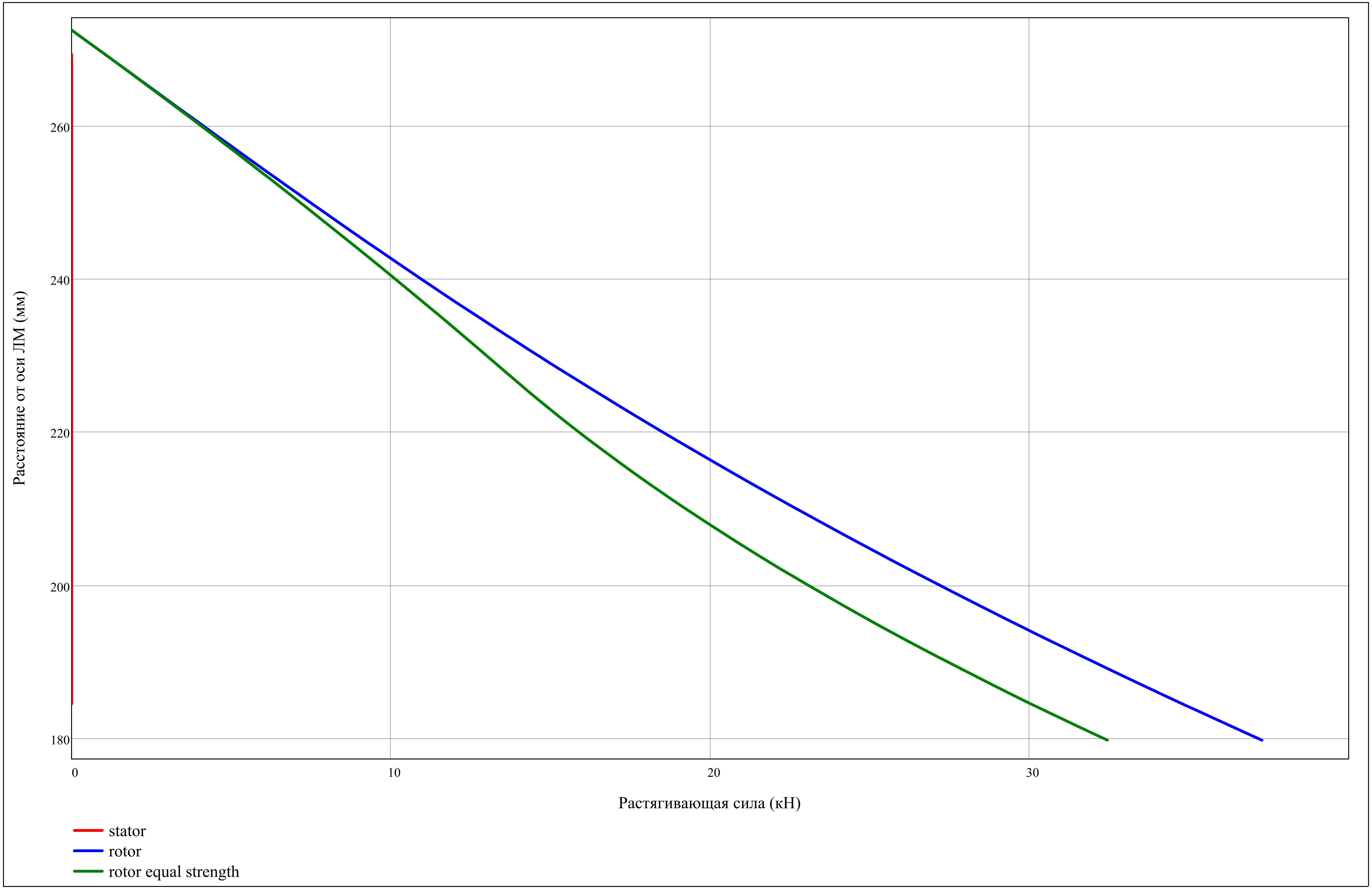
$$z_{rotor} := \left| \begin{array}{ll} \mathrm{mean}(Rj_{1,1}, Rj_{2,1}), \mathrm{mean}(Rj_{1,1}, Rj_{2,1}) + \dfrac{\mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) - \mathrm{mean}(Rj_{1,1}, Rj_{2,1})}{100} .. \mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) & \text{if } type = \text{"compressor"} \\ \mathrm{mean}(Rj_{2,1}, Rj_{3,1}), \mathrm{mean}(Rj_{2,1}, Rj_{3,1}) + \dfrac{\mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) - \mathrm{mean}(Rj_{2,1}, Rj_{3,1})}{100} .. \mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) & \text{if } type = \text{"turbine"} \end{array} \right.$$

$$z_{stator} := \left| \begin{array}{ll} \mathrm{mean}(Rj_{2,1}, Rj_{3,1}), \mathrm{mean}(Rj_{2,1}, Rj_{3,1}) + \dfrac{\mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) - \mathrm{mean}(Rj_{2,1}, Rj_{3,1})}{100} .. \mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) & \text{if } type = \text{"compressor"} \\ \mathrm{mean}(Rj_{1,1}, Rj_{2,1}), \mathrm{mean}(Rj_{1,1}, Rj_{2,1}) + \dfrac{\mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) - \mathrm{mean}(Rj_{1,1}, Rj_{2,1})}{100} .. \mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) & \text{if } type = \text{"turbine"} \end{array} \right.$$

