Подключение библиотек

Основные уравнения, алгоритмы, зависимости и ф-и

Параметры расчета

Исходные данные

Коэф. запаса: $safety = 1.3$

Степень двухконтурности: $m2 = 6$

РТ: Воздух

$compressor = \text{"КВД"}$

Число Маха: $M = 0$

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

Массовый расход (кг/с):

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

Полная температура на входе в К (К):

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

Полное давление на входе в К (Па):

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

Степень повышения давления КВД:

$$\pi^*_K = \begin{vmatrix} 1.6 \;\; \text{if } compressor = \text{"Вл"} \\ \frac{3.2}{1.6} \;\; \text{if } compressor = \text{"КНД"} \\ 9 \;\; \text{if } compressor = \text{"КВД"} \end{vmatrix} = 9.000$$

Ожидаемый адиабатический КПД ОК:

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

Частота вращения ротора (с$^{-1}$):

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

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

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

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

Частота вращения ротора (об/мин):

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

Закон профилирования проточной части (ЗППЧ):

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

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:

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

увеличение несущественно увеличивает π

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

понижение существенно увеличивает π

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

увеличение несущественно увеличивает π

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

[16, с. 234]

увеличение существенно увеличивает π

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

	1	2	3	4	5	6	7	8
1	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
2	0.990	0.980	0.970	0.960	0.950	0.950	0.950	0.950
3	0.863	0.873	0.888	0.893	0.893	0.888	0.873	0.863
4	0.222	0.212	0.202	0.192	0.182	0.172	0.162	0.152
5	0.268	0.308	0.338	0.348	0.368	0.338	0.308	0.288

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

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

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

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

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

$$\bar{H}_{Tcp} = \frac{\sum_{i=1}^{\text{rows}(z_{\sim})} \bar{H}_{\sim T_i}}{\text{rows}(z_{\sim})} = 0.3208$$

$$0.25 \le \bar{H}_{Tcp} \le 0.32 = 0$$

Исходные данные

Распределение основных параметров ОК по ступеням

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

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

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

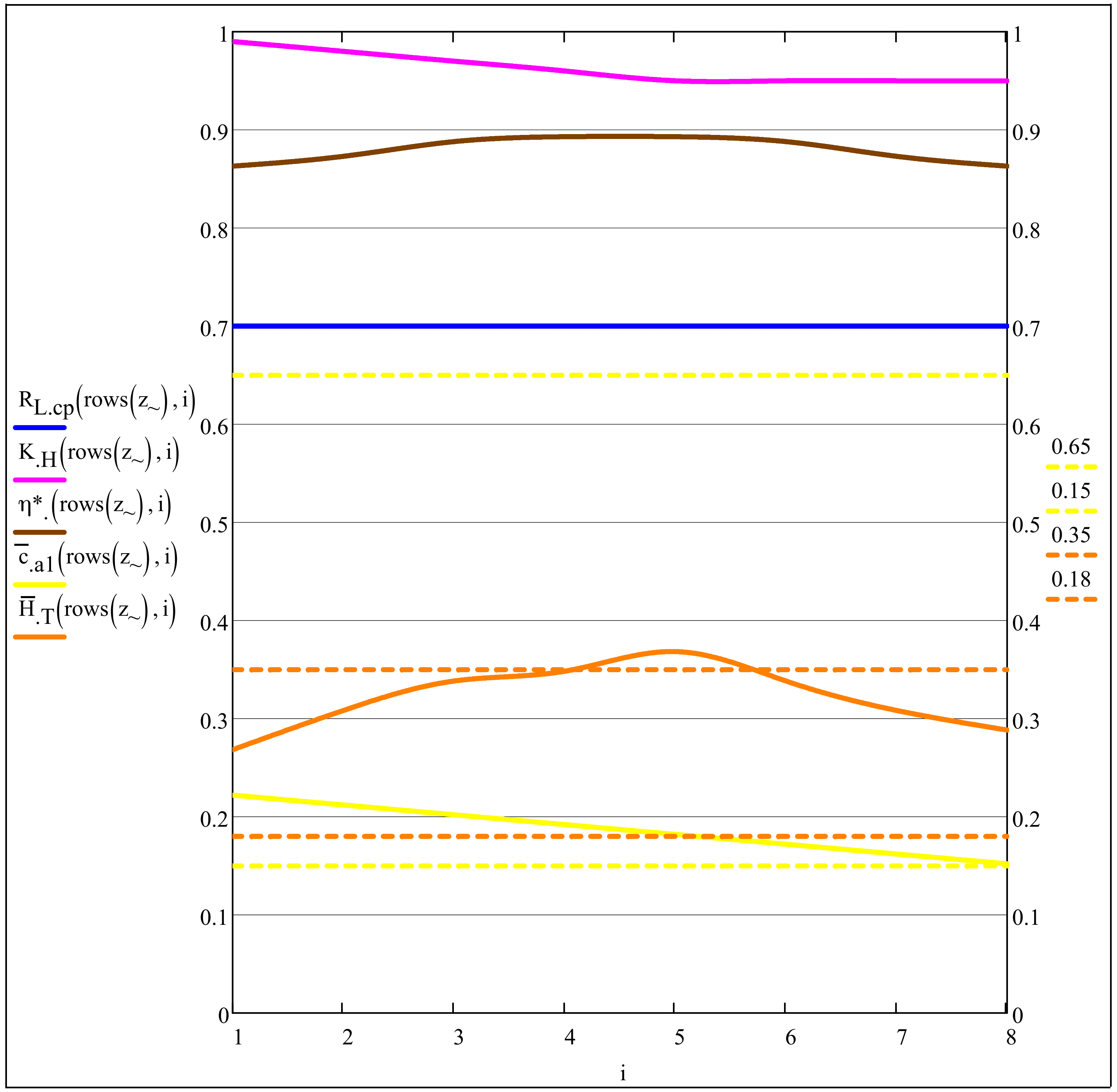
Коэф. расхода: $\overline{c}_{\sim a1}(i) := \text{interp}\left(\text{lspline}\left(\frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{c}_{\sim a1}\right), \frac{z_{\sim}}{\text{rows}(z_{\sim})}, \overline{c}_{\sim a1}, i\right)$

