Подключение библиотек

Основные уравнения, алгоритмы, зависимости и ф-и

Параметры расчета

Исходные данные

Коэф. запаса: $safety = 1.3$

Степень двухконтурности: $m2 = 6$

РТ: Воздух

$compressor = \text{"КНД"}$

Число Маха: $M = 0$

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

Массовый расход (кг/с):

$$G = \begin{vmatrix} 35.65 + 213.93 & \text{if } compressor = \text{"Вл"} \\ 35.65 & \text{if } compressor = \text{"КНД"} \\ 34.81 & \text{if } compressor = \text{"КВД"} \end{vmatrix} = 35.65$$

Полная температура на входе в К (К):

$$T^*_{K1} = \begin{vmatrix} 418.2 & \text{if } compressor = \text{"КВД"} \\ 288.2 & \text{otherwise} \end{vmatrix} = 288.2$$

Полное давление на входе в К (Па):

$$P^*_{K1} = \begin{vmatrix} 316.2\cdot 10^3 & \text{if } compressor = \text{"КВД"} \\ 101325 & \text{otherwise} \end{vmatrix} = 101.3\cdot 10^3$$

Степень повышения давления КВД:

$$\pi^*_K = \begin{vmatrix} 1.6 & \text{if } compressor = \text{"Вл"} \\ \frac{3.2}{1.6} & \text{if } compressor = \text{"КНД"} \\ 9 & \text{if } compressor = \text{"КВД"} \end{vmatrix} = 2.000$$

Ожидаемый адиабатический КПД ОК:

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

Частота вращения ротора (с$^{-1}$):

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

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

$$\bar{d}_1 = \begin{vmatrix} 0.40 \text{ if compressor = "Вл"} \\ 0.75 \text{ if compressor = "КНД"} \\ 0.65 \text{ if compressor = "КВД"} \end{vmatrix} = 0.75$$

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

Частота вращения ротора (об/мин): $n = \frac{60\cdot\omega}{2\cdot\pi} = 5300$

Закон профилирования проточной части (ЗППЧ):

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

Относ. параметры по относительным ступеням:

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

Тип компрессора	Номер ступени и $\bar{L}_{CT.i}$							
	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:

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

увеличение несущественно увеличивает π

$$\bar{c}_{\sim a1} = \bar{c}_{\sim a1} - \begin{cases} 0.10 & \text{if compressor = "Вл"} \\ 0.141 & \text{if compressor = "КНД"} \\ 0.213 & \text{if compressor = "КВД"} \end{cases}$$

понижение существенно увеличивает π

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

увеличение несущественно увеличивает π

$$\bar{H}_{\sim T} = \bar{H}_{\sim T} + \begin{cases} 0.0145 & \text{if compressor = "Вл"} \\ 0.0164 & \text{if compressor = "КНД"} \\ 0.0183 & \text{if compressor = "КВД"} \end{cases}$$

[16, с. 234]

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

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

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

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

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

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

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

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

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

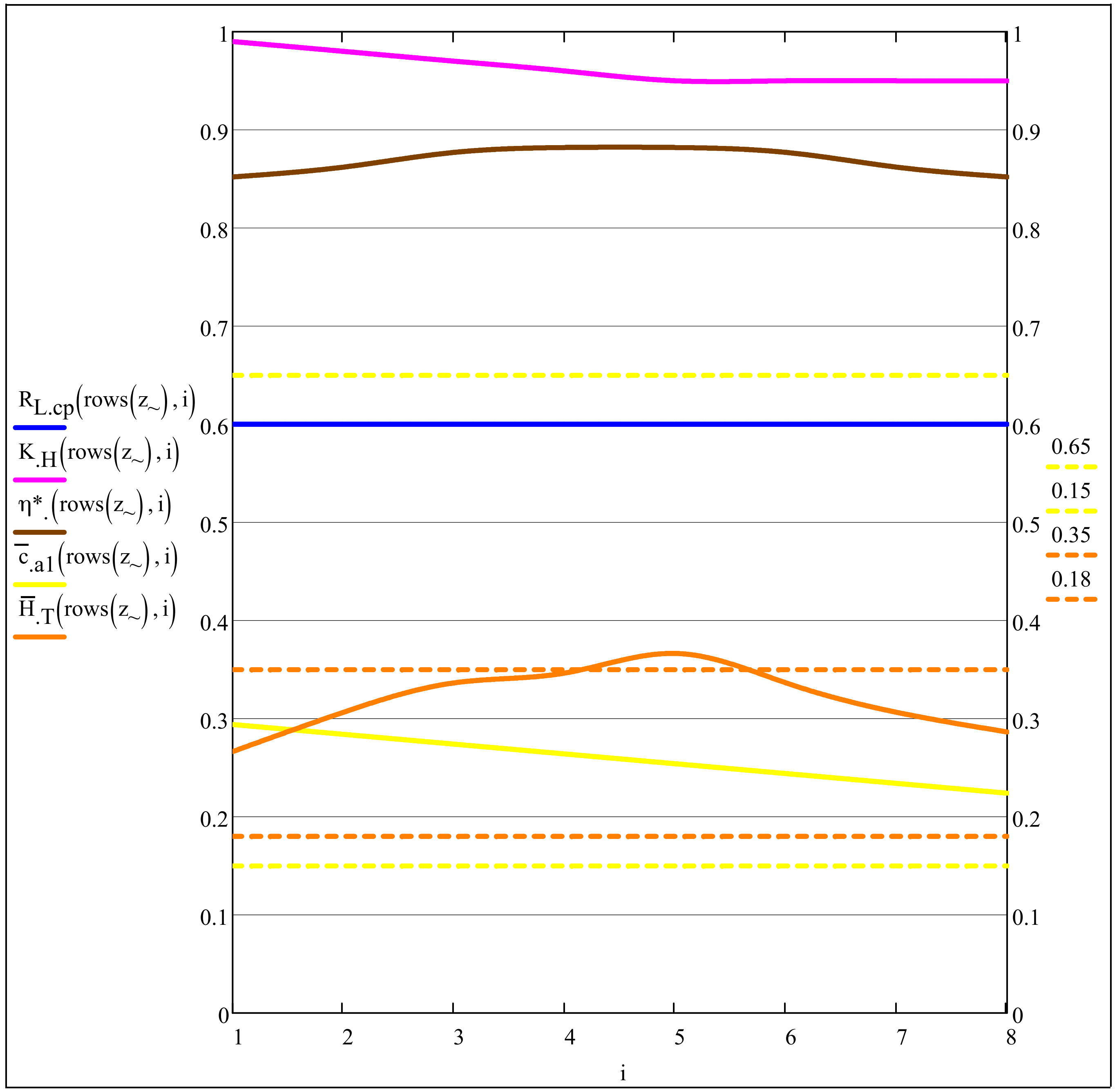
Коэф. расхода: $\overline{c}_{\sim a1}(i) = \mathrm{interp}\left(\mathrm{lspline}\left(\frac{z_\sim}{\mathrm{rows}(z_\sim)}, \overline{c}_{\sim a1}\right), \frac{z_\sim}{\mathrm{rows}(z_\sim)}, \overline{c}_{\sim a1}, i\right)$

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

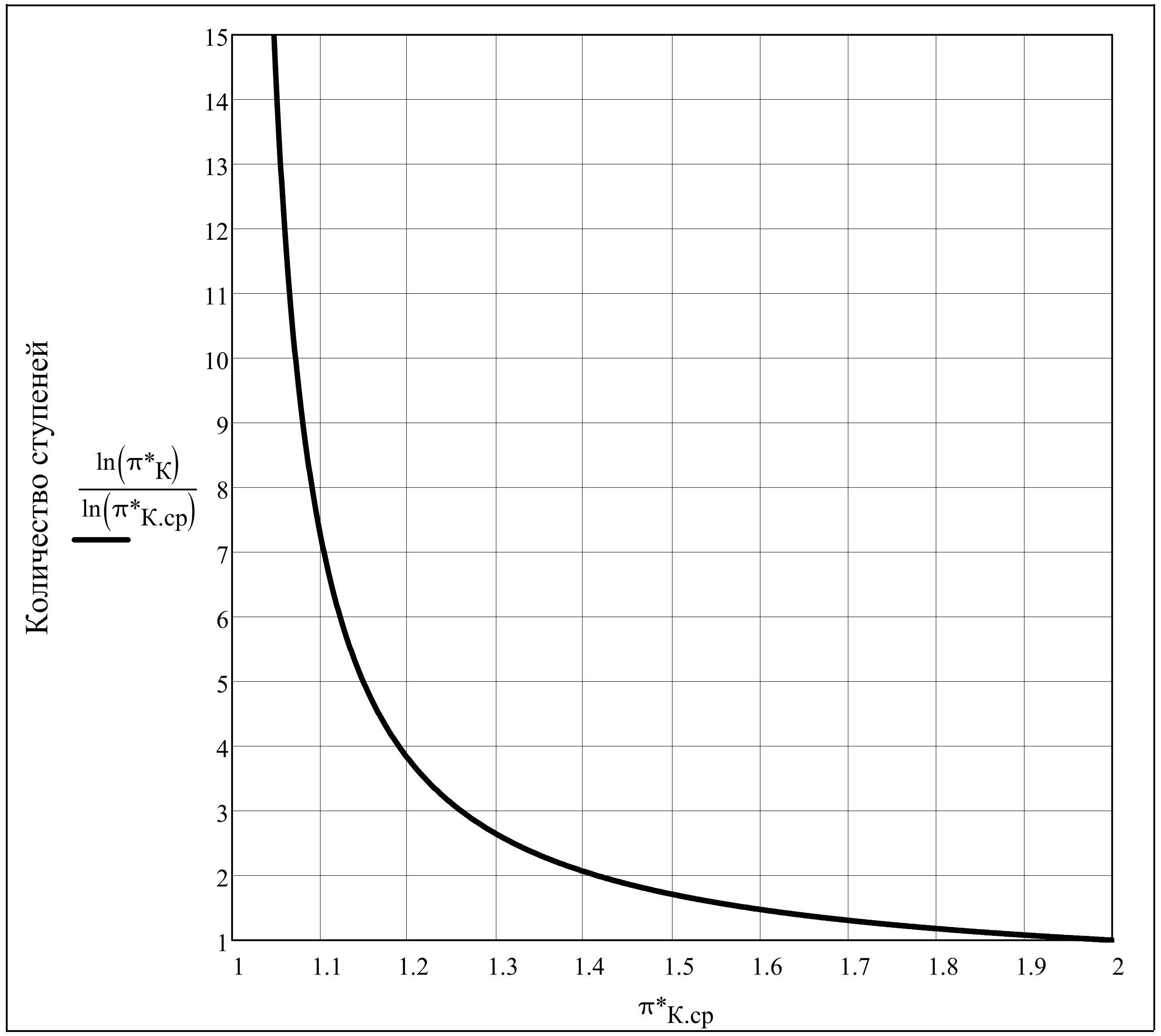
$$\begin{pmatrix} R_{L.cp} \\ K_{.H} \\ \eta^*_{.} \\ \bar{c}_{.a1} \\ \bar{H}_{.T} \end{pmatrix} = \left| \begin{array}{l}
R_{L.cp}(Z,i) = \left| \begin{array}{ll} R_{L\sim cp}\left(\dfrac{1}{rows(z_\sim)}\right) & \text{if } i<1 \\ R_{L\sim cp}(1) & \text{if } i>Z \\ R_{L\sim cp}\left(\dfrac{i}{Z}\right)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

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

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



Распределение основных параметров ОК по ступеням



Количество ступеней
$\frac{\ln(\pi^*_K)}{\ln(\pi^*_{K.cp})}$
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
$\pi^*_{K.cp}$

Нулевые приближения

Показатель адиаьаты перед К []: $k_{К1} = k_{ад}\left(Cp_{воздух}\left(P^*_{К1}, T^*_{К1}\right), R_в\right) = 1.401$

Полное давление после К [Па]: $P^*_{К3} = \pi^*_К \cdot P^*_{К1} = 203\cdot 10^3$

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

Количество итераций []: $iteration_3 = 1$

Полная температура после К [К]: $T^*_{К3} = 360.9$

Показатель адиаьаты после К []: $k_{К3} = 1.398$

Полная плотность перед и после К [кг/м^3]: $\begin{pmatrix} \rho^*_{К1} \\ \rho^*_{К3} \end{pmatrix} = \dfrac{1}{R_в}\cdot\begin{pmatrix} \dfrac{P^*_{К1}}{T^*_{К1}} \\ \dfrac{P^*_{К3}}{T^*_{К3}} \end{pmatrix} = \begin{pmatrix} 1.224 \\ 1.955 \end{pmatrix}$

Критические скорости перед и после К [м/с]: $\begin{pmatrix} a^*_{с.вх} \\ a^*_{с.вых} \end{pmatrix} = \begin{pmatrix} a_{кр}\left(k_{К1}, R_в, T^*_{К1}\right) \\ a_{кр}\left(k_{К3}, R_в, T^*_{К3}\right) \end{pmatrix} = \begin{pmatrix} 310.8 \\ 347.6 \end{pmatrix}$

Ср. показатель адиабаты К []: $k_{ср} = k_{ад}\left(Cp_{воздух.ср}\left(P^*_{К1}, P^*_{К3}, T^*_{К1}, T^*_{К3}\right), R_в\right) = 1.4$

Теоретический напор [Дж/кг]: $H_{ТК} = \dfrac{Cp_{воздух.ср}\left(P^*_{К1}, P^*_{К3}, T^*_{К1}, T^*_{К3}\right)\cdot T^*_{К1}\cdot\left(\pi^{*\frac{k_{ср}-1}{k_{ср}}}_{К} - 1\right)}{\eta^*_К} = 72.9\cdot 10^3$

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

Количество итераций []: $iteration_u = 2$

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

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

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

Приведенная скорость перед К []: $\lambda_{вх} = 0.2685$

Плотность перед К [кг/м^3]: $\rho_{K1} = 1.188$

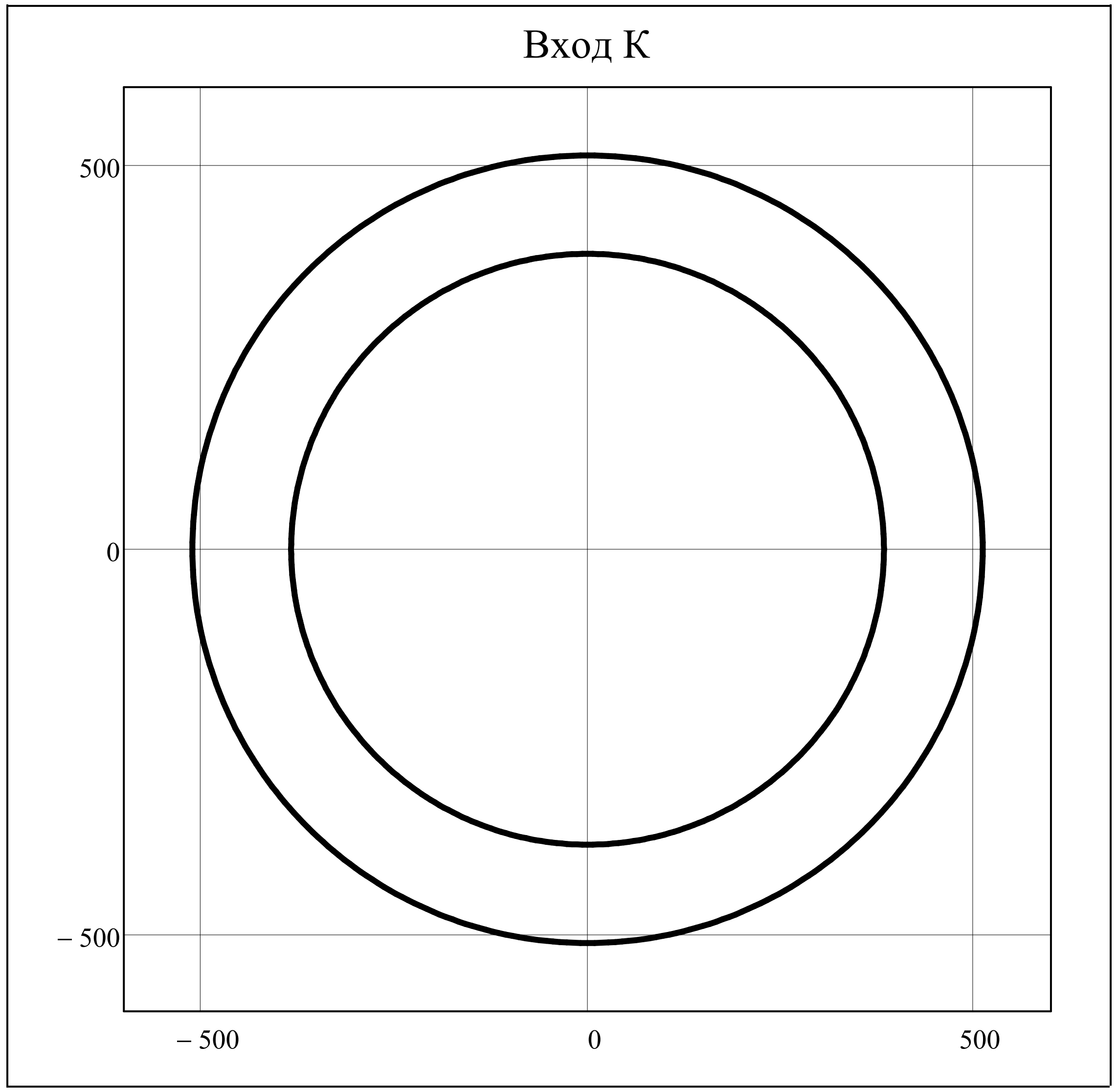
Кольцевая площадь перед К [м²]: $F_{вх} := \dfrac{G \cdot \sqrt{R_в \cdot T^*_{K1}}}{m_q\left(k_{K1}\right) \cdot P^*_{K1} \cdot ГДФ\left(\text{"G"}, \lambda_{вх}, k_{K1}\right)} = 0.3596$

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

Диамтеры перед К [м]: $D'_{ср1} := \overline{r}_{ср}\left(\overline{d}_1\right) \cdot D'_{пер1} = 904 \cdot 10^{-3}$

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

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



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

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

Нулевые приближения

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

Расчет ВНА:

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

$\sigma_{BHA} = 1.0000$

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

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

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

$\begin{pmatrix} \overline{d}_{1BHA} \\ \overline{d}_{3BHA} \end{pmatrix} = \begin{pmatrix} 0.7500 \\ 0.7500 \end{pmatrix}$ $\begin{pmatrix} F_{1BHA} \\ F_{3BHA} \end{pmatrix} = \begin{pmatrix} 0.3596 \\ 0.3596 \end{pmatrix}$

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

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

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

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

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

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

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

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

$$\overline{c}_{a3BHA_r} = \overline{c}_{.a1}(Z, 1)$$

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

$$\alpha_{3BHA_r} = \begin{cases} \text{atan}\left(\dfrac{\overline{c}_{a1BHA_r}}{\overline{c}_{u1BHA_r}}\right) & \text{if } BHA = 1 \\ \dfrac{\pi}{2} & \text{otherwise} \end{cases}$$

$$c_{a3BHA_r} = c_{a1BHA_r} - \begin{cases} 10 & \text{if } BHA = 1 \\ 0 & \text{otherwise} \end{cases}$$

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

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

$$\lambda_{3BHA_r} = \frac{c_{3BHA_r}}{\ldots}$$

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

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

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

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

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

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

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

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

$\text{submatrix}\left(a_{кр1BHA}, av(N_r), av(N_r), 1, 1\right) = (310.8)$

$\text{submatrix}\left(a_{кр3BHA}, av(N_r), av(N_r), 1, 1\right) = (310.8)$

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

$\text{submatrix}\left(\overline{c}_{a3BHA}, av(N_r), av(N_r), 1, 1\right) = (0.277)$

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

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

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

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

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

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

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

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

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

$\text{submatrix}\left(\lambda_{3BHA}, av(N_r), av(N_r), 1, 1\right) = (0.268)$

$$\lambda_{3ВНА_r} = \frac{c_{3ВНА_r}}{a_{кр3ВНА_r}}$$

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

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

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

Расчет ВНА:

Поступенчатый расчет ОК по ср. ЛТ

$$
\begin{pmatrix}
R_L & \pi^* \\
K_H & \eta^* \\
Cp & k \\
\bar{H}_T & H_T \\
L^* & L \\
T^* & T \\
P^* & P \\
\rho^* & \rho \\
a^*_c & a_{зв} \\
\lambda_c & \lambda_c \\
F & F \\
D & R \\
\bar{d} & h \\
\bar{c}_a & \bar{c}_u \\
c_a & c_u \\
u & w_u \\
c & w \\
M_c & M_w \\
\alpha & \beta \\
\varepsilon_{rotor} & \varepsilon_{stator}
\end{pmatrix}
=
\left|
\begin{array}{l}
r = av(N_r) \\
T^*_{st(1,1),r} = T^*_{3BHA_r} \\
P^*_{st(1,1),r} = P^*_{3BHA_r} \\
\rho^*_{st(1,1),r} = \rho^*_{3BHA_r} \\
Cp_{st(1,1),r} = Cp_{воздух}\left(P^*_{st(1,1),r}, T^*_{st(1,1),r}\right) \\
k_{st(1,1),r} = k_{ад}\left(Cp_{st(1,1),r}, R_B\right) \\
a^*_{c_{st(1,1),r}} = a_{кр}\left(k_{st(1,1),r}, R_B, T^*_{st(1,1),r}\right) \\
\bar{c}_{a_{st(1,1),r}} = \bar{c}_{a3BHA_r} \\
\bar{c}_{u_{st(1,1),r}} = \bar{c}_{u3BHA_r} \\
c_{a_{st(1,1),r}} = c_{a3BHA_r} \\
u_{st(1,1),N_r} = u_{1пер} \\
\alpha_{st(1,1),r} = \alpha_{3BHA_r} \\
c_{st(1,1),r} = \dfrac{c_{a_{st(1,1),r}}}{\sin\left(\alpha_{st(1,1),r}\right)} \\
\lambda_{c_{st(1,1),r}} = \dfrac{c_{st(1,1),r}}{a^*_{c_{st(1,1),r}}} \\
F_{st(1,1)} = \dfrac{G \cdot \sqrt{R_B \cdot T^*_{st(1,1),r}}}{m_{\ldots}\left(k_{st(1,1)}\ldots\right) \cdot ГДФ\left("G", \lambda \ldots k_{st(1,1)}\ldots\right) \cdot \sin\left(\alpha_{st(1,1)}\ldots\right) \cdot P^*_{st(1,1)}\ldots}
\end{array}
\right.
$$

$$m_q(k_{st(1,1),r})\cdot ГДФ\left(\ \ ,\lambda_{c_{st(1,1),r}},k_{st(1,1),r}\right)\cdot \sin(\alpha_{st(1,1),r})\cdot F_{st(1,1),r}$$

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

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

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

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

for $i \in 1..Z$

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

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

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

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

$$L^*_i \leftarrow L_i\cdot\eta^*_i$$

$$iteration_{12} \leftarrow 0$$

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

while $0 < 1$

$$iteration_{12} \leftarrow iteration_{12} + 1$$

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

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

$$Cp_{12} \leftarrow \frac{k_{12}}{k_{12}-1}\cdot R_в$$

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

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

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

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

$k'_2 = k_{ад}(Cp_{st(i,2),r}, R_в)$

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

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

break

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

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

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

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

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

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

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

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

$iteration_3 = 0$

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

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

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

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

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

while $0 < 1$

$iteration_3 = iteration_3 + 1$

trace(concat("   iteration.3 = ", num2str($iteration_3$)))

if $(ЗППЧ_i \neq "пер") \wedge (ЗППЧ_i \neq "кор") \wedge (ЗППЧ_i \neq "ср")$

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

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

if $ЗППЧ_i = "пер"$

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

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

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"

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

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

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

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

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

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

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

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

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

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

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

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

iteration [illegible] 1 if (|eps("rel", F', F [illegible])| < epsilon)

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

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

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

$$iteration_2 = 0$$

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

while $0 < 1$

$$iteration_2 = iteration_2 + 1$$

$$trace\left(concat\left(\text{"   iteration.2 = "}, num2str\left(iteration_2\right)\right)\right)$$

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

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

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

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

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

if $ЗППЧ_i = \text{"пер"}$

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

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

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

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

if $ЗППЧ_i = \text{"кор"}$

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

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

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

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

if $ЗППЧ_i = \text{"ср"}$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

for $a \in 1..3$

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

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

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

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

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

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

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

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

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

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

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

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

for $radius \in 1..N_r$

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

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

for $i \in 1..Z$

for $a \in 1..3$

for $r \in 1..N_r$

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

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

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

Поступенчатый расчет ОК по ср. ЛТ

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

Расчет CA:

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

$\sigma_{CA} = 1.0000$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\text{submatrix}\left(a_{кр1CA}, av(N_r), av(N_r), 1, 1\right) = (347.9)$

$\text{submatrix}\left(a_{кр3CA}, av(N_r), av(N_r), 1, 1\right) = (347.9)$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Расчет СА:

Результаты поступенчатого расчета по ср. ЛТ

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

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

$\bar{\Delta}G^T =$ (·%)

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

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

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

Количество ступеней ОК: $Z = 3$

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	1.300	1.297	1.187												

[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												

Полученная степень повышения полного давления []: $\prod_{i=1}^{Z} \pi^*_i = 2.000$

Степень повышения давления в ЛА: $\pi^*_{ЛА} = \dfrac{P^*_{3СА_{av(N_r)}}}{P^*_{1ВНА_{av(N_r)}}} = 2.000$ $\pi^*_{ЛА} \ge \pi^*_К = 1$

$H_T^T =$

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

$\cdot 10^3$

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

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

Адиабатная КПД К []: $\eta^*_K = \frac{L^*_K}{L_K} = 87.02 \cdot \%$

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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.60	0.60	0.60												

$K_H{}^T =$

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

$\eta^{*T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	87.25	88.13	85.20												

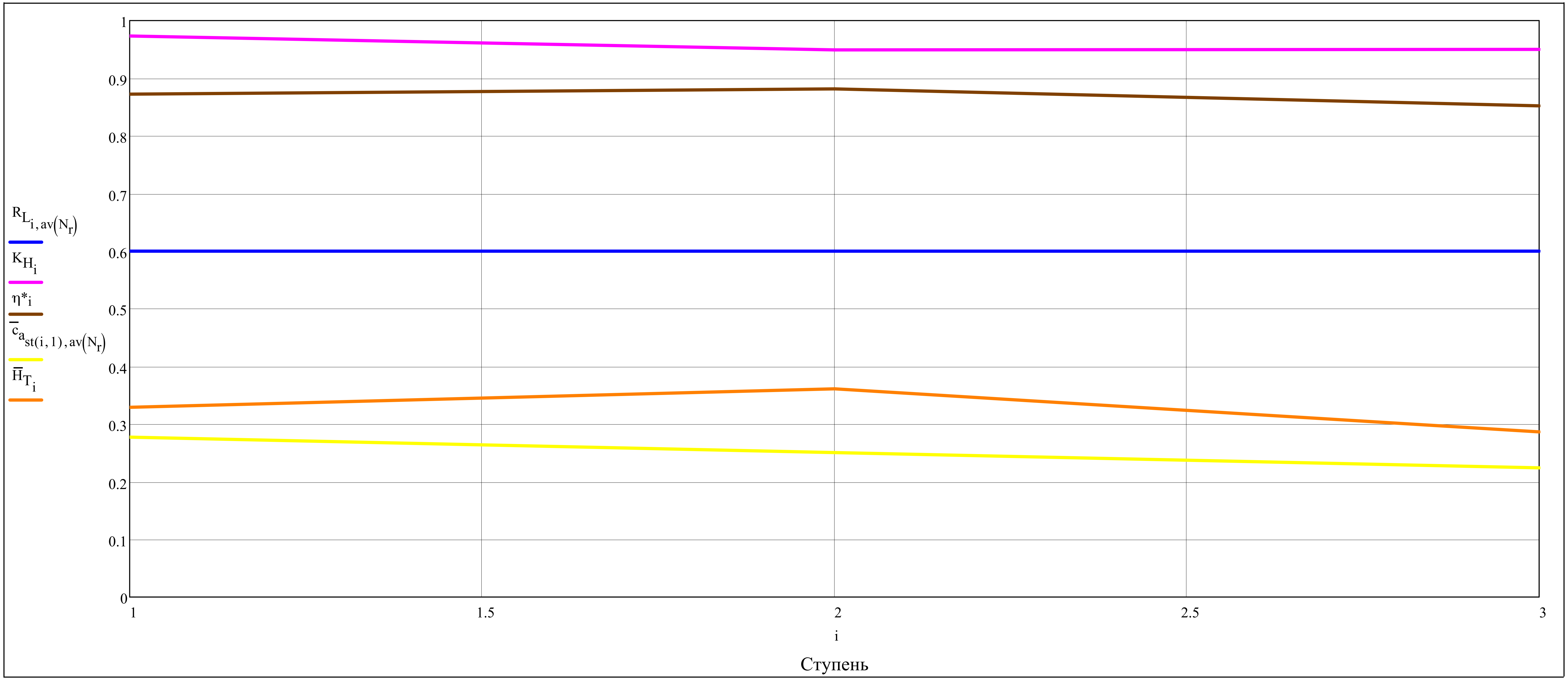
$\cdot\%$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.277	0.264	0.251	0.237	0.224	0.224	0.224													

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

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



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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1002.6	1004.1	1004.1	1006.4	1006.4	1008.5	1008.5												

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.401	1.401	1.401	1.399	1.399	1.398	1.398														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	288.2	313.9	313.9	341.4	341.4	361.5	361.5														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	284.7	305.6	310.5	326.2	338.3	349	359														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	101.3	131.7	131.7	170.8	170.8	202.7	202.7											

$\cdot 10^3$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	97.1	119.8	126.7	145.5	165.3	179.1	197.7											

$\cdot 10^3$

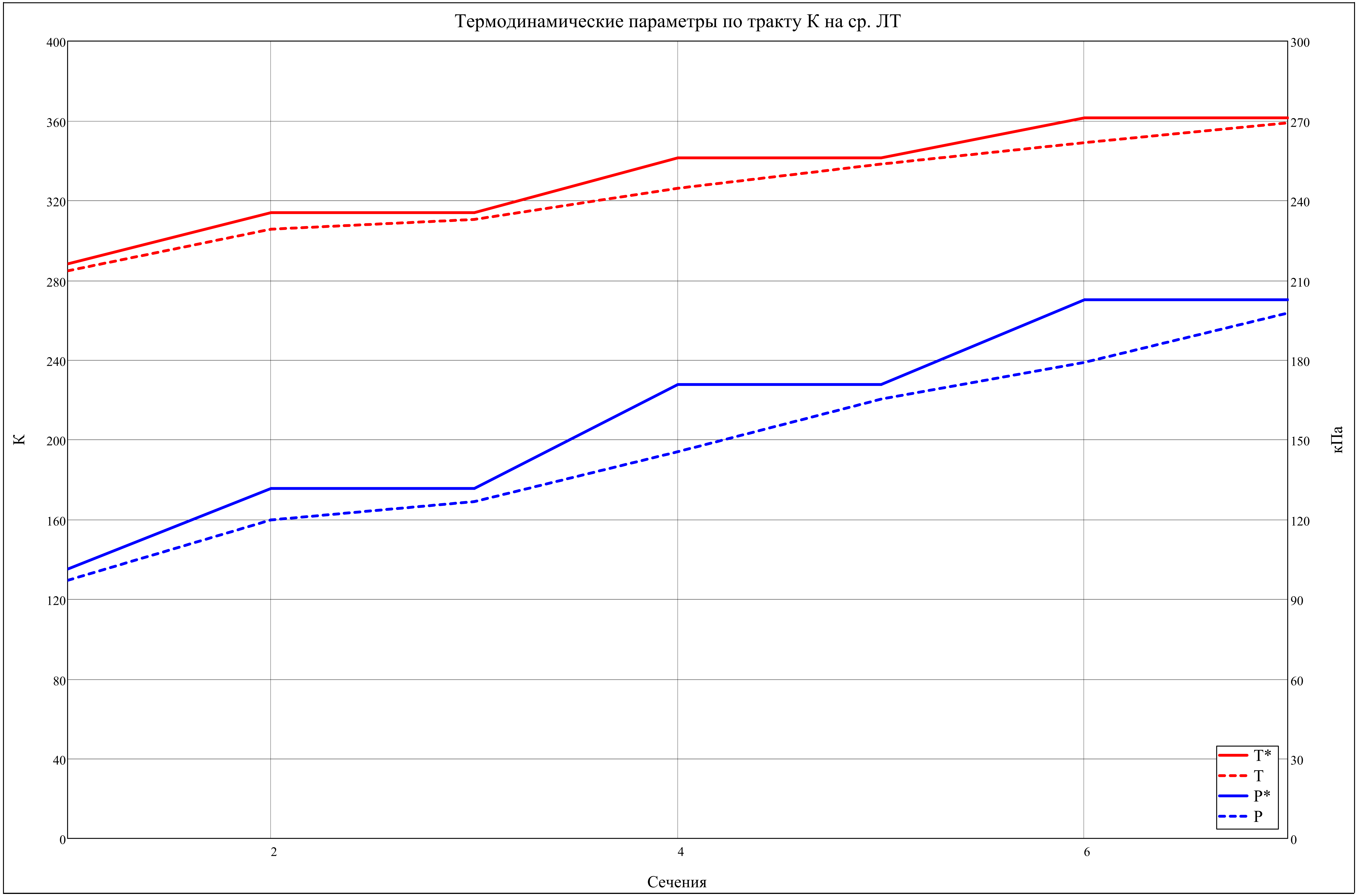
$\mathrm{submatrix}\left(\rho^*, 1, 2Z+1, \mathrm{av}\left(N_r\right), \mathrm{av}\left(N_r\right)\right)^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1.224	1.461	1.461	1.742	1.742	1.952	1.952												

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1.188	1.366	1.421	1.553	1.702	1.787	1.918												

$$k_{\text{ср}} = k_{\text{ад}}\left(Cp_{\text{воздух.ср}}\left(P^*_{st(1,1),\mathrm{av}\left(N_r\right)}, P^*_{st(Z,3),\mathrm{av}\left(N_r\right)}, T^*_{st(1,1),\mathrm{av}\left(N_r\right)}, T^*_{st(Z,3),\mathrm{av}\left(N_r\right)}\right), R_{\text{в}}\right) = 1.400$$