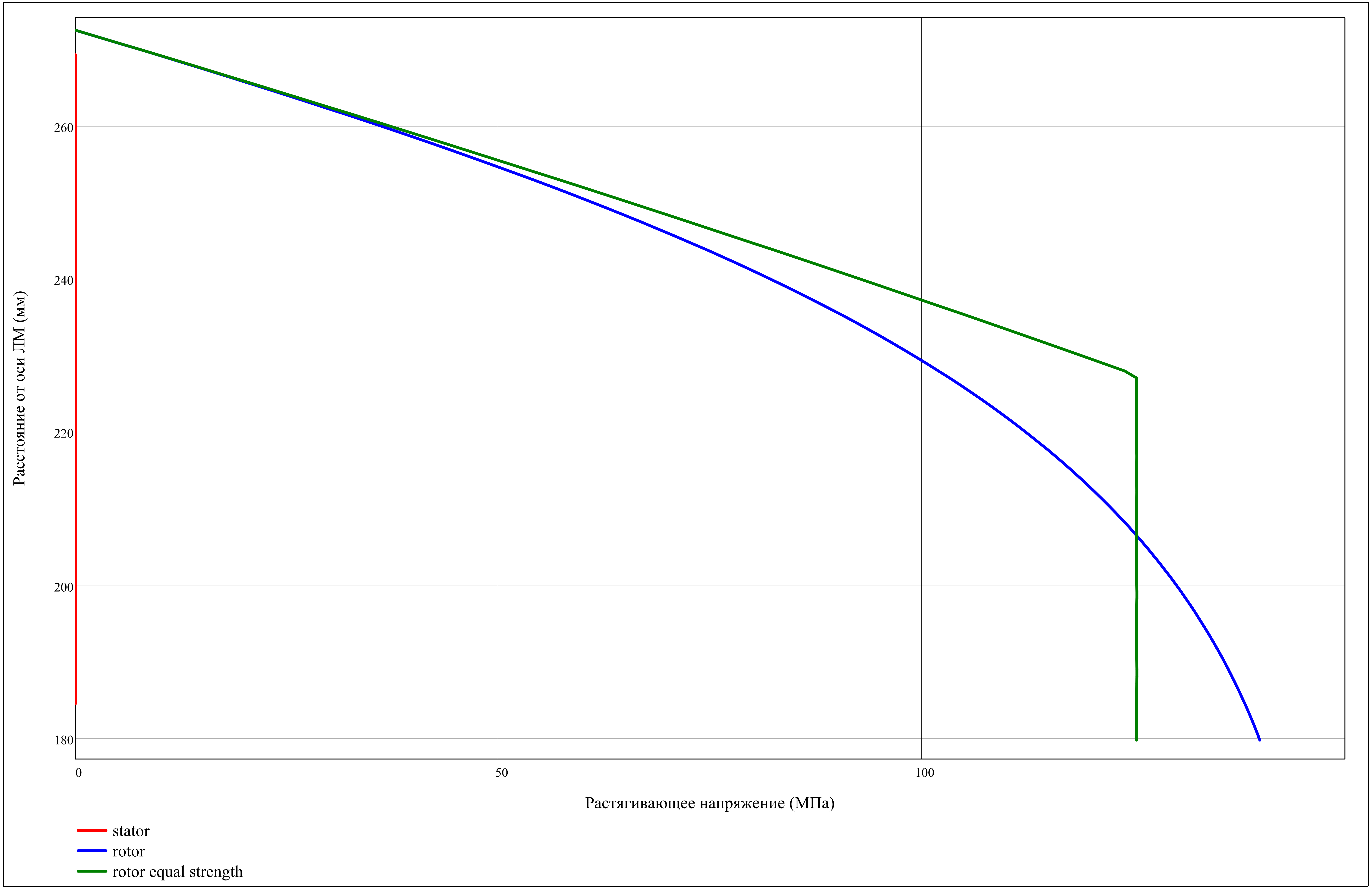
Результаты расчета на прочность Л

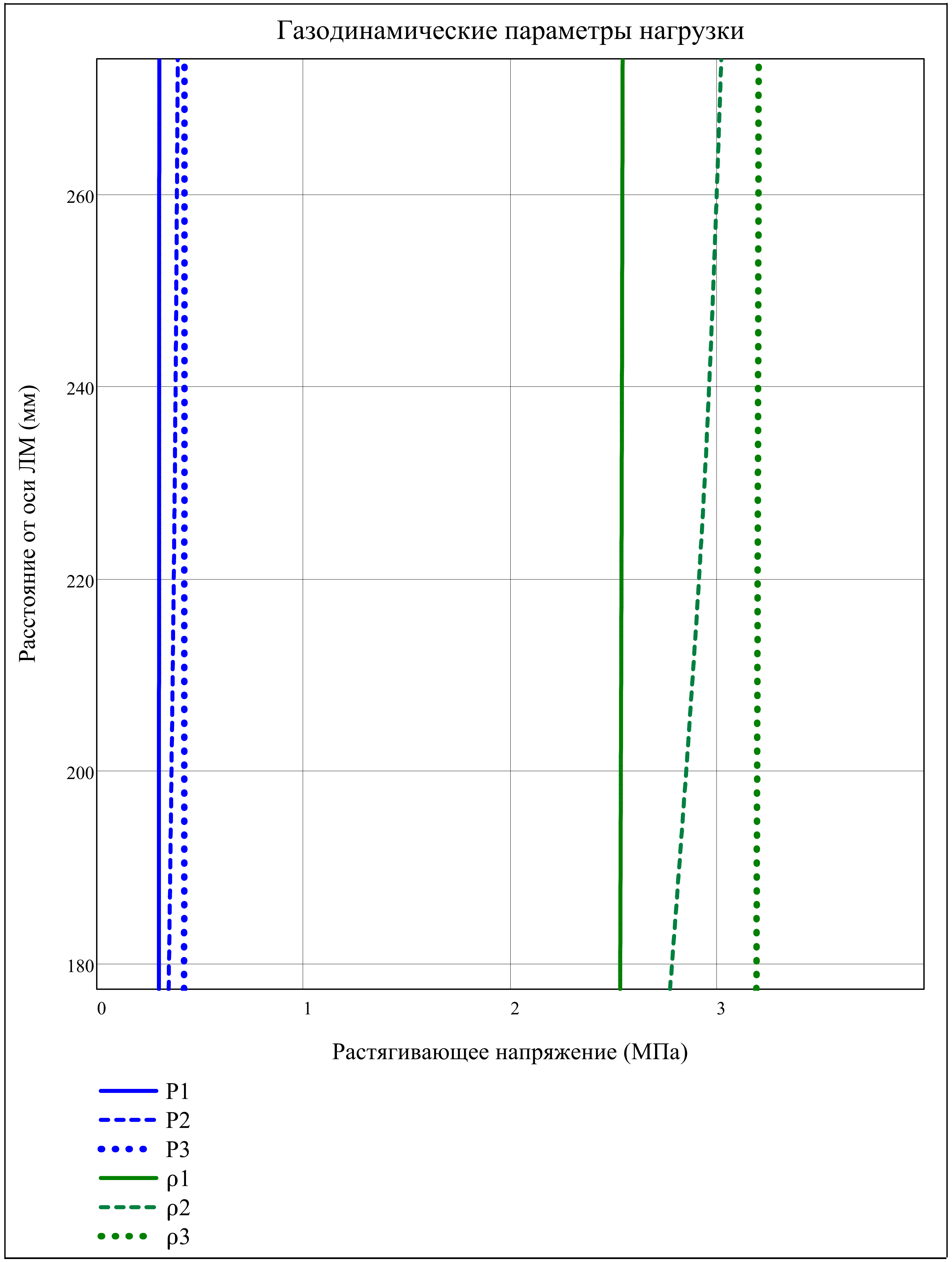


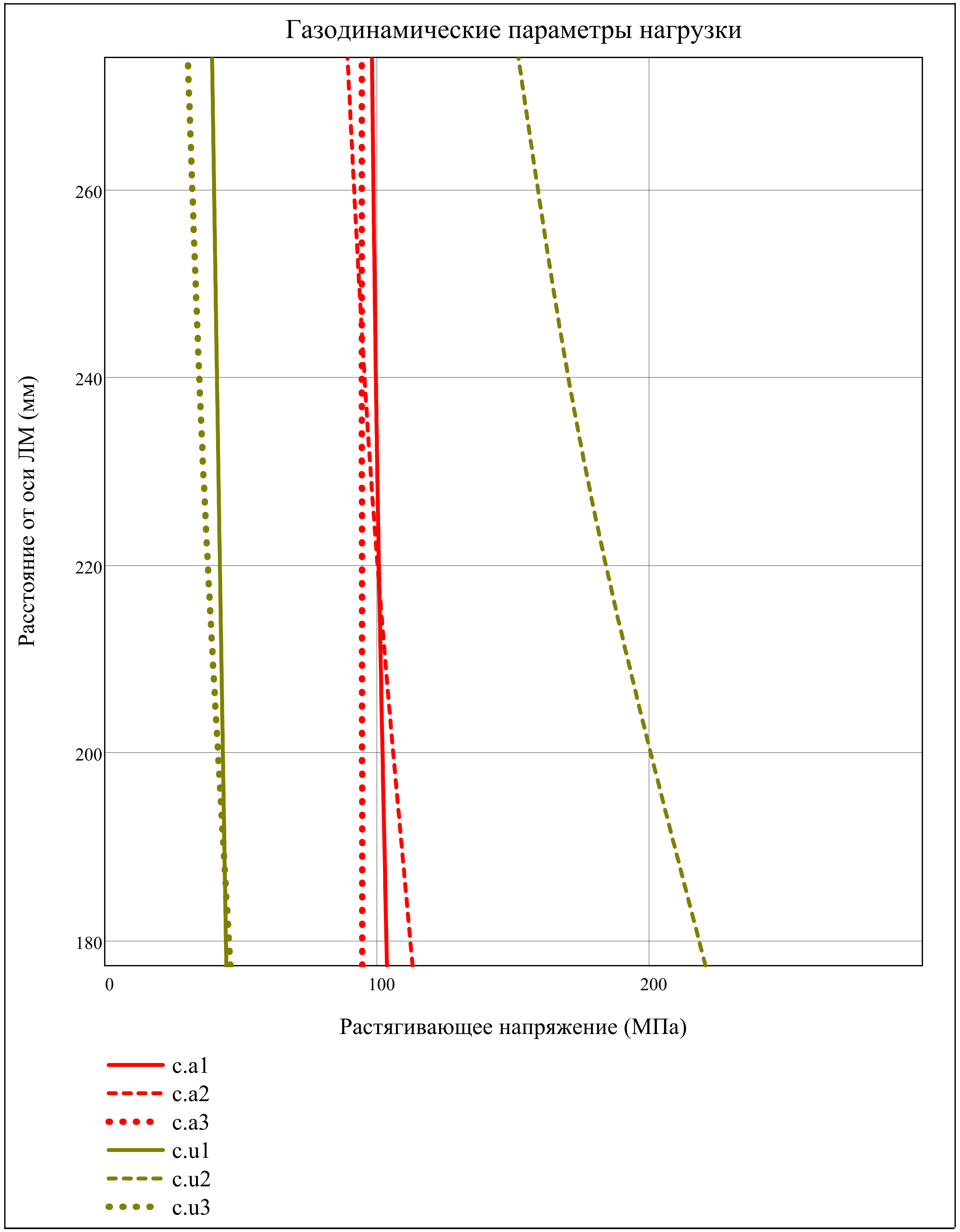
Расстояние от оси ЛМ (мм)
260
240
220
200
180
0
100
200
Площадь поперечного сечения Л (мм^2)
stator
rotor
rotor equal strength