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

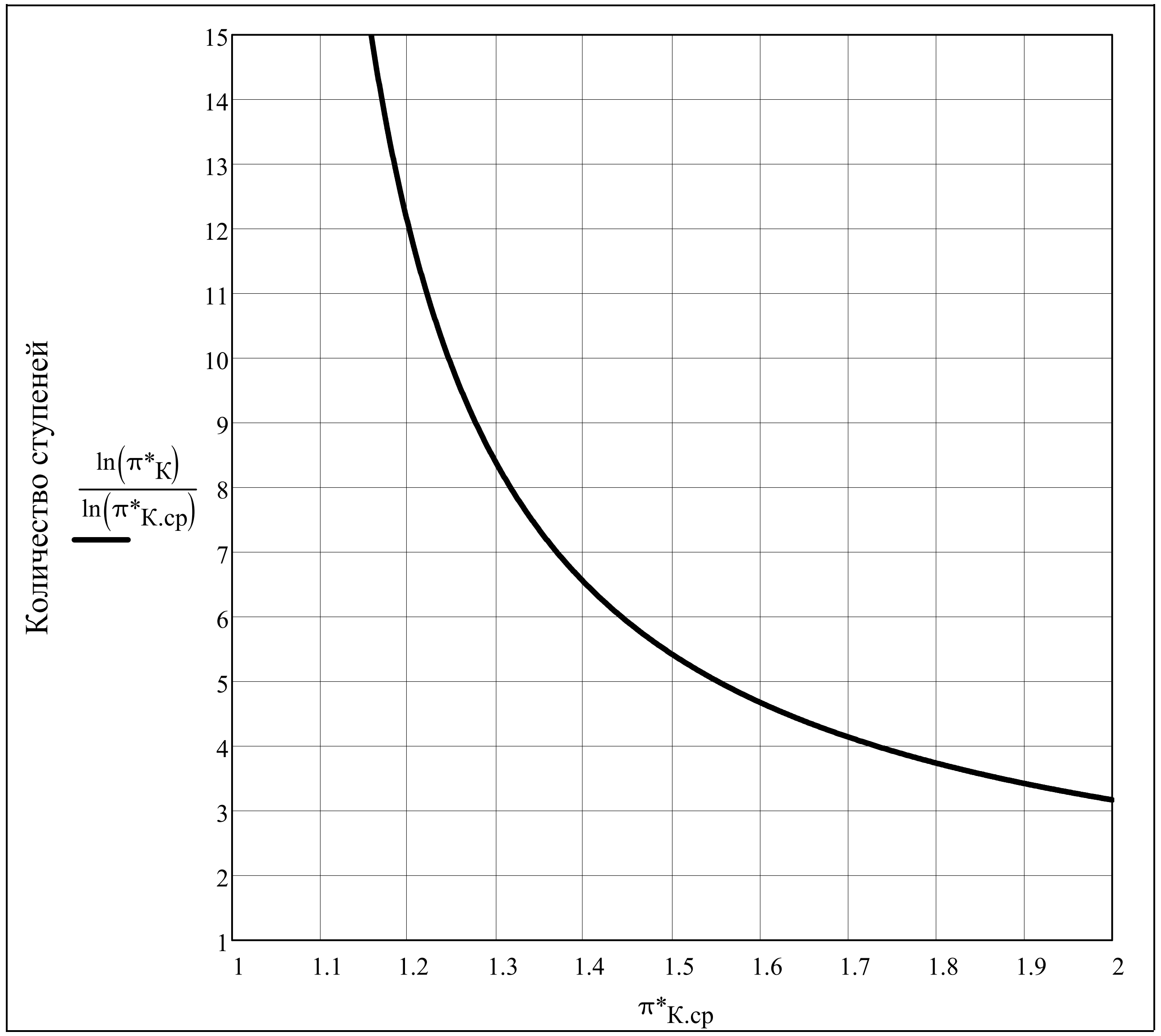
$$\begin{pmatrix} R_{L.cp} \\ K_{.H} \\ \eta^*_{.} \\ \overline{c}_{.a1} \\ \overline{H}_{.T} \end{pmatrix} = \left| \begin{array}{l} R_{L.cp}(Z,i) = \begin{cases} R_{L\sim cp}\left(\dfrac{1}{rows(z_\sim)}\right) & \text{if } i < 1 \\ R_{L\sim cp}(1) & \text{if } i > Z \\ R_{L\sim cp}\left(\dfrac{i}{Z}\right)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

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

$$\begin{pmatrix} R_{L.cp}(Z_{temp}, i_{temp}) \\ K_{.H}(Z_{temp}, i_{temp}) \\ \eta^*_{.}(Z_{temp}, i_{temp}) \\ \overline{c}_{.a1}(Z_{temp}, i_{temp}) \\ \overline{H}_{.T}(Z_{temp}, i_{temp}) \end{pmatrix} = \begin{pmatrix} 0.700 \\ 0.950 \\ 0.863 \\ 0.152 \\ 0.288 \end{pmatrix}$$



Распределение основных параметров ОК по ступеням


Количество ступеней
ln(π*K) / ln(π*K.cp)
π*K.cp
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2