Термодинамические параметры по тракту К на ср. ЛТ
К
кПа
Сечения
0
40
80
120
160
200
240
280
320
360
400
0
30
60
90
120
150
180
210
240
270
300
2
4
6
T*
T
P*
P

$F^T =$ $\cdot 10^{-6}$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	359639	348398	352628	347646	343267	340438	331025														

$\overline{d}^T =$

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

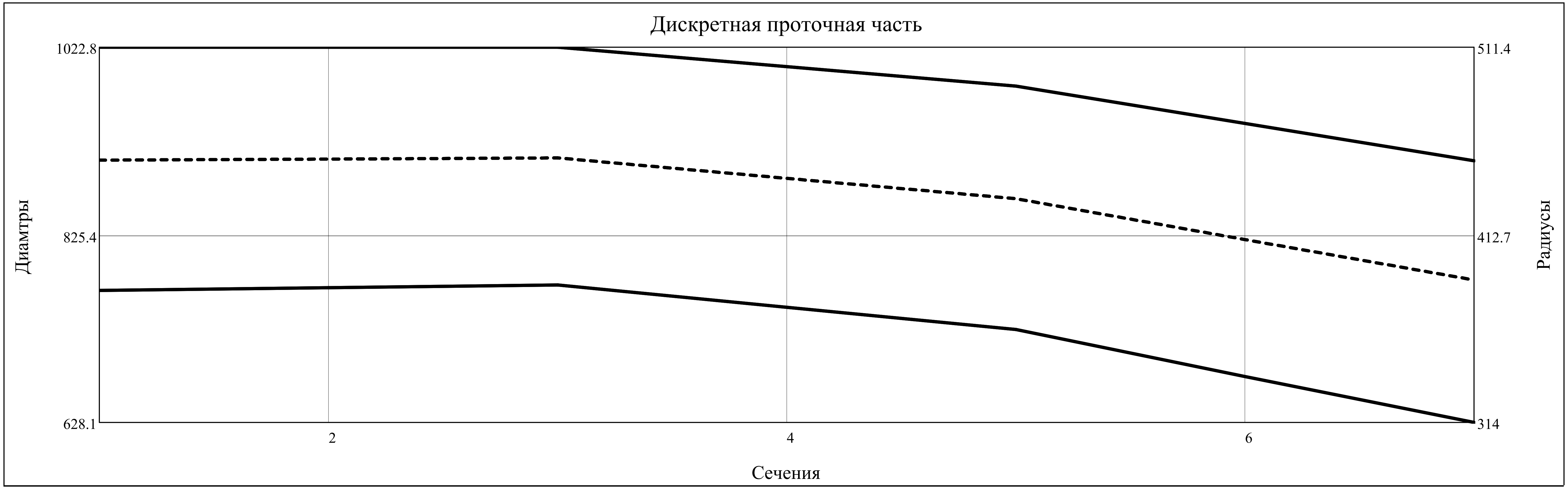
$\overline{d}_{st(Z,3)} = 0.6953$ $\overline{d}_{st(Z,3)} \le 0.9 = 1$

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

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

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

	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	383.4	384.9	386.3	374.6	363.0	338.2	314.0																		
2	452.0	452.6	453.2	442.4	431.7	410.2	389.0																		
3	511.4	511.4	511.4	501.1	490.9	471.3	451.6																		



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

	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	127.9	126.5	125.0	126.6	128.0	133.1	137.6																		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	310.8	324.3	324.3	338.2	338.2	347.9	347.9														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	338.5	350.6	353.4	362	368.7	374.3	379.6														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	83.4	129.4	83	175.2	79.8	158.8	71.8														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	278.7	163.8	220.5	106.2	197.8	99.2															

$u^T =$

	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	212.8	213.6	214.4	207.9	201.4	187.7	174.3																		
2	250.8	251.2	251.5	245.5	239.6	227.6	215.9																		
3	283.8	283.8	283.8	278.1	272.5	261.6	250.7																		

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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	83.4	74.9	71.1	66	61	58.6	56.1														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0	105.6	42.8	162.3	51.5	147.6	44.7														

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	265.9	145.6	208.7	83.3	188.1	80.1	171.2														

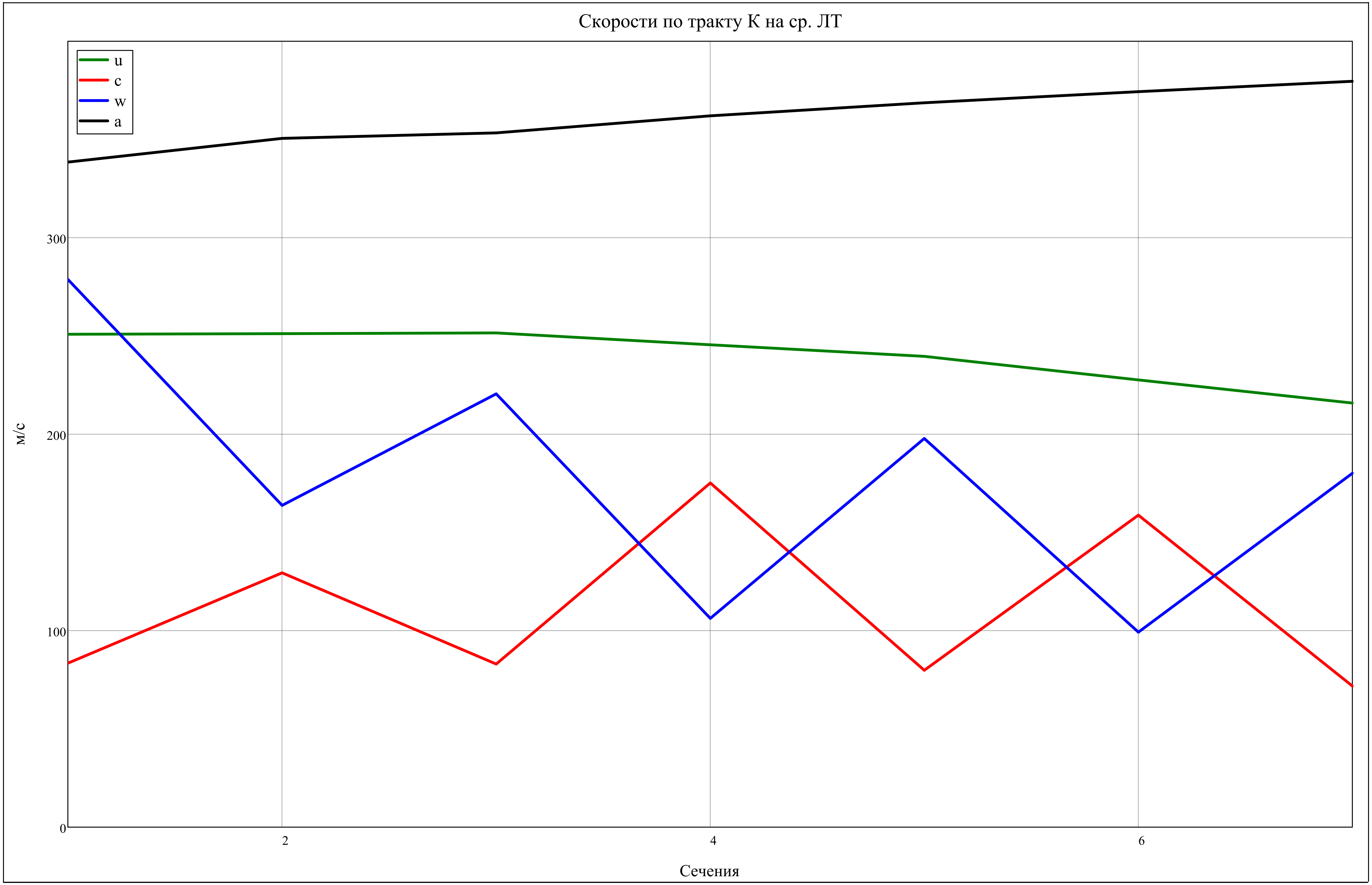
$$\Delta c_{a_{i,\mathrm{av}(N_r)}} = \left(c_{a_{st(i,2),\mathrm{av}(N_r)}} - c_{a_{st(i,1),\mathrm{av}(N_r)}}\right)$$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	-8.51	-5.13	-2.44																		

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

	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																											


Скорости по тракту К на ср. ЛТ
u
c
w
a
м/с
300
200
100
0
2
4
6
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	90.00	35.37	58.97	22.13	49.86	21.65	51.49														

$\cdot °$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	17.42	27.23	18.82	38.41	17.97	36.19	18.16														

$\cdot °$

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

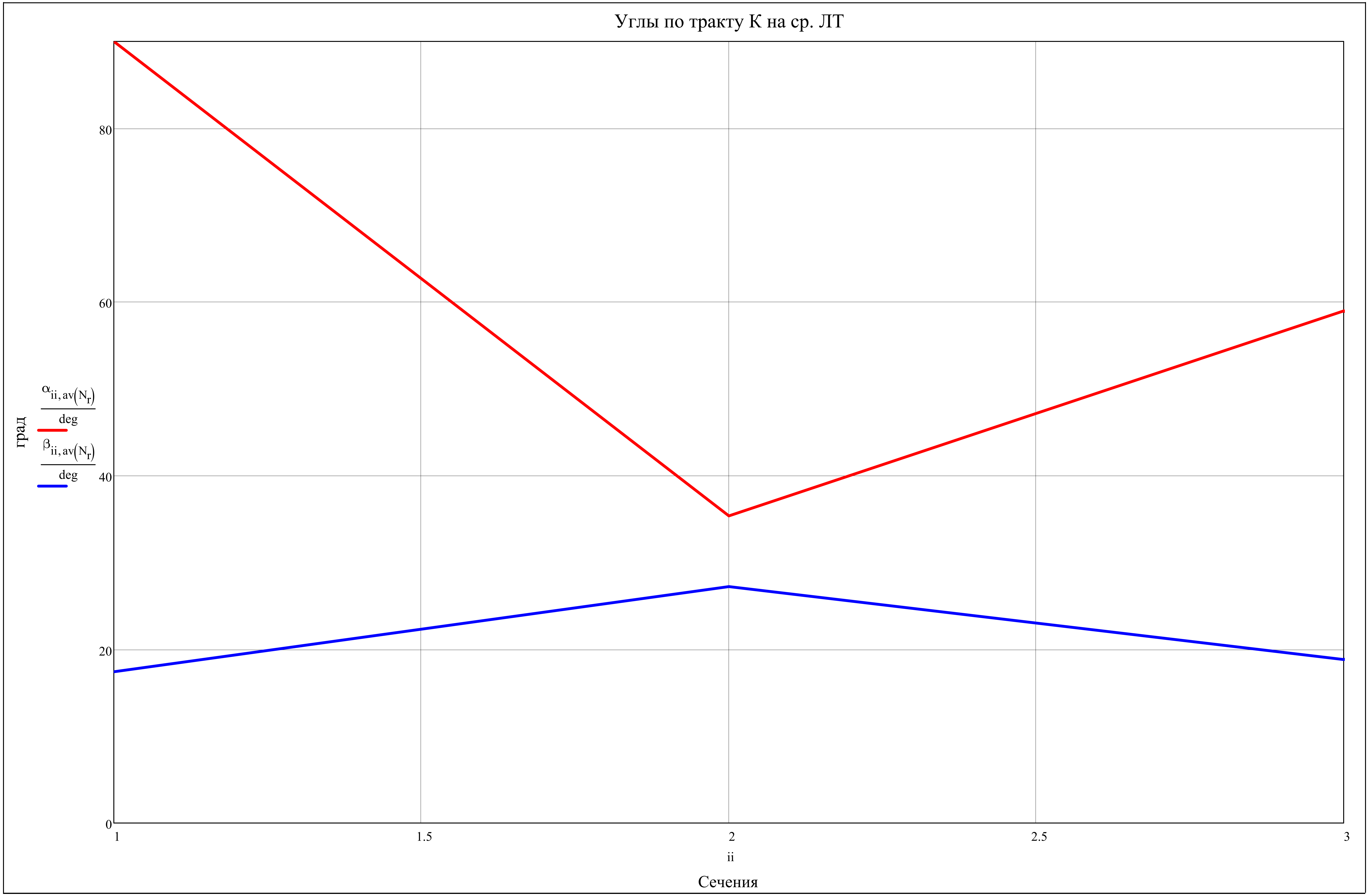
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	9.81	19.59	18.22																		

$\cdot °$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	23.61	27.72	29.84																		

$\cdot °$



Углы по тракту К на ср. ЛТ
80
60
40
20
0
1
1.5
2
2.5
3
ii
Сечения
град
$\frac{\alpha_{ii,av(N_r)}}{deg}$
$\frac{\beta_{ii,av(N_r)}}{deg}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.2685	0.3991	0.2560	0.5181	0.2361	0.4564	0.2062												

[16, c. 87] $\text{submatrix}\left(\lambda_c, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T \le 0.85 =$

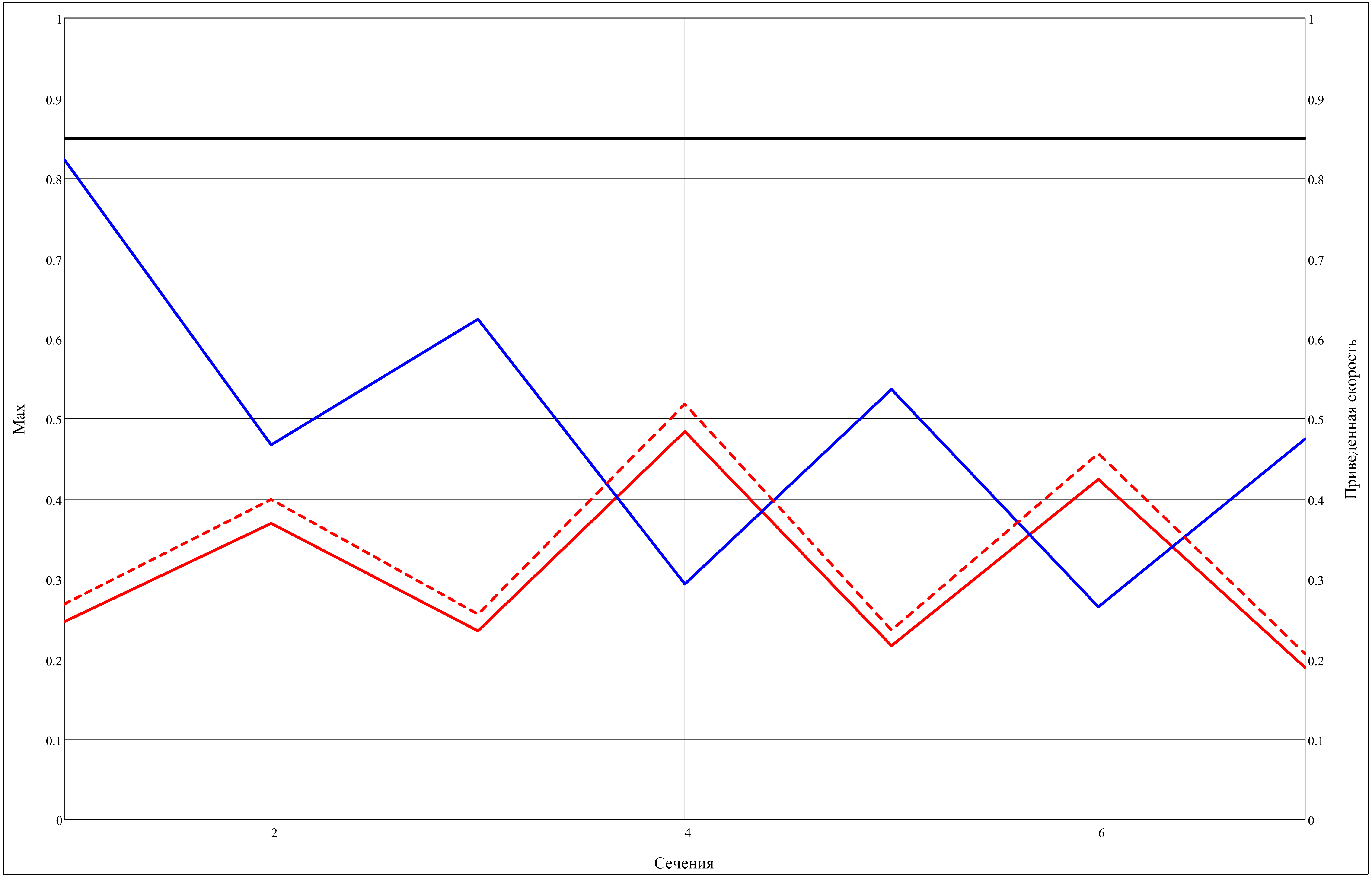
	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.8234	0.4672	0.6241	0.2935	0.5365	0.2651													

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.2465	0.3693	0.2349	0.4840	0.2166	0.4242	0.1890												


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Max
2
4
6
Сечения
Приведенная скорость

Результаты поступенчатого расчета по ср. ЛТ

Вывод результатов поступенчатого расчета по ср. ЛТ ОК в EXCEL:

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]

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

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

$$m_i := \left| \begin{array}{ll} 0.4 & \text{if compressor} = \text{"Вл"} \\ m_i & \text{otherwise} \end{array} \right.$$

$m^T =$

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

$$\begin{pmatrix} T^* & T \\ P^* & P \\ \rho^* & \rho \\ Cp & k \\ a^*_c & a_{зв} \\ c_u & c_a \\ \alpha & \beta \\ c & w \\ \lambda_c & w_u \\ M_w & M_c \\ R_L & R_L \\ \varepsilon_{rotor} & \varepsilon_{stator} \end{pmatrix} := \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } a \in 1..3 \\ \quad\quad \text{for } r \in 1..N_r \\ \quad\quad\quad T^*_{st(i,a),r} \leftarrow T^*_{st(i,a),av(N_r)} \\ \quad\quad\quad P^*_{st(i,a),r} \leftarrow P^*_{st(i,a),av(N_r)} \\ \quad\quad\quad \rho^*_{st(i,a),r} \leftarrow \rho^*_{st(i,a),av(N_r)} \\ \quad\quad\quad Cp_{st(i,a),r} \leftarrow Cp_{воздух}\left(P^*_{st(i,a),r}, T^*_{st(i,a),r}\right) \\ \quad\quad\quad k_{st(i,a),r} \leftarrow \dfrac{Cp_{воздух}\left(P^*_{st(i,a),r}, T^*_{st(i,a),r}\right)}{Cp_{воздух}\left(P^*_{st(i,a),r}, T^*_{st(i,a),r}\right) - R_B} \\ \quad\quad\quad a^*c_{st(i,a),r} \leftarrow \sqrt{\dfrac{2 \cdot k_{st(i,a),r}}{k_{st(i,a),r}+1} \cdot R_B \cdot T^*_{st(i,a),r}} \\ \quad\quad\quad \text{if } \Delta H_{Tmax} = 0 \end{array} \right.$$

$$A_{st(i,a),r} = \left(1 - R_{L_{i,av(N_r)}}\right)\cdot\omega\cdot\left(R_{st(i,a),av(N_r)}\right)$$

$$B_{st(i,a),r} = \frac{H_{T_{i,av(N_r)}}}{2\cdot\omega}$$

$$c_{u_{st(i,a),r}} = \begin{cases} c_{u_{st(i,a),av(N_r)}} & \text{if } (a = 1) \\ \dfrac{A_{st(i,a),r}}{\left(R_{st(i,a),r}\right)^{m_i}} + \dfrac{B_{st(i,a),r}}{\left(R_{st(i,a),r}\right)} & \text{if } (a = 2) \\ \dfrac{A_{st(i,a),r}}{\left(R_{st(i,a),r}\right)^{m_i}} - \dfrac{B_{st(i,a),r}}{\left(R_{st(i,a),r}\right)} & \text{if } (a = 3) \end{cases}$$

$c_{a_{st(i,a),r}} =$ if $m_i = -1$

$$c_{a_{st(i,a),av(N_r)}} \quad \text{if } (a = 1)$$

$$\sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 + 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\left(R_{st(i,a),av(N_r)}\right)^2 - 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\left(R_{st(i,a),r}\right)^2 - 4\cdot A_{st(i,a),r}\cdot B_{st(i,a),r}\cdot\left(\ln\left(R_{st(i,a),r}\right) - \ln\left(R_{st(i,a),av(N_r)}\right)\right)} \quad \text{if } (a = 2)$$

$$\sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 + 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\left(R_{st(i,a),av(N_r)}\right)^2 - 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\left(R_{st(i,a),r}\right)^2 + 4\cdot A_{st(i,a),r}\cdot B_{st(i,a),r}\cdot\left(\ln\left(R_{st(i,a),r}\right) - \ln\left(R_{st(i,a),av(N_r)}\right)\right)} \quad \text{if } (a = 3)$$

if $m_i = 0$

$$c_{a_{st(i,a),av(N_r)}} \quad \text{if } (a = 1)$$

$$\sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 + 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\ln\left(R_{st(i,a),av(N_r)}\right) - 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\ln\left(R_{st(i,a),r}\right) + \frac{2\cdot A_{st(i,a),r}\cdot B_{st(i,a),r}}{R_{st(i,a),r}} - \frac{2\cdot A_{st(i,a),r}\cdot B_{st(i,a),r}}{R_{st(i,a),av(N_r)}}} \quad \text{if } (a = 2)$$

$$\sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 + 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\ln\left(R_{st(i,a),av(N_r)}\right) - 2\cdot\left(A_{st(i,a),r}\right)^2\cdot\ln\left(R_{st(i,a),r}\right) - \frac{2\cdot A_{st(i,a),r}\cdot B_{st(i,a),r}}{R_{st(i,a),r}} + \frac{2\cdot A_{st(i,a),r}\cdot B_{st(i,a),r}}{R_{st(i,a),av(N_r)}}} \quad \text{if } (a = 3)$$

otherwise

$$c_{a_{st(i,a),av(N_r)}} \quad \text{if } (a = 1)$$

$$\sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 + \frac{A_{st(i,a),r}\cdot\left(m_i - 1\right)\cdot\left[A_{st(i,a),r}\cdot\left[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{st(i,a),av(N_r)}\right) - \left(R_{st(i,a),r}\right)\cdot\left(R_{st(i,a),av(N_r)}\right)^{2\cdot m_i+1}\right] + 2\cdot B_{st(i,a),r}\cdot m_i\cdot\left[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{s}\right.\right.}{m_i\cdot\left(m_i + 1\right)\cdot\left(R_{st(i,a),r}\right.}}$$

$$\sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2 + \frac{A_{st(i,a),r}\cdot\left(m_i - 1\right)\cdot\left[A_{st(i,a),r}\cdot\left[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{st(i,a),av(N_r)}\right) - \left(R_{st(i,a),r}\right)\cdot\left(R_{st(i,a),av(N_r)}\right)^{2\cdot m_i+1}\right] - 2\cdot B_{st(i,a),r}\cdot m_i\cdot\left[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{s}\right.\right.}{m_i\cdot\left(m_i + 1\right)\cdot\left(R_{st(i,a),r}\right.}}$$

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

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

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

$$c_{u_{st(i,a),r}} = \begin{cases} c_{u_{st(i,a),av(N_r)}} & \text{if } (a=1) \\ A_{st(i,a),r}\cdot R_{st(i,a),r}+\dfrac{B_{st(i,a),r}}{R_{st(i,a),r}}+\dfrac{H_{T_{i,r}}}{\omega\cdot R_{st(i,a),r}} & \text{if } (a=2) \\ A_{st(i,a),r}\cdot R_{st(i,a),r}+\dfrac{B_{st(i,a),r}}{R_{st(i,a),r}} & \text{if } (a=3) \end{cases}$$

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

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

$$c_{a_{st(i,a),r}} = \begin{cases} c_{a_{st(i,a),av(N_r)}} & \text{if } (a=1) \\ \sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2-2\cdot\left(A_{st(i,a),r}\right)^2\cdot\left[\left(R_{st(i,a),r}\right)^2-\left(R_{st(i,a),av(N_r)}\right)^2\right]-\left(6\cdot\dfrac{A_{st(i,a),r}}{\omega}-2\right)\cdot k_{HT}\cdot\left(R_{st(i,a),r}-R_{st(i,a),av(N_r)}\right)-2\cdot\dfrac{k_{HT}}{\omega}\cdot\left(B_{st(i,a),r}+\dfrac{b_{HT}}{\omega}\right)\cdot\dfrac{R_{st(i,a),r}-R_{s}}{R_{st(i,a),r}\cdot R_{st}}} & \\ \sqrt{\left(c_{a_{st(i,a),av(N_r)}}\right)^2-2\cdot\left(A_{st(i,a),r}\right)^2\cdot\left[\left(R_{st(i,a),r}\right)^2-\left(R_{st(i,a),av(N_r)}\right)^2\right]-4\cdot A_{st(i,a),r}\cdot B_{st(i,a),r}\cdot\ln\left(\dfrac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right)} & \text{if } (a=3) \end{cases}$$

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

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

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

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

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

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

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

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

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

for $r \in 1..N_r$

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

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

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

$$
\begin{pmatrix} c_{u1BHA} & c_{u3BHA} \\ c_{a1BHA} & c_{a3BHA} \\ \alpha_{1BHA} & \alpha_{3BHA} \\ \varepsilon_{BHA} & \varepsilon_{BHA} \end{pmatrix} =
\left|
\begin{array}{l}
\text{for } i \in 1 \\
\quad \text{for } r \in 1..N_r \\
\quad\quad \begin{pmatrix} c_{u1BHA_r} \\ c_{u3BHA_r} \end{pmatrix} = \begin{pmatrix} c_{u1BHA_{av(N_r)}} \\ c_{u_{st(i,1),r}} \end{pmatrix} \\
\quad\quad \begin{pmatrix} c_{a1BHA_r} \\ c_{a3BHA_r} \end{pmatrix} = \begin{pmatrix} c_{a1BHA_{av(N_r)}} \\ c_{a_{st(i,1),r}} \end{pmatrix} \\
\quad\quad \begin{pmatrix} \alpha_{1BHA_r} \\ \alpha_{3BHA_r} \end{pmatrix} = \begin{pmatrix} 90 \cdot {}^{\circ} \\ \alpha_{st(1,1),r} \end{pmatrix} \\
\quad\quad \varepsilon_{BHA_r} = -1 \cdot \left(\alpha_{3BHA_r} - \alpha_{1BHA_r}\right) \\
\begin{pmatrix} c_{u1BHA} & c_{u3BHA} \\ c_{a1BHA} & c_{a3BHA} \\ \alpha_{1BHA} & \alpha_{3BHA} \\ \varepsilon_{BHA} & \varepsilon_{BHA} \end{pmatrix}
\end{array}
\right. \quad \text{if } BHA = 1
$$

$$
\begin{pmatrix} c_{u1CA} & c_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ \alpha_{1CA} & \alpha_{3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{pmatrix} =
\left|
\begin{array}{l}
\text{for } i \in Z \\
\quad \text{for } r \in 1..N_r \\
\quad\quad \begin{pmatrix} c_{u1CA_r} \\ c_{u3CA_r} \end{pmatrix} = \begin{pmatrix} c_{u_{st(i,3),r}} \\ c_{u3CA_{av(N_r)}} \end{pmatrix} \\
\quad\quad \begin{pmatrix} c_{a1CA_r} \\ c_{a3CA_r} \end{pmatrix} = \begin{pmatrix} c_{a_{st(i,3),r}} \\ c_{a3CA_{av(N_r)}} \end{pmatrix} \\
\quad\quad \begin{pmatrix} \alpha_{1CA_r} \\ \alpha_{3CA_r} \end{pmatrix} = \begin{pmatrix} \alpha_{st(i,3),r} \\ 90 \cdot {}^{\circ} \end{pmatrix} \\
\quad\quad \varepsilon_{CA_r} = \left(\alpha_{3CA_r} - \alpha_{1CA_r}\right) \\
\begin{pmatrix} c_{u1CA} & c_{u3CA} \\ c_{a1CA} & c_{a3CA} \\ \alpha_{1CA} & \alpha_{3CA} \\ \varepsilon_{CA} & \varepsilon_{CA} \end{pmatrix}
\end{array}
\right. \quad \text{if } CA = 1
$$

$c_{u1BHA} = \begin{pmatrix} 0.00 \\ 0.00 \end{pmatrix}$

$c_{u1CA} = 0.00$

$c_{u3BHA} = 0.00$

$c_{u3CA} = \begin{pmatrix} 0.00 \\ 44.67 \end{pmatrix}$

$c_{a1BHA} = \begin{pmatrix} 0.00 \\ 83.44 \end{pmatrix}$

$c_{a1CA} = 0.00$

$c_{a3BHA} = 0.00$

$c_{a3CA} = \begin{pmatrix} 0.00 \\ 56.15 \end{pmatrix}$

$\alpha_{1BHA} = 0.00 \cdot ^\circ$

$\alpha_{1CA} = 0.00 \cdot ^\circ$

$\alpha_{3BHA} = 0.00 \cdot ^\circ$

$\alpha_{3CA} = 0.00 \cdot ^\circ$

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

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

Расчет параметров потока по высоте Л

Результаты расчета параметров потока по высоте Л

$T*^T =$

	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	288.2	313.9	313.9	341.4	341.4	361.5	361.5																		
2	288.2	313.9	313.9	341.4	341.4	361.5	361.5																		
3	288.2	313.9	313.9	341.4	341.4	361.5	361.5																		

$T^T =$

	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	284.7	295.0	310.3	322.1	339.0	346.0	358.9																		
2	284.7	299.4	310.3	327.0	339.0	350.4	359.3																		
3	284.7	302.0	310.3	329.7	339.0	352.7	359.4																		

$P*^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	101.3	131.7	131.7	170.8	170.8	202.7	202.7														
2	101.3	131.7	131.7	170.8	170.8	202.7	202.7														
3	101.3	131.7	131.7	170.8	170.8	202.7	202.7														

$\cdot 10^3$

$P^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	97.1	105.9	126.4	139.2	166.5	173.7	197.6														
2	97.1	111.6	126.4	146.7	166.5	181.6	198.3														
3	97.1	115.0	126.4	151.0	166.5	185.8	198.6														

$\cdot 10^3$

$\rho*^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.224	1.461	1.461	1.742	1.742	1.952	1.952														
2	1.224	1.461	1.461	1.742	1.742	1.952	1.952														
3	1.224	1.461	1.461	1.742	1.742	1.952	1.952														

$\rho^T =$

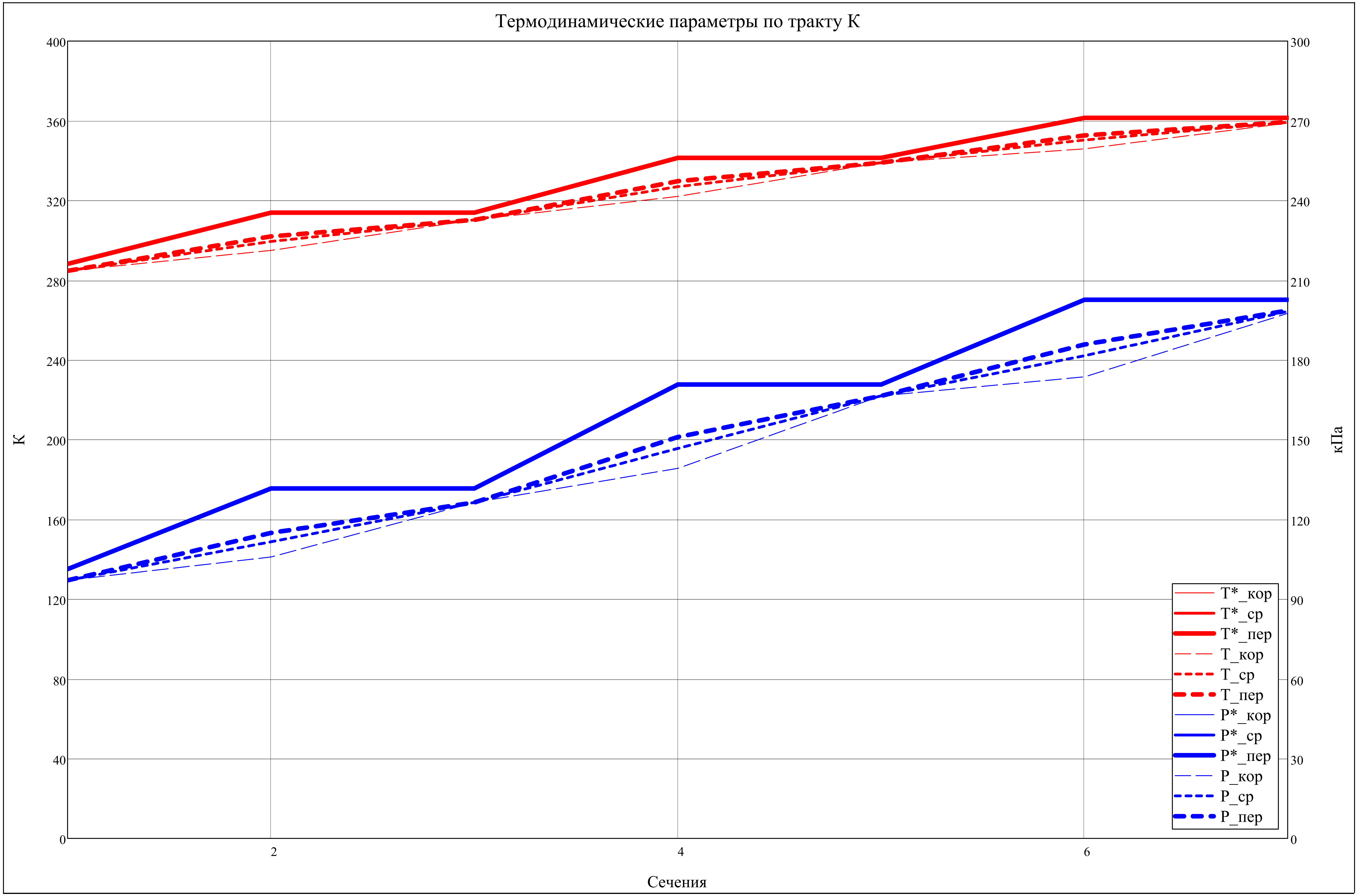
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.188	1.250	1.419	1.505	1.711	1.748	1.917														
2	1.188	1.298	1.419	1.563	1.711	1.805	1.922														
3	1.188	1.326	1.419	1.595	1.711	1.835	1.925														

$Cp^T =$

	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	1003	1004	1004	1006	1006	1009	1009																		
2	1003	1004	1004	1006	1006	1009	1009																		
3	1003	1004	1004	1006	1006	1009	1009																		