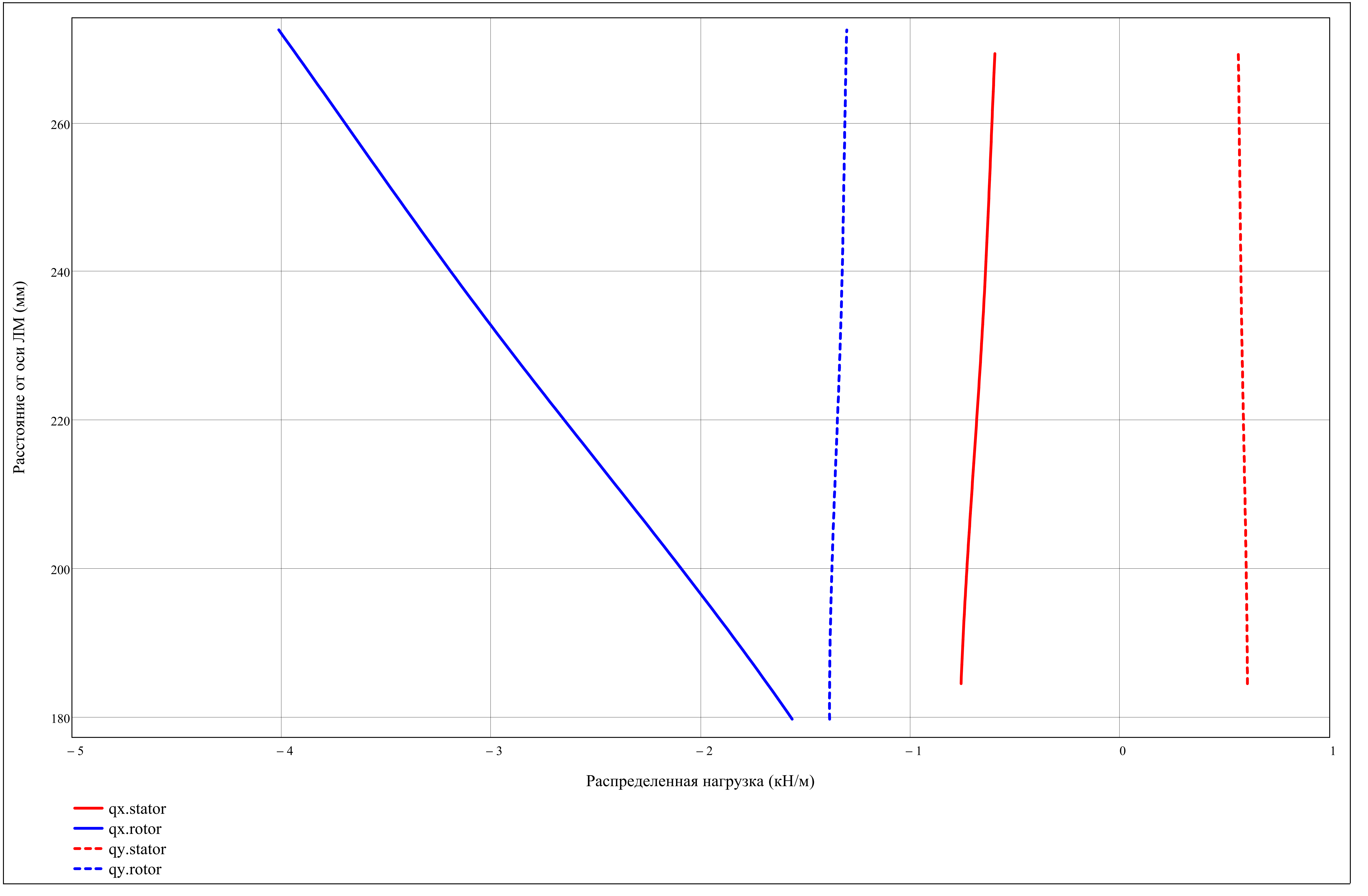


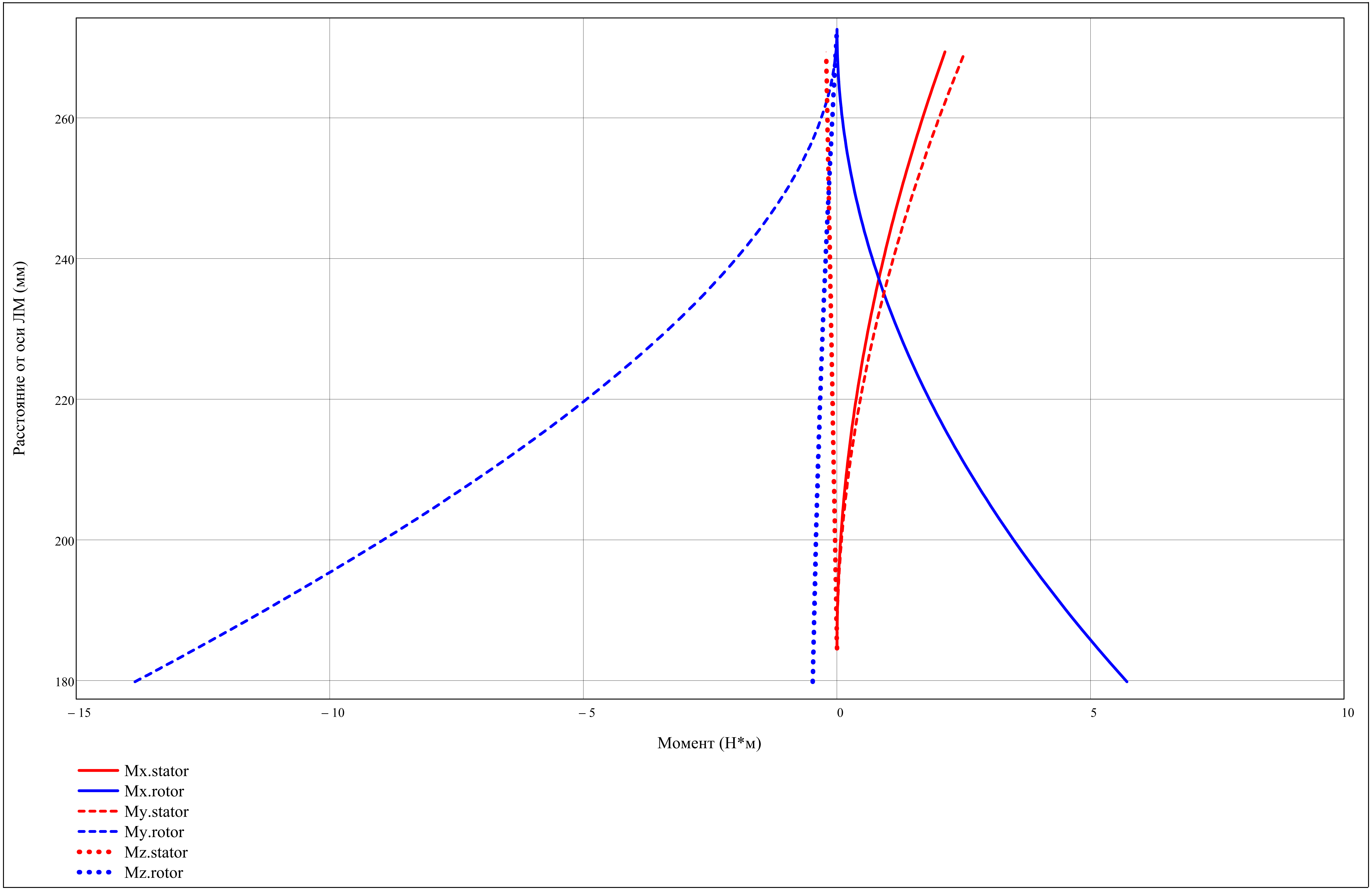
Расстояние от оси ЛМ (мм)
260
240
220
200
180
0
10
20
30
Растягивающая сила (кН)
stator
rotor
rotor equal strength


Расстояние от оси ЛМ (мм)
260
240
220
200
180
0
50
100
Растягивающее напряжение (МПа)
stator
rotor
rotor equal strength

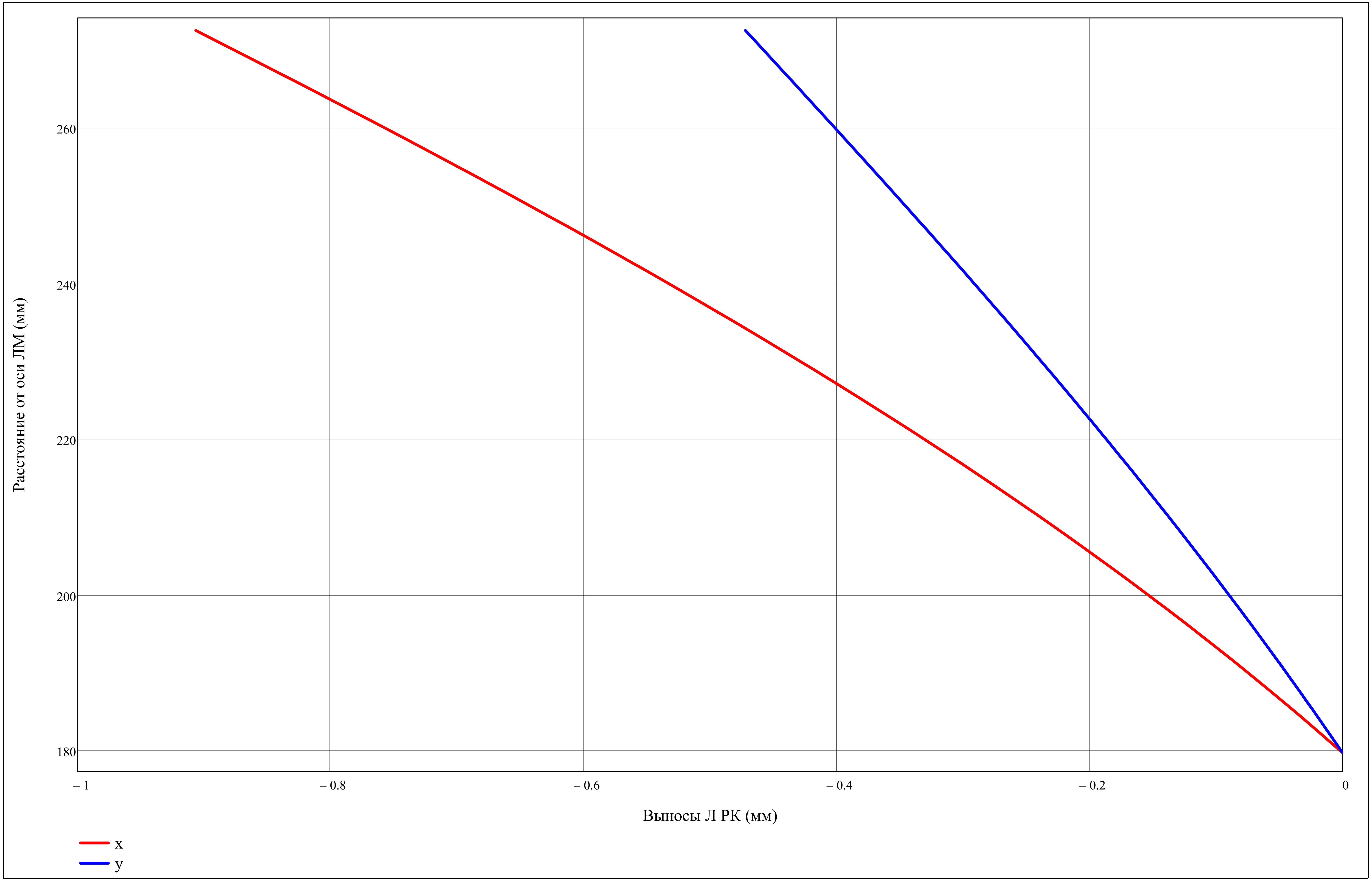

Газодинамические параметры нагрузки
Расстояние от оси ЛМ (мм)
180
200
220
240
260
0
1
2
3
Растягивающее напряжение (МПа)
P1
P2
P3
ρ1
ρ2
ρ3


Газодинамические параметры нагрузки
Расстояние от оси ЛМ (мм)
180
200
220
240
260
0
100
200
Растягивающее напряжение (МПа)
c.a1
c.a2
c.a3
c.u1
c.u2
c.u3