Нулевые приближения

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

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

```
(iteration3, T*K3, kK3) = | iteration3 = 0
                          | kK3 = kK1
                          | while 0 < 1
                          |   | iteration3 = iteration3 + 1
                          |   | trace("iteration.3 = ", num2str(iteration3))
                          |   | kcp = mean(kK1, kK3)
                          |   | T*K3 = T*K1·(1 + (π*K^((kcp−1)/kcp) − 1)/η*K)
                          |   | CpK3 = Cpвоздух(P*K3, T*K3)
                          |   | k'K3 = kад(CpK3, Rв)
                          |   | if |eps("rel", kK3, k'K3)| ≤ epsilon
                          |   |   | kK3 = k'K3
                          |   |   | break
                          |   | kK3 = k'K3
                          | (iteration3, T*K3, kK3)
```

Количество итераций []: $iteration_3 = 2$

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

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

Полная плотность перед и после К [кг/м^3]: $\begin{pmatrix} \rho^*_{К1} \\ \rho^*_{К3} \end{pmatrix} = \frac{1}{R_в} \cdot \begin{pmatrix} \frac{P^*_{К1}}{T^*_{К1}} \\ \frac{P^*_{К3}}{T^*_{К3}} \end{pmatrix} = \begin{pmatrix} 2.633 \\ 12.297 \end{pmatrix}$

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

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

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

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

Количество итераций []: $iteration_u = 2$

Окружная скорость на перифкрии перед К [м/с]: $u_{1пер} = 436.7$

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

Абс. скорость перед К [м/с]: $c_{вх} = 96.9$

Приведенная скорость перед К []: $\lambda_{вх} = 0.2592$

Плотность перед К [кг/м^3]: $\rho_{K1} = 2.560$

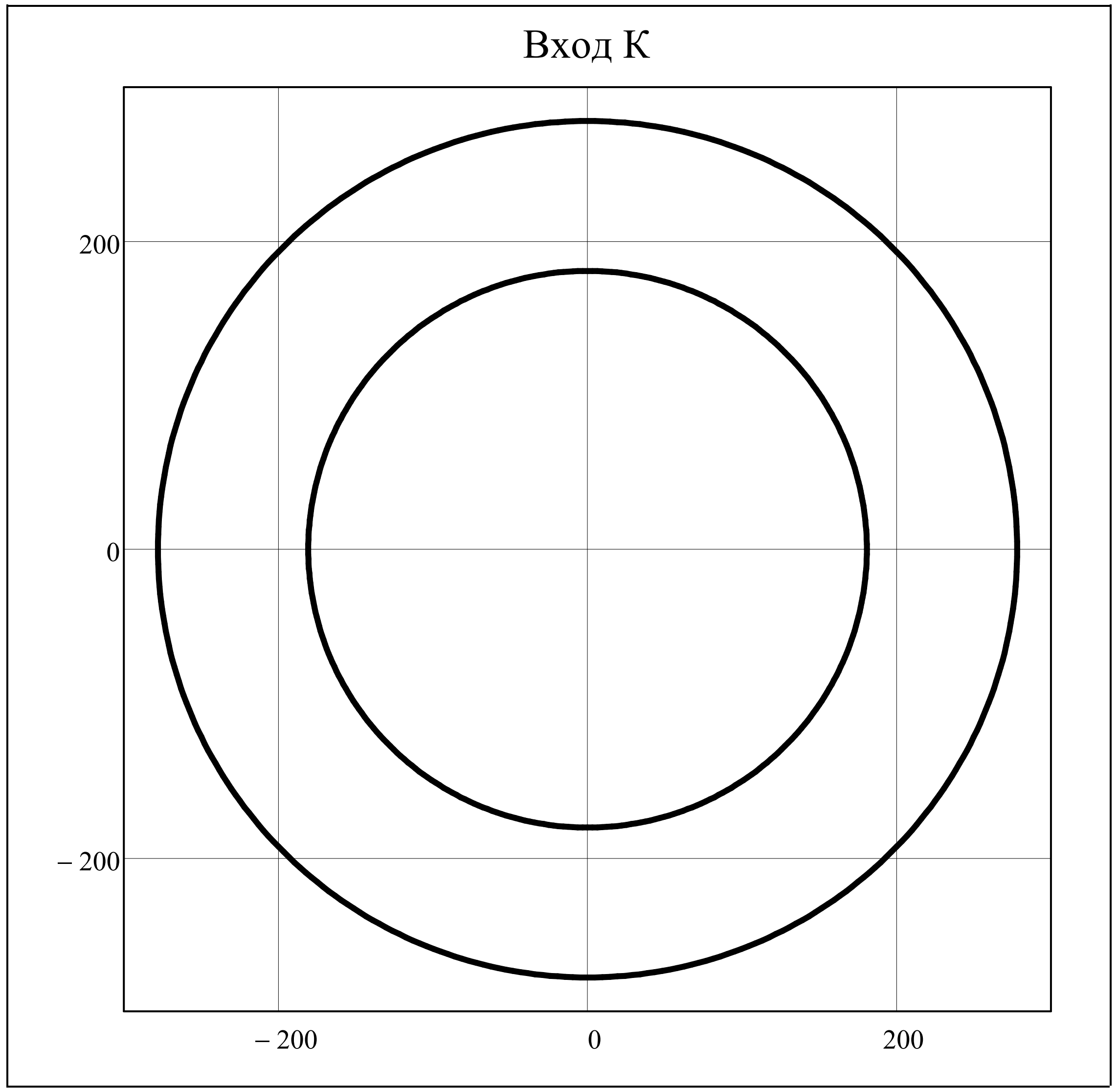
Кольцевая площадь перед К [м^2]: $F_{вх} := \dfrac{G \cdot \sqrt{R_в \cdot T^*_{K1}}}{m_q(k_{K1}) \cdot P^*_{K1} \cdot ГДФ("G", \lambda_{вх}, k_{K1})} = 0.1403$

$$D'_{пер1} := \frac{2 \cdot u_{1пер}}{\omega} = 556 \cdot 10^{-3}$$

Диамтеры перед К [м]: $D'_{cp1} := \overline{r}_{cp}(\overline{d}_1) \cdot D'_{пер1} = 468.9 \cdot 10^{-3}$

$$D'_{кор1} := \overline{d}_1 \cdot D'_{пер1} = 361.4 \cdot 10^{-3}$$

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



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

Количество ступеней []:
$$Z := \begin{vmatrix} 1 & \text{if } compressor = \text{"Вл"} \\ 3 & \text{if } compressor = \text{"КНД"} \\ 9 & \text{if } compressor = \text{"КВД"} \end{vmatrix} = 9$$