$k^T =$

	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	1.401	1.401	1.401	1.399	1.399	1.398	1.398																		
2	1.401	1.401	1.401	1.399	1.399	1.398	1.398																		
3	1.401	1.401	1.401	1.399	1.399	1.398	1.398																		


Термодинамические параметры по тракту К
К
кПа
Сечения
0
40
80
120
160
200
240
280
320
360
400
0
30
60
90
120
150
180
210
240
270
300
2
4
6
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	310.8	324.3	324.3	338.2	338.2	347.9	347.9																		
2	310.8	324.3	324.3	338.2	338.2	347.9	347.9																		
3	310.8	324.3	324.3	338.2	338.2	347.9	347.9																		

$a_{зв}{}^T =$

	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	338.5	344.4	353.2	359.7	369.0	372.7	379.6																		
2	338.5	347.0	353.2	362.4	369.0	375.0	379.8																		
3	338.5	348.5	353.2	363.9	369.0	376.3	379.9																		

$c^T =$

	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	83.4	195.2	85.8	197.3	70.4	177.1	72.6																		
2	83.4	170.6	85.8	170.7	70.4	149.7	67.3																		
3	83.4	154.9	85.8	153.9	70.4	133.4	64.6																		

$w^T =$

	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	228.6	82.0	181.1	69.6	177.1	62.1	140.1																		
2	264.4	123.3	215.7	110.1	213.4	107.3	187.4																		
3	295.8	166.1	246.4	154.0	245.0	153.3	225.8																		

$u^T =$

	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	212.8	213.6	214.4	207.9	201.4	187.7	174.3																		
2	250.8	251.2	251.5	245.5	239.6	227.6	215.9																		
3	283.8	283.8	283.8	278.1	272.5	261.6	250.7																		

$c_a{}^T =$

	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	83.4	74.9	71.1	66.0	61.0	58.6	56.1																		
2	83.4	74.9	71.1	66.0	61.0	58.6	56.1																		
3	83.4	74.9	71.1	66.0	61.0	58.6	56.1																		

$c_u{}^T =$

	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	0.0	180.2	47.9	186.0	35.1	167.1	46.0																		
2	0.0	153.3	47.9	157.4	35.1	137.8	37.1																		
3	0.0	135.6	47.9	139.0	35.1	119.9	32.0																		

$w_u{}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	212.8	33.4	166.5	21.9	166.3	20.6	128.3																		
2	250.8	97.9	203.6	88.1	204.5	89.9	178.8																		
3	283.8	148.2	235.9	139.1	237.3	141.7	218.7																		

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

$\Delta c_a^{\;T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.00	-8.51	-3.78	-5.13	-4.98	-2.44	-2.44														
2	0.00	-8.51	-3.78	-5.13	-4.98	-2.44	-2.44														
3	0.00	-8.51	-3.78	-5.13	-4.98	-2.44	-2.44														

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

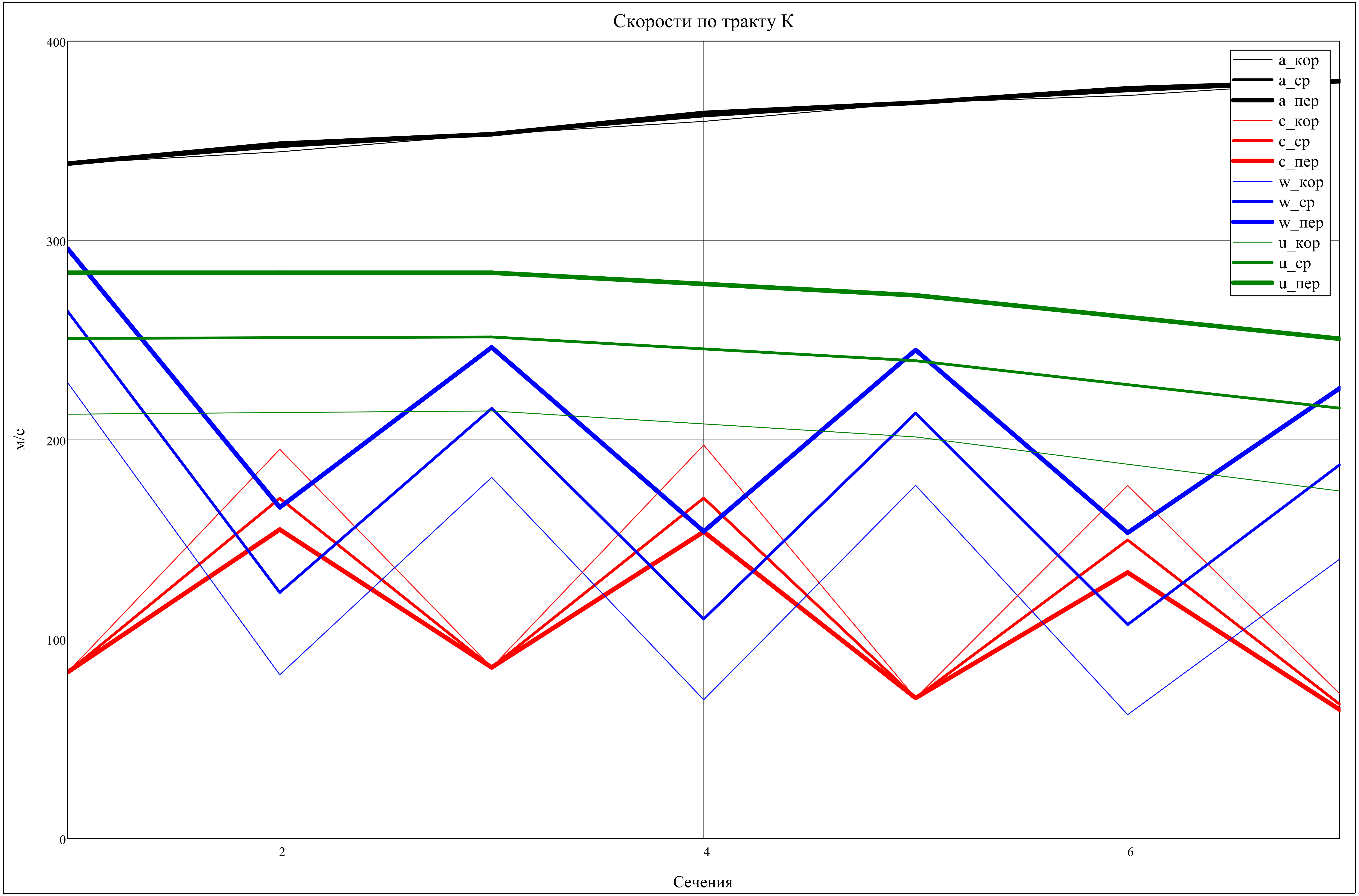
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	1	1	1	1	1	1														
2	1	1	1	1	1	1	1														
3	1	1	1	1	1	1	1														

$R_L^{\;T} =$

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.5774	0.4463	0.4803									
2	0.6947	0.5869	0.6300									
3	0.7611	0.6674	0.7097									

$R_L^{\;T} \geq 0 =$

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



Скорости по тракту К
400
300
200
100
0
м/с
2
4
6
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

$\alpha^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	90.00	22.58	56.05	19.54	60.07	19.32	50.69																		
2	90.00	26.05	56.05	22.75	60.07	23.04	56.54																		
3	90.00	28.92	56.05	25.40	60.07	26.04	60.35																		

$\cdot°$

$\beta^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	21.41	65.96	23.13	71.62	20.15	70.63	23.63														
2	18.40	37.42	19.26	36.84	16.62	33.10	17.44														
3	16.38	26.82	16.78	25.38	14.42	22.47	14.40														

$\cdot°$

$\beta^T \le 91\cdot° =$

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

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

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

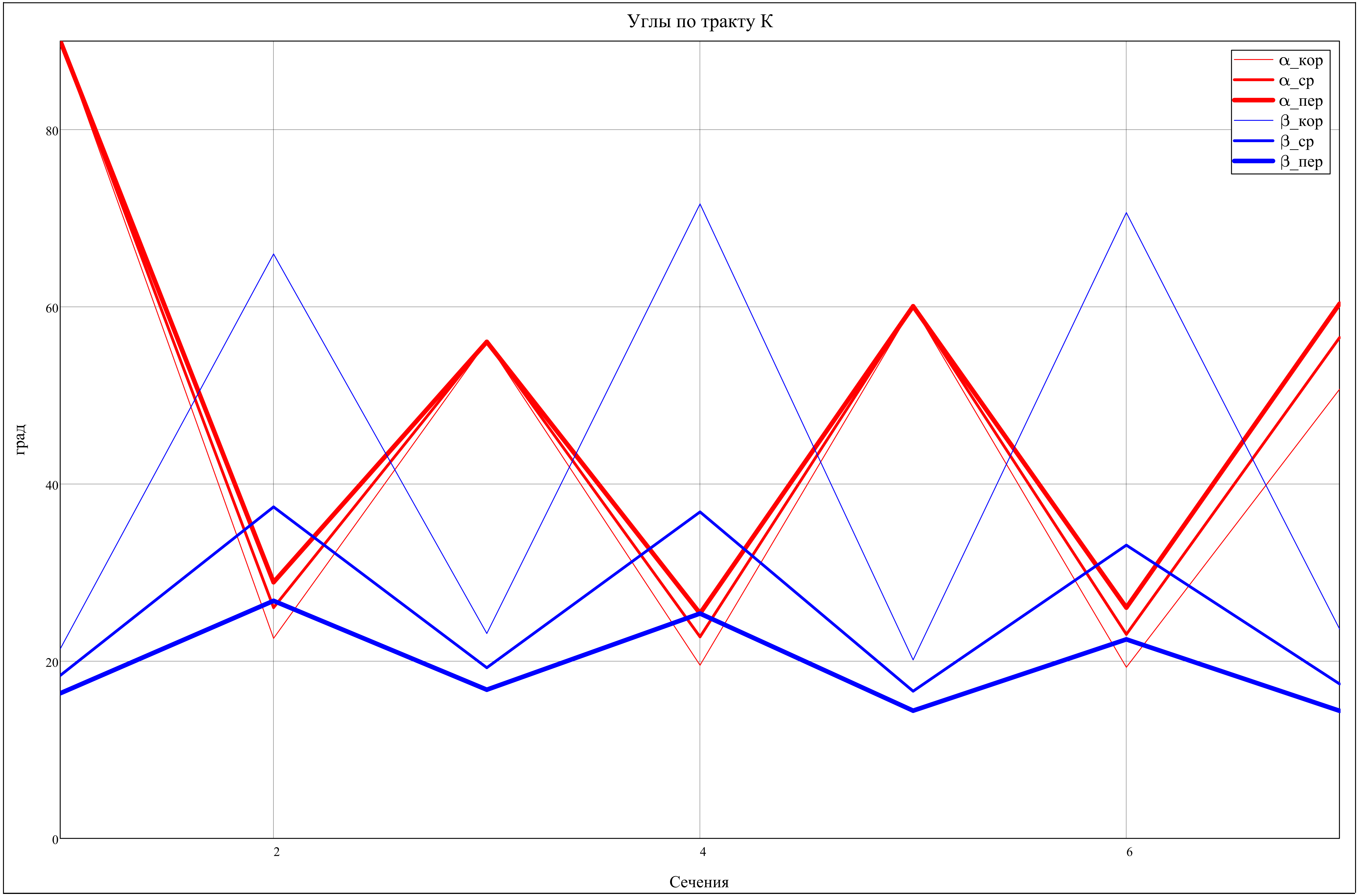
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	44.55	48.48	50.47												
2	19.02	17.59	16.48												
3	10.44	8.60	8.05												

$\cdot°$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	29.12	36.05	31.37												
2	29.99	37.32	33.50												
3	30.26	37.74	34.31												

$\cdot°$


Углы по тракту К
α_кор
α_ср
α_пер
β_кор
β_ср
β_пер
град
0
20
40
60
80
2
4
6
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	0.2685	0.6017	0.2644	0.5835	0.2083	0.5089	0.2086																
2	0.2685	0.5260	0.2644	0.5048	0.2083	0.4303	0.1935																
3	0.2685	0.4778	0.2644	0.4550	0.2083	0.3836	0.1857																

[16, c. 87]

$\lambda_c^T \leq 0.85 =$

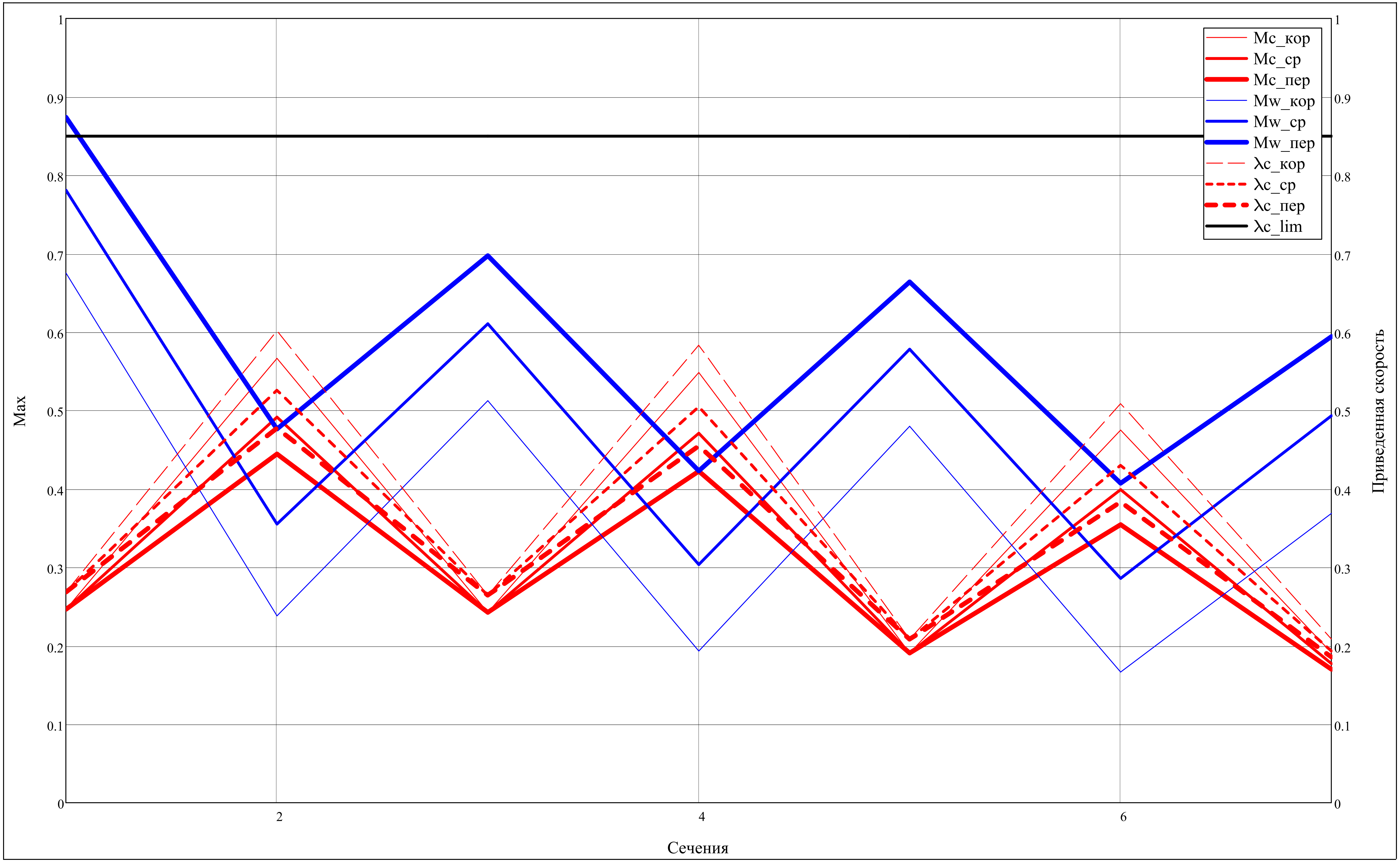
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1	1	1	1	1												
2	1	1	1	1	1	1	1												
3	1	1	1	1	1	1	1												

$M_c^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.2465	0.5666	0.2428	0.5485	0.1908	0.4751	0.1912																
2	0.2465	0.4916	0.2428	0.4710	0.1908	0.3991	0.1772																
3	0.2465	0.4446	0.2428	0.4228	0.1908	0.3546	0.1701																

$M_w^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.6753	0.2382	0.5126	0.1934	0.4800	0.1667	0.3690																
2	0.7810	0.3553	0.6106	0.3037	0.5782	0.2861	0.4934																
3	0.8740	0.4765	0.6976	0.4232	0.6640	0.4075	0.5944																



Результаты расчета параметров потока по высоте Л

Вывод результатов 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

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

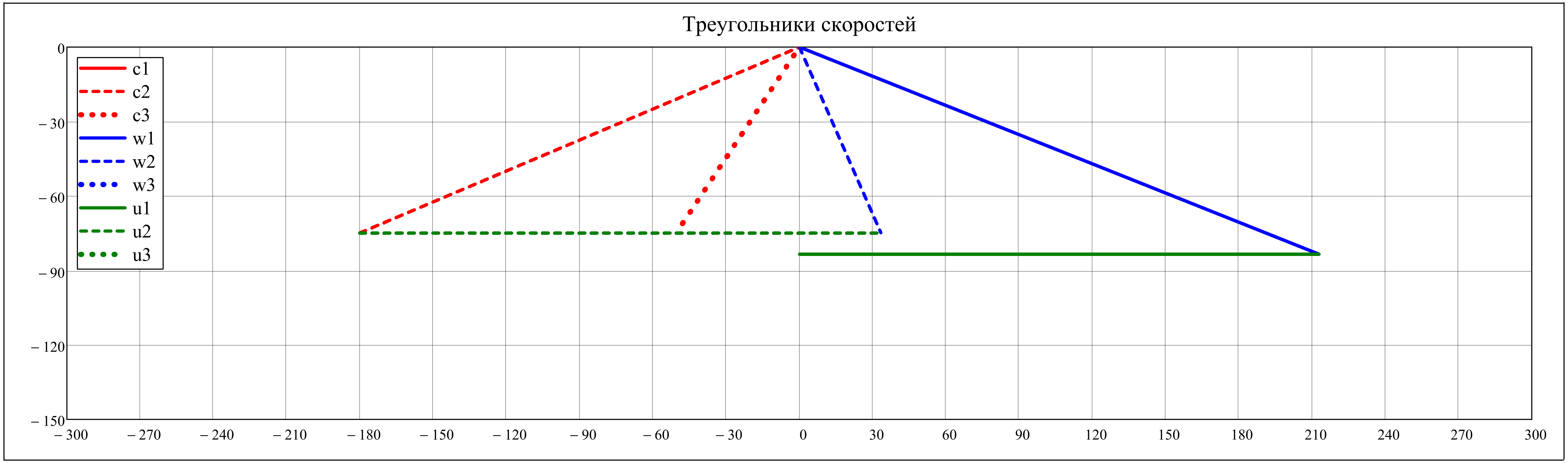
$$\Delta_w(v,i,j,r) = \left| \begin{array}{l} -\tan\left(\beta_{st(i,j),r}\right)\cdot v \quad \text{if } \left(-\tan\left(\beta_{st(i,j),r}\right) \ge 0\right) \wedge \left(-\left|w_{st(i,j),r}\cdot\cos\left(\beta_{st(i,j),r}\right)\right| \le v \le 0\right) \wedge (j \ne 3) \\ -\tan\left(\beta_{st(i,j),r}\right)\cdot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

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

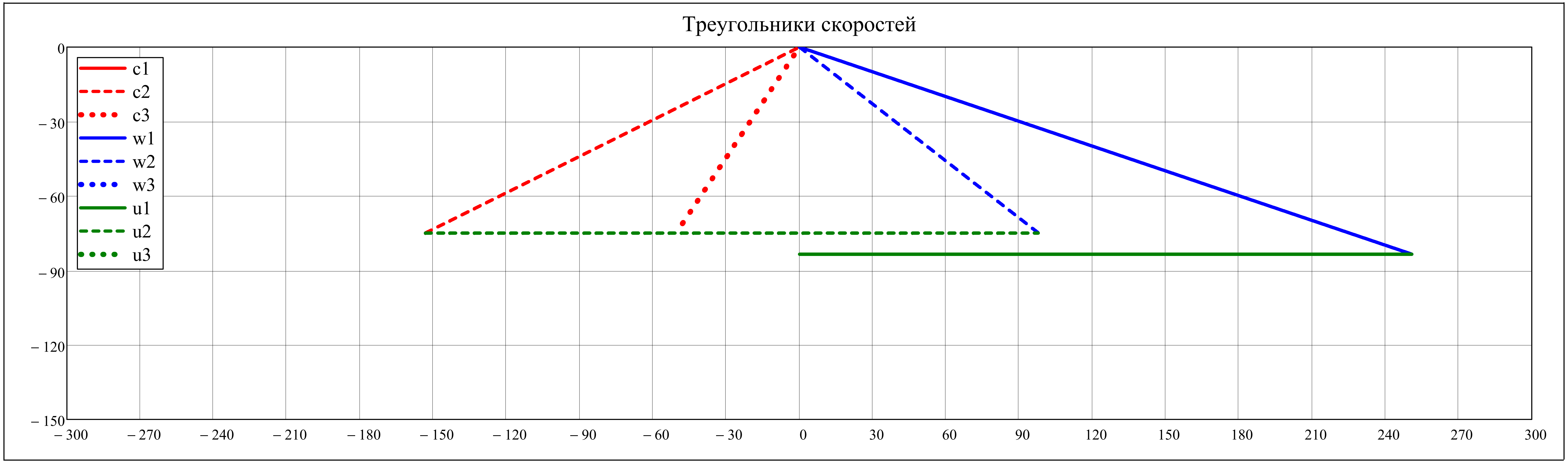
$$v_{lim} = \text{ceil}\left(\frac{\max(c,w,u)}{10^2}\right)\cdot 10^2 = 300$$

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

r = 1

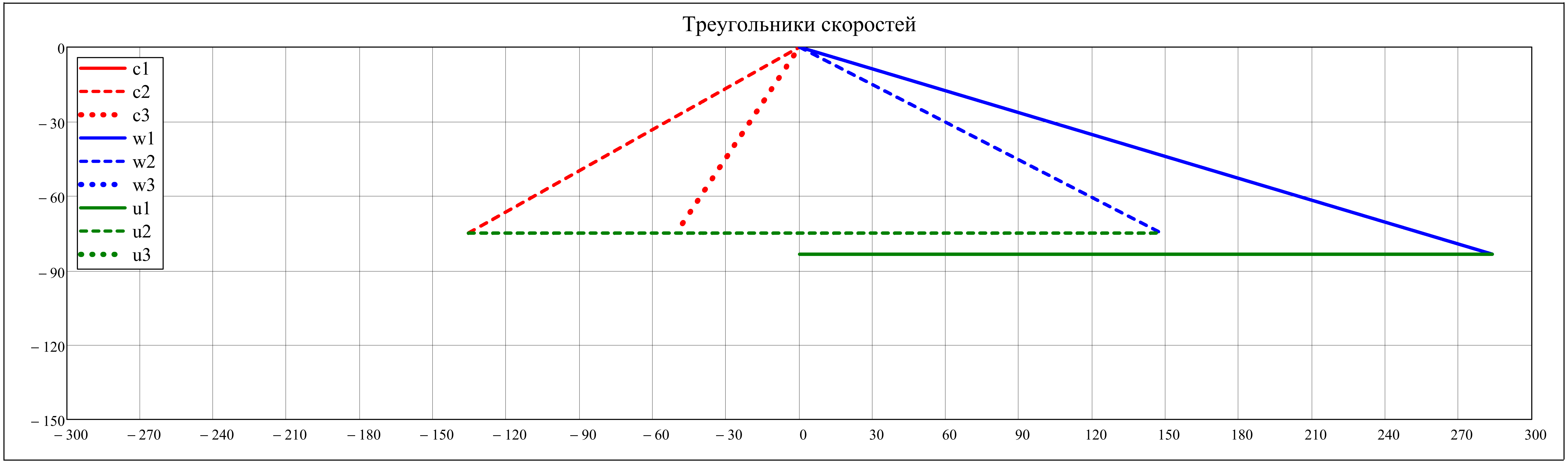

Треугольники скоростей
c1
c2
c3
w1
w2
w3
u1
u2
u3
0
− 30
− 60
− 90
− 120
− 150
− 300
− 270
− 240
− 210
− 180
− 150
− 120
− 90
− 60
− 30
0
30
60
90
120
150
180
210
240
270
300

$r = av(N_r)$



Треугольники скоростей
c1
c2
c3
w1
w2
w3
u1
u2
u3
0
− 30
− 60
− 90
− 120
− 150
− 300
− 270
− 240
− 210
− 180
− 150
− 120
− 90
− 60
− 30
0
30
60
90
120
150
180
210
240
270
300

$r = N_r$



Построение треугольников скоростей в 3х сечениях

Определение степени повышения полного давлеия по 2ум контурам

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

Кольцевые площади (м^2):

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

	1	2	3	4	5	6	7
1	0.0514	0.0509	0.0504	0.0497	0.0490	0.0484	0.0473
2	0.3083	0.3053	0.3023	0.2985	0.2942	0.2902	0.2837
3	0.3596	0.3484	0.3526	0.3476	0.3433	0.3404	0.3310

Радиус и диаметр двухконтурности (м):

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

	1	2	3	4	5	6	7
1	404.2	405.4	406.6	395.2	383.9	360.2	337.1
2	808.4	810.8	813.1	790.3	767.7	720.4	674.3

$\cdot 10^{-3}$

$$
\begin{pmatrix} \pi^*_{II} \\ \pi^*_{I} \end{pmatrix} = \left|
\begin{array}{l}
\text{for } i \in 1..Z \\
\quad \text{for } a \in 1 \\
\quad\quad Cp_{.}(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,a), st(i,a), 1, N_r\right)^T, \text{submatrix}\left(Cp, 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(Cp, st(i,a), st(i,a), 1, N_r\right)^T, z\right) \\
\quad\quad k_{.}(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,a), st(i,a), 1, N_r\right)^T, \text{submatrix}\left(k, 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(k, st(i,a), st(i,a), 1, N_r\right)^T, z\right) \\
\quad\quad T^*_{.}(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,a), st(i,a), 1, N_r\right)^T, \text{submatrix}\left(T^*, 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(T^*, st(i,a), st(i,a), 1, N_r\right)^T, z\right) \\
\quad\quad H_{T.}(z) = \text{interp}\left(\text{lspline}\left(\text{submatrix}\left(R, st(i,a), st(i,a), 1, N_r\right)^T, \text{submatrix}\left(H_T, i, i, 1, N_r\right)^T\right), \text{submatrix}\left(R, st(i,a), st(i,a), 1, N_r\right)^T, \text{submatrix}\left(H_T, i, i, 1, N_r\right)^T, z\right) \\
\quad\quad \pi^*_{II_i} = \left| \begin{array}{l} 1 \quad \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 \quad \text{otherwise} \end{array} \right. \\
\quad\quad \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	1.300	1.297	1.187									
2	1.300	1.297	1.187									

$$\prod_{i=1}^{Z} \pi^*_{I_i} = 2.000 \qquad \prod_{i=1}^{Z} \pi^*_{II_i} = 2.000$$

Определение степени повышения полного давлеия по 2ум контурам

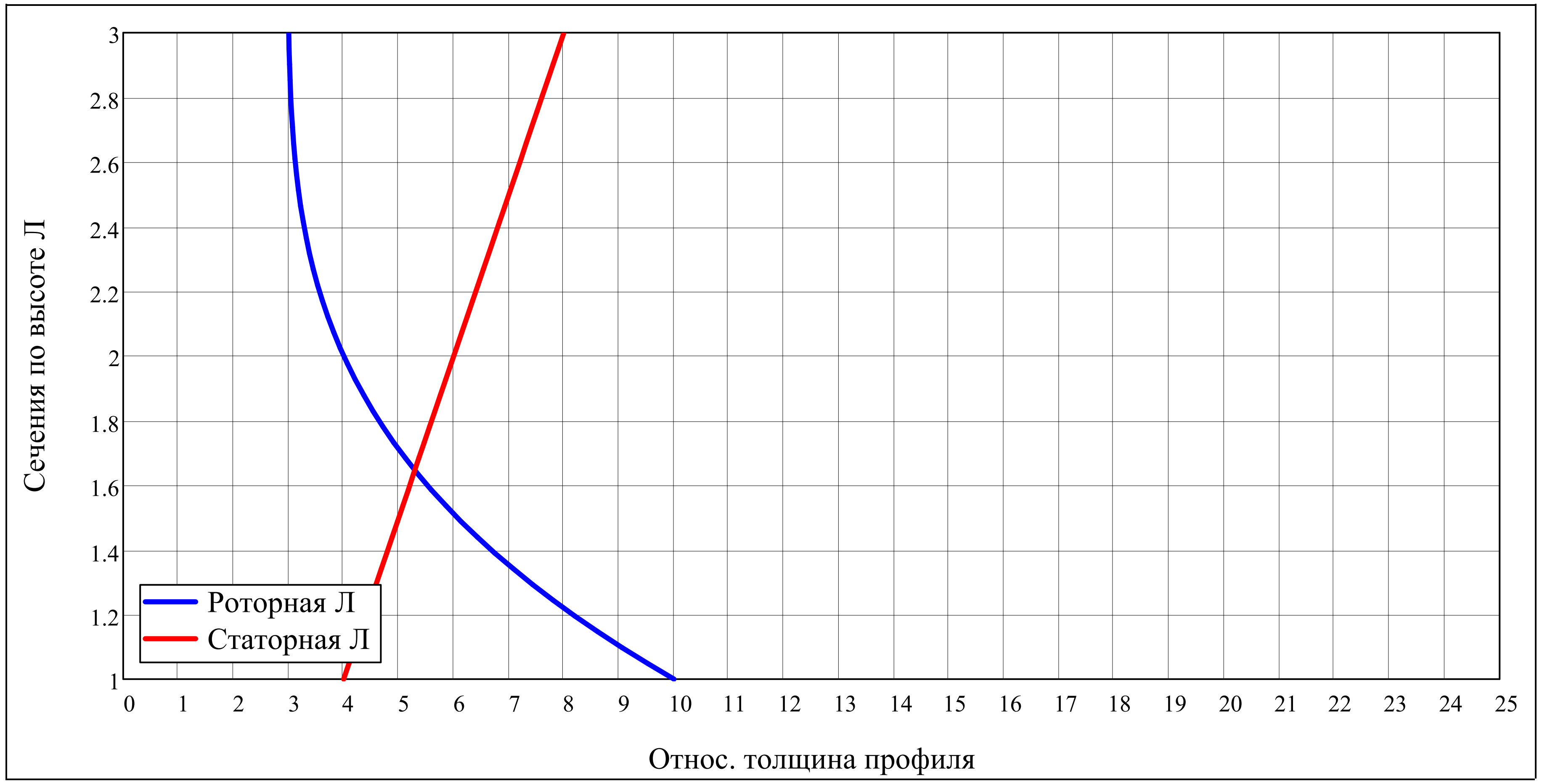
Относ. толщины и радиусы профилей

Относ. толщины Л РК и СА:

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

$$\overline{c}_{stator.}(r) = \mathrm{interp}\left[\mathrm{cspline}\left[\begin{pmatrix}1\\ av(N_r)\\ N_r\end{pmatrix}, \begin{pmatrix}4\\ 6\\ 8\end{pmatrix}\%\right], \begin{pmatrix}1\\ av(N_r)\\ N_r\end{pmatrix}, \begin{pmatrix}4\\ 6\\ 8\end{pmatrix}\%, r\right]$$

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



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

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

	1
1	4.00
2	6.00
3	8.00

$\cdot\%$

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

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

	1	2	3
1	4.00	4.00	4.00
2	6.00	6.00	6.00
3	8.00	8.00	8.00

$\cdot\%$

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

	1	2	3
1	10.00	10.00	10.00
2	4.00	4.00	4.00
3	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	4.00
2	6.00
3	8.00

$\cdot\%$

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

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

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

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

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

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

	1	2	3
1	0.800	0.800	0.800
2	1.200	1.200	1.200
3	1.600	1.600	1.600

$\cdot\%$

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

	1	2	3
1	2.000	2.000	2.000
2	0.800	0.800	0.800
3	0.600	0.600	0.600

$\cdot\%$

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

	1	2	3
1	0.400	0.400	0.400
2	0.600	0.600	0.600
3	0.800	0.800	0.800

$\cdot\%$

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

	1	2	3
1	1.000	1.000	1.000
2	0.400	0.400	0.400
3	0.300	0.300	0.300

$\cdot\%$

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

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

Относ. толщины и радиусы профилей

Распределение параметров по высоте Л

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

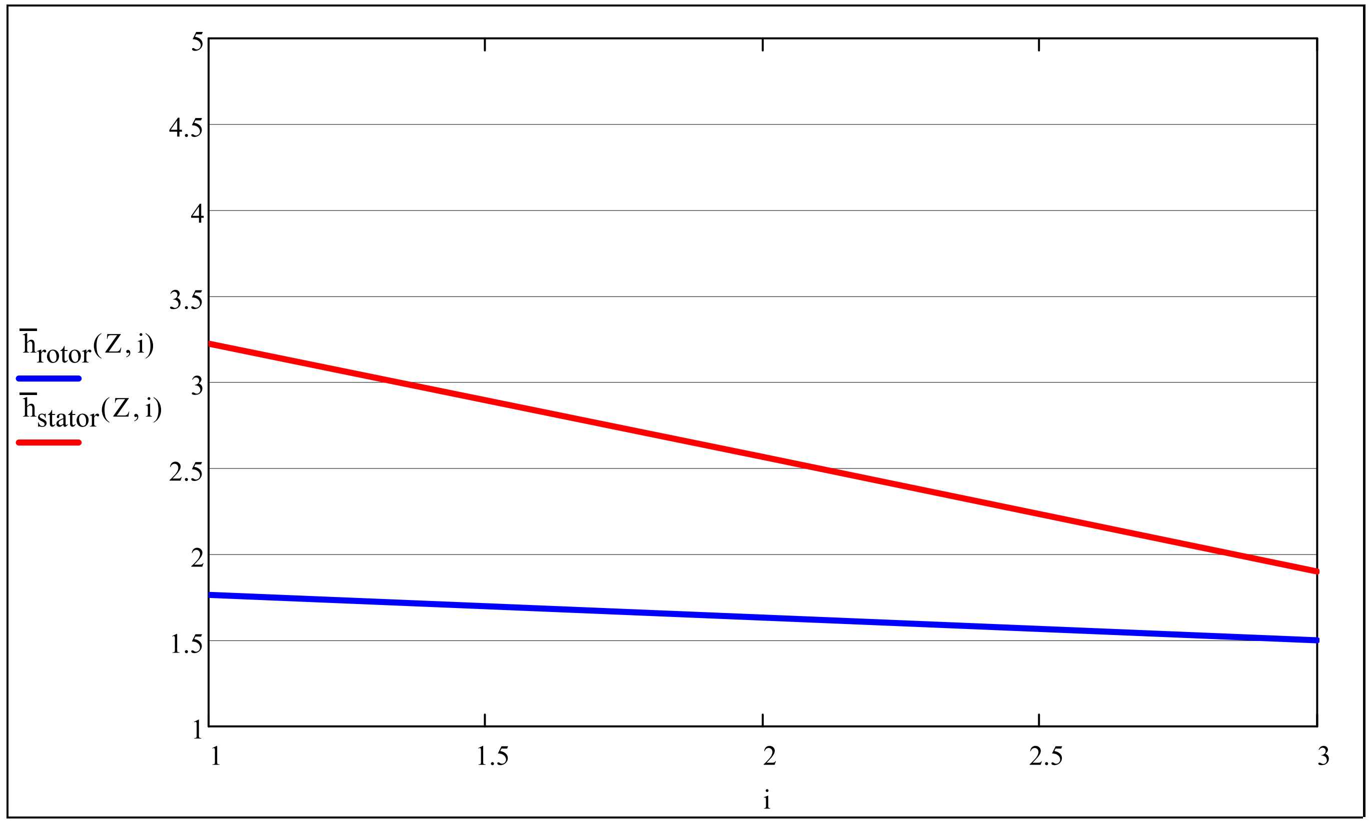
$$\overline{h}_{\sim rotor} = (2\ \ 1.9\ \ 1.85\ \ 1.8\ \ 1.75\ \ 1.7\ \ 1.65\ \ 1.6)^T + \begin{vmatrix} 1.1 \ \text{ if compressor = "Вл"} \\ -0.1 \ \text{ if compressor = "КНД"} \\ -0.55 \ \text{ if compressor = "КВД"} \end{vmatrix}$$