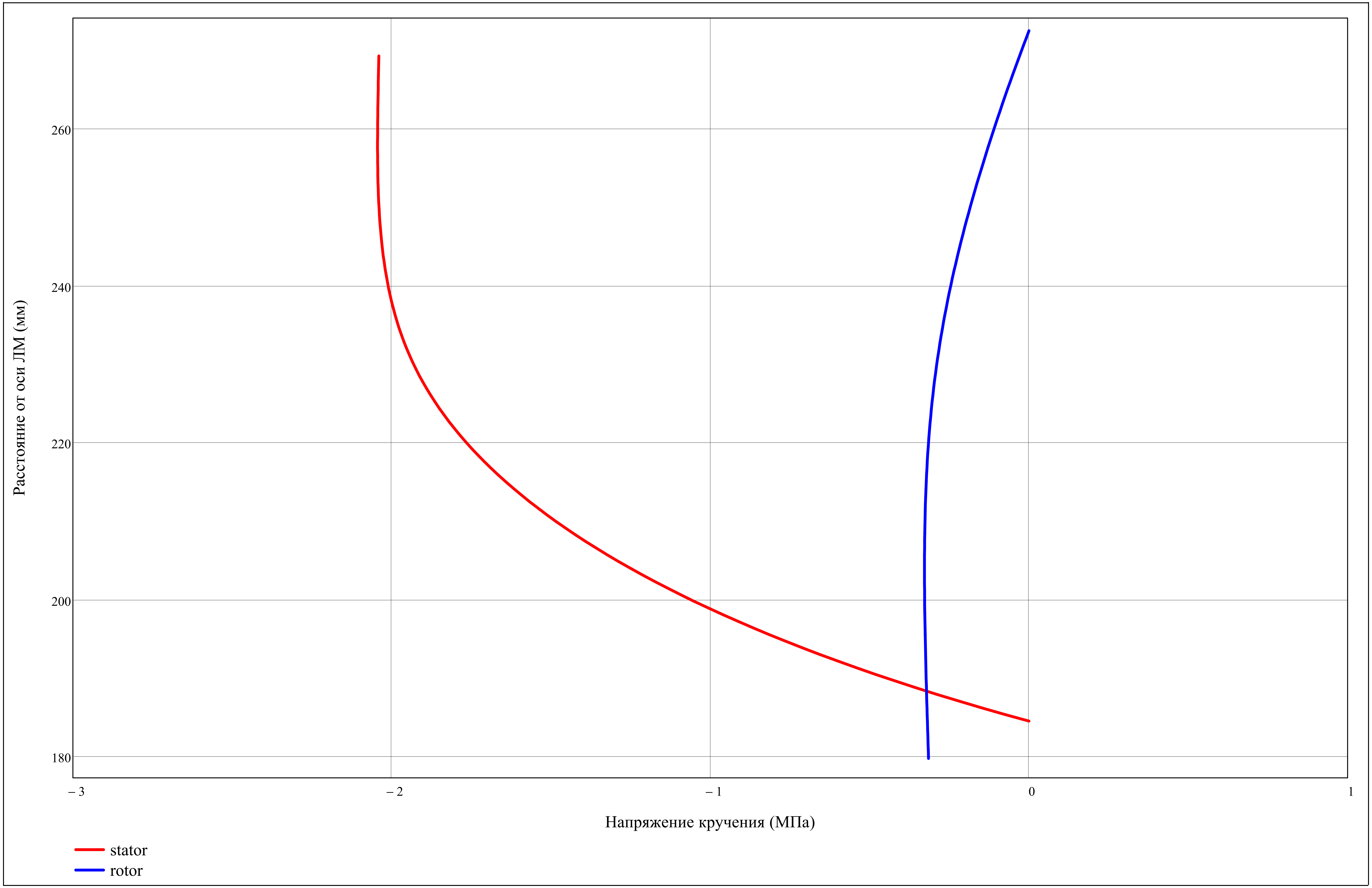

260
240
220
200
180
Расстояние от оси ЛМ (мм)
– 5
– 4
– 3
– 2
– 1
0
1
Распределенная нагрузка (кН/м)
qx.stator
qx.rotor
qy.stator
qy.rotor



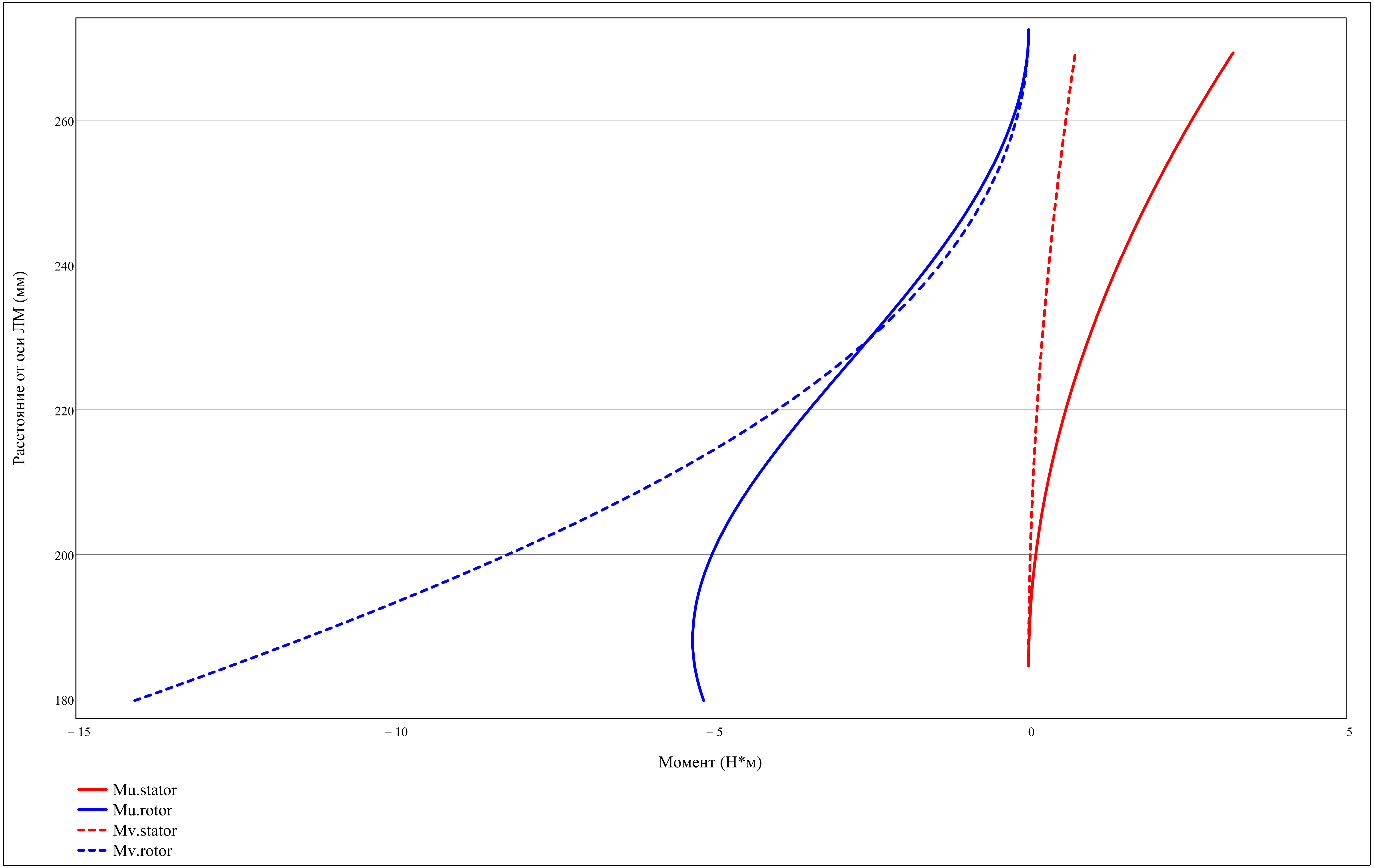
Расстояние от оси ЛМ (мм)
260
240
220
200
180
– 15
– 10
– 5
0
5
10
Момент (Н*м)
Mx.stator
Mx.rotor
My.stator
My.rotor
Mz.stator
Mz.rotor