Нулевые приближения

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

Расчет ВНА:

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

$\sigma_{BHA} = 0.9983$

$submatrix\left(\varepsilon_{BHA}, av(N_r), av(N_r), 1, 1\right) = (22.94)\cdot deg$

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

$submatrix\left(\alpha_{3BHA}, av(N_r), av(N_r), 1, 1\right) = (67.06)\cdot deg$

$\begin{pmatrix} \overline{d}_{1BHA} \\ \overline{d}_{3BHA} \end{pmatrix} = \begin{pmatrix} 0.6500 \\ 0.6500 \end{pmatrix}$ $\begin{pmatrix} F_{1BHA} \\ F_{3BHA} \end{pmatrix} = \begin{pmatrix} 0.1403 \\ 0.1564 \end{pmatrix}$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\mathrm{submatrix}\left(P^*_{3BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (315.7)\cdot 10^3$$

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

$$\mathrm{submatrix}\left(\rho^*_{3BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (2.629)$$

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

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

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

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

$$\mathrm{submatrix}\left(\overline{c}_{a1BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.222)$$

$$\mathrm{submatrix}\left(\overline{c}_{a3BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.223)$$

$$\mathrm{submatrix}\left(\overline{c}_{u1BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.094)$$

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

$$\mathrm{submatrix}\left(c_{a1BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (96.9)$$

$$\mathrm{submatrix}\left(c_{a3BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (86.9)$$

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

$$\mathrm{submatrix}\left(c_{u3BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (36.8)$$

$$\mathrm{submatrix}\left(c_{1BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (96.9)$$

$$\mathrm{submatrix}\left(c_{3BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (94.4)$$

$$\mathrm{submatrix}\left(\lambda_{1BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.259)$$

$$\mathrm{submatrix}\left(\lambda_{3BHA}, av\left(N_r\right), av\left(N_r\right), 1, 1\right) = (0.252)$$

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

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

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

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

Расчет ВНА:

Поступенчатый расчет ОК по ср. ЛТ

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

$r = av(N_r)$

$T^*_{st(1,1),r} = T^*_{3ВНА_r}$

$P^*_{st(1,1),r} = P^*_{3ВНА_r}$

$\rho^*_{st(1,1),r} = \rho^*_{3ВНА_r}$

$Cp_{st(1,1),r} = Cp_{воздух}\left(P^*_{st(1,1),r}, T^*_{st(1,1),r}\right)$

$k_{st(1,1),r} = k_{ад}\left(Cp_{st(1,1),r}, R_B\right)$

$a^*_{c_{st(1,1),r}} = a_{кр}\left(k_{st(1,1),r}, R_B, T^*_{st(1,1),r}\right)$

$\overline{c}_{a_{st(1,1),r}} = \overline{c}_{a3ВНА_r}$

$\overline{c}_{u_{st(1,1),r}} = \overline{c}_{u3ВНА_r}$

$c_{a_{st(1,1),r}} = c_{a3ВНА_r}$

$u_{st(1,1),N_r} = u_{1пер}$

$\alpha_{st(1,1),r} = \alpha_{3ВНА_r}$

$$c_{st(1,1),r} = \frac{c_{a_{st(1,1),r}}}{\sin\left(\alpha_{st(1,1),r}\right)}$$

$$\lambda_{c_{st(1,1),r}} = \frac{c_{st(1,1),r}}{a^*_{c_{st(1,1),r}}}$$

$$F_{st(1,1)} = \frac{G\cdot\sqrt{R_B\cdot T^*_{st(1,1),r}}}{m\,(k\ldots)\cdot ГДФ("G", \lambda\ldots k\ldots)\cdot\sin(\alpha\ldots)\cdot P^*\ldots}$$

$$m_q(k_{st(1,1),r})\cdot ГДФ\left(G,\lambda c_{st(1,1),r},k_{st(1,1),r}\right)\cdot \sin(\alpha_{st(1,1),r})\cdot P^*_{st(1,1),r}$$