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

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

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

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



Для компрессора газогенератора

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

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

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

$\frac{h_{PK}}{S_{PK}}$=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

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

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

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

Расчет длин хорд по высоте Л

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

$\bar{x}_f = 0.5$

Определение количества Л РК и НА

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

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

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

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

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

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

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

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

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

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

$$
\begin{array}{l}
\text{for } i \in 1..Z \\
\quad \text{for } r \in av\left(N_r\right) \\
\quad\quad \begin{pmatrix} \varepsilon_{PK(b/t)=1_{i,r}} \\ \varepsilon_{HA(b/t)=1_{i,r}} \end{pmatrix} = \begin{pmatrix} \varepsilon_{(b/t)=1}\left(\beta_{st(i,2),r}\right) \\ \varepsilon_{(b/t)=1}\left(\alpha_{st(i,3),r}\right) \end{pmatrix} \\
\quad\quad \begin{pmatrix} b/t_{PK_{i,r}} \\ b/t_{HA_{i,r}} \end{pmatrix} = \begin{pmatrix} b/t{=}1\left(\dfrac{\varepsilon_{rotor_{i,r}}}{\varepsilon_{PK(b/t)=1_{i,r}}}\right) \\ b/t{=}1\left(\dfrac{\varepsilon_{stator_{i,r}}}{\varepsilon_{HA(b/t)=1_{i,r}}}\right) \end{pmatrix} \\
\quad\quad \begin{pmatrix} t_{rotor_{i,r}} \\ t_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \dfrac{chord_{rotor_{i,r}}}{b/t_{PK_{i,r}}} \\ \dfrac{chord_{stator_{i,r}}}{b/t_{HA_{i,r}}} \end{pmatrix} \\
\quad\quad \begin{pmatrix} t_{rotor_{i,r}} \\ t_{stator_{i,r}} \end{pmatrix} = \dfrac{2}{3}\begin{pmatrix} chord_{rotor_{i,r}}\cdot\cos\left(\beta_{st(i,1),r}\right) \\ chord_{stator_{i,r}}\cdot\cos\left(\alpha_{st(i,2),r}\right) \end{pmatrix} \\
\quad\quad Z_{stator_i} = \left| \begin{array}{l} round\left(\dfrac{\pi\cdot mean\left(D_{st(i,2),r}, D_{st(i,3),r}\right)}{t_{stator_{i,r}}}\right) \text{ if } mod\left(round\left(\dfrac{\pi\cdot mean\left(D_{st(i,2),r}, D_{st(i,3),r}\right)}{t_{stator_{i,r}}}\right), 2\right) = 0 \\ round\left(\dfrac{\pi\cdot mean\left(D_{st(i,2),r}, D_{st(i,3),r}\right)}{t_{stator_{i,r}}}\right) + 1 \quad \text{otherwise} \end{array} \right. \\
\quad\quad Z_{rotor_i} = \left| \; Z_{rotor_i} = round\left(\dfrac{\pi\cdot mean\left(D_{st(i,1),r}, D_{st(i,2),r}\right)}{t_{rotor_{i,r}}}\right) \right.
\end{array}
$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\begin{pmatrix} \zeta_{rotor_{i,r}} \\ \zeta_{stator_{i,r}} \end{pmatrix} = \begin{pmatrix} \dfrac{\zeta\text{•}\sin(\beta3)/(2b/t)\ \left(D_{rotor_{i,r}}\right)\cdot 2\cdot\dfrac{chord_{rotor_{i,r}}}{t_{rotor_{i,r}}}}{\sin\left(\beta_{st(i,2),r}\right)} \\ \dfrac{\zeta\text{•}\sin(\beta3)/(2b/t)\ \left(D_{stator_{i,r}}\right)\cdot 2\cdot\dfrac{chord_{stator_{i,r}}}{t_{stator_{i,r}}}}{\sin\left(\alpha_{st(i,3),r}\right)} \end{pmatrix}$$

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

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

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

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

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

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

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

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

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

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

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

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

Определение количества Л РК и НА

Результаты расчета количества Л и параметров решеток РК и НА

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

Длина хорды Л (м):

$chord_{rotor}^{T} =$

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

$\cdot 10^{-3}$

$chord_{stator}^{T} =$

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

$\cdot 10^{-3}$

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

Радисы входных и выходных кромок профилей Л (мм):

$r\_inlet_{BHA} = 0.00 \cdot 10^{-3}$ $r\_outlet_{BHA} = 0.00 \cdot 10^{-3}$

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

	1	2	3
1	1.24	1.33	1.50
2	0.58	0.62	0.70
3	0.48	0.52	0.58

$\cdot 10^{-3}$

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

	1	2	3
1	0.62	0.66	0.75
2	0.29	0.31	0.35
3	0.24	0.26	0.29

$\cdot 10^{-3}$

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

	1	2	3
1	0.28	0.36	0.51
2	0.47	0.59	0.85
3	0.68	0.86	1.23

$\cdot 10^{-3}$

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

	1	2	3
1	0.14	0.18	0.26
2	0.23	0.30	0.43
3	0.34	0.43	0.62

$\cdot 10^{-3}$

$r\_inlet_{CA} = 0.00 \cdot 10^{-3}$ $r\_outlet_{CA} = 0.00 \cdot 10^{-3}$

Угол поворота потока:

$\varepsilon_{BHA(b/t)=1_{av(N_r)}} = ■\cdot°$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	10.13	9.95	8.82												

$\cdot°$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	17.90	19.81	18.16												

$\cdot°$

$\varepsilon_{CA(b/t)=1_{av(N_r)}} = ■\cdot°$

Густота решетки:

$\frac{chord_{BHA}}{t_{BHA}} = ■$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-305.947	-411.265	-1019.428												
2	288.710	387.361	956.340												
3	1.926	2.868	8.574												

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

	1	2	3
1	68.783	90.392	154.460
2	-63.250	-83.302	-143.804
3	8.424	11.159	19.786

$\frac{chord_{CA}}{t_{CA}} = ■$

Количество Л:

$Z_{BHA} = 0$

$Z_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	63	59	49												

$Z_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	122	90	58												

$Z_{CA} = 0$

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

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

$t_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	38.31	40.52	44.95												
2	45.11	47.69	53.98												
3	51.00	53.91	61.69												

$\cdot 10^{-3}$

Шаг решетки (м):

$t_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	19.86	25.74	35.33												
2	23.32	30.51	43.29												
3	26.34	34.63	49.99												

$\cdot 10^{-3}$

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

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

$i_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.552	1.594	1.664												
2	1.495	1.538	1.531												
3	1.457	1.500	1.445												

$\cdot {}^{\circ}$

Угол атаки:

$i_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-0.566	-0.652	-0.450												
2	-0.821	-0.938	-0.885												
3	-0.988	-1.121	-1.142												

$\cdot {}^{\circ}$

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

$m_{BHA} = 0.0000$

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	0.2781	0.2668	0.2687												
2	0.3352	0.3363	0.3438												
3	0.3564	0.3592	0.3651												

$m_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.2979	0.2899	0.3086												
2	0.2979	0.2899	0.2969												
3	0.2979	0.2899	0.2893												

$m_{CA} = 0.0000$

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

Угол изгиба ср. линии профиля:

$\theta_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	55.02	59.24	61.65												
2	23.85	21.82	20.50												
3	12.53	9.91	9.31												

$\cdot {}^\circ$

$\theta_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	38.24	47.04	41.26												
2	40.04	49.52	44.74												
3	40.85	50.64	46.21												

$\cdot {}^\circ$

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

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

Угол отставания:

$$\delta_{rotor}{}^{T} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & 12.017 & 12.349 & 12.837 \\ 2 & 6.324 & 5.775 & 5.549 \\ 3 & 3.549 & 2.816 & 2.704 \end{array} \cdot {}^\circ$$

$$\delta_{stator}{}^{T} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & 8.554 & 10.339 & 9.439 \\ 2 & 9.225 & 11.260 & 10.354 \\ 3 & 9.606 & 11.785 & 10.761 \end{array} \cdot {}^\circ$$

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

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

Угол установки Л:

$$\upsilon_{rotor}{}^{T} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & 50.47 & 54.35 & 52.64 \\ 2 & 31.82 & 31.71 & 28.40 \\ 3 & 24.11 & 23.24 & 20.52 \end{array} \cdot {}^\circ$$

$$\upsilon_{stator}{}^{T} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & 41.13 & 42.41 & 39.50 \\ 2 & 45.25 & 46.57 & 44.52 \\ 3 & 48.36 & 49.61 & 48.01 \end{array} \cdot {}^\circ$$

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

$R_{СЛ.ВНА} = 0.00 \cdot 10^{-3}$

Радиус дуги ср. линии (м):

$R_{СЛ.rotor}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	67.23	67.13	73.07												
2	174.40	203.44	244.59												
3	369.87	499.10	600.03												

$\cdot 10^{-3}$

$R_{СЛ.stator}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	53.77	56.11	91.24												
2	56.95	59.19	93.61												
3	60.56	62.82	98.30												

$\cdot 10^{-3}$

$R_{СЛ.СА} = 0.00 \cdot 10^{-3}$

$K_{ВНА} = 0.0000$

Фактор диффузорности решетки:

$K_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.8980	0.9279	0.9600												
2	0.8980	0.9279	0.9600												
3	0.8980	0.9279	0.9600												

$K_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.9495	0.9246	0.9583												
2	0.9495	0.9246	0.9583												
3	0.9495	0.9246	0.9583												

$K_{СА} = 0.0000$

$D_{BHA} = 0.0000$

Диффузорность решетки:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.8832	0.8596	0.8963												
2	0.7146	0.6554	0.6637												
3	0.5835	0.4977	0.4980												

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.7516	0.8628	0.7781												
2	0.6819	0.8079	0.7546												
3	0.6229	0.7598	0.7293												

$D_{CA} = 0.0000$

$D_{BHA} \le 0.6 = 1$

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

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

[18, с. 71]

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

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

$D_{CA} \le 0.6 = 1$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.2471	0.2242	0.2554												
2	0.2169	0.1822	0.2054												
3	0.1848	0.1445	0.1600												

Коэф. потерь полного давления:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.1990	0.2632	0.2381												
2	0.1492	0.2083	0.1854												
3	0.1170	0.1710	0.1538												

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	5.734	6.291	5.846												
2	6.287	7.441	7.445												
3	6.853	8.446	9.029												

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	6.987	5.575	6.233												
2	8.601	6.664	7.521												
3	10.134	7.700	8.628												

КПД элементарной ступени: $\eta_{stage}{}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	72.26	70.26	70.77												
2	72.36	73.21	72.91												
3	71.67	74.02	73.68												

$\cdot\%$

Результаты расчета количества Л и параметров решеток РК и НА

Вывод параметров решеток

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

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

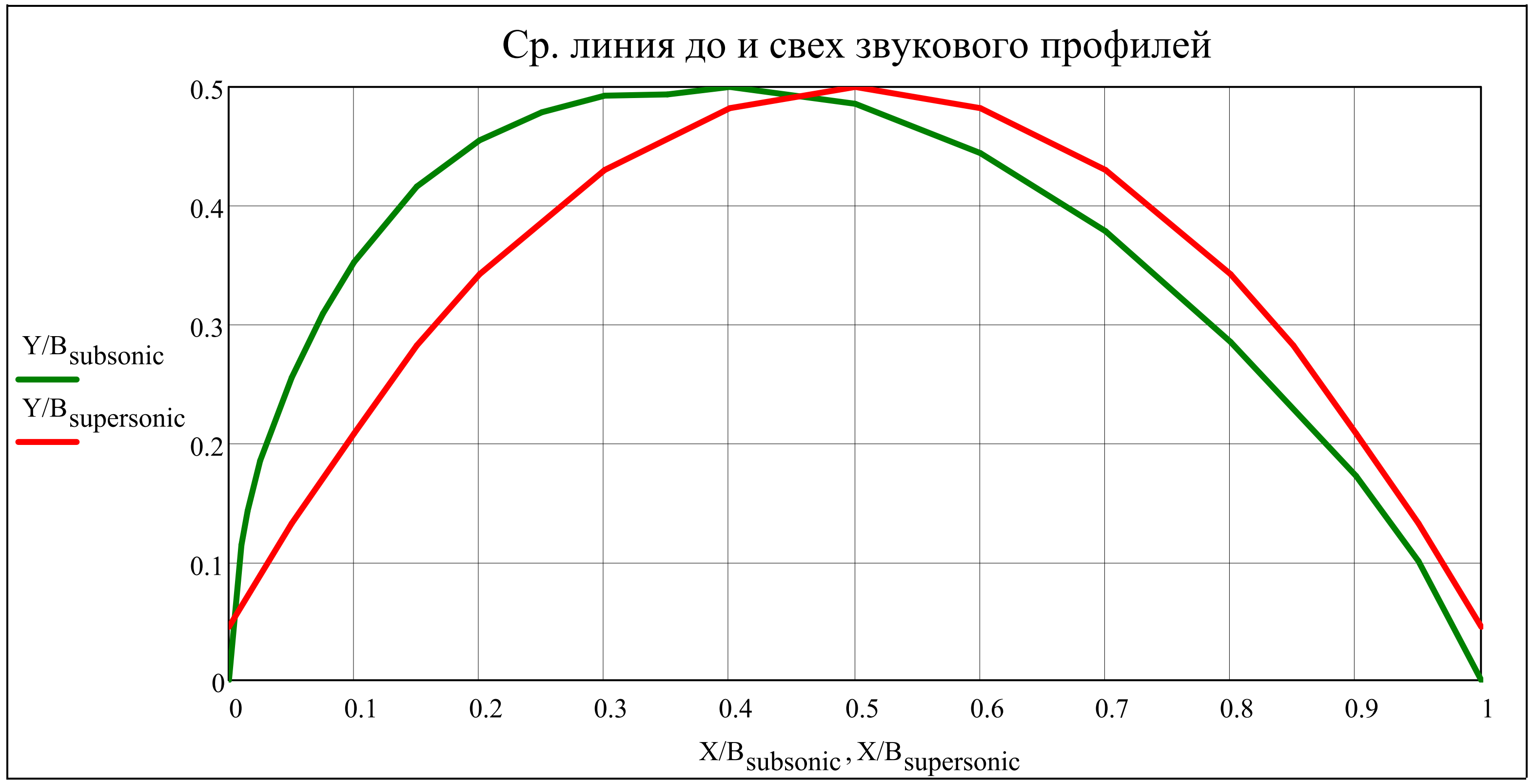
$Y/B_{supersonic} = submatrix(EXCEL_{AIRFOIL.supersonic}, 2, rows(EXCEL_{AIRFOIL.supersonic}), ORIGIN + 1, ORIGIN + 1)$

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

	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

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

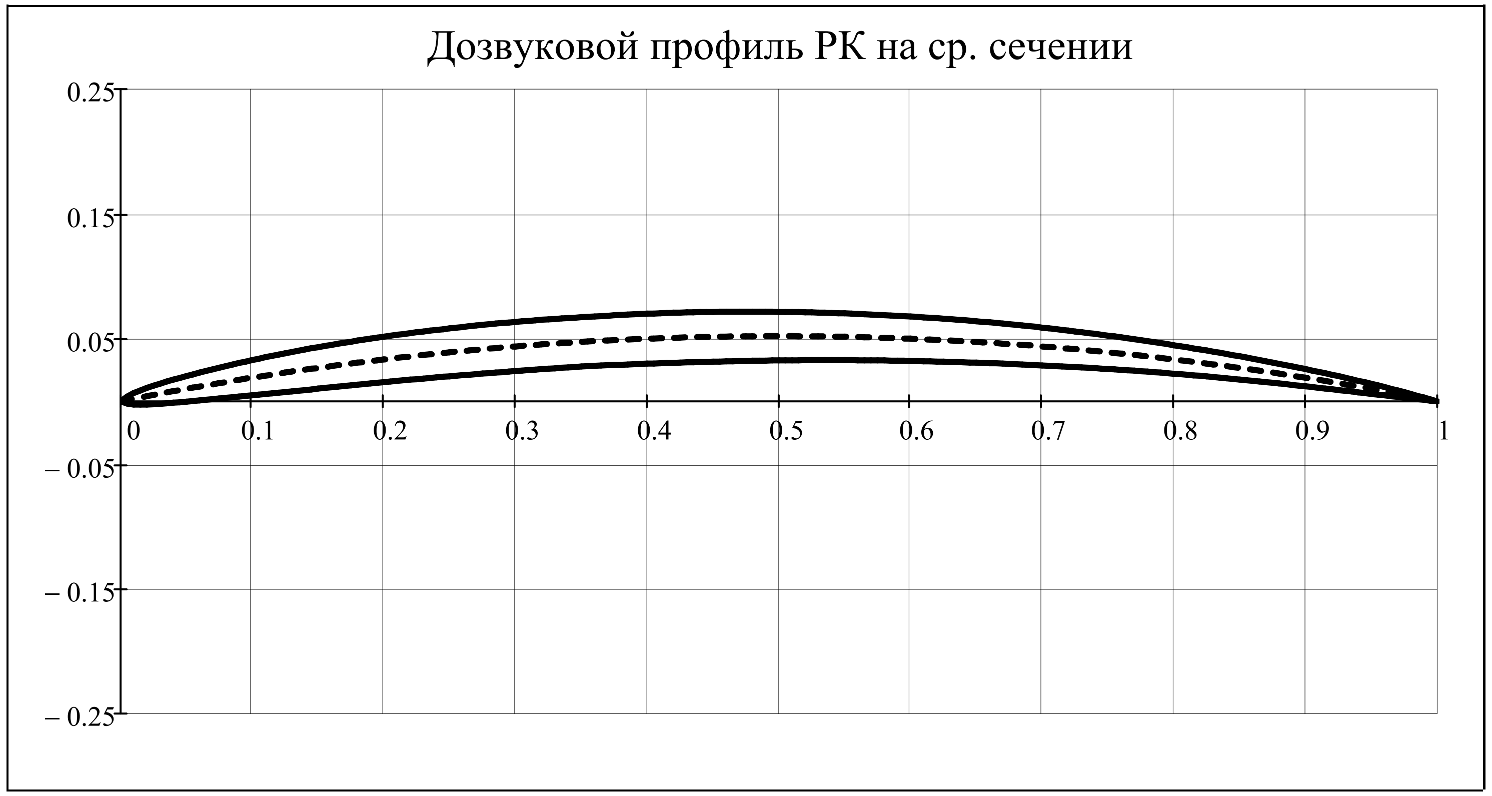
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.000	0.050	0.100	0.150	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.850	0.900	0.950	1.000
2	0.045	0.132	0.208	0.282	0.342	0.430	0.482	0.500	0.482	0.430	0.342	0.282	0.208	0.132	0.045



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

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

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



Подключение симметричного профиля

Определение относительных геометрических характеристик сечений Л

Результат расчета абсолютных геометрических характеристик сечений Л

Определение абсолютных геометрических характеристик сечений Л

Результат расчета абсолютных геометрических характеристик сечений Л

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

	1	2	3
1	35.93	46.01	65.72
2	40.04	51.34	73.44
3	43.69	56.07	80.14

$\cdot 10^{-3}$

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

	1	2	3
1	65.96	70.93	80.31
2	72.89	77.81	87.86
3	81.10	86.58	97.68

$\cdot 10^{-3}$

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

	1	2	3
1	35.42	45.21	64.72
2	39.17	49.99	71.69
3	42.45	54.12	77.59

$\cdot 10^{-3}$

$l\_lower_{rotor}^{T} =$

	1	2	3
1	62.71	67.15	75.88
2	72.20	77.14	87.14
3	80.78	86.30	97.38

$\cdot 10^{-3}$

$area_{stator}^{T} =$

	1	2	3
1	36.30	58.66	120.92
2	66.72	107.87	222.74
3	104.53	168.95	348.25

$\cdot 10^{-6}$

$area_{rotor}^{T} =$

	1	2	3
1	282.07	321.98	410.06
2	151.96	173.54	221.57
3	143.01	163.24	207.90

$\cdot 10^{-6}$

$Sx_{stator}^{T} =$

	1	2	3
1	62.4	159.5	409.6
2	130.9	336.5	893.9
3	224.4	577.8	1550.7

$\cdot 10^{-9}$

$Sx_{rotor}^{T} =$

	1	2	3
1	1323.3	1762.4	2642.1
2	347.8	392.2	530.0
3	200.7	201.6	271.1

$\cdot 10^{-9}$

$Sy_{stator}^{T} =$

	1	2	3
1	577.4	1186.4	3511.0
2	1175.0	2415.3	7167.0
3	1995.5	4100.1	12134.0

$\cdot 10^{-9}$

$Sy_{rotor}^{T} =$

	1	2	3
1	7911.0	9648.4	13867.0
2	4946.1	6036.3	8708.5
3	5214.2	6359.3	9139.7

$\cdot 10^{-9}$

$x0_{stator}^{T} =$

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

$\cdot 10^{-3}$

$x0_{rotor}^{T} =$

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

$\cdot 10^{-3}$

$y0_{stator}^{T} =$

	1	2	3
1	1.72	2.72	3.39
2	1.96	3.12	4.01
3	2.15	3.42	4.45

$\cdot 10^{-3}$

$y0_{rotor}^{T} =$

	1	2	3
1	4.69	5.47	6.44
2	2.29	2.26	2.39
3	1.40	1.23	1.30

$\cdot 10^{-3}$

$Jx_{stator}^{T} =$

	1	2	3
1	122	488	1572
2	304	1210	4186
3	602	2358	8388

$\cdot 10^{-12}$

$Jx_{rotor}^{T} =$

	1	2	3
1	7468	11432	20046
2	952	1075	1557
3	361	340	496

$\cdot 10^{-12}$

$Jy_{stator}^{T} =$

	1	2	3
1	11751	30696	130423
2	26473	69192	295031
3	48737	127306	540911

$\cdot 10^{-12}$

$Jy_{rotor}^{T} =$

	1	2	3
1	283876	369905	599965
2	205969	268621	437896
3	243225	316934	514049

$\cdot 10^{-12}$

$Jxy_{stator}^{T} =$

	1	2	3
1	1033	3353	12363
2	2397	7832	29900
3	4453	14575	56168

$\cdot 10^{-12}$

$Jxy_{rotor}^{T} =$

	1	2	3
1	38570	54877	92836
2	11770	14185	21659
3	7611	8166	12392

$\cdot 10^{-12}$

$Jx0_{stator}^{T} =$

	1	2	3
1	14.96	53.81	184.87
2	47.48	160.40	598.97
3	120.03	382.19	1482.56

$\cdot 10^{-12}$

$Jx0_{rotor}^{T} =$

	1	2	3
1	1259.80	1785.68	3022.44
2	155.78	188.19	289.25
3	79.09	91.28	143.05

$\cdot 10^{-12}$

$Jy0_{stator}^{T} =$

	1	2	3
1	2566	6703	28480
2	5781	15109	64424
3	10644	27803	118130

$\cdot 10^{-12}$

$Jy0_{rotor}^{T} =$

	1	2	3
1	61996	80784	131027
2	44976	58657	95620
3	53111	69207	112249

$\cdot 10^{-12}$

$Jxy0_{stator}^{T} =$

	1	2	3
1	39.38	127.45	471.01
2	91.39	297.46	1137.97
3	169.73	552.57	2136.86

$\cdot 10^{-12}$

$Jxy0_{rotor}^{T} =$

	1	2	3
1	1455.94	2065.59	3488.98
2	450.49	543.14	829.53
3	291.83	313.19	475.31

$\cdot 10^{-12}$

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

	1	2	3
1	0.88	1.10	0.95
2	0.91	1.14	1.02
3	0.92	1.15	1.05

$\cdot \circ$

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

	1	2	3
1	1.37	1.50	1.56
2	0.58	0.53	0.50
3	0.32	0.26	0.24

$\cdot \circ$

$Ju_{stator}{}^{T} =$

	1	2	3
1	14.35	51.37	177.03
2	46.02	154.49	578.69
3	117.29	371.06	1443.42

$\cdot 10^{-12}$

$Jv_{stator}{}^{T} =$

	1	2	3
1	2567	6705	28487
2	5782	15115	64444
3	10646	27814	118170

$\cdot 10^{-12}$

$Juv_{stator}{}^{T} =$

	1	2	3
1	0.00	0.00	0.00
2	-0.00	0.00	0.00
3	-0.00	-0.00	0.00

$\cdot 10^{-12}$

$Jp_{stator}{}^{T} =$

	1	2	3
1	2581	6757	28665
2	5828	15269	65023
3	10764	28185	119613

$\cdot 10^{-12}$

$Wp_{stator}{}^{T} =$

	1	2	3
1	133.1	273.5	809.3
2	271.4	558.0	1655.6
3	462.4	950.1	2811.8

$\cdot 10^{-9}$

$stiffness_{stator}{}^{T} =$

	1	2	3
1	17.53	45.78	194.52
2	88.84	232.19	990.06
3	290.75	759.46	3226.88

$\cdot 10^{-12}$

$Ju_{rotor}{}^{T} =$

	1	2	3
1	1224.92	1731.71	2927.42
2	151.25	183.15	282.03
3	77.48	89.86	141.03

$\cdot 10^{-12}$

$Jv_{rotor}{}^{T} =$

	1	2	3
1	62031	80838	131122
2	44981	58662	95628
3	53113	69208	112251

$\cdot 10^{-12}$

$Juv_{rotor}{}^{T} =$

	1	2	3
1	0.00	0.00	0.00
2	-0.00	0.00	0.00
3	0.00	0.00	0.00

$\cdot 10^{-12}$

$Jp_{rotor}{}^{T} =$

	1	2	3
1	63256	82570	134050
2	45132	58845	95910
3	53190	69298	112393

$\cdot 10^{-12}$

$Wp_{rotor}{}^{T} =$

	1	2	3
1	1840.1	2244.1	3225.2
2	1140.0	1391.3	2007.2
3	1200.9	1464.6	2104.9

$\cdot 10^{-9}$

$stiffness_{rotor}{}^{T} =$

	1	2	3
1	2646.10	3448.00	5592.45
2	307.19	400.64	653.10
3	204.05	265.89	431.26

$\cdot 10^{-12}$

$CPx_{stator}^{T} =$

	1	2	3
1	12.328	15.673	22.502
2	13.648	17.353	24.936
3	14.794	18.807	27.002

$\cdot 10^{-3}$

$CPx_{rotor}^{T} =$

	1	2	3
1	21.736	23.223	26.207
2	25.225	26.956	30.459
3	28.256	30.189	34.069

$\cdot 10^{-3}$

$CPy_{stator}^{T} =$

	1	2	3
1	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000

$\cdot 10^{-3}$

$CPy_{rotor}^{T} =$

	1	2	3
1	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000

$\cdot 10^{-3}$

Результат расчета абсолютных геометрических характеристик сечений Л

Вывод результатов расчета геометрических хар-к сечений Л

Профилирование решеток

Абс. координаты профиля:

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

Профилирование решеток

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

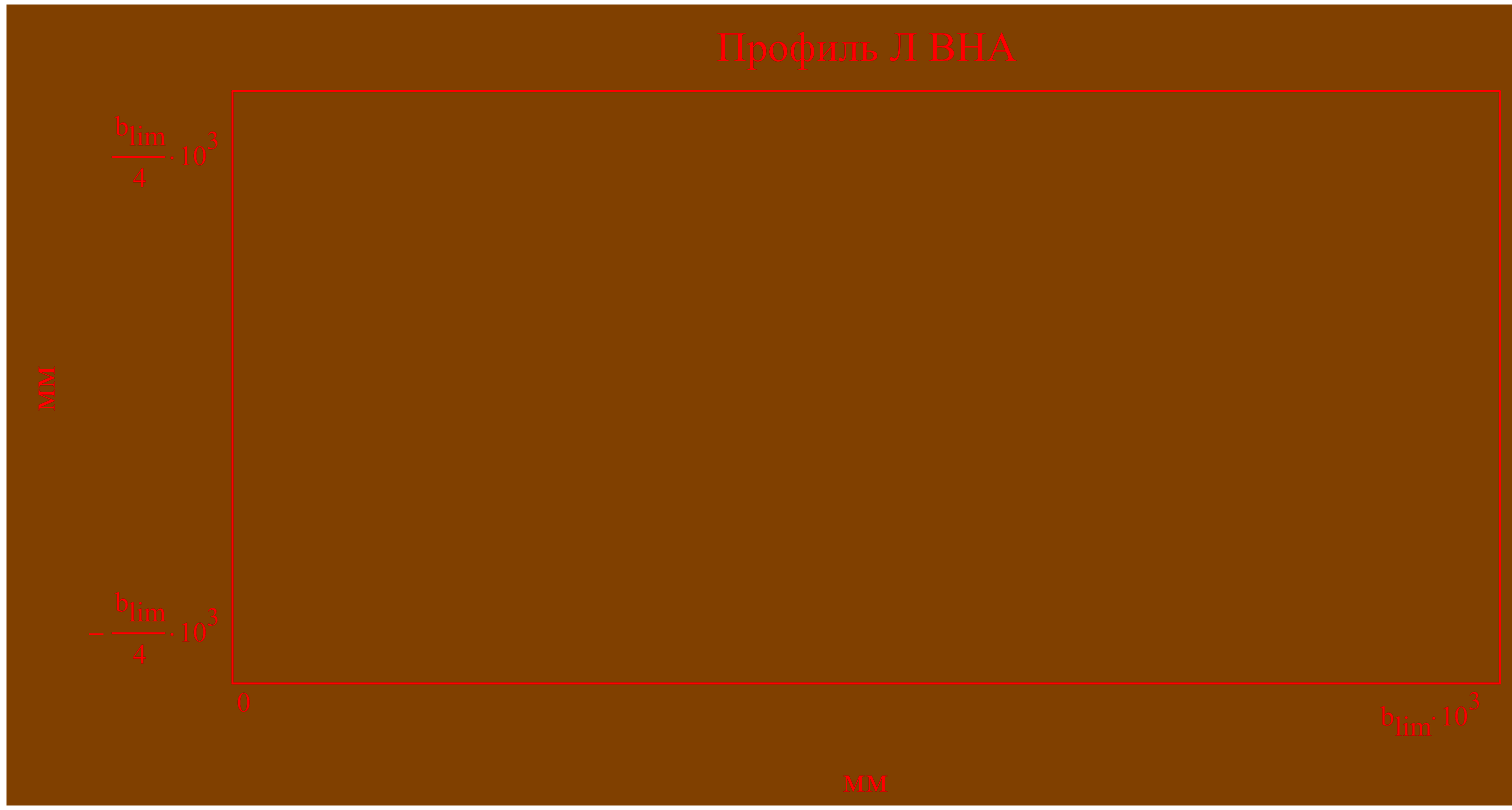
Построение профилей Л РК и НА

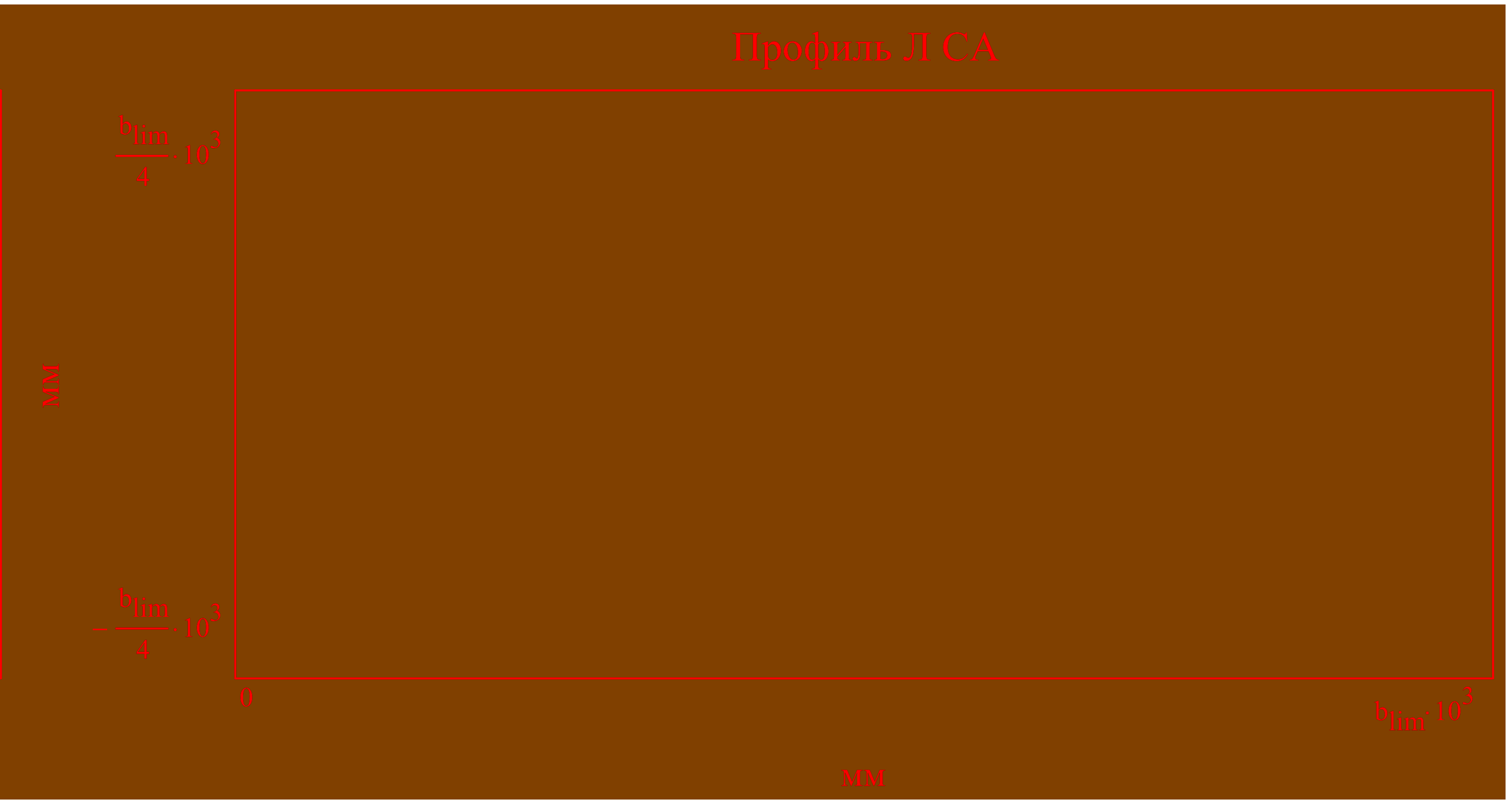
$$AXLE0(type, x, i, r) = \left| \begin{array}{ll} \dfrac{y0rotor_{i,r}}{chord_{rotor_{i,r}}} + \tan\left(\alpha\_major_{rotor_{i,r}}\right)\cdot\left(x - \dfrac{x0rotor_{i,r}}{chord_{rotor_{i,r}}}\right) & \text{if } type = \text{"rotor"} \\ \dfrac{y0stator_{i,r}}{chord_{stator_{i,r}}} + \tan\left(\alpha\_major_{stator_{i,r}}\right)\cdot\left(x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