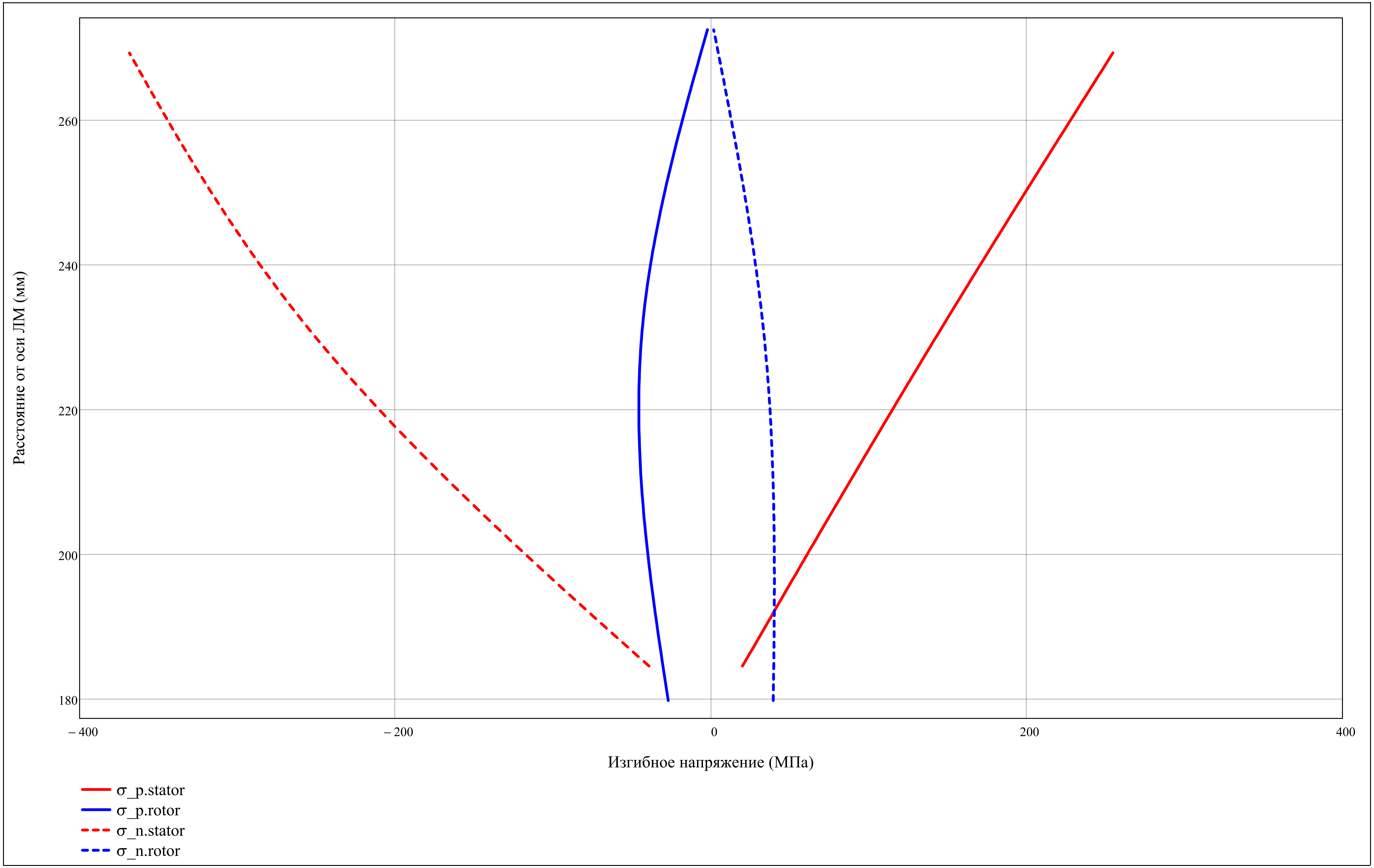
260
240
220
200
180
Расстояние от оси ЛМ (мм)
– 1
– 0.8
– 0.6
– 0.4
– 0.2
0
Выносы Л РК (мм)
x
y



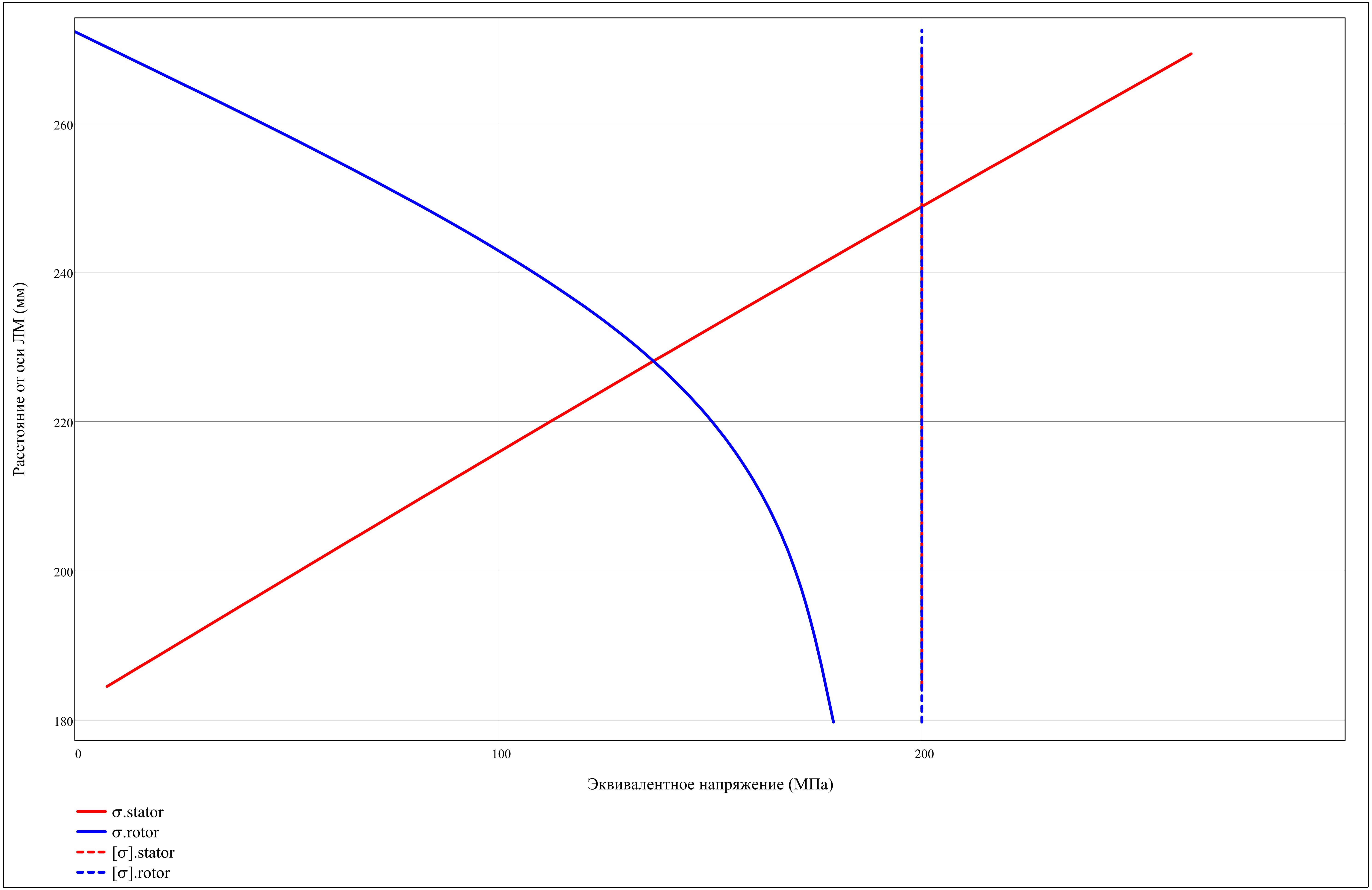
Расстояние от оси ЛМ (мм)
260
240
220
200
180
− 3
− 2
− 1
0
1
Напряжение кручения (МПа)
stator
rotor



Расстояние от оси ЛМ (мм)
260
240
220
200
180
– 15
– 10
– 5
0
5
Момент (Н*м)
Mu.stator
Mu.rotor
Mv.stator
Mv.rotor



Расстояние от оси ЛМ (мм)
260
240
220
200
180
– 400
– 200
0
200
400
Изгибное напряжение (МПа)
σ_p.stator
σ_p.rotor
σ_n.stator
σ_n.rotor



Расстояние от оси ЛМ (мм)
260
240
220
200
180
0
100
200
Эквивалентное напряжение (МПа)
σ.stator
σ.rotor
[σ].stator
[σ].rotor

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

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u\_u_{rotor_{j,r}} & v\_u_{rotor_{j,r}} \\ u\_l_{rotor_{j,r}} & v\_l_{rotor_{j,r}} \\ u\_u_{stator_{j,r}} & v\_u_{stator_{j,r}} \\ u\_l_{stator_{j,r}} & v\_l_{stator_{j,r}} \end{pmatrix} =$$

	1	2
1	-2.51	4.24
2	29.48	-5.20
3	0.21	0.77
4	12.34	-1.74

$\cdot 10^{-3}$

Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma\_p_{rotor_{j,r}} & \sigma\_p_{stator_{j,r}} \\ \sigma\_n_{rotor_{j,r}} & \sigma\_n_{stator_{j,r}} \end{pmatrix} = \begin{pmatrix} -25 & 1 \\ 39 & -2 \end{pmatrix} \cdot 10^{6}$$

Эквивалентные напряжения (Па):

$$\begin{pmatrix} \sigma_{stator_{j,r}} \\ \sigma_{rotor_{j,r}} \end{pmatrix} = \begin{pmatrix} 1 \\ 178 \end{pmatrix} \cdot 10^{6}$$

Коэф. запаса:

$$\begin{pmatrix} safety_{stator_{j,r}} \\ safety_{rotor_{j,r}} \end{pmatrix} =$$

	1
1	248.077
2	1.122

$$\begin{pmatrix} v\_p \\ v\_n \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} v\_u_{rotor_{j,r}} \\ v\_l_{rotor_{j,r}} \end{pmatrix} & \text{if } blade = "rotor" \\ \begin{pmatrix} v\_u_{stator_{j,r}} \\ v\_l_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. =$$