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

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

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

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

for $i \in 1..Z$

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

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

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

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

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

$$iteration_{12} = 0$$

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

while $0 < 1$

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

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

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

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

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

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

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

$$Cp_{st(i,2),r} = Cp_{воздух}\left(P*_{st(i,2),r}, T*_{st(i,2),r}\right)$$
$$k'_2 = k_{ад}\left(Cp_{st(i,2),r}, R_в\right)$$
$$\text{if } \left|eps\left(\text{"rel"}, k_{st(i,2),r}, k'_2\right)\right| < epsilon$$
$$k_{st(i,2),r} = k'_2$$
break
$$k_{st(i,2),r} = k'_2$$
$$a*_{c_{st(i,2),r}} = a_{кр}\left(k_{st(i,2),r}, R_в, T*_{st(i,2),r}\right)$$
$$T*_{st(i,3),r} = T*_{st(i,2),r}$$
$$P*_{st(i,3),r} = P*_{st(i,2),r}$$
$$Cp_{st(i,3),r} = Cp_{воздух}\left(P*_{st(i,3),r}, T*_{st(i,3),r}\right)$$
$$k_{st(i,3),r} = k_{ад}\left(Cp_{st(i,3),r}, R_в\right)$$
$$a*_{c_{st(i,3),r}} = a_{кр}\left(k_{st(i,3),r}, R_в, T*_{st(i,3),r}\right)$$
$$\overline{c}_{a_{st(i,3),r}} = \overline{c}.a1(Z, i+1)$$
$$iteration_3 = 0$$
$$\begin{pmatrix} \alpha_{st(i,3),r} \\ u_{st(i,3),N_r} \end{pmatrix} = \begin{pmatrix} \alpha_{st(i,1),r} \\ u_{st(i,1),N_r} \end{pmatrix}$$
$$c_{a_{st(i,3),r}} = \overline{c}_{a_{st(i,3),r}} \cdot u_{st(i,3),N_r}$$
$$c_{st(i,3),r} = \frac{c_{a_{st(i,3),r}}}{\sin\left(\alpha_{st(i,3),r}\right)}$$
$$\lambda_{c_{st(i,3),r}} = \frac{c_{st(i,3),r}}{a*_{c_{st(i,3),r}}}$$
$$F_{st(i,3)} = \frac{F_{st(i,1)} \cdot m_q\left(k_{st(i,1),r}\right) \cdot ГДФ\left(\text{"G"}, \lambda_{c_{st(i,1),r}}, k_{st(i,1),r}\right) \cdot \sin\left(\alpha_{st(i,1),r}\right) \cdot P*_{st(i,1),r} \cdot \sqrt{T*_{st(i,3),r}}}{m_q\left(k_{st(i,3),r}\right) \cdot ГДФ\left(\text{"G"}, \lambda_{c_{st(i,3),r}}, k_{st(i,3),r}\right) \cdot \sin\left(\alpha_{st(i,3),r}\right) \cdot P*_{st(i,3),r} \sqrt{T*_{st(i,1),r}}}$$
while $0 < 1$
$$iteration_3 = iteration_3 + 1$$
trace(concat("   iteration.3 = ", num2str($iteration_3$)))
if (ЗППЧ$_i$ ≠ "пер") ∧ (ЗППЧ$_i$ ≠ "кор") ∧ (ЗППЧ$_i$ ≠ "ср")
$$D_{st(i,3),N_r} = D_{st(i,1),N_r} \cdot str2num\left(ЗППЧ_i\right)$$
$$D_{st(i,3),1} = \sqrt{\left(D_{st(i,3),N_r}\right)^2 - \frac{4F_{st(i,3)}}{\pi}}$$
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"

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$iteration_2 \leftarrow 0$$

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

while $0 < 1$

$$iteration_2 \leftarrow iteration_2 + 1$$

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

if $\left(ЗППЧ_i \ne "пер"\right) \wedge \left(ЗППЧ_i \ne "кор"\right) \wedge \left(ЗППЧ_i \ne "ср"\right)$

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

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

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

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

if $ЗППЧ_i = "пер"$

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

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

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

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

if $ЗППЧ_i = "кор"$

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

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

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

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

if $ЗППЧ_i = "ср"$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 $r \in 1..N_r$

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

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

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

Поступенчатый расчет ОК по ср. ЛТ

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

Расчет CA:

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

$\sigma_{CA} = 0.9984$

$submatrix\left(\varepsilon_{CA}, av(N_r), av(N_r), 1, 1\right) = (37.78)\cdot deg$

$submatrix\left(\alpha_{1CA}, av(N_r), av(N_r), 1, 1\right) = (52.22)\cdot deg$

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

$$\begin{pmatrix} \overline{d}_{1CA} \\ \overline{d}_{3CA} \end{pmatrix} = \begin{pmatrix} 0.8253 \\ 0.8253 \end{pmatrix} \qquad \begin{pmatrix} F_{1CA} \\ F_{3CA} \end{pmatrix} = \begin{pmatrix} 0.0532 \\ 0.0648 \end{pmatrix}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$\text{submatrix}\left(T^*_{1CA}, av(N_r), av(N_r), 1, 1\right) = (827.2)$

$\text{submatrix}\left(T^*_{3CA}, av(N_r), av(N_r), 1, 1\right) = (827.2)$

$\text{submatrix}\left(P^*_{1CA}, av(N_r), av(N_r), 1, 1\right) = (2847.9)\cdot 10^3$

$\text{submatrix}\left(P^*_{3CA}, av(N_r), av(N_r), 1, 1\right) = (2843.3)\cdot 10^3$

$\text{submatrix}\left(\rho^*_{1CA}, av(N_r), av(N_r), 1, 1\right) = (11.990)$

$\text{submatrix}\left(\rho^*_{3CA}, av(N_r), av(N_r), 1, 1\right) = (11.971)$

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

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

$\text{submatrix}\left(a_{кр1CA}, av(N_r), av(N_r), 1, 1\right) = (522.5)$

$\text{submatrix}\left(a_{кр3CA}, av(N_r), av(N_r), 1, 1\right) = (522.5)$

$\text{submatrix}\left(\bar{c}_{a1CA}, av(N_r), av(N_r), 1, 1\right) = (0.152)$

$\text{submatrix}\left(\bar{c}_{a3CA}, av(N_r), av(N_r), 1, 1\right) = (0.152)$

$\text{submatrix}\left(\bar{c}_{u1CA}, av(N_r), av(N_r), 1, 1\right) = (0.118)$

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

$\text{submatrix}\left(c_{a1CA}, av(N_r), av(N_r), 1, 1\right) = (55.0)$

$\text{submatrix}\left(c_{a3CA}, av(N_r), av(N_r), 1, 1\right) = (45.0)$

$\text{submatrix}\left(c_{u1CA}, av(N_r), av(N_r), 1, 1\right) = (42.6)$

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

$\text{submatrix}\left(c_{1CA}, av(N_r), av(N_r), 1, 1\right) = (69.6)$

$\text{submatrix}\left(c_{3CA}, av(N_r), av(N_r), 1, 1\right) = (45.0)$

$\text{submatrix}\left(\lambda_{1CA}, av(N_r), av(N_r), 1, 1\right) = (0.133)$

$\text{submatrix}\left(\lambda_{3CA}, av(N_r), av(N_r), 1, 1\right) = (0.086)$

1 otherwise

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

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

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

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

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

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

Расчет СА:

Результаты поступенчатого расчета по ср. ЛТ

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

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

$\overline{\Delta}G^T =$ (·%)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.00	0.00	0.07	0.00	0.03	0.00	0.17	0.00	0.13	0.00	0.09	0.00	0.07	0.00	0.04	0.00	0.03	0.00	0.04

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

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

Количество ступеней ОК: $Z = 9$

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

Дискритизация ступеней: $i = 1..Z$

$\pi^{*T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.406	1.379	1.364	1.317	1.285	1.251	1.202	1.169	1.147						

[16, с 114] $\pi^{*T} \le 1.9 =$

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

Полученная степень повышения полного давления []: $\prod_{i=1}^{Z} \pi^*_i = 9.022$

Степень повышения давления в ЛА: $\pi^*_{ЛА} = \dfrac{P^*_{3CA_{av(N_r)}}}{P^*_{1BHA_{av(N_r)}}} = 8.992$ $\qquad \pi^*_{ЛА} \ge \pi^*_K = 0$

$H_T^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	50.29	52.83	56.05	54.46	54.19	52.44	46.15	41.77	38.78						
2	50.29	52.83	56.05	54.46	54.19	52.44	46.15	41.77	38.78						
3	50.29	52.83	56.05	54.46	54.19	52.44	46.15	41.77	38.78						

$\cdot 10^3$

Действительная работа К (Дж/кг): $L_K = \sum_{i=1}^{Z} L_i = 430.7 \cdot 10^3$

Адиабатная работа К [Дж/кг]: $L^*_K = \sum_{i=1}^{Z} L^*_i = 379 \cdot 10^3$

Адиабатная КПД К []: $\eta^*_K = \dfrac{L^*_K}{L_K} = 88.00 \cdot \%$

Мощность К (Вт): $N_K = G \cdot L_K = 14.99 \cdot 10^6$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70						

$K_H^T =$

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

$\eta^{*T} =$

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

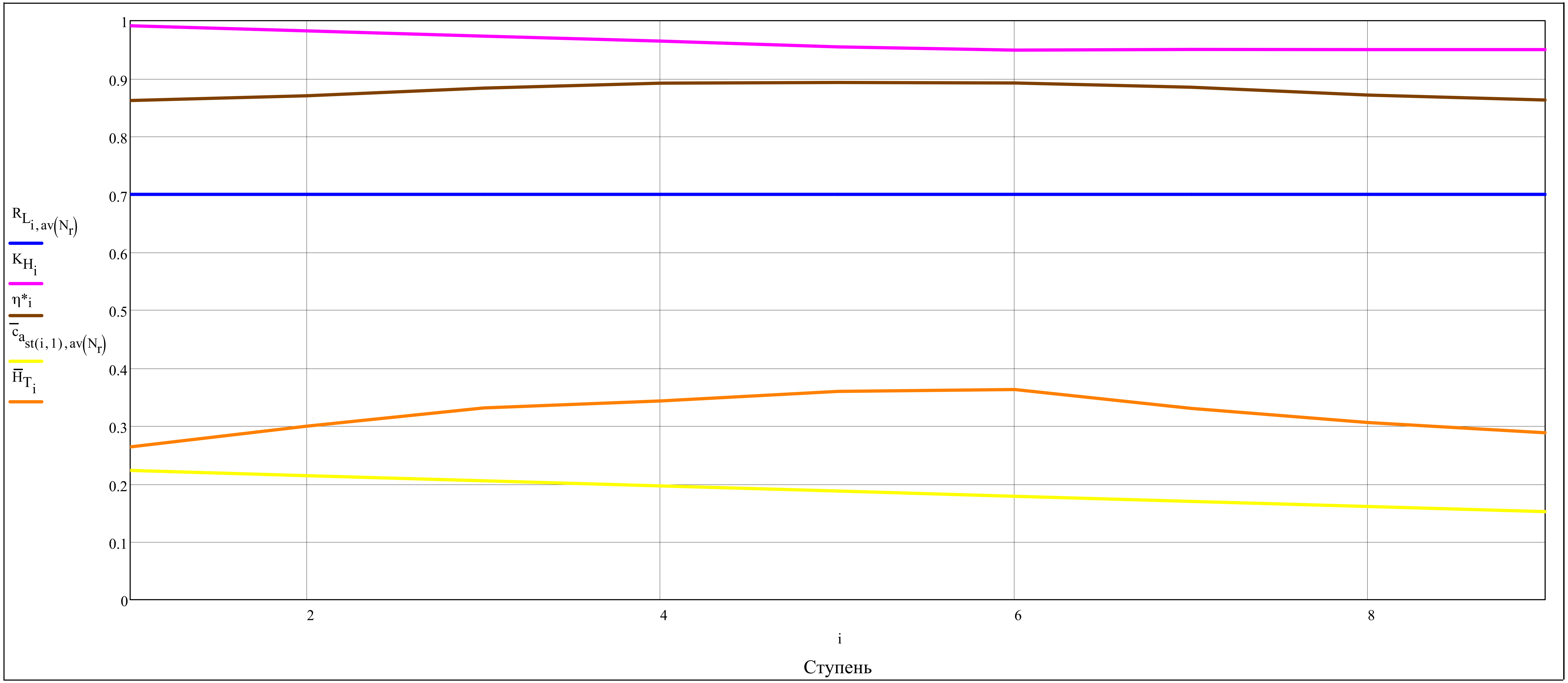
$\cdot\%$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.223	0.219	0.214	0.210	0.205	0.201	0.196	0.192	0.188	0.183	0.179	0.174	0.170	0.165	0.161	0.156	0.152	0.152	0.152	