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

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

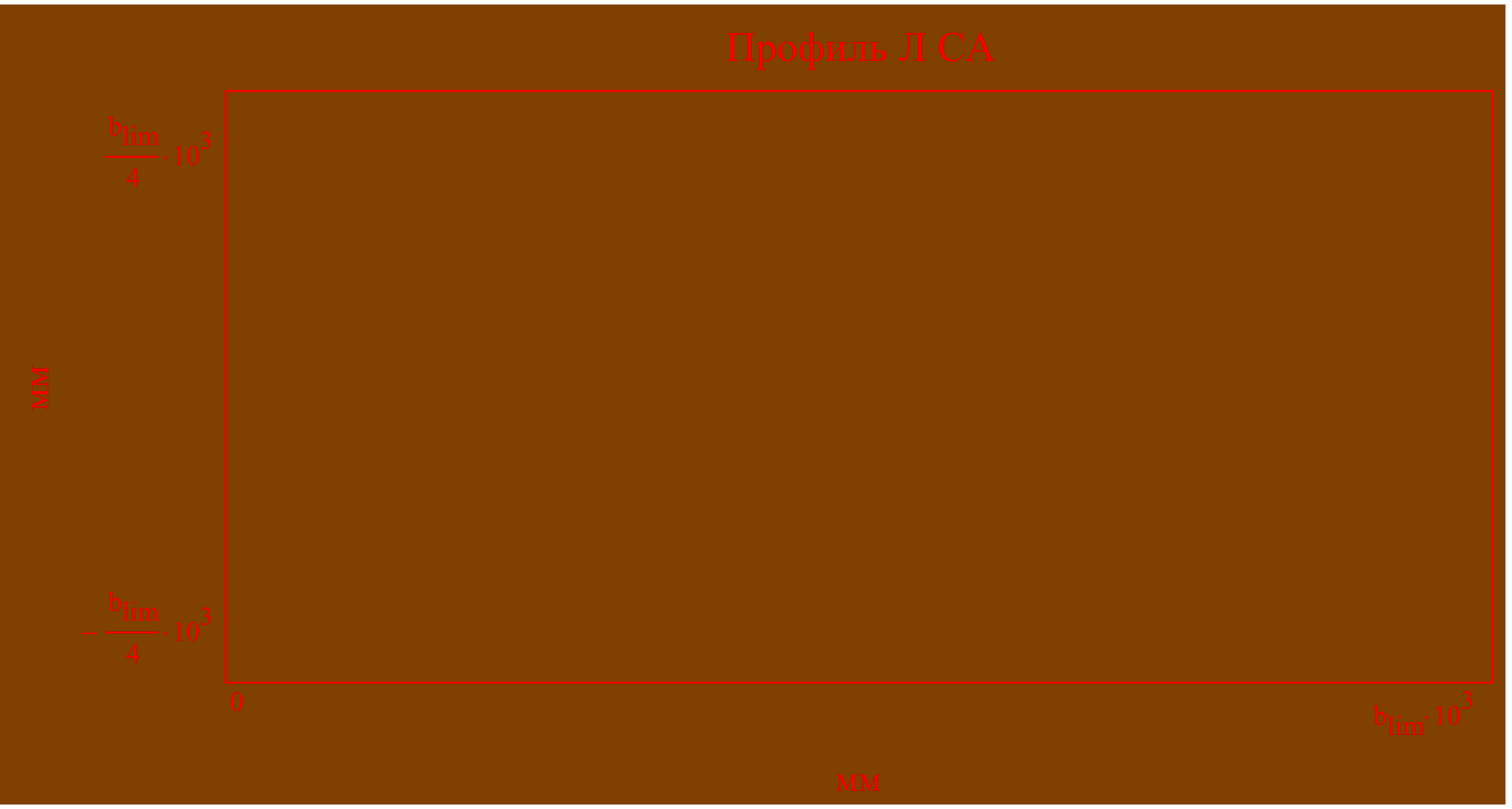
r = 1


Профиль Л ВНА
$\frac{b_{lim}}{4} \cdot 10^3$
$-\frac{b_{lim}}{4} \cdot 10^3$
мм
0
$b_{lim} \cdot 10^3$
мм


Профиль Л СА
$\frac{b_{lim}}{4} \cdot 10^3$
$-\frac{b_{lim}}{4} \cdot 10^3$
мм
0
$b_{lim} \cdot 10^3$
мм

$r = av(N_r)$

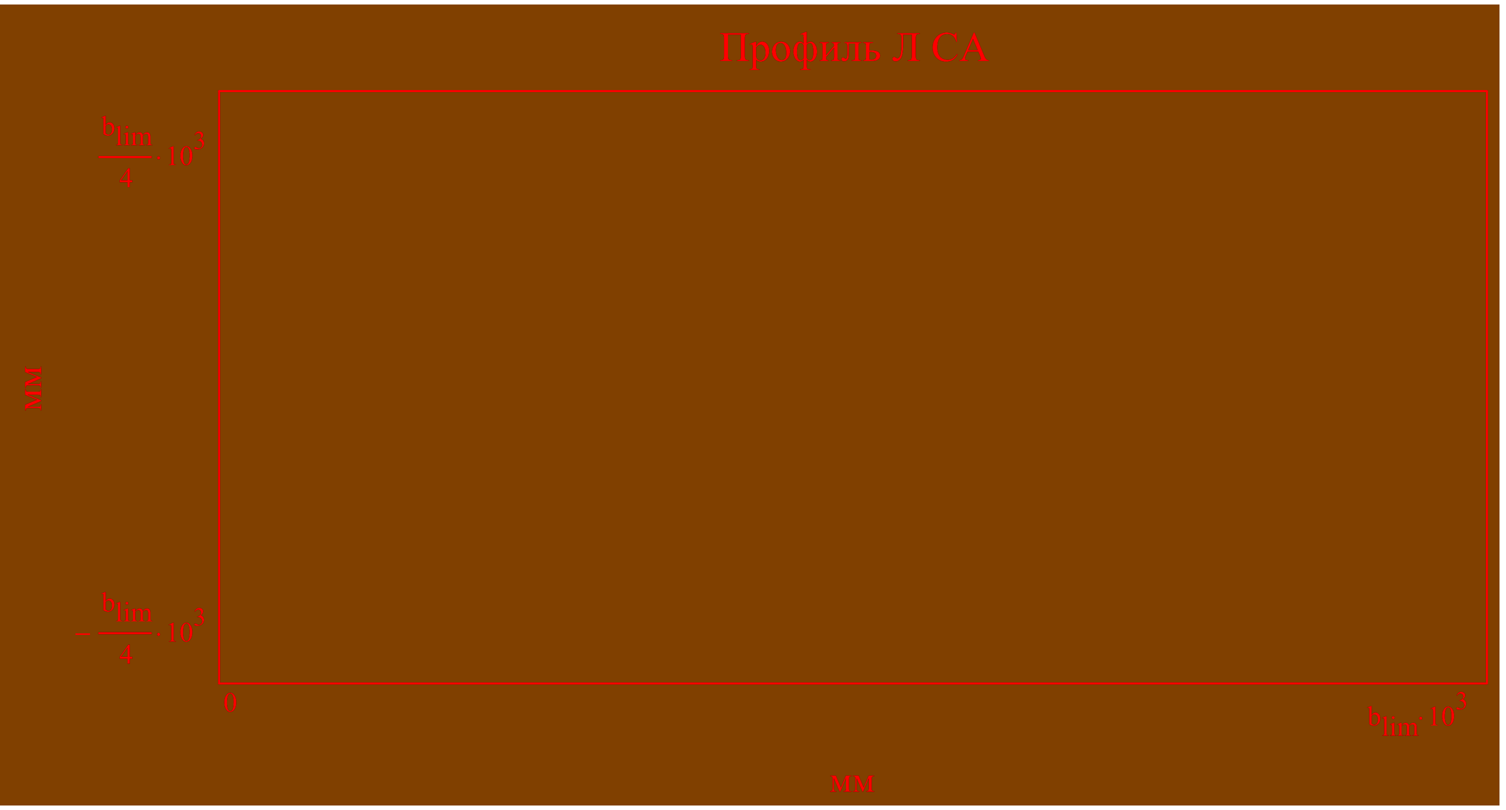
Профиль Л ВНА
$\frac{b_{lim}}{4} \cdot 10^3$
$-\frac{b_{lim}}{4} \cdot 10^3$
мм
0
$b_{lim} \cdot 10^3$
мм



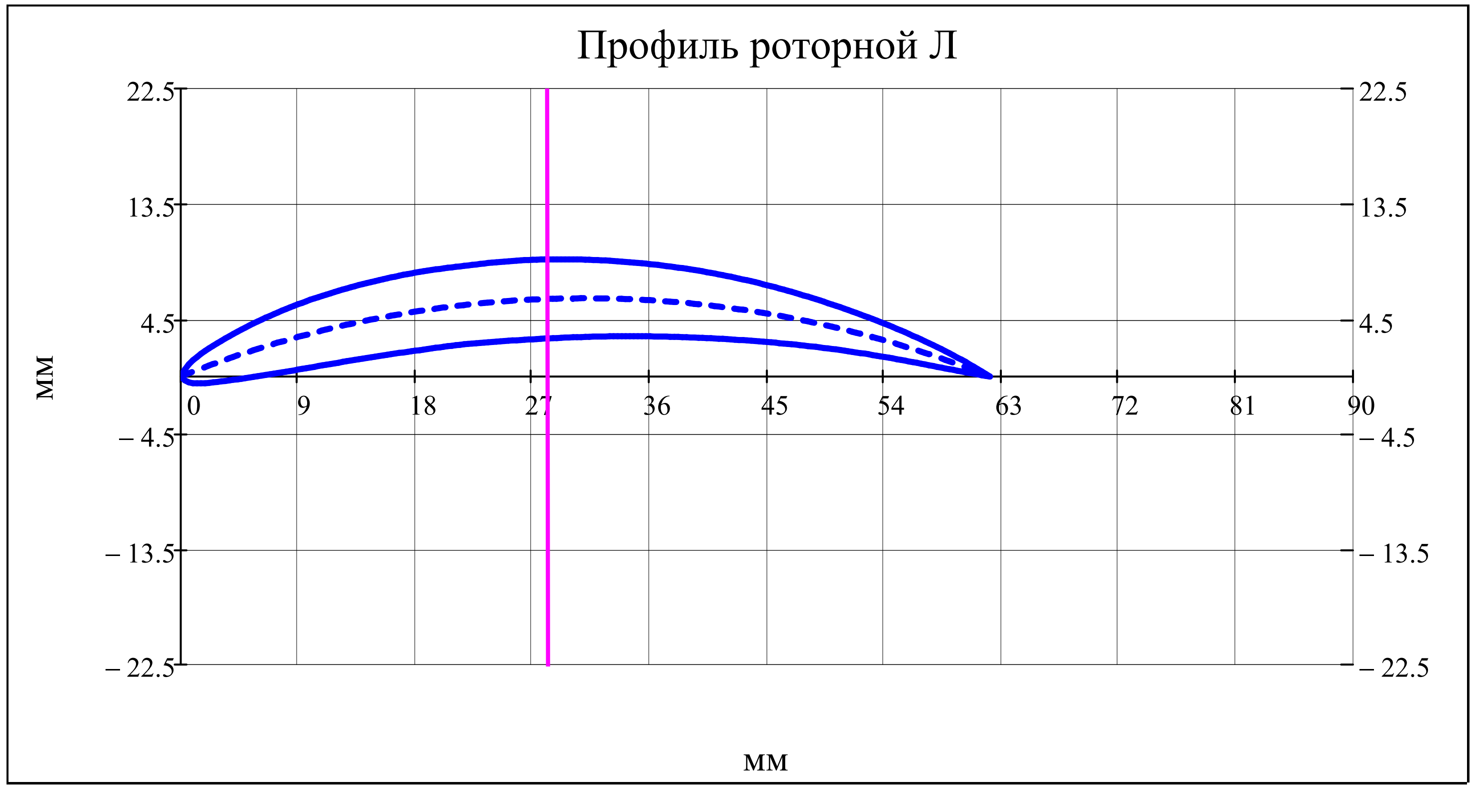
Профиль Л СА
$\frac{b_{lim}}{4} \cdot 10^3$
$-\frac{b_{lim}}{4} \cdot 10^3$
мм
0
$b_{lim} \cdot 10^3$
мм

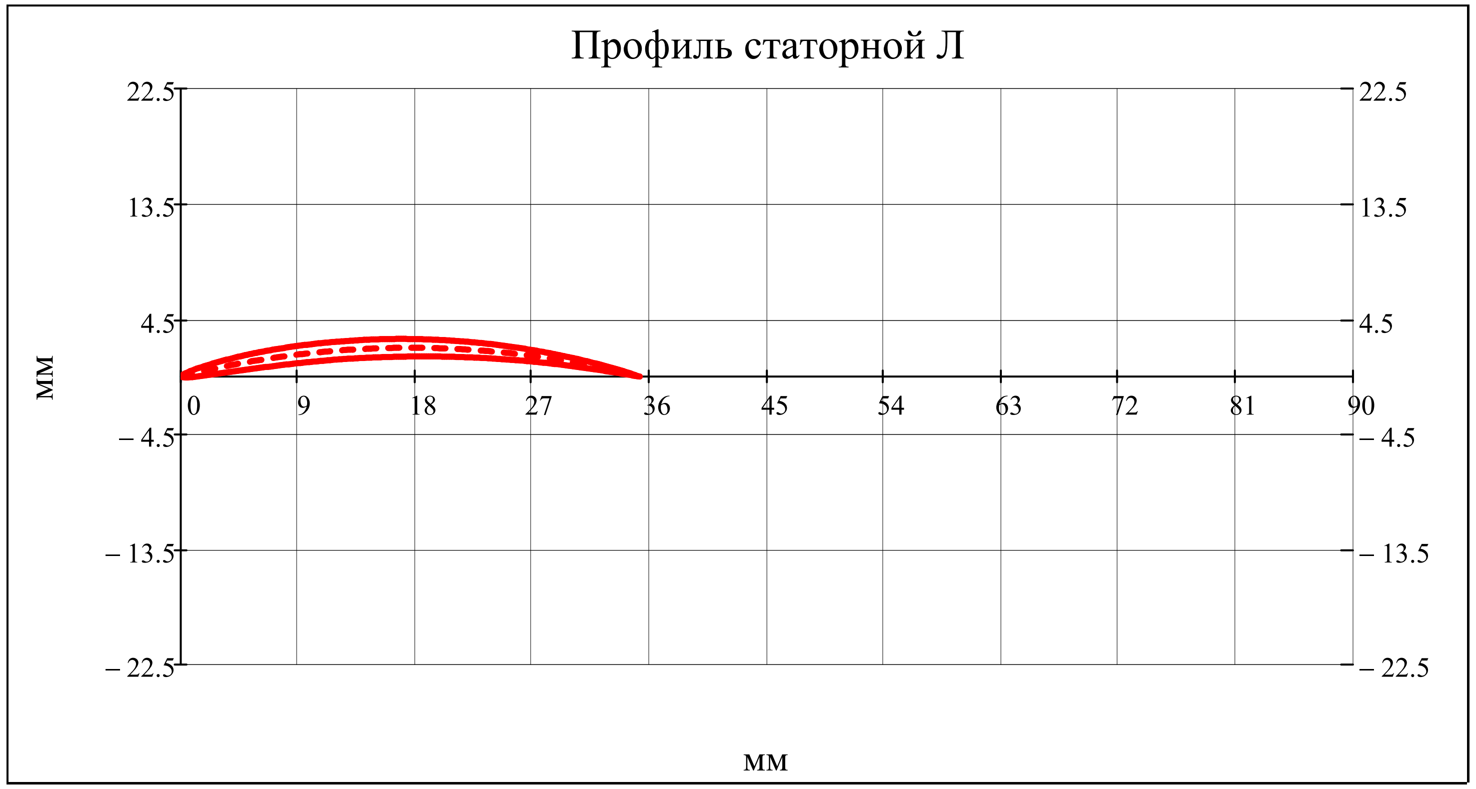
$r = N_r$


Профиль Л ВНА
$\frac{b_{lim}}{4} \cdot 10^3$
$-\frac{b_{lim}}{4} \cdot 10^3$
мм
0
$b_{lim} \cdot 10^3$
мм

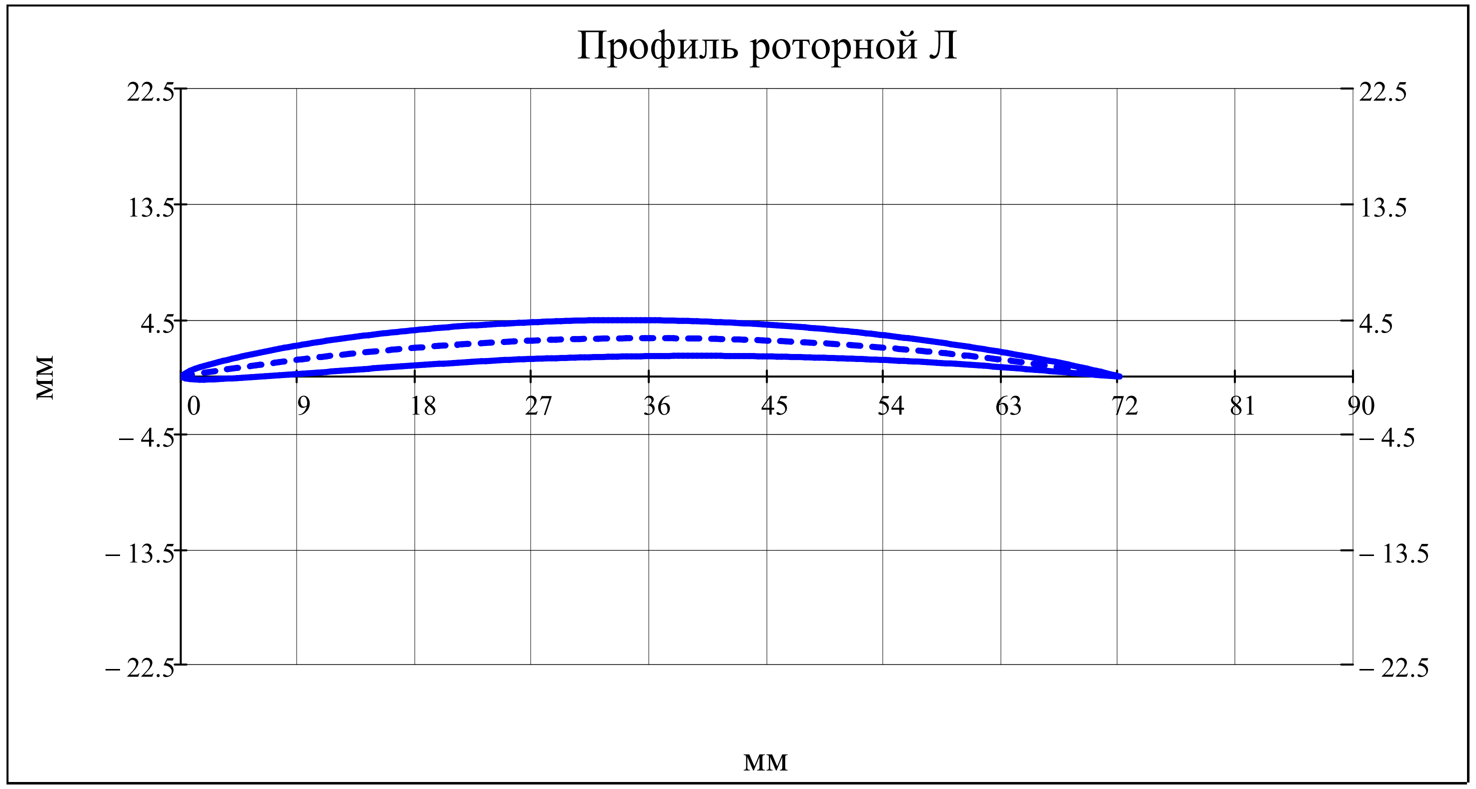

Профиль Л СА
$\frac{b_{lim}}{4} \cdot 10^3$
$-\frac{b_{lim}}{4} \cdot 10^3$
мм
0
$b_{lim} \cdot 10^3$
мм

r = 1

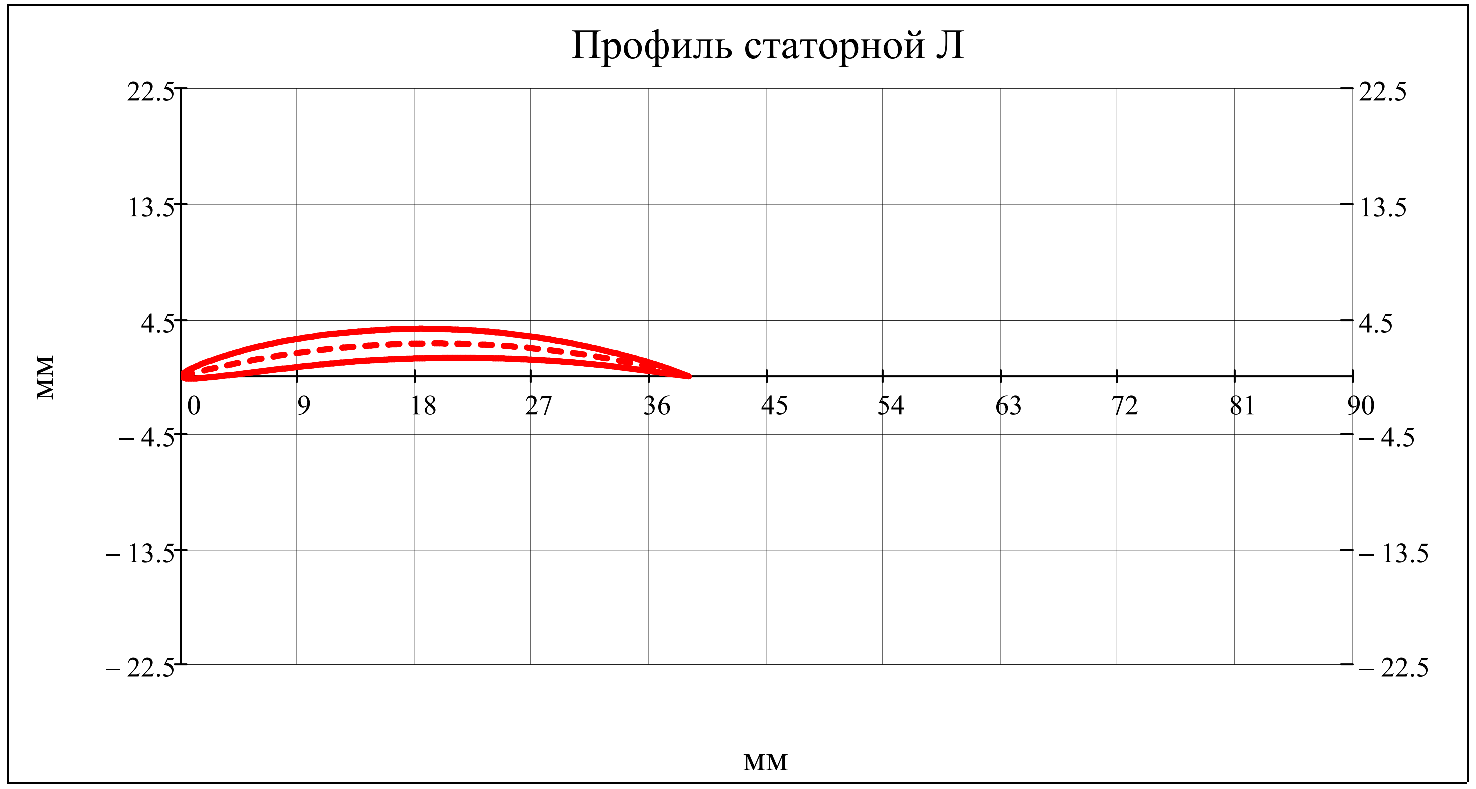

Профиль роторной Л
22.5
13.5
4.5
− 4.5
− 13.5
− 22.5
0
9
18
27
36
45
54
63
72
81
90
мм
мм


Профиль статорной Л
22.5
13.5
4.5
− 4.5
− 13.5
− 22.5
0
9
18
27
36
45
54
63
72
81
90
мм
мм

$r = av(N_r)$

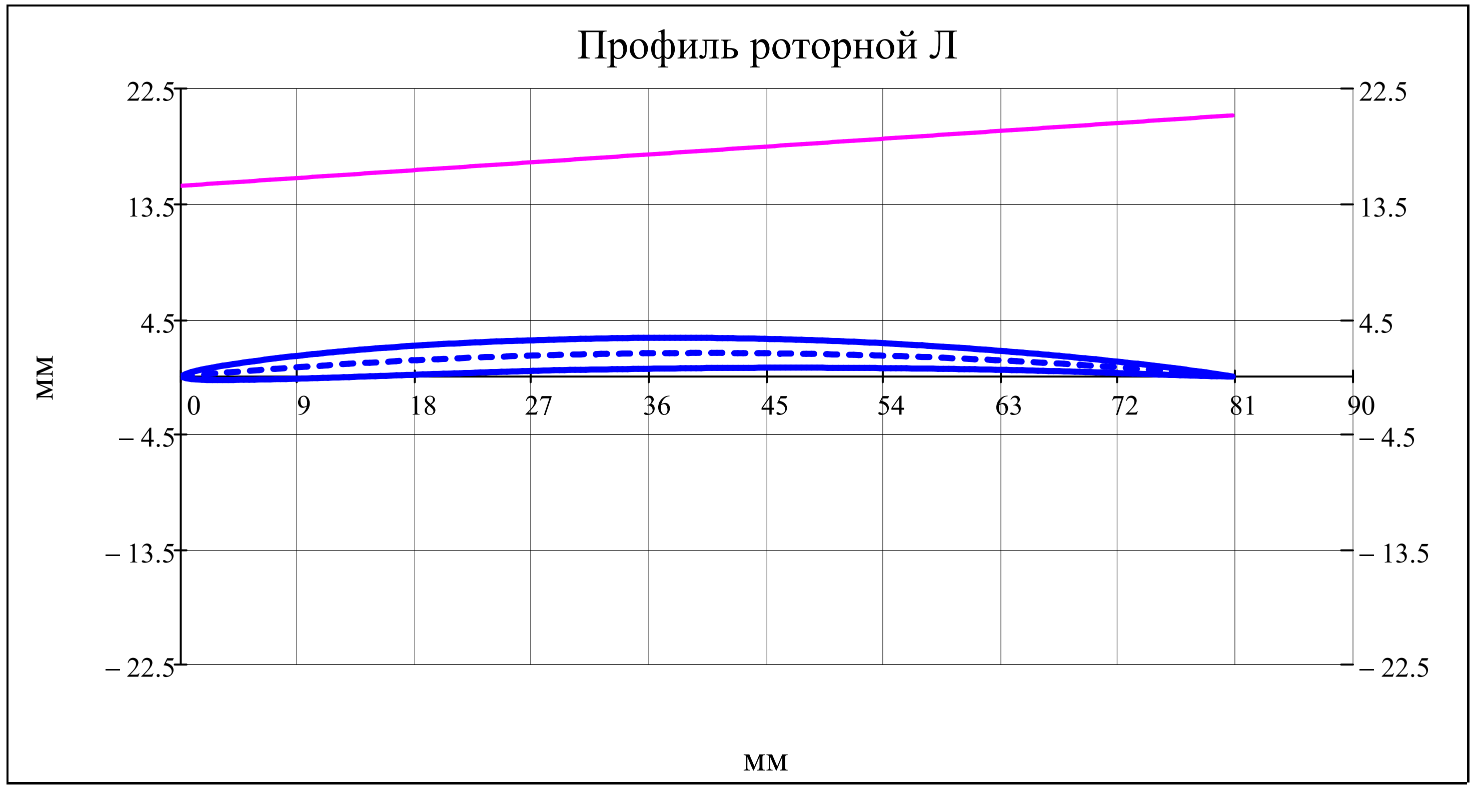


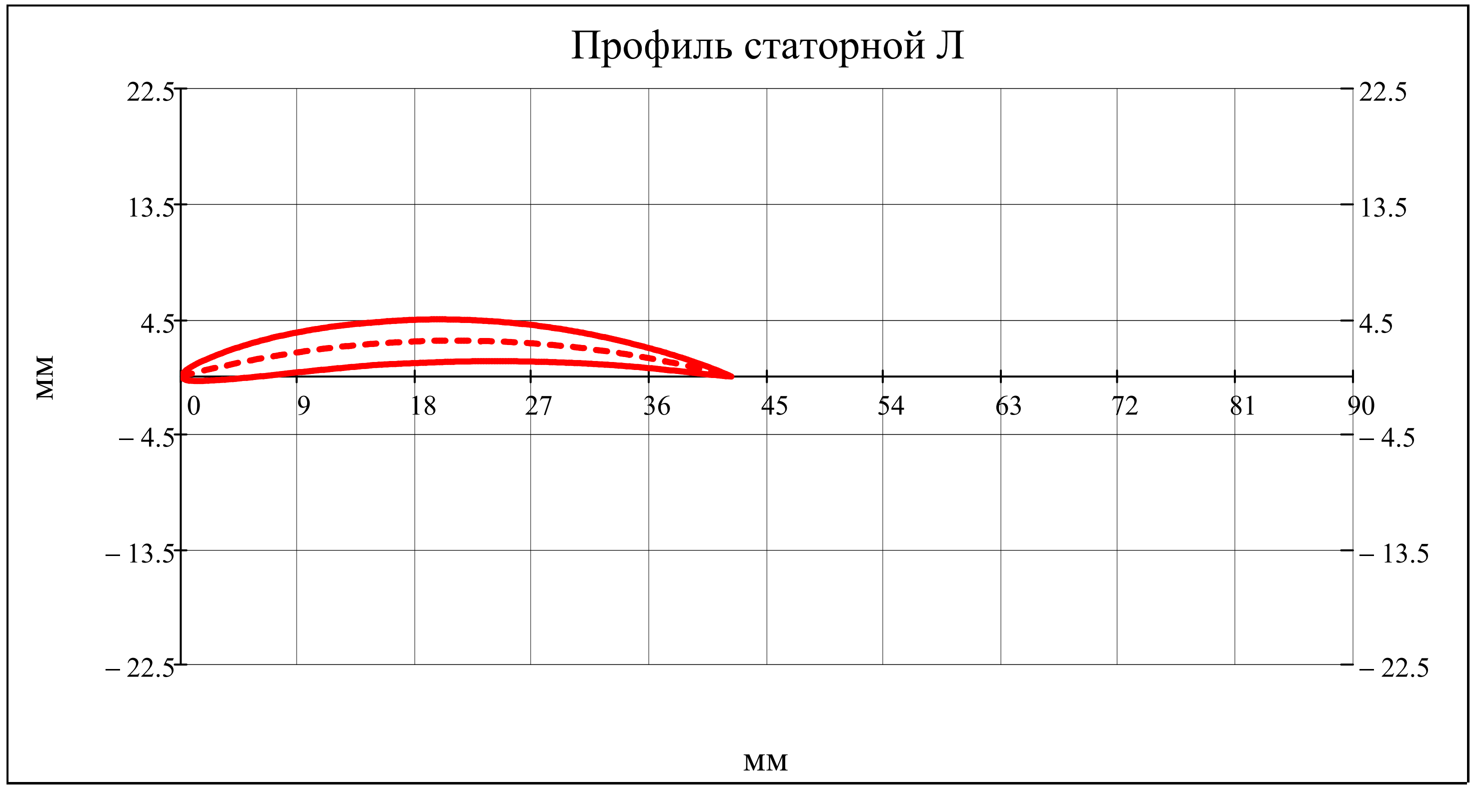
Профиль роторной Л
22.5
13.5
4.5
– 4.5
– 13.5
– 22.5
0
9
18
27
36
45
54
63
72
81
90
мм
мм



Профиль статорной Л
22.5
13.5
4.5
– 4.5
– 13.5
– 22.5
0
9
18
27
36
45
54
63
72
81
90
мм
мм