	1
1	4.237
2	-5.196

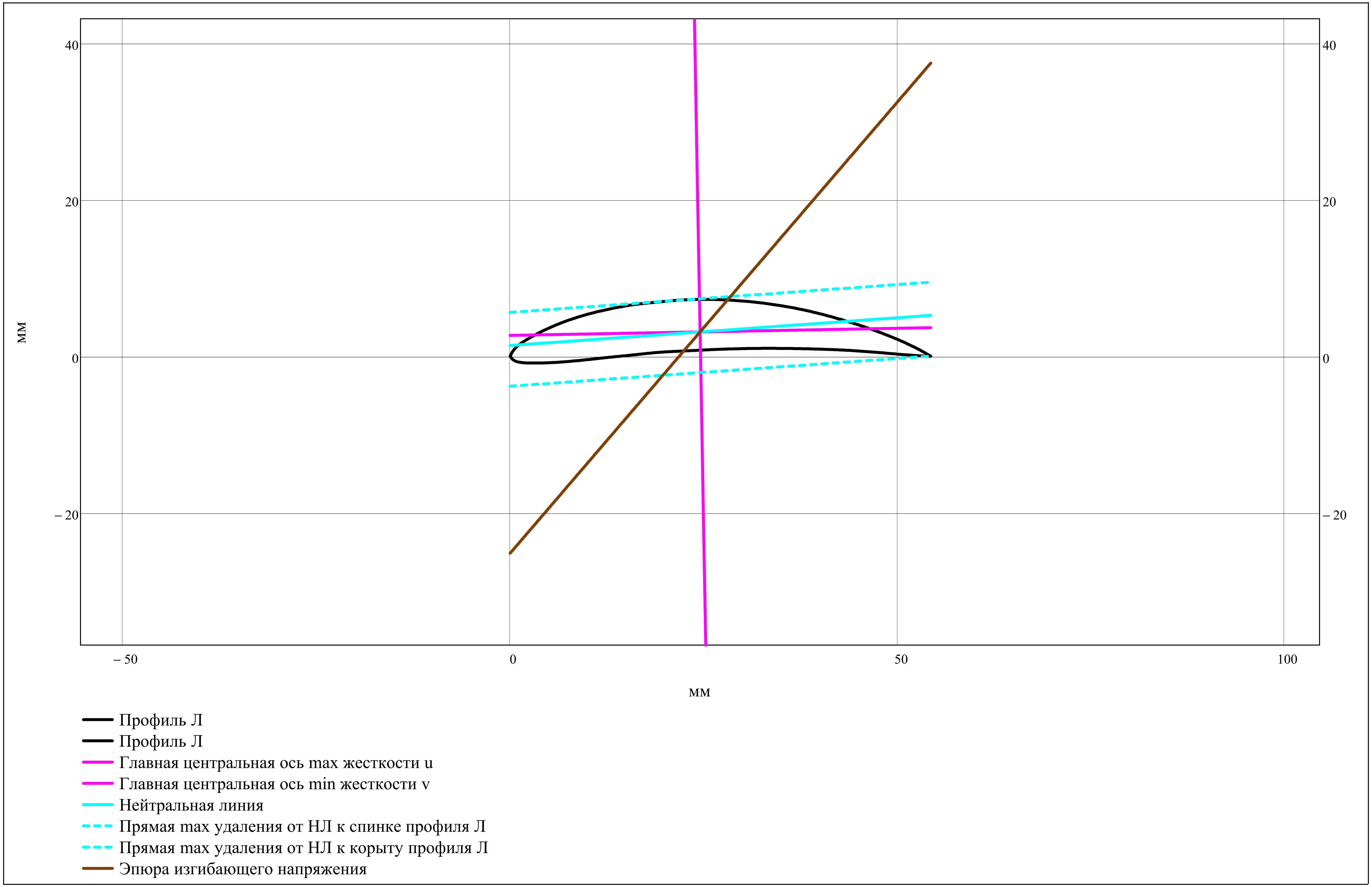
$\cdot 10^{-3}$

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} x0_{rotor_{j,r}} \\ y0_{rotor_{j,r}} \end{pmatrix} & \text{if } blade = "rotor" \\ \begin{pmatrix} x0_{stator_{j,r}} \\ y0_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. =$$

	1
1	24.522
2	3.097

$\cdot 10^{-3}$

$$chord = \left| \begin{array}{ll} chord_{rotor_{j,r}} & \text{if } blade = "rotor" \\ chord_{stator_{j,r}} & \text{if } blade = "stator" \end{array} \right. = 54 \cdot 10^{-3}$$



40
20
0
− 20
40
20
0
− 20
− 50
0
50
100
мм
мм
Профиль Л
Профиль Л
Главная центральная ось max жесткости u
Главная центральная ось min жесткости v
Нейтральная линия
Прямая max удаления от НЛ к спинке профиля Л
Прямая max удаления от НЛ к корыту профиля Л
Эпюра изгибающего напряжения

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

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u\_u_{rotor_{j,r}} & v\_u_{rotor_{j,r}} \\ u\_l_{rotor_{j,r}} & v\_l_{rotor_{j,r}} \\ u\_u_{stator_{j,r}} & v\_u_{stator_{j,r}} \\ u\_l_{stator_{j,r}} & v\_l_{stator_{j,r}} \end{pmatrix} =$$

	1	2
1	-1.35	1.90
2	-19.72	-1.51
3	-0.02	1.08
4	13.70	-1.87

$\cdot 10^{-3}$

Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma\_p_{rotor_{j,r}} & \sigma\_p_{stator_{j,r}} \\ \sigma\_n_{rotor_{j,r}} & \sigma\_n_{stator_{j,r}} \end{pmatrix} = \begin{pmatrix} -44 & 145 \\ 33 & -254 \end{pmatrix} \cdot 10^6$$

Эквивалентные напряжения (Па):

$$\begin{pmatrix} \sigma_{stator_{j,r}} \\ \sigma_{rotor_{j,r}} \end{pmatrix} = \begin{pmatrix} 145 \\ 131 \end{pmatrix} \cdot 10^6$$

Коэф. запаса: $\begin{pmatrix} safety_{stator_{j,r}} \\ safety_{rotor_{j,r}} \end{pmatrix} =$

	1
1	1.381
2	1.527

$$\begin{pmatrix} v\_p \\ v\_n \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} v\_u_{rotor_{j,r}} \\ v\_l_{rotor_{j,r}} \end{pmatrix} & \text{if } blade = \text{"rotor"} \\ \begin{pmatrix} v\_u_{stator_{j,r}} \\ v\_l_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. =$$

	1
1	1.901
2	-1.511

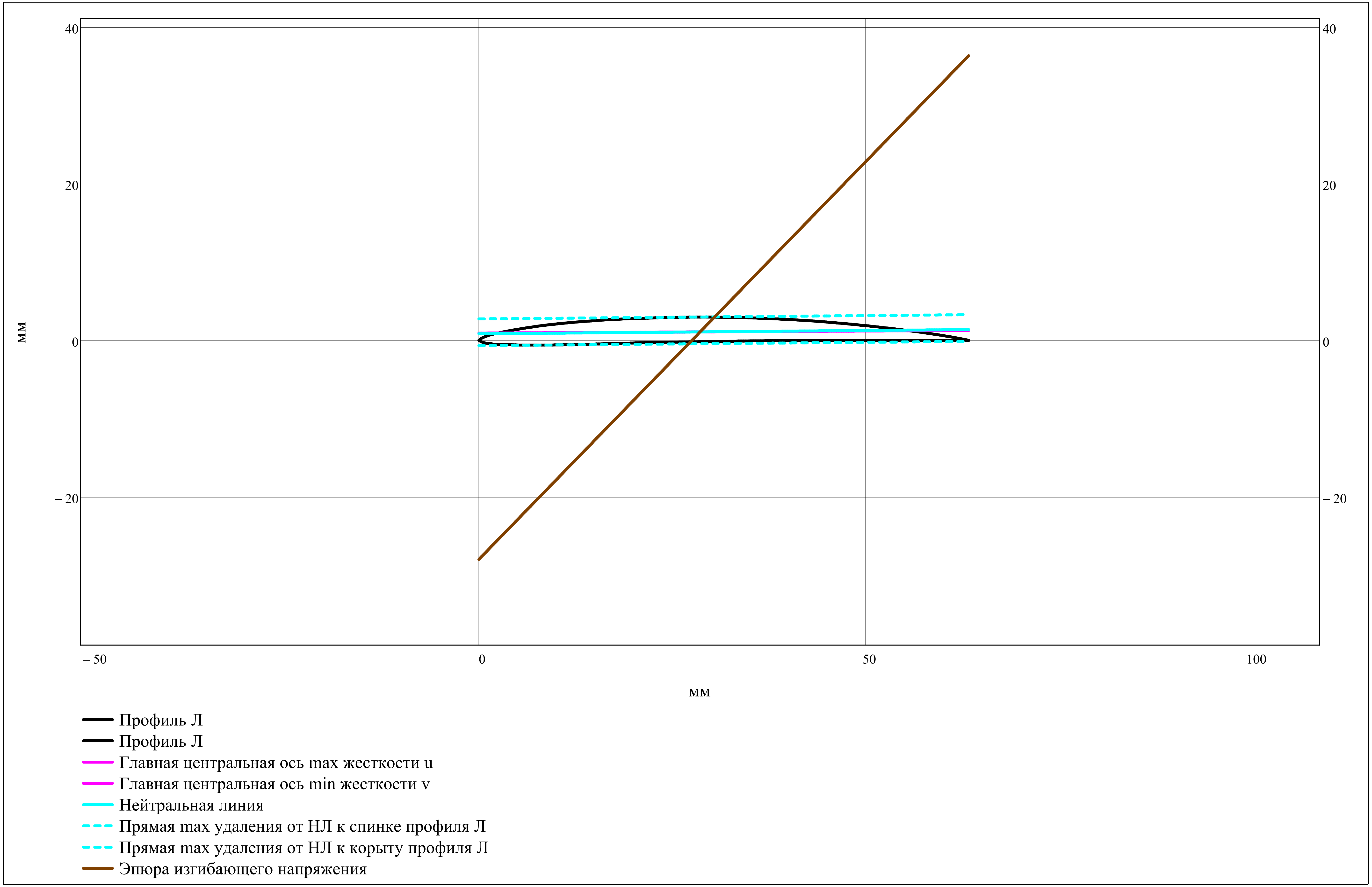
$\cdot 10^{-3}$

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} x0_{rotor_{j,r}} \\ y0_{rotor_{j,r}} \end{pmatrix} & \text{if } blade = \text{"rotor"} \\ \begin{pmatrix} x0_{stator_{j,r}} \\ y0_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. =$$

	1
1	28.557
2	1.079

$\cdot 10^{-3}$

$$chord = \left| \begin{array}{ll} chord_{rotor_{j,r}} & \text{if } blade = \text{"rotor"} \\ chord_{stator_{j,r}} & \text{if } blade = \text{"stator"} \end{array} \right. = 63 \cdot 10^{-3}$$