$\bar{H}_T^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.26	0.30	0.33	0.34	0.36	0.36	0.33	0.31	0.29						



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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1016.2	1024.5	1024.5	1034.3	1034.3	1045.4	1045.4	1056.6	1056.6	1067.8	1067.8	1078.6	1078.6	1088.0	1088.0	1096.3	1096.3	1103.9	1103.9

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.394	1.389	1.389	1.384	1.384	1.379	1.379	1.373	1.373	1.368	1.368	1.363	1.363	1.359	1.359	1.355	1.355	1.352	1.352		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	418.2	467.3	467.3	517.9	517.9	570.6	570.6	620.9	620.9	669.9	669.9	716.5	716.5	757.1	757.1	793.6	793.6	827.2	827.2		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	413.8	446.8	462.7	498.3	514	550.6	567.3	602.1	618.1	651.8	667.4	699.4	714.1	742.1	754.8	779.9	791.4	814.4	825		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	315.7	443.9	443.9	612.3	612.3	835.1	835.1	1099.7	1099.7	1412.8	1412.8	1767.6	1767.6	2124.9	2124.9	2483.1	2483.1	...

$\cdot 10^3$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	304.1	378.3	428.7	533.0	595.9	733.2	817.6	982.1	1081.4	1276.3	1393.5	1614.7	1745.7	1969.1	2100.4	2323.7	2456.5	...

$\cdot 10^3$

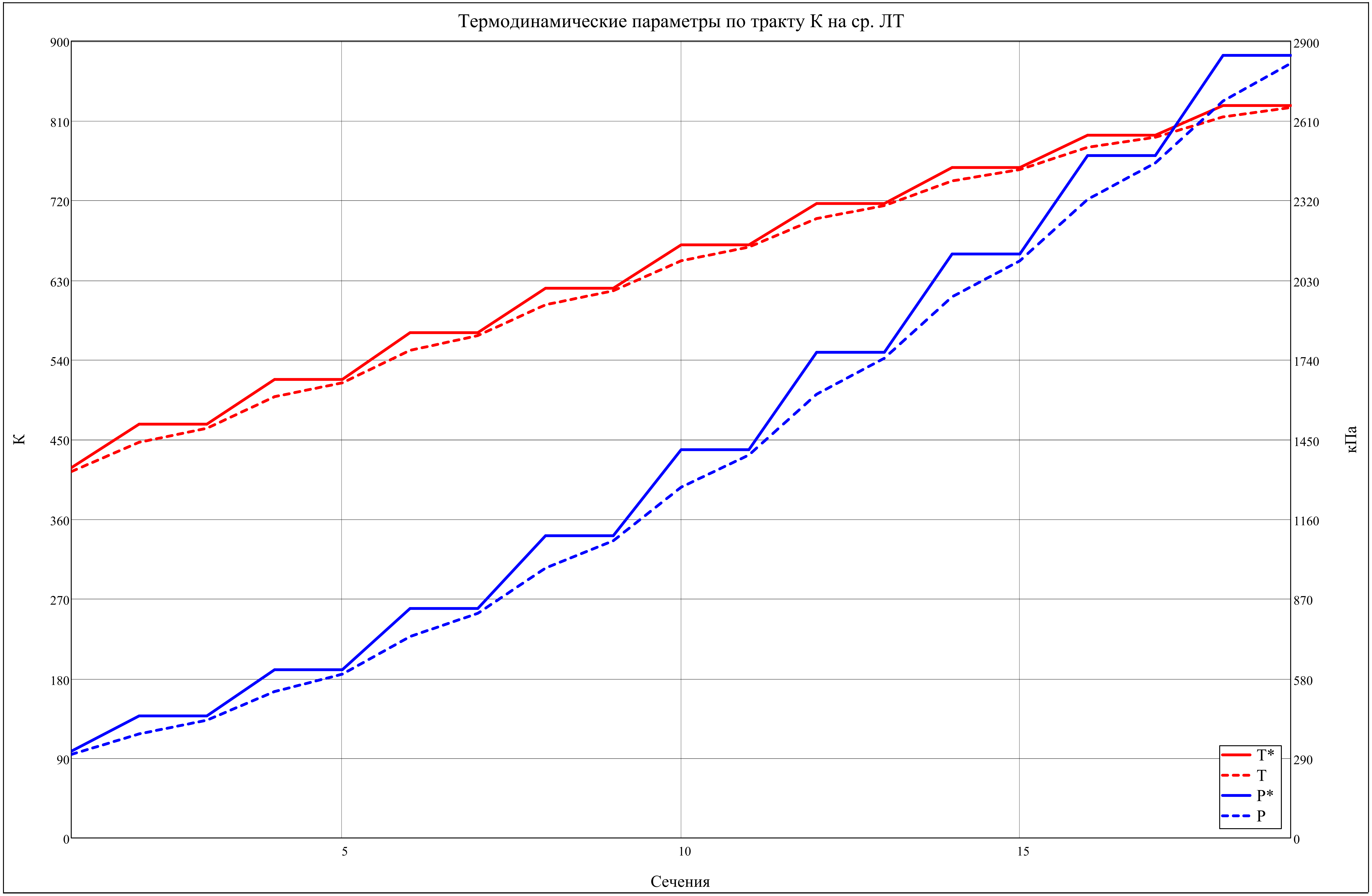
$\mathrm{submatrix}\left(\rho^*, 1, 2Z+1, av\left(N_r\right), av\left(N_r\right)\right)^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	2.629	3.308	3.308	4.117	4.117	5.096	5.096	6.168	6.168	7.345	7.345	8.592	8.592	9.774	9.774	10.897	10.897	11.99	11.99