$r = N_r$





Построение профилей Л РК и НА

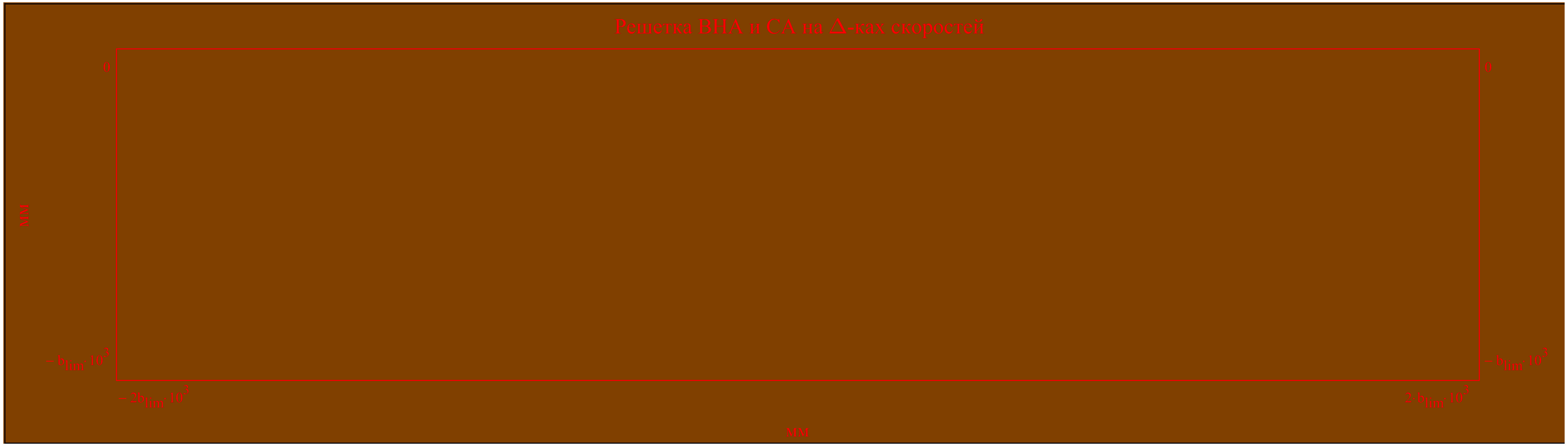
Вывод координат для построения профиля Л

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

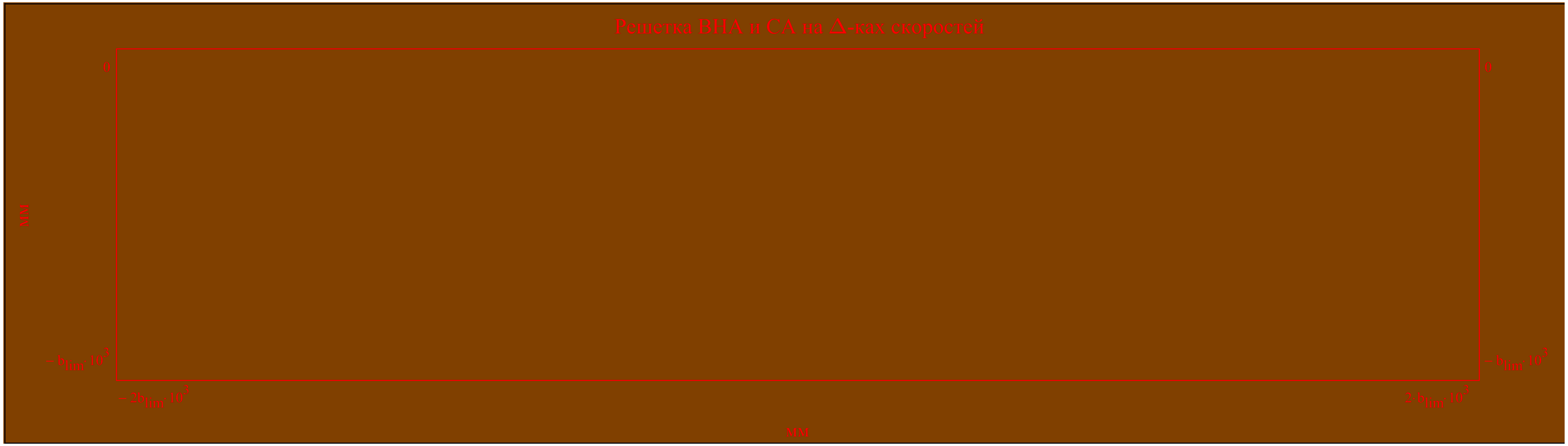
$$b_{lim} := \frac{\mathrm{ceil}\left(\max\left(\mathrm{chord}_{rotor_{j,N_r}}, \mathrm{chord}_{stator_{j,N_r}}\right)\cdot 10^2\right)}{10^2} = 90\cdot 10^{-3}$$

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

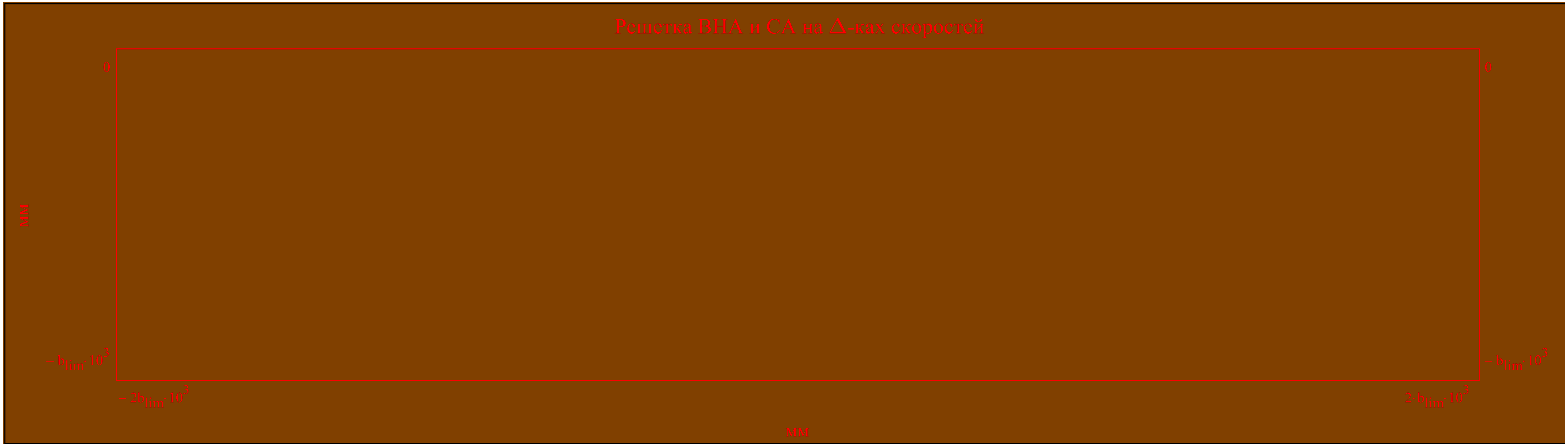
$r := 1$



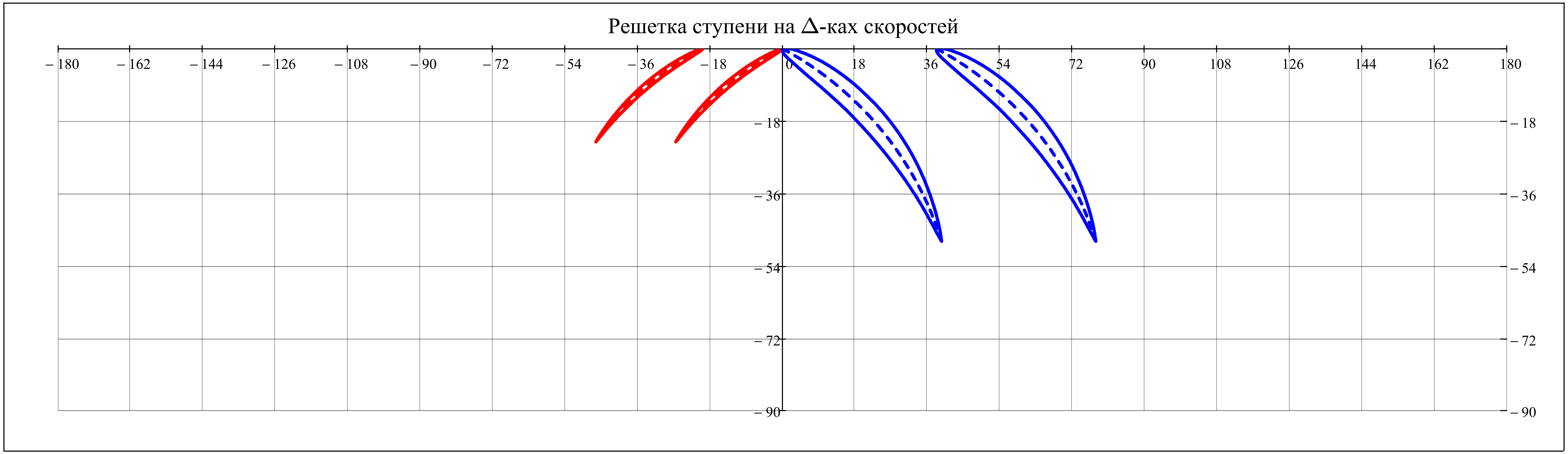
$r = av(N_r)$


Решетка ВНА и СА на Δ-ках скоростей
0
0
мм
− b_lim·10^3
− b_lim·10^3
− 2b_lim·10^3
2·b_lim·10^3
мм

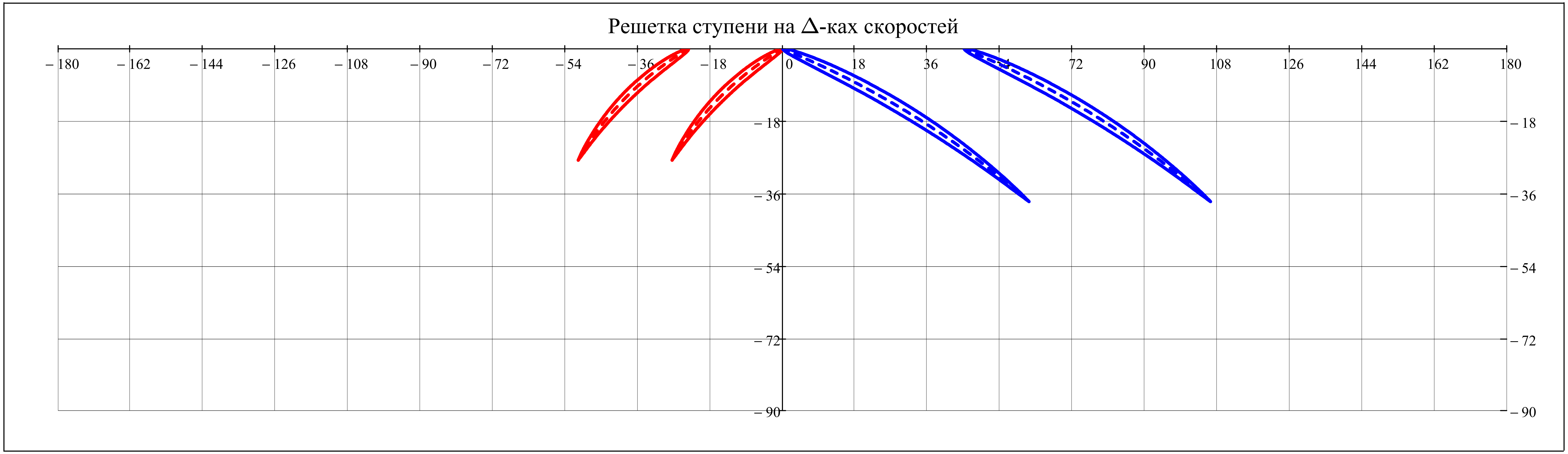
$r = N_r$


Решетка ВНА и СА на Δ-ках скоростей
0
0
$-b_{lim} \cdot 10^3$
$-b_{lim} \cdot 10^3$
$-2b_{lim} \cdot 10^3$
$2 \cdot b_{lim} \cdot 10^3$
мм
мм

$r = 1$


Решетка ступени на Δ-ках скоростей
– 180
– 162
– 144
– 126
– 108
– 90
– 72
– 54
– 36
– 18
0
18
36
54
72
90
108
126
144
162
180
– 18
– 36
– 54
– 72
– 90

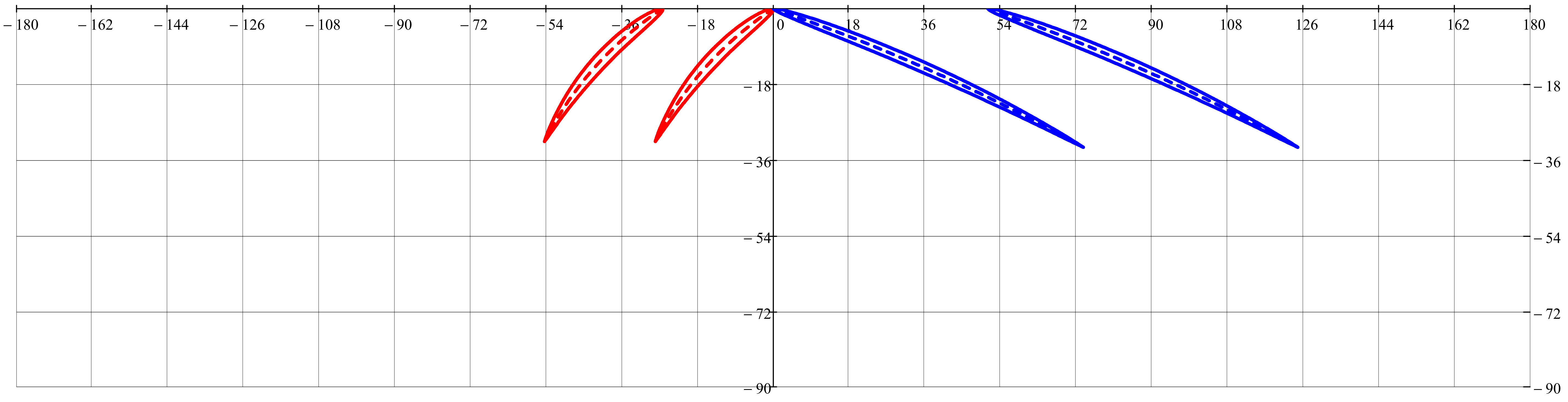
$r = av(N_r)$



Решетка ступени на Δ-ках скоростей
– 180
– 162
– 144
– 126
– 108
– 90
– 72
– 54
– 36
– 18
0
18
36
72
90
108
126
144
162
180
– 18
– 36
– 54
– 72
– 90

$r = N_r$

Решетка ступени на Δ-ках скоростей



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

Вывод данных по построению профиля Л rotor и stator на треугольниках скоростей

Радиальные и осевые зазоры и длина К

Радиальный зазор (м)
[с.64 казаджан]:

$\overline{\Delta}r = 0.0025$

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

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

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

	1	2	3
1	2.56	2.51	2.36

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

$\overline{\Delta}a = 0.17$

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

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

$\Delta a^T =$ $\cdot 10^{-3}$

	1	2	3
1	12.25	13.09	14.79

Односторонний осевой зазор (м):

$\frac{\Delta a^T}{2} =$ $\cdot 10^{-3}$

	1	2	3
1	6.13	6.55	7.40

Длина ОК (м):

$$Length = \left[\Delta a_1 + \begin{vmatrix} chord_{BHA_{av(N_r)}} \cdot \sin\left(\upsilon_{BHA_{av(N_r)}}\right) & \text{if } BHA = 1 \\ 0 & \text{otherwise}\end{vmatrix} \ldots \\ + \sum_{i=1}^{Z}\left(chord_{rotor_{i,av(N_r)}} \cdot \sin\left(\upsilon_{rotor_{i,av(N_r)}}\right)\right) + 2\cdot\sum_{i=1}^{Z}\Delta a_i + \sum_{i=1}^{Z}\left(chord_{stator_{i,av(N_r)}} \cdot \sin\left(\upsilon_{stator_{i,av(N_r)}}\right)\right) \ldots \\ + \begin{vmatrix} chord_{CA_{av(N_r)}} \cdot \sin\left(\upsilon_{CA_{av(N_r)}}\right) & \text{if } CA = 1 \\ 0 & \text{otherwise}\end{vmatrix} + \Delta a_Z\right] = 340.9\cdot 10^{-3}$$

Радиальные и осевые зазоры и длина К

Проточная часть

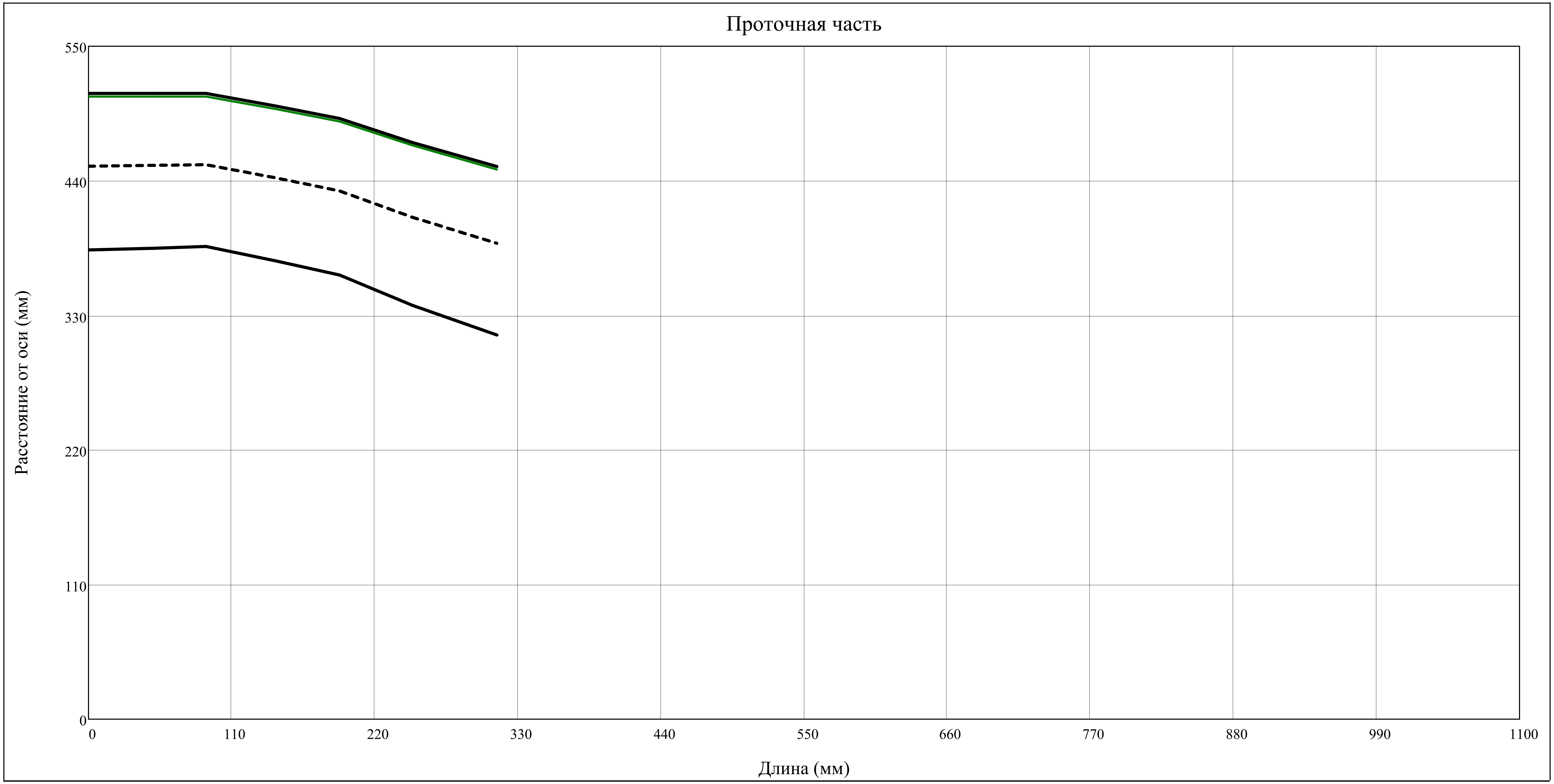
$$\begin{pmatrix} x_{ПЧ} \\ y_{ПЧпер} \\ y_{ПЧср} \\ y_{ПЧкор} \\ y_{Лпер} \end{pmatrix} = \left| \begin{array}{l} c \leftarrow 1 \\ x_{ПЧ_c} \leftarrow \left| \begin{array}{l} chord_{BHA_{av(N_r)}} \cdot \sin\left(\upsilon_{BHA_{av(N_r)}}\right) \ \text{if } BHA = 1 \\ 0 \ \text{otherwise} \end{array}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

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

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

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

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



Проточная часть

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

▾ Поперечная часть ступени

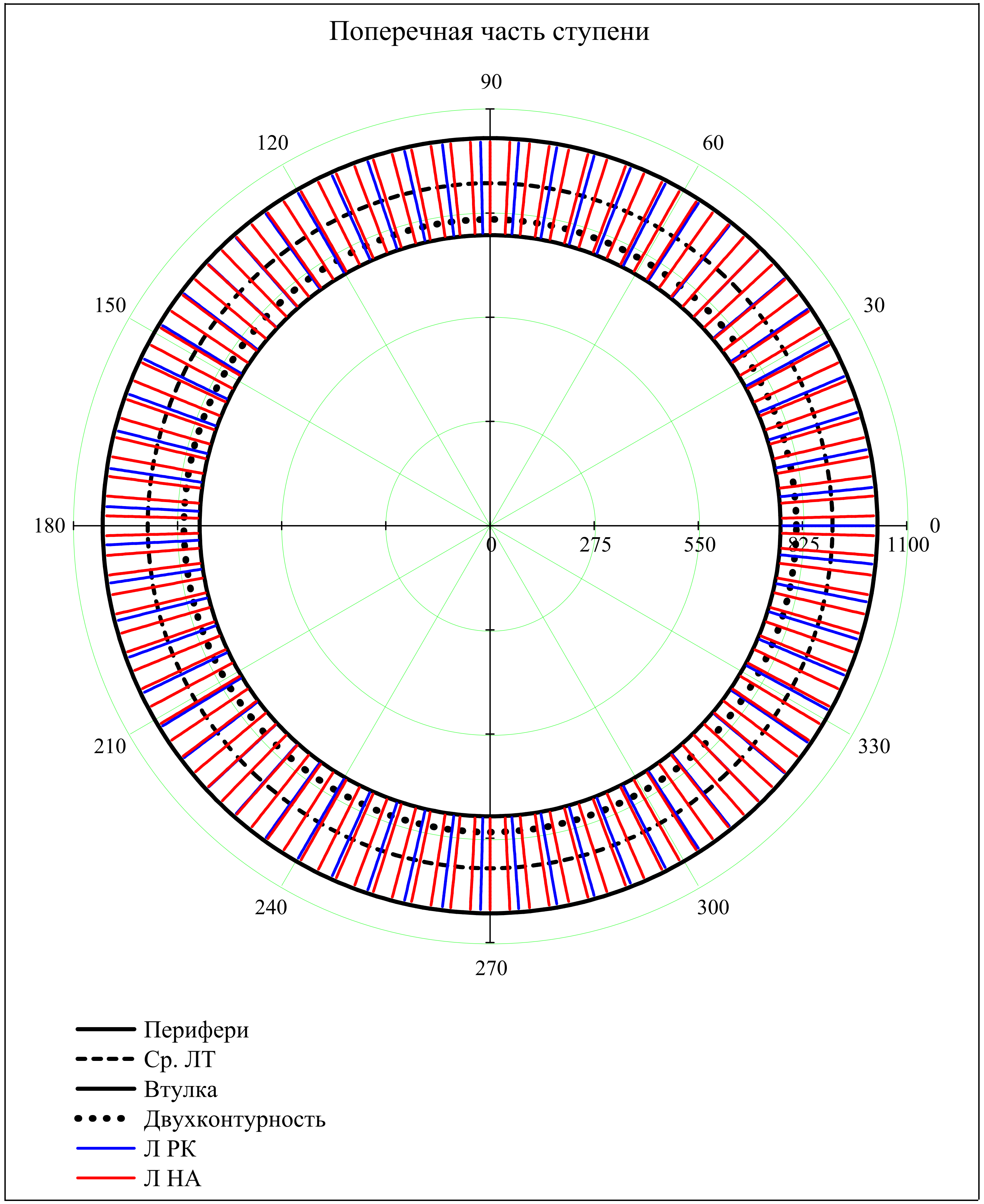
$$r := \min(D), \min(D) + \frac{\max(D) - \min(D)}{N_{dis}} .. \max(D)$$

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

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

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

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



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	"ВТ6"	"ВТ6"	"ВТ6"						

$\rho\_blade^T =$

	1	2	3
1	4430	4430	4430

$\sigma\_blade\_long^T =$

	1	2	3
1	210.0	210.0	210.0

$\cdot 10^6$

Выбор материала Л

Расчет собственных частот колебаний Л

$$\begin{pmatrix} \nu0_{изг.stator} & \nu0_{изг.rotor} \\ \nu0_{угл.stator} & \nu0_{угл.rotor} \\ \nu0_{угл.stator\_bondage} & \nu0_{угл.rotor\_bondage} \end{pmatrix} = \left| \begin{array}{l} \text{for } i \in 1..Z \\ \quad \text{for } r \in av(N_r) \\ \quad\quad \text{for } mode \in 1..6 \\ \quad\quad\quad \left| \begin{array}{l} \nu0_{изг.stator_{i,mode}} = \nu0_{изгиб}\left(mode, mean\left(h_{st(i,2)}, h_{st(i,3)}\right), E\_blade, \rho\_blade_i, area_{stator_{i,r}}, Ju_{stator_{i,r}}\right) \\ \nu0_{изг.rotor_{i,mode}} = \nu0_{изгиб}\left(mode, mean\left(h_{st(i,1)}, h_{st(i,2)}\right), E\_blade, \rho\_blade_i, area_{rotor_{i,r}}, Ju_{rotor_{i,r}}\right) \\ \nu0_{угл.stator_{i,mode}} = \nu0_{угл}\left(mode, 0, mean\left(h_{st(i,2)}, h_{st(i,3)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{stator_{i,r}}, Jp_{stator_{i,r}}\right) \\ \nu0_{угл.rotor_{i,mode}} = \nu0_{угл}\left(mode, 0, mean\left(h_{st(i,1)}, h_{st(i,2)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{rotor_{i,r}}, Jp_{rotor_{i,r}}\right) \\ \nu0_{угл.stator\_bondage_{i,mode}} = \nu0_{угл}\left(mode, 1, mean\left(h_{st(i,2)}, h_{st(i,3)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{stator_{i,r}}, Jp_{stator_{i,r}}\right) \\ \nu0_{угл.rotor\_bondage_{i,mode}} = \nu0_{угл}\left(mode, 1, mean\left(h_{st(i,1)}, h_{st(i,2)}\right), Jung(2, \mu\_steel, E\_blade), \rho\_blade_i, stiffness_{rotor_{i,r}}, Jp_{rotor_{i,r}}\right) \end{array} \right. \\ \begin{pmatrix} \nu0_{изг.stator} & \nu0_{изг.rotor} \\ \nu0_{угл.stator} & \nu0_{угл.rotor} \\ \nu0_{угл.stator\_bondage} & \nu0_{угл.rotor\_bondage} \end{pmatrix} \end{array} \right.$$

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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1048	1034	973	692	700	675												
2	3144	3103	2919	2077	2100	2024												
3	5240	5172	4865	3462	3501	3374												
4	7336	7240	6812	4846	4901	4724												
5	9432	9309	8758	6231	6301	6073												
6	11528	11378	10704	7616	7702	7423												

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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	202	285	339	238	250	255												
2	1268	1784	2124	1489	1567	1599												
3	3551	4996	5947	4169	4389	4476												
4	6963	9797	11663	8175	8607	8778												
5	11506	16188	19272	13508	14222	14505												
6	17183	24176	28782	20173	21240	21663												

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	2096	2069	1946	1385	1400	1350												
2	4192	4137	3892	2769	2801	2699												
3	6288	6206	5839	4154	4201	4049												
4	8384	8275	7785	5539	5601	5398												
5	10480	10343	9731	6923	7002	6748												
6	12576	12412	11677	8308	8402	8098												

Расчет собственных частот колебаний Л

Вывод результатов расчета собственных частот колебаний Л

Расчетный узел: $type = "compressor"$

Объем бандажной полки (м³): $V_{бп} = 0$

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

Расчет Л на прочность

$$\begin{pmatrix} R0_{rotor} & area0_{rotor} \\ N0_{rotor} & \sigma0\_z_{rotor} \\ area_{rotor.} & area_{stator.} \\ N_{rotor} & \sigma\_z_{rotor} \\ P_1 & \rho_1 \\ P_2 & \rho_2 \\ P_3 & \rho_3 \\ c_{a1} & c_{u1} \\ c_{a2} & c_{u2} \\ c_{a3} & c_{u3} \\ qx_{rotor} & qx_{stator} \\ qy_{rotor} & qy_{stator} \\ Mx_{rotor} & Mx_{stator} \\ My_{rotor} & My_{stator} \\ shift\_x_{rotor} & shift\_y_{rotor} \\ x0_{rotor.} & x0_{stator.} \\ y0_{rotor.} & y0_{stator.} \\ \alpha\_major_{rotor.} & \alpha\_major_{stator.} \\ Ju_{rotor.} & Ju_{stator.} \\ Jv_{rotor.} & Jv_{stator.} \\ CPx_{rotor.} & CPx_{stator.} \\ CPy_{rotor.} & CPy_{stator.} \\ CPx_{rotor.axis} & CPx_{stator.axis} \\ CPy_{rotor.axis} & CPy_{stator.axis} \end{pmatrix} = \left| \begin{array}{l} \chi_{rotor}(i,z) = \dfrac{area_{rotor_{i,N_r}}}{area_{rotor_{i,1}}} \\ R0_{rotor}(i,z) = \dfrac{1}{\sqrt{1-\ln(\chi_{rotor}(i,z))}} \cdot \left| \begin{array}{ll} \sqrt{mean(R_{st(i,1),1}, R_{st(i,2),1})^2 - mean(R_{st(i,1),N_r}, R_{st(i,2),N_r})^2 \cdot \ln(\chi_{rotor}(i,z))} & \text{if } type = "compressor" \\ \sqrt{mean(R_{st(i,2),1}, R_{st(i,3),1})^2 - mean(R_{st(i,2),N_r}, R_{st(i,3),N_r})^2 \cdot \ln(\chi_{rotor}(i,z))} & \text{if } type = "turbine" \end{array} \right. \\ \sigma0_{rotor.max}(i,z) = \dfrac{\rho\_blade_i \cdot \omega^2}{2} \cdot \left| \begin{array}{ll} \left[mean(R_{st(i,1),N_r}, R_{st(i,2),N_r})^2 - (R0_{rotor}(i,z))^2\right] & \text{if } type = "compressor" \\ \left[mean(R_{st(i,2),N_r}, R_{st(i,3),N_r})^2 - (R0_{rotor}(i,z))^2\right] & \text{if } type = "turbine" \end{array} \right. \\ \quad \left| \left(\dfrac{\rho\_blade_i \cdot \omega^2}{\ldots} \int^{R0_{rotor}(i,z)} \ldots \right) \right. \end{array} \right.$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\left(\begin{array}{cc} R0_{rotor} & area0_{rotor} \\ N0_{rotor} & \sigma0\_z_{rotor} \\ area_{rotor.} & area_{stator.} \\ N_{rotor} & \sigma\_z_{rotor} \end{array}\right.$$

$$
\begin{pmatrix}
P_1 & \rho_1 \\
P_2 & \rho_2 \\
P_3 & \rho_3 \\
c_{a1} & c_{u1} \\
c_{a2} & c_{u2} \\
c_{a3} & c_{u3} \\
qx_{rotor} & qx_{stator} \\
qy_{rotor} & qy_{stator} \\
Mx_{rotor} & Mx_{stator} \\
My_{rotor} & My_{stator} \\
shift\_x_{rotor} & shift\_y_{rotor} \\
x0_{rotor.} & x0_{stator.} \\
y0_{rotor.} & y0_{stator.} \\
\alpha\_major_{rotor.} & \alpha\_major_{stator.} \\
Ju_{rotor.} & Ju_{stator.} \\
Jv_{rotor.} & Jv_{stator.} \\
CPx_{rotor.} & CPx_{stator.} \\
CPy_{rotor.} & CPy_{stator.} \\
CPx_{rotor.axis} & CPx_{stator.axis} \\
CPy_{rotor.axis} & CPy_{stator.axis} \\
Wp_{rotor.} & Wp_{stator.} \\
M\tau_{rotor} & M\tau_{stator} \\
\tau_{rotor} & \tau_{stator} \\
\varphi\_uv_{rotor} & \varphi\_uv_{stator} \\
Mu_{rotor} & Mu_{stator} \\
Mv_{rotor} & Mv_{stator} \\
\varphi\_neutral_{rotor} & \varphi\_neutral_{stator}
\end{pmatrix}
$$

Расчет Л на прочность

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

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

Определение координат точек профиля Л, наиболее удаленных от НЛ

Наиболее удаленные точки от НЛ (мм):

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

	1	2	3	4	5	6	7	8	9
1	11.510	-7.516	-10.283						
2	-1.514	-0.810	-0.812						
3	-1.203	-0.930	-0.930						

$\cdot 10^{-3}$

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

	1	2	3
1	5.593	4.960	5.638
2	2.125	2.066	2.027
3	36.468	1.552	1.530

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	-26.080	32.904	32.015						
2	39.465	39.489	39.493						
3	-1.647	44.264	44.265						

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	-9.924	-10.163	-12.780						
2	-3.120	-2.654	-2.492						
3	-44.263	-1.411	-1.324						

$\cdot 10$

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

	1	2	3	4	5	6	7	8	9
1	-0.038	-0.029	-0.035						
2	-0.033	-0.020	-0.027						
3	-0.448	-0.008	-0.438						

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	1.210	1.330	1.249						
2	1.744	1.884	1.811						
3	2.317	2.472	2.401						

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	19.285	19.266	19.279						
2	21.345	21.321	21.334						
3	23.134	23.106	23.119						

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	-2.036	-2.544	-2.202						
2	-2.340	-2.942	-2.630						
3	-2.586	-3.258	-2.953						

$\cdot 10^{-3}$

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

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

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

	1	2	3	4	5	6	7	8	9
1	4.83	-5.84	-3.21						
2	-7.45	-17.31	-12.40						
3	0.00	-0.23	-0.49						

$\cdot 10^{6}$

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

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

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

	1	2	3	4	5	6	7	8	9
1	-9.28	14.13	7.99						
2	12.37	23.63	16.24						
3	0.00	0.22	0.44						