40
20
0
− 20
− 50
0
50
100
мм
мм
Профиль Л
Профиль Л
Главная центральная ось max жесткости u
Главная центральная ось min жесткости v
Нейтральная линия
Прямая max удаления от НЛ к спинке профиля Л
Прямая max удаления от НЛ к корыту профиля Л
Эпюра изгибающего напряжения

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

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u\_u_{rotor_{j,r}} & v\_u_{rotor_{j,r}} \\ u\_l_{rotor_{j,r}} & v\_l_{rotor_{j,r}} \\ u\_u_{stator_{j,r}} & v\_u_{stator_{j,r}} \\ u\_l_{stator_{j,r}} & v\_l_{stator_{j,r}} \end{pmatrix} =$$

	1	2
1	-1.35	1.90
2	-19.72	-1.51
3	-0.02	1.08
4	13.70	-1.87

$\cdot 10^{-3}$

Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma\_p_{rotor_{j,r}} & \sigma\_p_{stator_{j,r}} \\ \sigma\_n_{rotor_{j,r}} & \sigma\_n_{stator_{j,r}} \end{pmatrix} = \begin{pmatrix} -44 & 145 \\ 33 & -254 \end{pmatrix} \cdot 10^{6}$$

Эквивалентные напряжения (Па):

$$\begin{pmatrix} \sigma_{stator_{j,r}} \\ \sigma_{rotor_{j,r}} \end{pmatrix} = \begin{pmatrix} 145 \\ 131 \end{pmatrix} \cdot 10^{6}$$

Коэф. запаса: $\begin{pmatrix} safety_{stator_{j,r}} \\ safety_{rotor_{j,r}} \end{pmatrix} =$

	1
1	1.381
2	1.527

$$\begin{pmatrix} v\_p \\ v\_n \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} v\_u_{rotor_{j,r}} \\ v\_l_{rotor_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v\_u_{stator_{j,r}} \\ v\_l_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. =$$

	1
1	1.085
2	-1.873

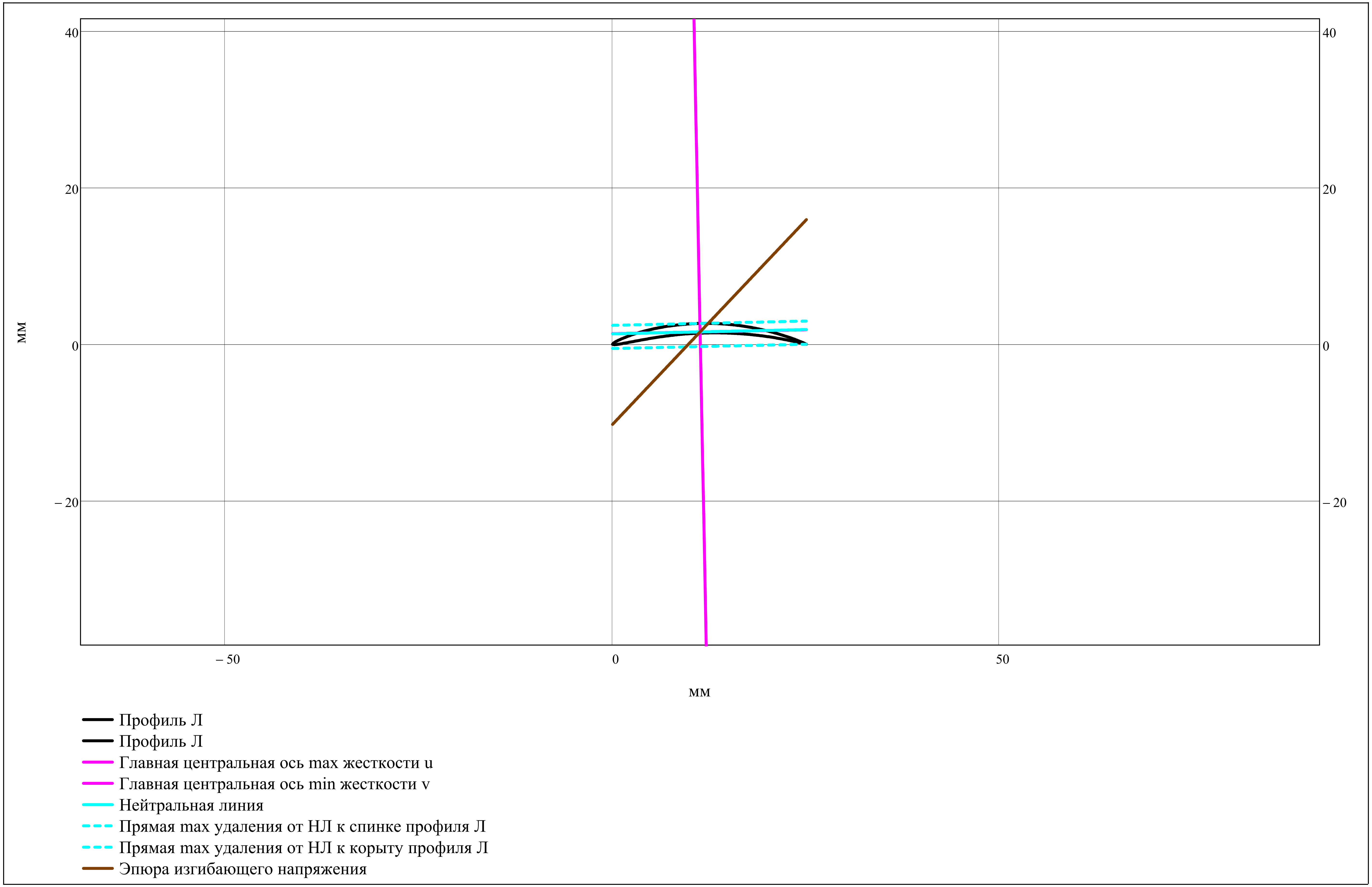
$\cdot 10^{-3}$

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} x0_{rotor_{j,r}} \\ y0_{rotor_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{stator_{j,r}} \\ y0_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. =$$

	1
1	11.312
2	1.573

$\cdot 10^{-3}$

$$chord = \left| \begin{array}{ll} chord_{rotor_{j,r}} & \text{if blade = "rotor"} \\ chord_{stator_{j,r}} & \text{if blade = "stator"} \end{array} \right. = 25 \cdot 10^{-3}$$



40
20
0
– 20
40
20
0
– 20
– 50
0
50
мм
мм
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Эпюра изгибающего напряжения

$$\begin{pmatrix} blade \\ r \end{pmatrix} = \begin{pmatrix} \text{"stator"} \\ 3 \end{pmatrix}$$

Наиболее удаленные точки от НЛ (мм):

$$\begin{pmatrix} u\_u_{rotor_{j,r}} & v\_u_{rotor_{j,r}} \\ u\_l_{rotor_{j,r}} & v\_l_{rotor_{j,r}} \\ u\_u_{stator_{j,r}} & v\_u_{stator_{j,r}} \\ u\_l_{stator_{j,r}} & v\_l_{stator_{j,r}} \end{pmatrix} = \cdot 10^{-3}$$

	1	2
1	-1.52	1.20
2	-18.47	-0.99
3	-0.01	1.43
4	14.81	-1.99

Изгибные напряжения (Па):

$$\begin{pmatrix} \sigma\_p_{rotor_{j,r}} & \sigma\_p_{stator_{j,r}} \\ \sigma\_n_{rotor_{j,r}} & \sigma\_n_{stator_{j,r}} \end{pmatrix} = \begin{pmatrix} -0 & 269 \\ 0 & -381 \end{pmatrix} \cdot 10^{6}$$

Эквивалентные напряжения (Па):

$$\begin{pmatrix} \sigma_{stator_{j,r}} \\ \sigma_{rotor_{j,r}} \end{pmatrix} = \begin{pmatrix} 269 \\ 5 \end{pmatrix} \cdot 10^{6}$$

Коэф. запаса: $\begin{pmatrix} safety_{stator_{j,r}} \\ safety_{rotor_{j,r}} \end{pmatrix} =$