$\cdot 10^{6}$

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

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

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

	1	2	3	4	5	6	7	8	9
1	0.01	0.34	0.50						
2	37.36	24.72	10.32						
3	65.67	41.71	15.67						

$\cdot 10^{6}$

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

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

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

	1	2	3	4	5	6	7	8	9
1	-0.02	-0.67	-0.90						
2	-50.93	-39.43	-15.28						
3	-75.09	-56.70	-19.83						

$\cdot 10^{6}$

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

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

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

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

$\sigma_{rotor}^T =$ $\cdot 10^6$

	1	2	3	4	5	6	7	8	9
1	51.98	62.05	56.18						
2	47.83	61.66	56.11						
3	0.00	3.78	6.97						

$\sigma_{stator}^T =$ $\cdot 10^6$

	1	2	3	4	5	6	7	8	9
1	0.01	0.35	0.51						
2	37.36	24.73	10.32						
3	65.67	41.71	15.67						

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

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

	1	2	3	4	5	6
1	4.04	3.38	3.74			
2	4.39	3.41	3.74			
3	0000000000000000000000000000000	55.63	30.14			

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

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

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

	1	2	3	4	5
1	15864.14	597.07	411.86		
2	5.62	8.49	20.34		
3	3.2	5.03	13.4		

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

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

Рассматриваемая ступень:

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

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

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	383.4	452.0	511.4
2	384.9	452.6	511.4
3	386.3	453.2	511.4

$\cdot 10^{-3}$

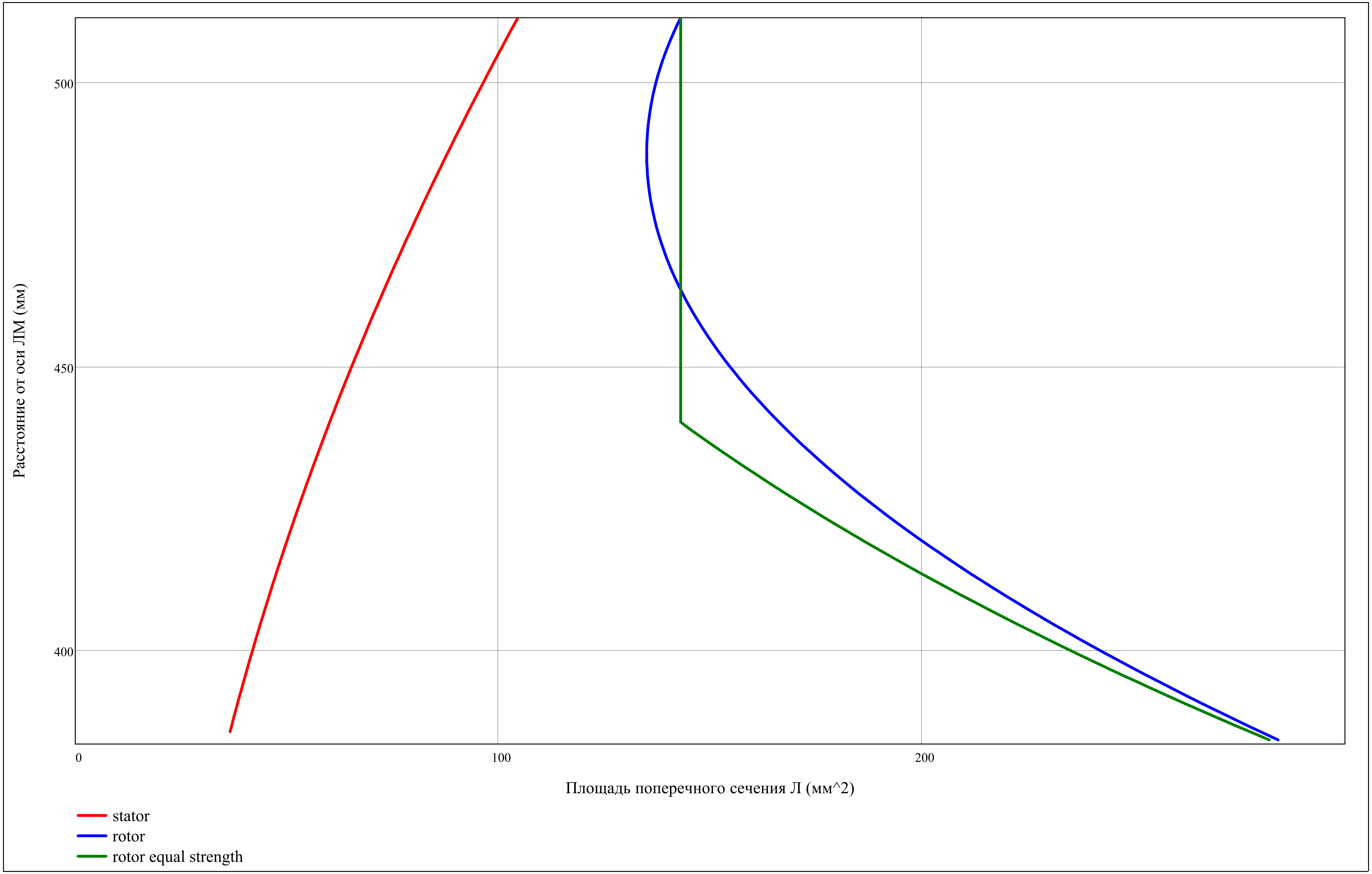
Дискретизация по высоте Л:

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

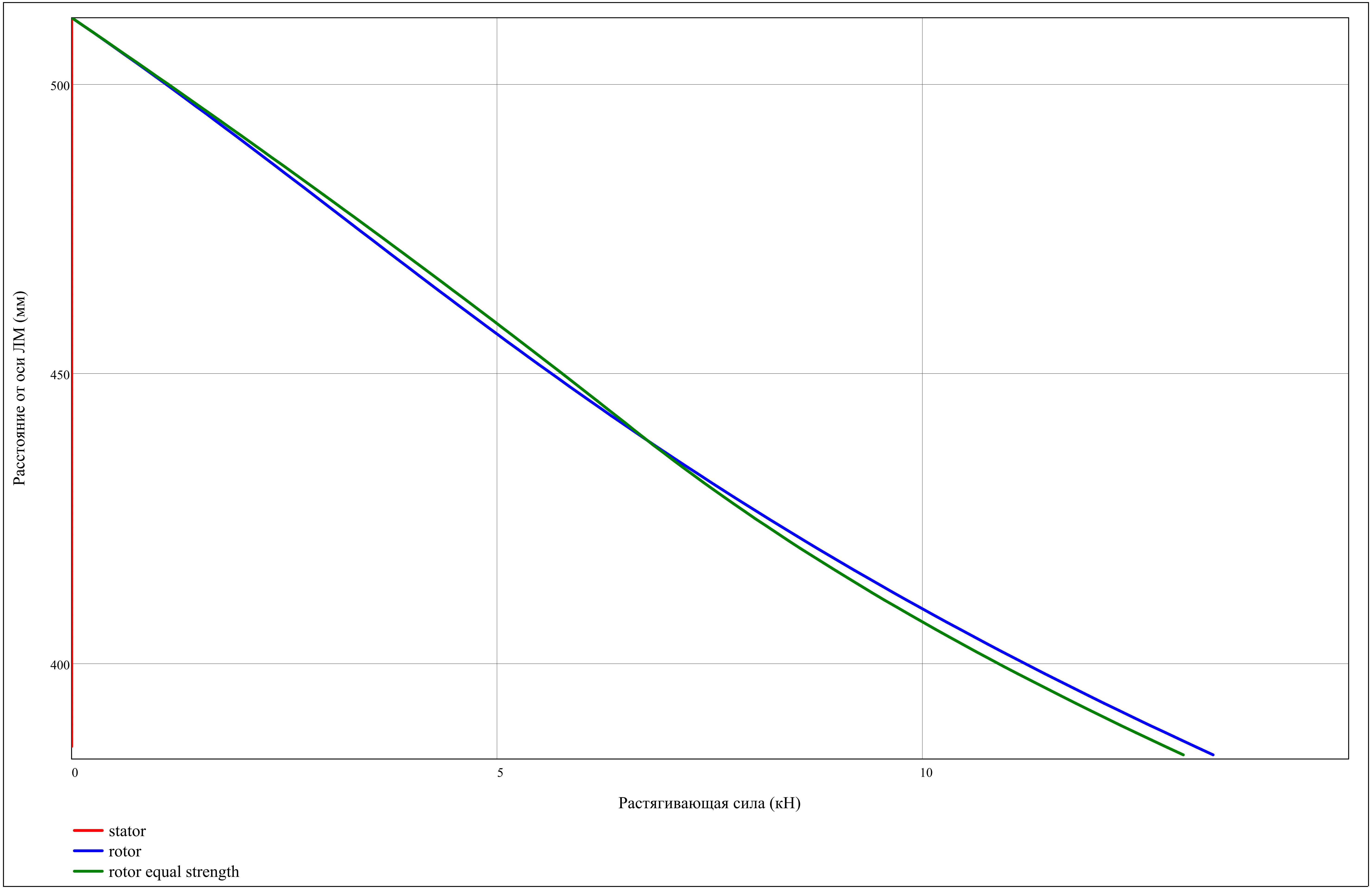
$$z_{rotor} := \begin{vmatrix} \mathrm{mean}(Rj_{1,1}, Rj_{2,1}), \mathrm{mean}(Rj_{1,1}, Rj_{2,1}) + \frac{\mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) - \mathrm{mean}(Rj_{1,1}, Rj_{2,1})}{100} .. \mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) & \text{if } type = \text{"compressor"} \\ \mathrm{mean}(Rj_{2,1}, Rj_{3,1}), \mathrm{mean}(Rj_{2,1}, Rj_{3,1}) + \frac{\mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) - \mathrm{mean}(Rj_{2,1}, Rj_{3,1})}{100} .. \mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) & \text{if } type = \text{"turbine"} \end{vmatrix}$$

$$z_{stator} := \begin{vmatrix} \mathrm{mean}(Rj_{2,1}, Rj_{3,1}), \mathrm{mean}(Rj_{2,1}, Rj_{3,1}) + \frac{\mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) - \mathrm{mean}(Rj_{2,1}, Rj_{3,1})}{100} .. \mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) & \text{if } type = \text{"compressor"} \\ \mathrm{mean}(Rj_{1,1}, Rj_{2,1}), \mathrm{mean}(Rj_{1,1}, Rj_{2,1}) + \frac{\mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) - \mathrm{mean}(Rj_{1,1}, Rj_{2,1})}{100} .. \mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) & \text{if } type = \text{"turbine"} \end{vmatrix}$$

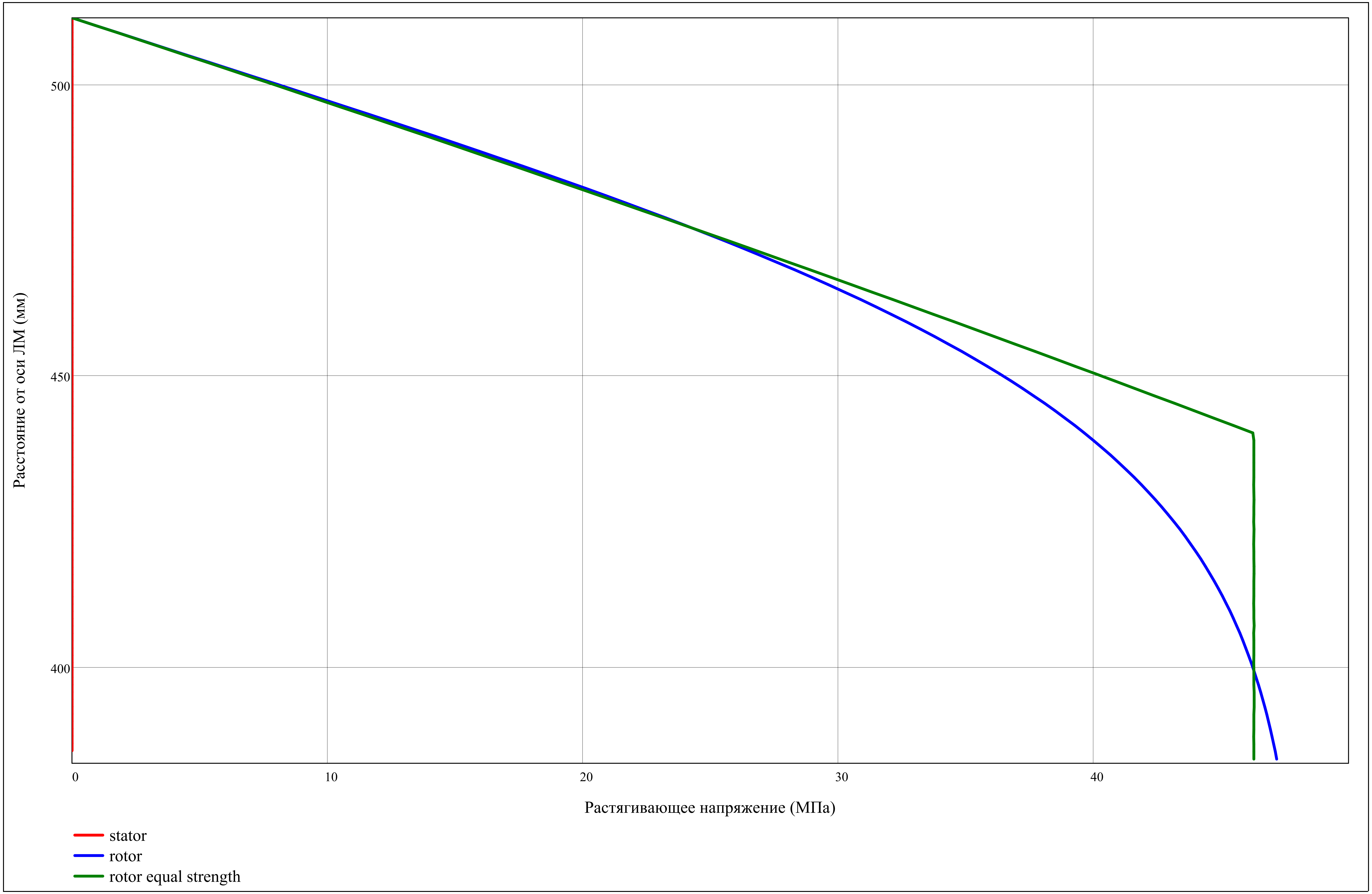
Результаты расчета на прочность Л



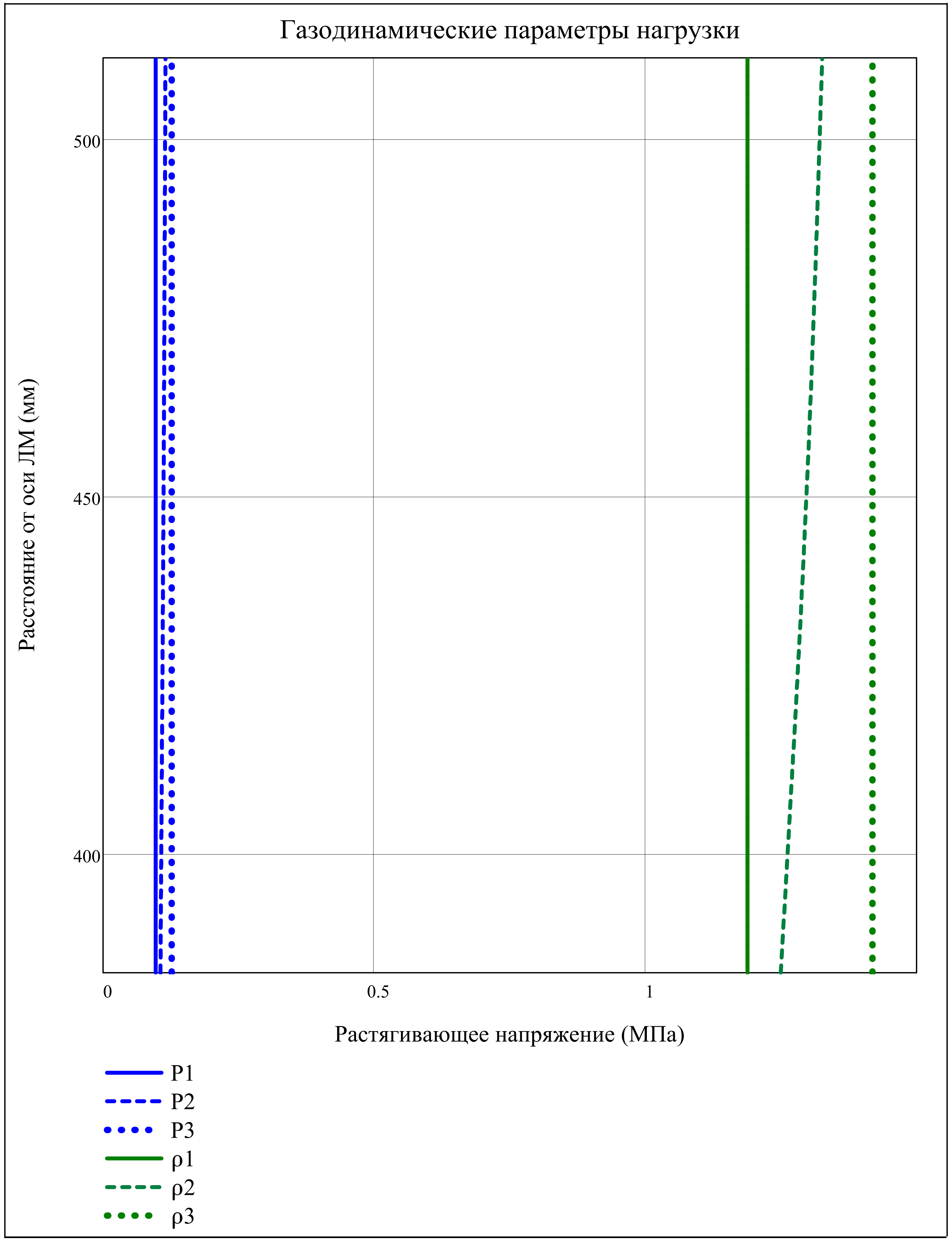
500
450
400
0
100
200
Расстояние от оси ЛМ (мм)
Площадь поперечного сечения Л (мм^2)
stator
rotor
rotor equal strength

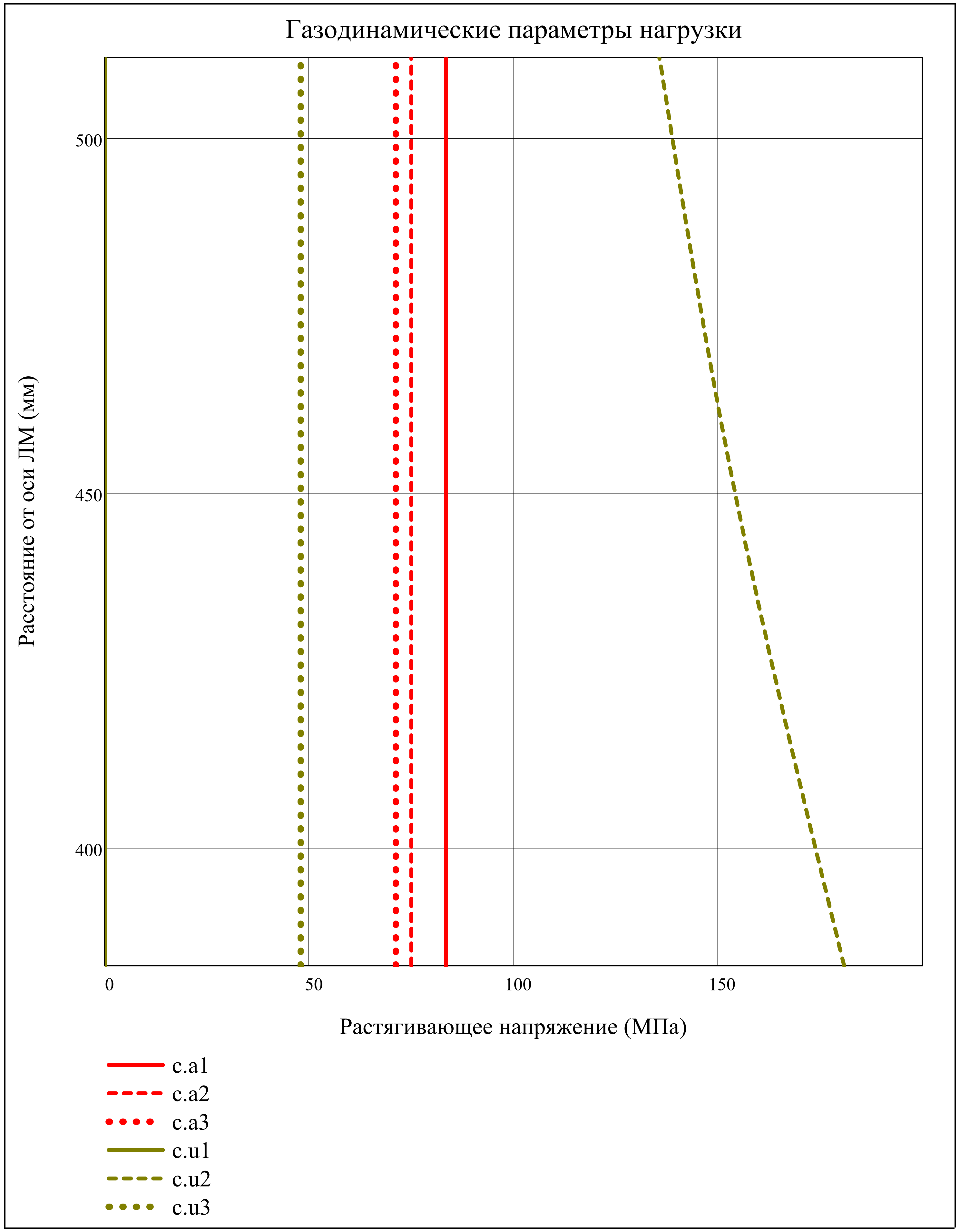


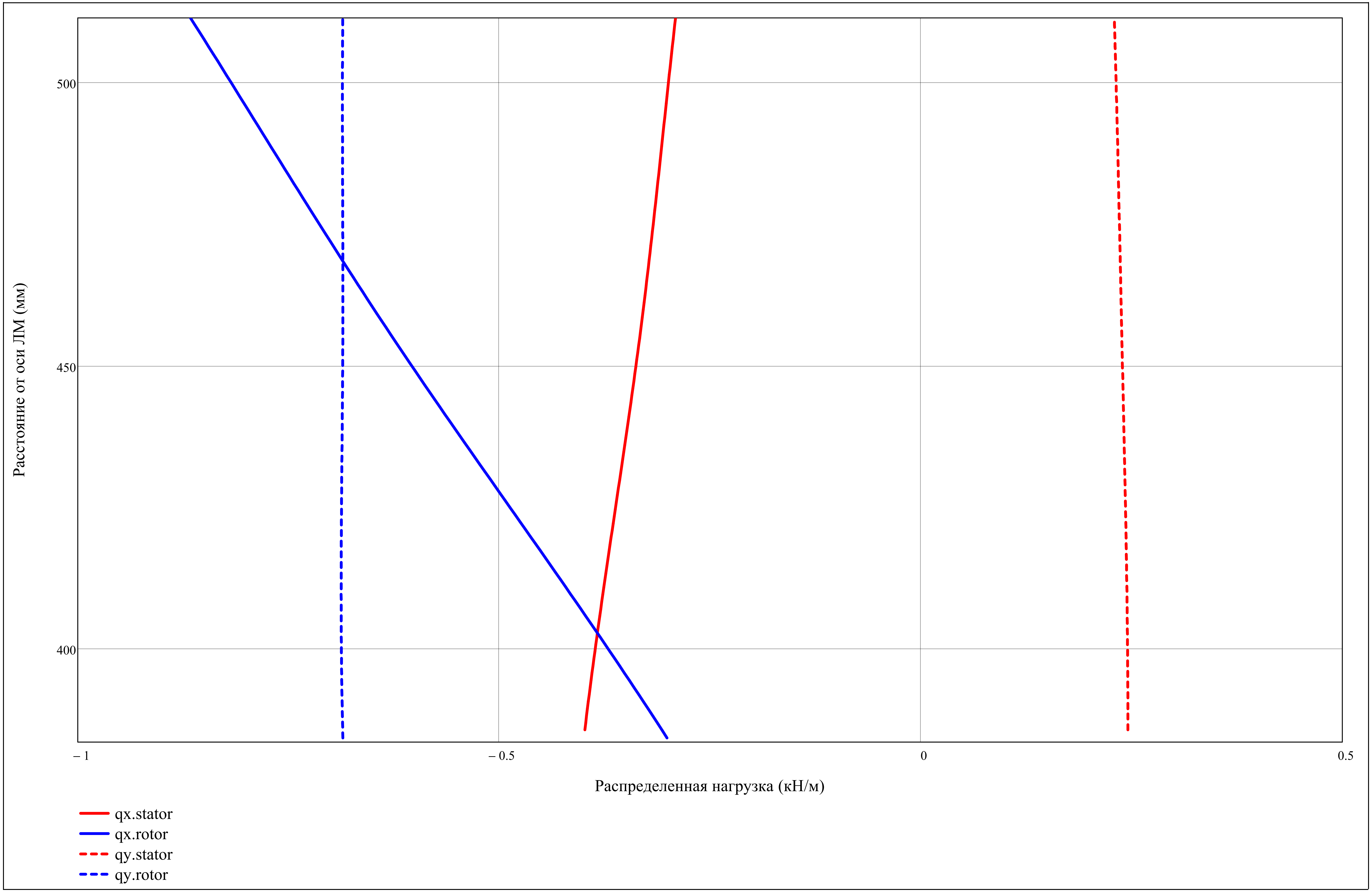
500
450
400
0
5
10
Расстояние от оси ЛМ (мм)
Растягивающая сила (кН)
stator
rotor
rotor equal strength



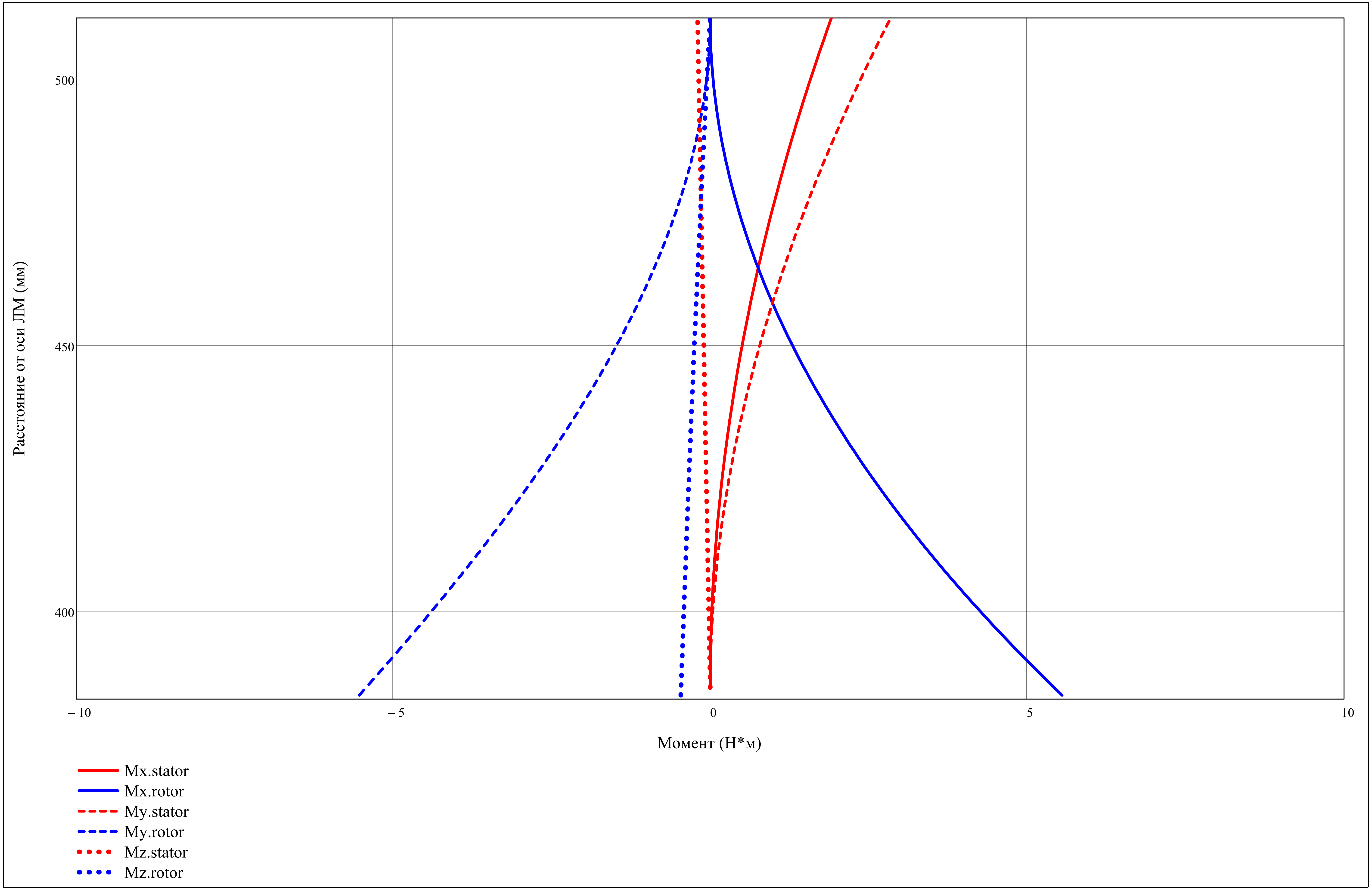
500
450
400
0
10
20
30
40
Расстояние от оси ЛМ (мм)
Растягивающее напряжение (МПа)
stator
rotor
rotor equal strength


Газодинамические параметры нагрузки
Расстояние от оси ЛМ (мм)
500
450
400
0
0.5
1
Растягивающее напряжение (МПа)
P1
P2
P3
ρ1
ρ2
ρ3

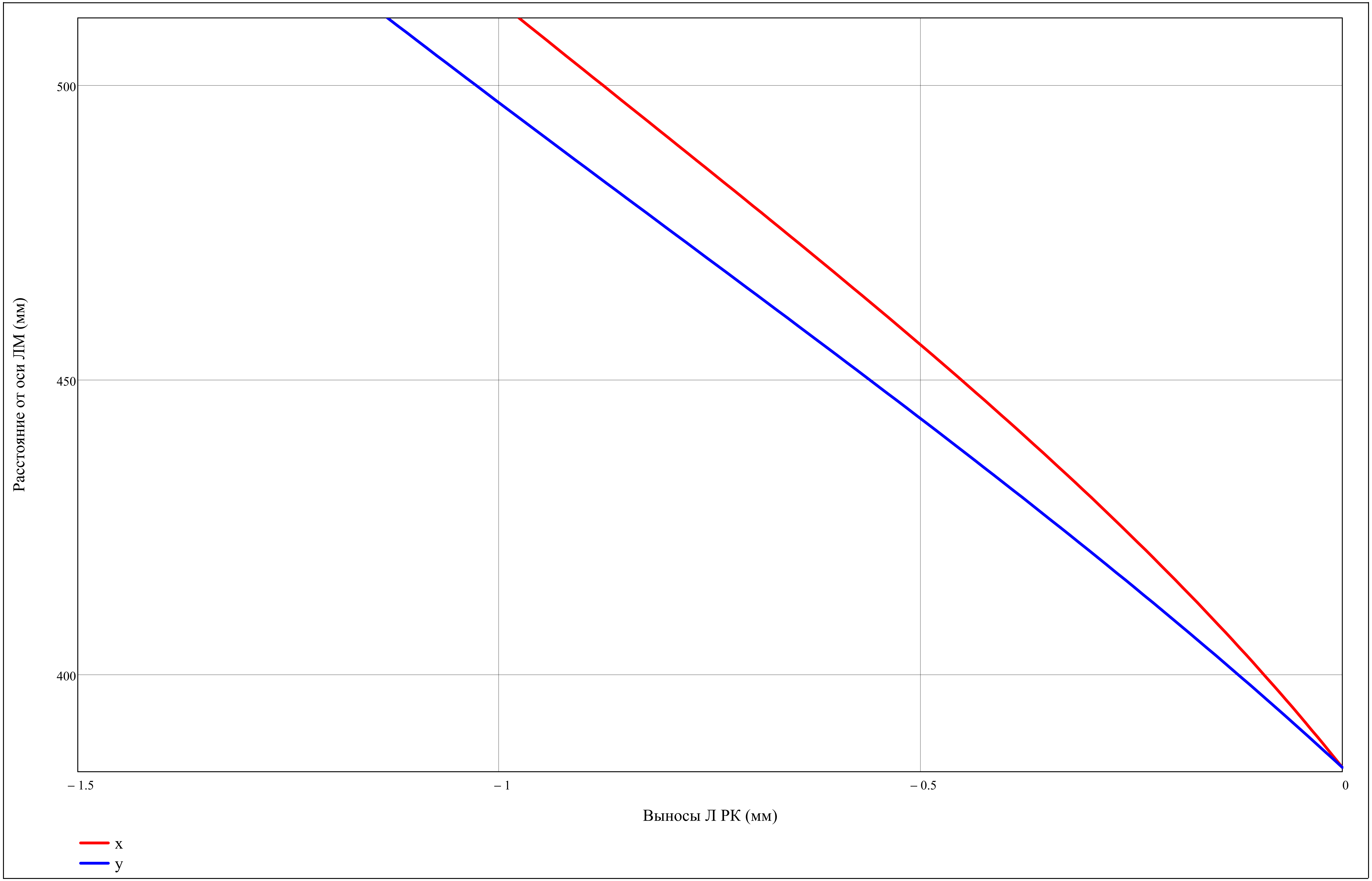

Газодинамические параметры нагрузки
Расстояние от оси ЛМ (мм)
500
450
400
0
50
100
150
Растягивающее напряжение (МПа)
c.a1
c.a2
c.a3
c.u1
c.u2
c.u3

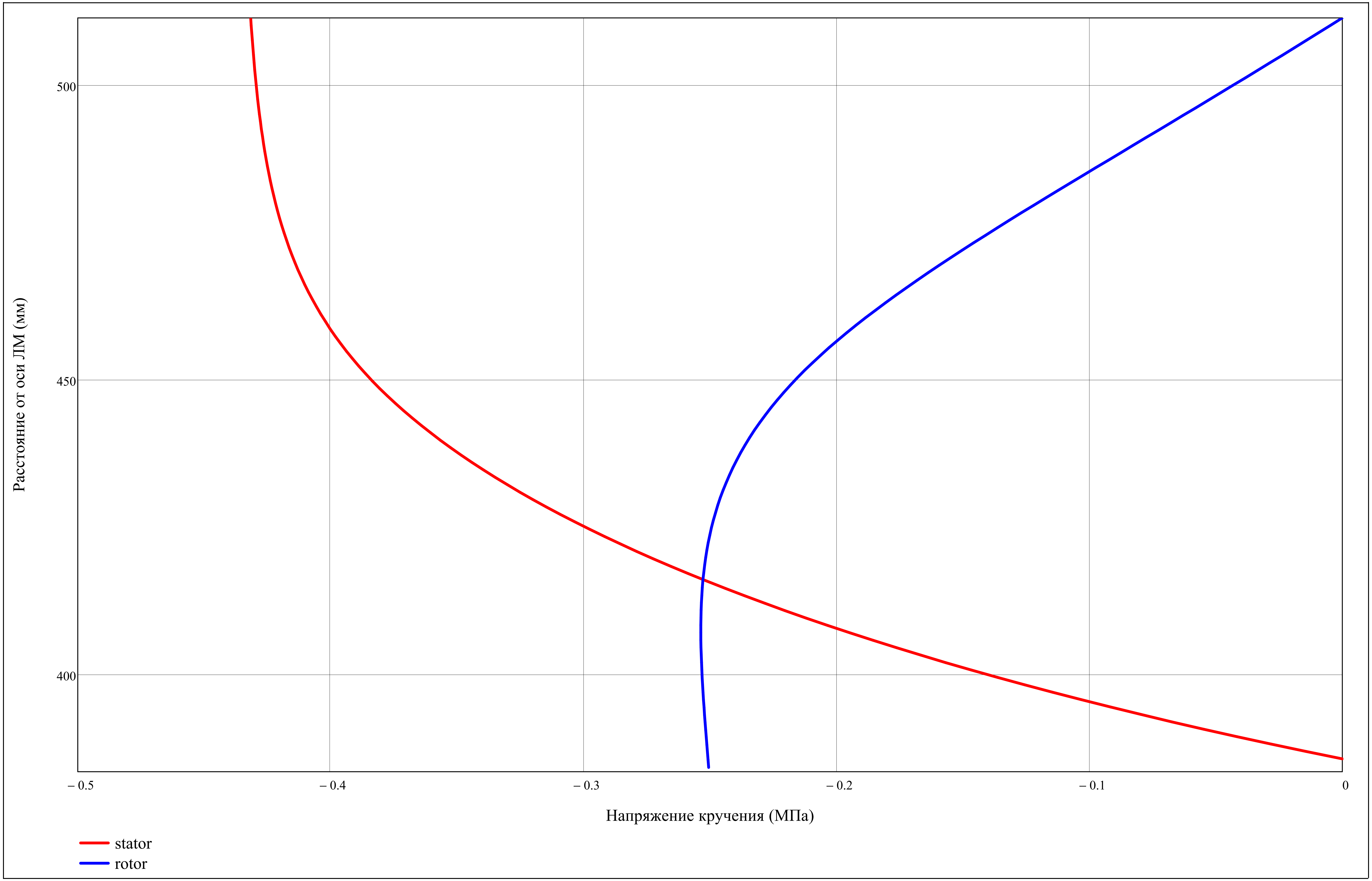


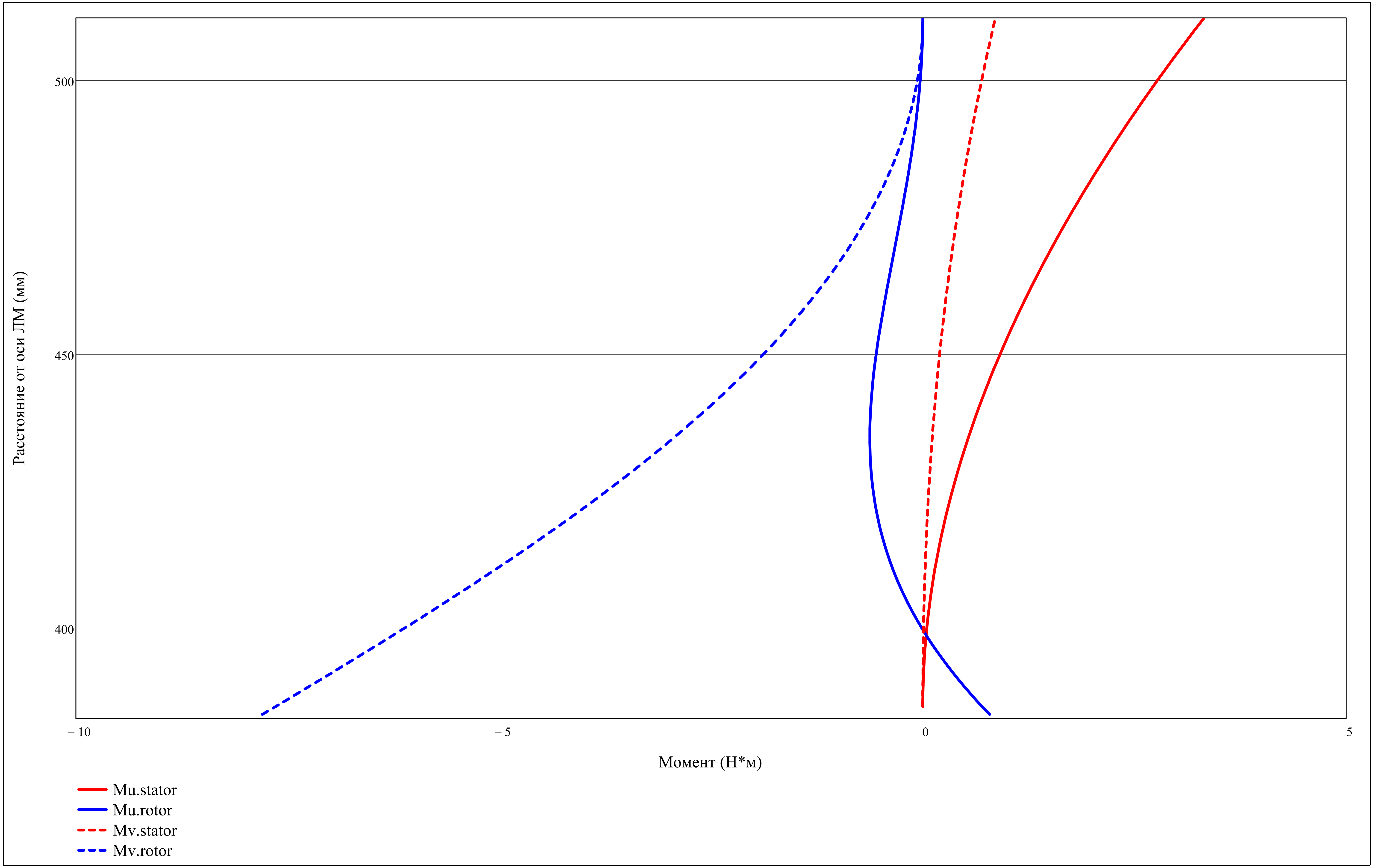
Расстояние от оси ЛМ (мм)
500
450
400
– 1
– 0.5
0
0.5
Распределенная нагрузка (кН/м)
qx.stator
qx.rotor
qy.stator
qy.rotor

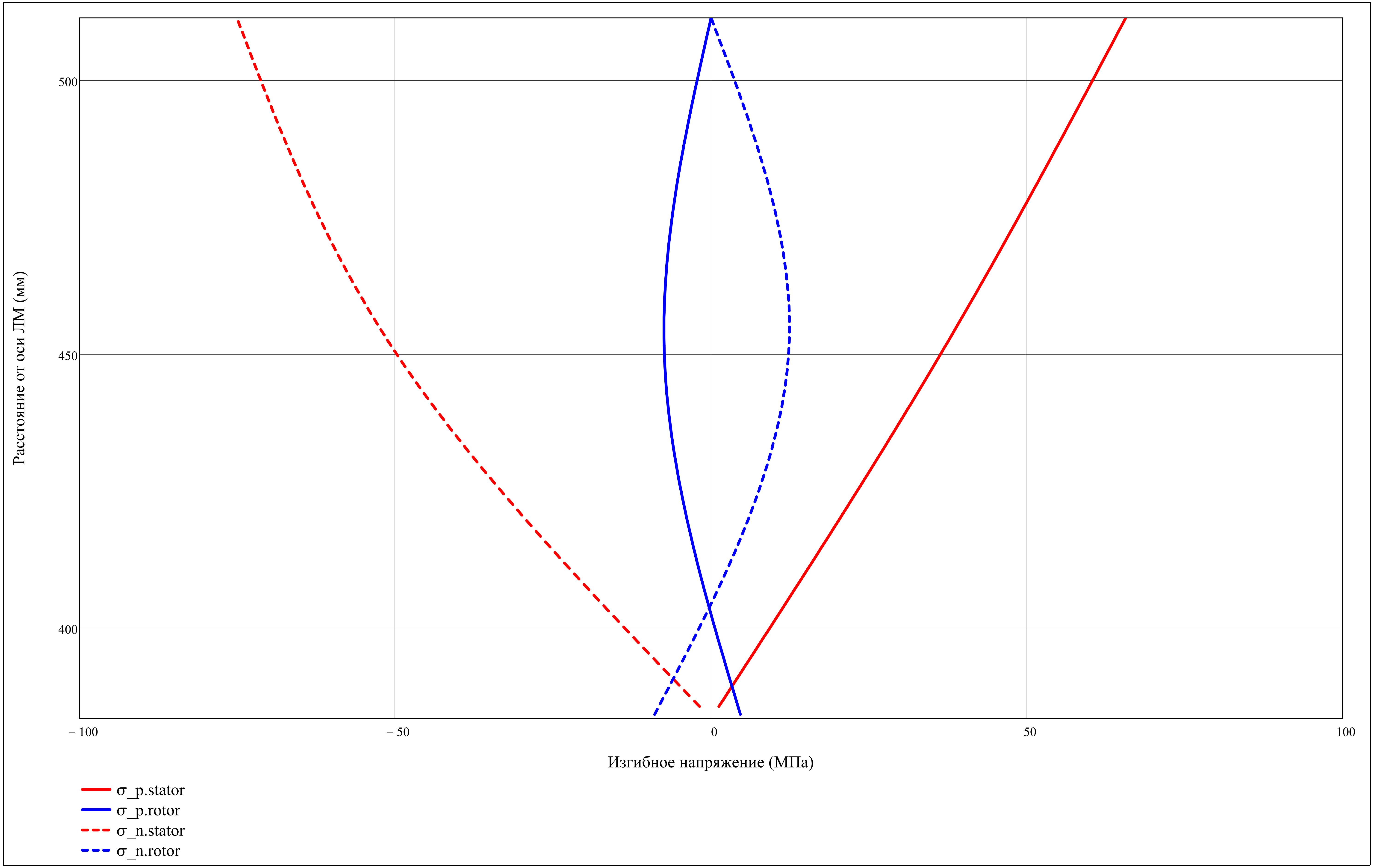


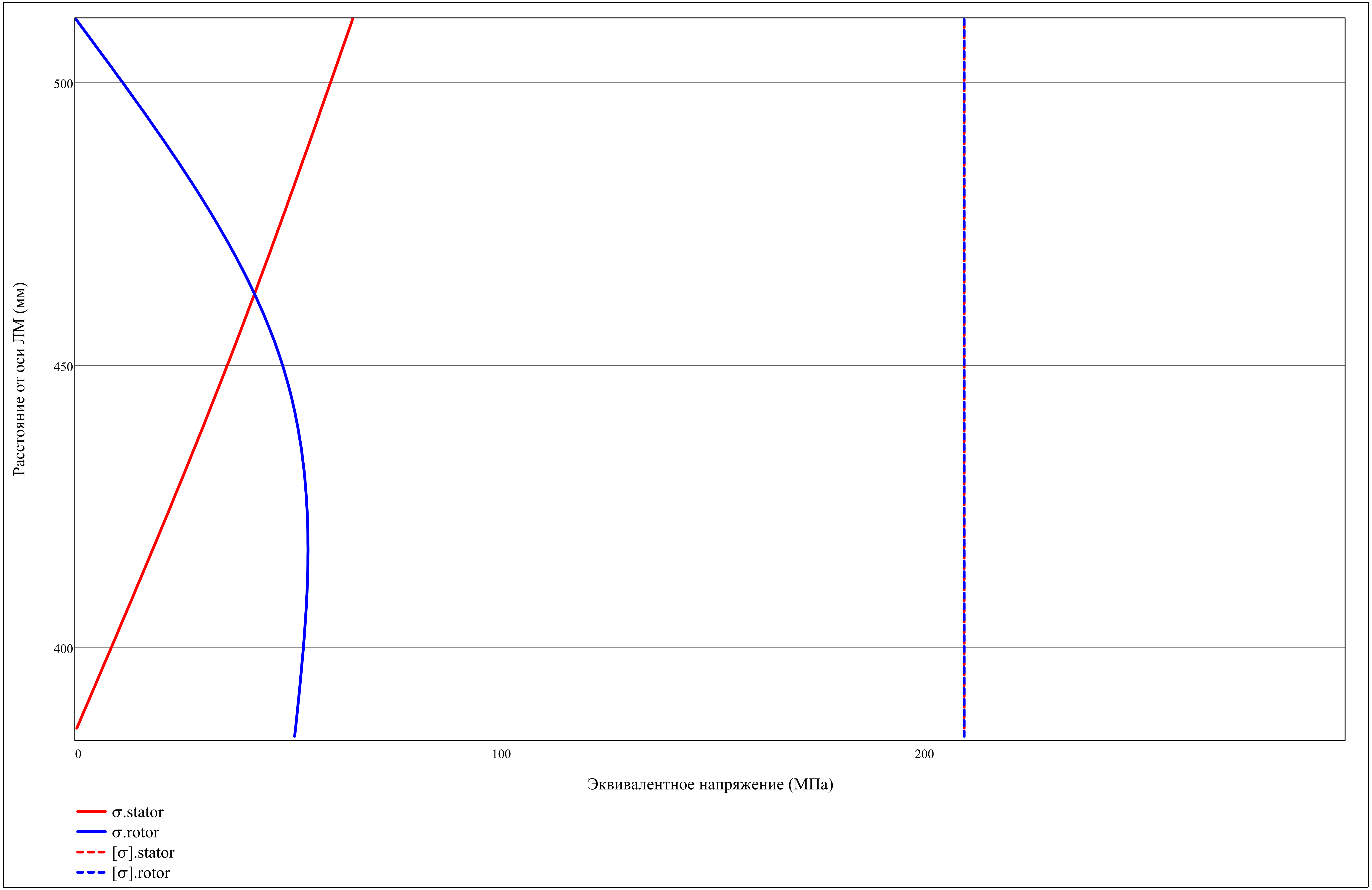
Расстояние от оси ЛМ (мм)
500
450
400
– 10
– 5
0
5
10
Момент (Н*м)
Mx.stator
Mx.rotor
My.stator
My.rotor
Mz.stator
Mz.rotor


Расстояние от оси ЛМ (мм)
500
450
400
− 1.5
− 1
− 0.5
0
Выносы Л РК (мм)
x
y


500
450
400
– 0.5
– 0.4
– 0.3
– 0.2
– 0.1
0
Расстояние от оси ЛМ (мм)
Напряжение кручения (МПа)
stator
rotor


500
450
400
Расстояние от оси ЛМ (мм)
– 10
– 5
0
5
Момент (Н*м)
Mu.stator
Mu.rotor
Mv.stator
Mv.rotor


Расстояние от оси ЛМ (мм)
500
450
400
– 100
– 50
0
50
100
Изгибное напряжение (МПа)
σ_p.stator
σ_p.rotor
σ_n.stator
σ_n.rotor



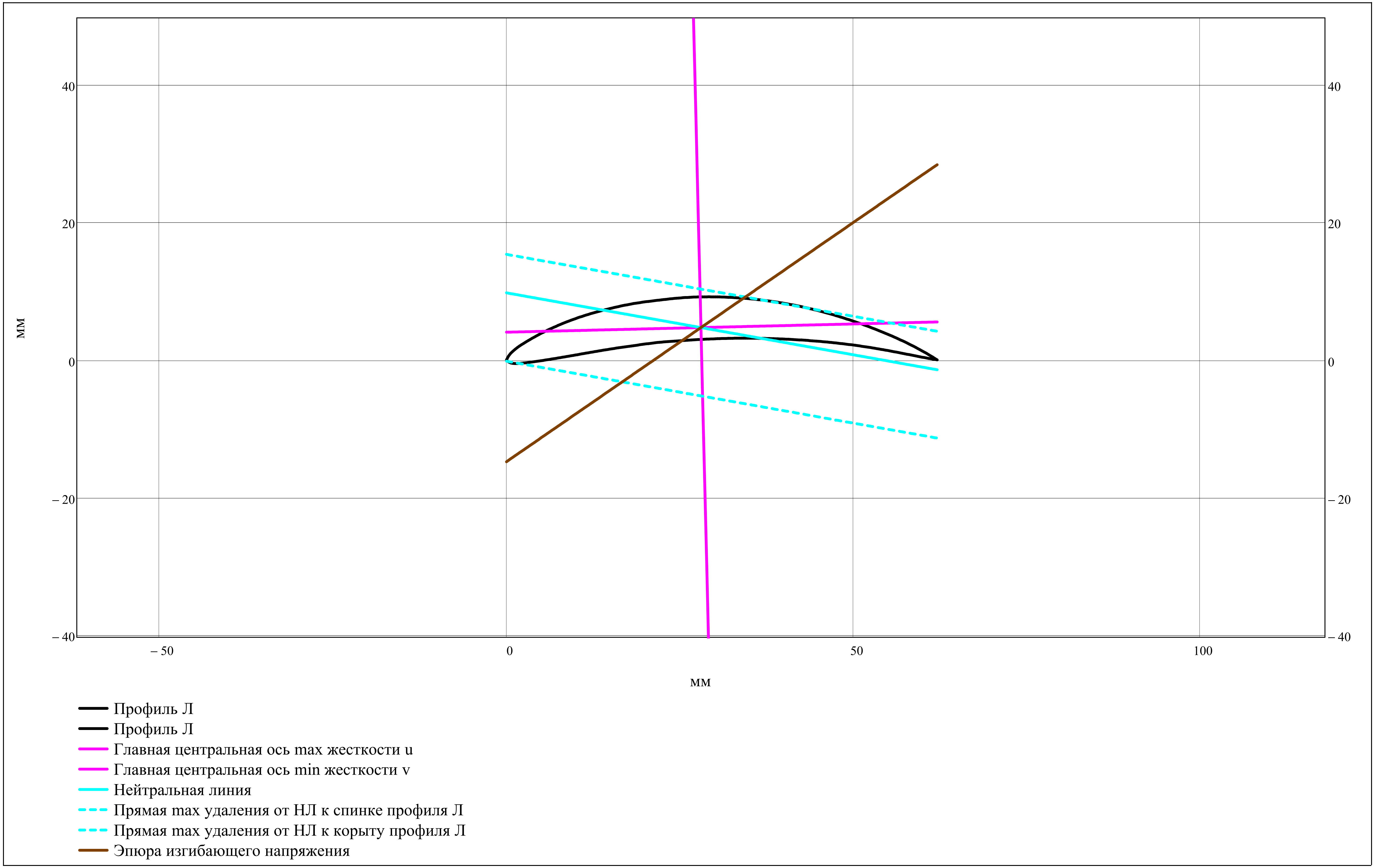
Расстояние от оси ЛМ (мм)
500
450
400
0
100
200
Эквивалентное напряжение (МПа)
σ.stator
σ.rotor
[σ].stator
[σ].rotor

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

$$\begin{pmatrix} v\_p \\ v\_n \end{pmatrix} = \left| \begin{array}{l} \begin{pmatrix} v\_u_{rotor_{j,r}} \\ v\_l_{rotor_{j,r}} \end{pmatrix} \text{ if blade = "rotor"} \\ \begin{pmatrix} v\_u_{stator_{j,r}} \\ v\_l_{stator_{j,r}} \end{pmatrix} \text{ otherwise} \end{array} \right. = \begin{array}{c|c} & 1 \\ \hline 1 & 5.593 \\ 2 & -9.924 \end{array} \cdot 10^{-3}$$

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \left| \begin{array}{l} \begin{pmatrix} x0_{rotor_{j,r}} \\ y0_{rotor_{j,r}} \end{pmatrix} \text{ if blade = "rotor"} \\ \begin{pmatrix} x0_{stator_{j,r}} \\ y0_{stator_{j,r}} \end{pmatrix} \text{ otherwise} \end{array} \right. = \begin{array}{c|c} & 1 \\ \hline 1 & 28.047 \\ 2 & 4.691 \end{array} \cdot 10^{-3}$$

$$\text{chord} = \left| \begin{array}{l} \text{chord}_{rotor_{j,r}} \text{ if blade = "rotor"} \\ \text{chord}_{stator_{j,r}} \text{ if blade = "stator"} \end{array} \right. = 62 \cdot 10^{-3}$$


40
20
0
– 20
– 40
40
20
0
– 20
– 40
– 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

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	11.51	5.59
2	-26.08	-9.92
3	-0.04	1.21
4	19.28	-2.04

$\cdot 10^{-3}$

$$\begin{pmatrix} \sigma\_p_{rotor_{j,r}} & \sigma\_p_{stator_{j,r}} \\ \sigma\_n_{rotor_{j,r}} & \sigma\_n_{stator_{j,r}} \end{pmatrix} = \begin{pmatrix} 4.83 & 0.01 \\ -9.28 & -0.02 \end{pmatrix} \cdot 10^6$$

$$\begin{pmatrix} \sigma_{stator_{j,r}} \\ \sigma_{rotor_{j,r}} \end{pmatrix} = \begin{pmatrix} 0.01 \\ 51.98 \end{pmatrix} \cdot 10^6$$

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

	1
1	15864.143
2	4.040

Результаты расчета на прочность Л

Вывод результатов расчета Л на прочность

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	"ВТ6"	"ВТ6"	"ВТ6"						

$\rho\_disk^T =$

	1	2	3
1	4430	4430	4430

$\sigma\_disk\_long^T =$

	1	2	3
1	210	210	210

$\cdot 10^6$

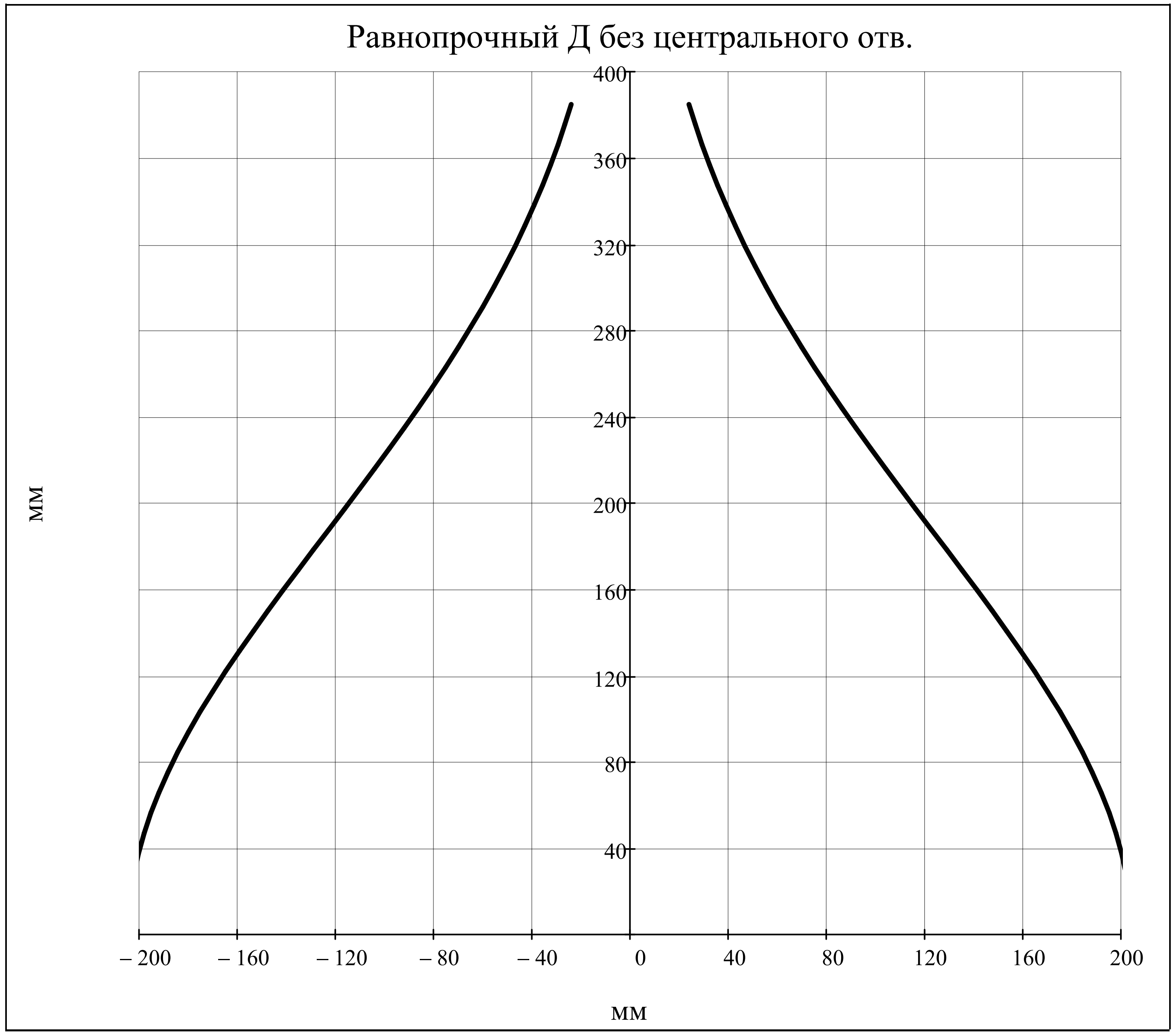
Выбор материала Д

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

Профилирование равнопрочного Д без центрального отв.

$$h(i,z) := \left| \begin{array}{ll} \left(chord_{rotor_{i,ORIGIN}} \cdot \sin\left(\upsilon_{rotor_{i,ORIGIN}}\right)\right) \cdot e^{\frac{\rho\_disk_i \cdot \omega^2}{2} \cdot \frac{1}{\sigma\_z_{rotor}\left(i, R_{st(i,2),ORIGIN}\right)} \cdot \left[\left(R_{st(i,2),ORIGIN}\right)^2 - z^2\right]} & \text{if } z \le R_{st(i,2),ORIGIN} \\ NaN & \text{otherwise} \end{array} \right.$$

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



Профилирование равнопрочного Д без центрального отв.

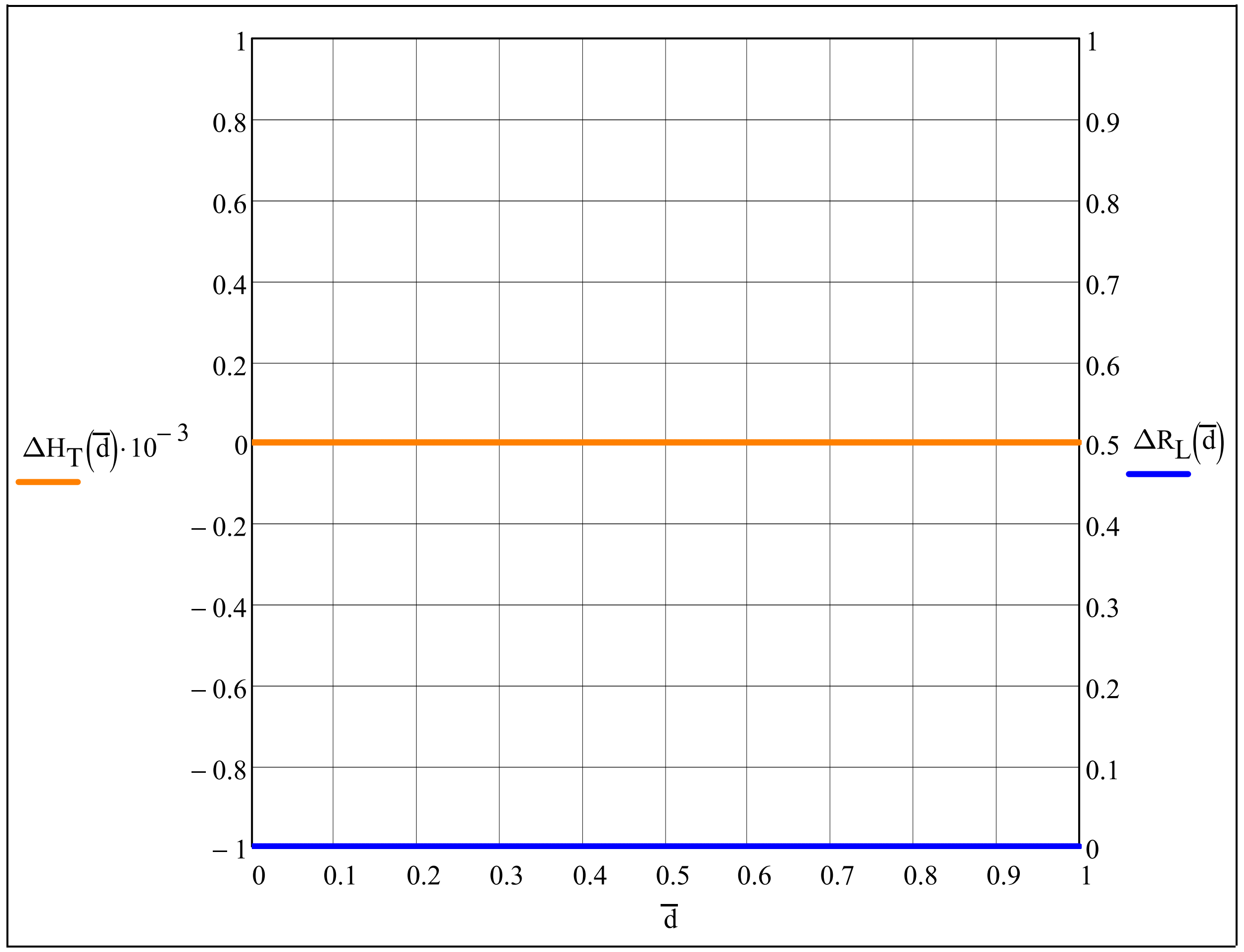
Max разница теор. напора ступени и реактивности
от периферии к корню по высоте Л (Дж/кг)
[16, с.118-119]:

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

$\Delta R_{Lmax} = 0.0$

$\Delta H_T(\overline{d}) = -\Delta H_{Tmax} \cdot \overline{d} + \Delta H_{Tmax}$

$\Delta R_L(\overline{d}) = -\Delta R_{Lmax} \cdot \overline{d} + \Delta R_{Lmax}$



$$\frac{\ldots st(i,a),av\left(N_r\right)\Big) - \left(R_{st(i,a),r}\right)^{m_i}\cdot\left(R_{st(i,a),av\left(N_r\right)}\right)^{2\cdot m_i+1}\Big] + A_{st(i,a),r}\cdot m_i\cdot\Big[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{st(i,a),av\left(N_r\right)}\right) - \left(R_{st(i,a),r}\right)\cdot\left(R_{st(i,a),av\left(N_r\right)}\right)^{2\cdot m_i+1}\Big]\Big]}{\ldots\cdot R_{st(i,a),av\left(N_r\right)}\Big)^{2\cdot m_i+1}} \quad \text{if } (a = 2)$$

$$\frac{\ldots st(i,a),av\left(N_r\right)\Big) - \left(R_{st(i,a),r}\right)^{m_i}\cdot\left(R_{st(i,a),av\left(N_r\right)}\right)^{2\cdot m_i+1}\Big] + A_{st(i,a),r}\cdot m_i\cdot\Big[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{st(i,a),av\left(N_r\right)}\right) - \left(R_{st(i,a),r}\right)\cdot\left(R_{st(i,a),av\left(N_r\right)}\right)^{2\cdot m_i+1}\Big]\Big]}{\ldots\cdot R_{st(i,a),av\left(N_r\right)}\Big)^{2\cdot m_i+1}} \quad \text{if } (a = 3)$$

$$,1\Big)\Big]\Big]$$

$$\frac{\ldots st(i,a),av(N_r)}{\ldots(i,a),av(N_r)} - 2\cdot\left[2\cdot A_{st(i,a),r}\cdot\left(B_{st(i,a),r} + \frac{b_{HT}}{\omega}\right) + \frac{k_{HT}^{\;2}}{\omega^2}\right]\cdot\ln\left(\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right) \quad \text{if } (a = 2)$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 83.4 \\ 195.2 \\ 85.8 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 83.4 \\ 74.9 \\ 71.1 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 228.6 \\ 82 \\ 181.1 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 90 \\ 22.58 \\ 56.05 \end{pmatrix} \cdot {}^\circ$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 212.8 \\ 213.6 \\ 214.4 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 21.41 \\ 65.96 \\ 23.13 \end{pmatrix} \cdot {}^\circ$$

$$\varepsilon_{stator_{j,r}} = 29.12 \cdot {}^\circ$$

$$\varepsilon_{rotor_{j,r}} = 44.55 \cdot {}^\circ$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 83.4 \\ 170.6 \\ 85.8 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 83.4 \\ 74.9 \\ 71.1 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 264.4 \\ 123.3 \\ 215.7 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 90 \\ 26.05 \\ 56.05 \end{pmatrix} \cdot {}^\circ$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 250.8 \\ 251.2 \\ 251.5 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 18.4 \\ 37.42 \\ 19.26 \end{pmatrix} \cdot {}^\circ$$

$$\varepsilon_{stator_{j,r}} = 29.99 \cdot {}^\circ$$

$$\varepsilon_{rotor_{j,r}} = 19.02 \cdot {}^\circ$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 83.4 \\ 154.9 \\ 85.8 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 83.4 \\ 74.9 \\ 71.1 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 295.8 \\ 166.1 \\ 246.4 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 90 \\ 28.92 \\ 56.05 \end{pmatrix} \cdot °$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 283.8 \\ 283.8 \\ 283.8 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 16.38 \\ 26.82 \\ 16.78 \end{pmatrix} \cdot °$$

$$\varepsilon_{stator_{j,r}} = 30.26 \cdot °$$

$$\varepsilon_{rotor_{j,r}} = 10.44 \cdot °$$

MM

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$,z\big)$

$\big)^{T},z\big)$

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