	1
1	0.745
2	39.764

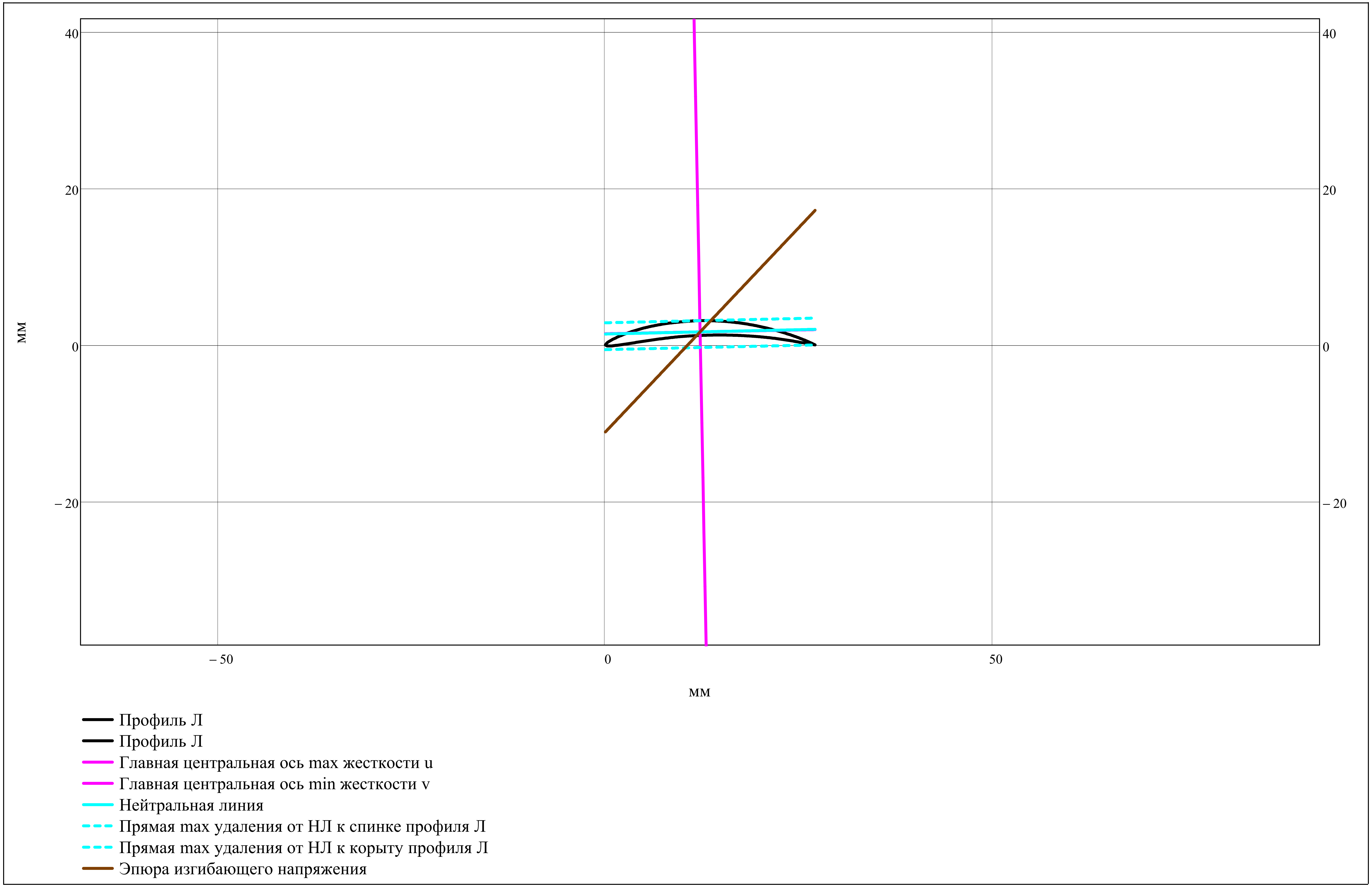
$$\begin{pmatrix} v\_p \\ v\_n \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} v\_u_{rotor_{j,r}} \\ v\_l_{rotor_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} v\_u_{stator_{j,r}} \\ v\_l_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. = \cdot 10^{-3}$$

	1
1	1.433
2	-1.994

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \left| \begin{array}{ll} \begin{pmatrix} x0_{rotor_{j,r}} \\ y0_{rotor_{j,r}} \end{pmatrix} & \text{if blade = "rotor"} \\ \begin{pmatrix} x0_{stator_{j,r}} \\ y0_{stator_{j,r}} \end{pmatrix} & \text{otherwise} \end{array} \right. = \cdot 10^{-3}$$

	1
1	12.233
2	1.667

$$chord = \left| \begin{array}{ll} chord_{rotor_{j,r}} & \text{if blade = "rotor"} \\ chord_{stator_{j,r}} & \text{if blade = "stator"} \end{array} \right. = 27 \cdot 10^{-3}$$



40
20
0
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0
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мм
мм
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Выбор материала Д

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

Выбранный материал Д:

$$material\_disk_i = \begin{cases} "ВТ23" & \text{if } compressor = "Вл" \\ "ВТ6" & \text{if } compressor = "КНД" \\ "ВТ9" & \text{if } compressor = "КВД" \end{cases}$$

Плотность материала Д (кг/м^3):

$$\rho\_disk_i = \begin{cases} 8266 & \text{if } material\_disk_i = "ВЖ175" \\ 8320 & \text{if } material\_disk_i = "ЭП742" \\ 8393 & \text{if } material\_disk_i = "ЖС-6К" \\ 7900 & \text{if } material\_disk_i = "ВТ41" \\ 4500 & \text{if } material\_disk_i = "ВТ25" \\ 4570 & \text{if } material\_disk_i = "ВТ23" \\ 4510 & \text{if } material\_disk_i = "ВТ9" \\ 4430 & \text{if } material\_disk_i = "ВТ6" \\ NaN & \text{otherwise} \end{cases}$$

Предел длительной прочности Д (Па):

$$\sigma\_disk\_long_i = 10^6 \cdot \begin{cases} 620 & \text{if } material\_disk_i = "ВЖ175" \\ 680 & \text{if } material\_disk_i = "ЭП742" \\ 125 & \text{if } material\_disk_i = "ЖС-6К" \\ 123 & \text{if } material\_disk_i = "ВТ41" \\ 150 & \text{if } material\_disk_i = "ВТ25" \\ 230 & \text{if } material\_disk_i = "ВТ23" \\ 200 & \text{if } material\_disk_i = "ВТ9" \\ 210 & \text{if } material\_disk_i = "ВТ6" \\ NaN & \text{otherwise} \end{cases}$$

$material\_disk^T =$

	1	2	3	4	5	6	7	8	9
1	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"

$\rho\_disk^T =$

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

$\sigma\_disk\_long^T =$

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

$\cdot 10^6$

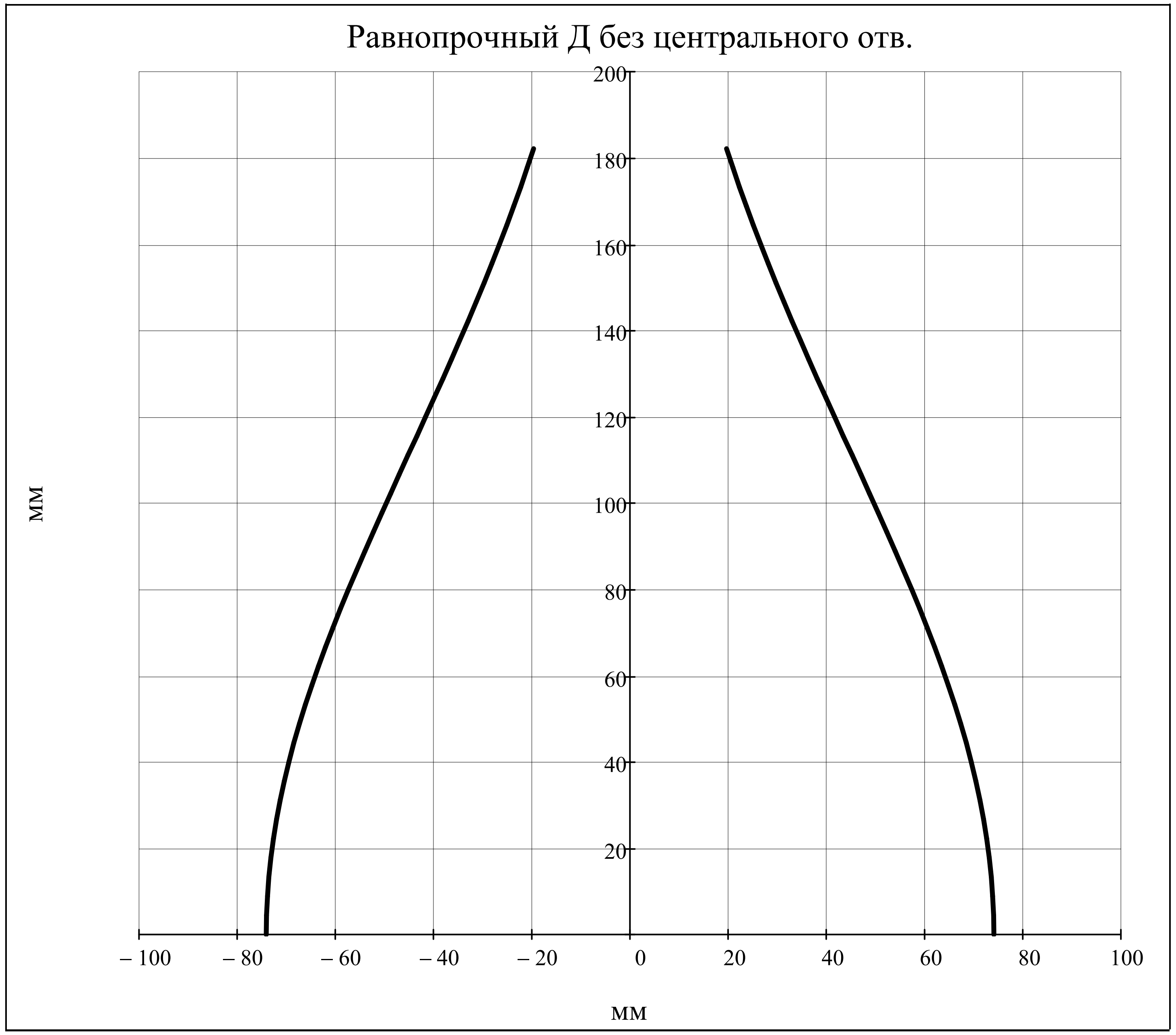
Выбор материала Д

Рассматриваемая ступень: $j = \left| \begin{array}{l} j = 1 \\ j = \left| \begin{array}{ll} \text{"Такой ступени не существует!"} & \text{if } (j < 1) \vee (j > Z) \\ j & \text{otherwise} \end{array} \right. \end{array} \right. = 1$

Профилирование равнопрочного Д без центрального отв.

$$h(i,z) = \left| \begin{array}{ll} \left(chord_{rotor_{i,ORIGIN}} \cdot \sin\left(\upsilon_{rotor_{i,ORIGIN}}\right)\right) \cdot e^{\frac{\rho\_disk_i \cdot \omega^2}{2} \cdot \frac{1}{\sigma\_z_{rotor}\left(i, R_{st(i,2),ORIGIN}\right)} \cdot \left[\left(R_{st(i,2),ORIGIN}\right)^2 - z^2\right]} & \text{if } z \le R_{st(i,2),ORIGIN} \\ NaN & \text{otherwise} \end{array} \right.$$

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



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