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	2.559	2.949	3.227	3.725	4.037	4.637	5.019	5.68	6.094	6.819	7.272	8.04	8.514	9.241	9.691	10.376	10.811	11.468	11.9

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



Термодинамические параметры по тракту К на ср. ЛТ
900
810
720
630
540
450
360
270
180
90
0
2900
2610
2320
2030
1740
1450
1160
870
580
290
0
К
кПа
5
10
15
Сечения
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	156448	126088	119848	107191	102019	92315	88485	81173	78356	72576	70421	65929	64381	61296	60381	58246	57741	54818	53166		

$\overline{d}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.5963	0.6405	0.6827	0.7045	0.7258	0.7378	0.7497	0.7595	0.7692	0.7774	0.7856	0.7922	0.7988	0.8034	0.8080	0.8111	0.8142	0.8197	0.8253				

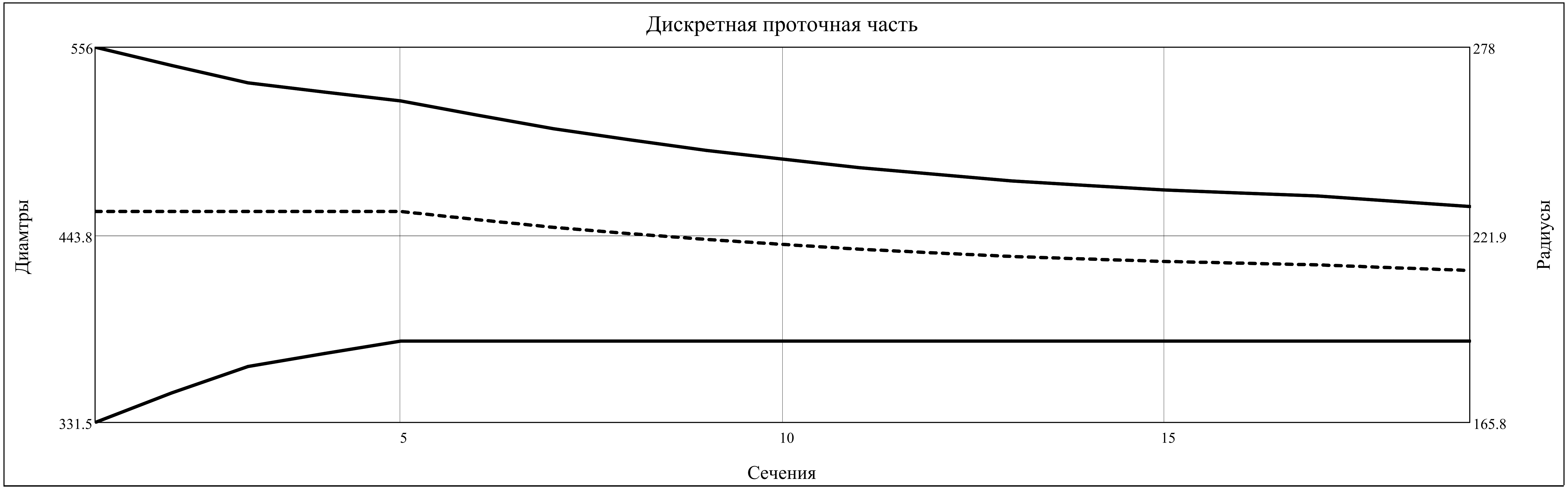
$\overline{d}_{st(Z,3)} = 0.8253$ $\quad$ $\overline{d}_{st(Z,3)} \le 0.9 = 1$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	331.5	349.2	365.0	372.8	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2	380.2		
2	457.7	457.7	457.7	457.7	457.7	452.9	448.2	444.5	441.0	438.0	435.2	432.9	430.8	429.3	427.8	426.8	425.8	424.1	422.4		
3	556.0	545.1	534.6	529.2	523.9	515.4	507.2	500.6	494.3	489.1	484.0	479.9	476.0	473.2	470.6	468.8	467.0	463.8	460.7		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	165.8	174.6	182.5	186.4	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1	190.1						
2	228.9	228.9	228.9	228.9	228.9	226.4	224.1	222.3	220.5	219.0	217.6	216.5	215.4	214.6	213.9	213.4	212.9	212.0	211.2						
3	278.0	272.5	267.3	264.6	261.9	257.7	253.6	250.3	247.1	244.5	242.0	240.0	238.0	236.6	235.3	234.4	233.5	231.9	230.4						



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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	112.2	98.0	84.8	78.2	71.8	67.6	63.5	60.2	57.0	54.4	51.9	49.9	47.9	46.5	45.2	44.3	43.4	41.8	40.2						

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	373.9	395.0	395.0	415.5	415.5	435.8	435.8	454.2	454.2	471.4	471.4	487.2	487.2	500.5	500.5	512.1	512.1	522.5	522.5		

$\mathrm{submatrix}\left(a_{3в}, 1, 2Z+1, av(N_r), av(N_r)\right)^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	407	422.2	429.7	445.1	452	466.9	473.9	487.2	493.7	506	512	523.2	528.6	538	542.6	550.8	554.9	562.2	565.8		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	94.4	204.7	96.3	201.2	89.6	204.6	83.2	199.3	77.2	196.4	72.7	191.8	71.7	181	70.9	173.2	70	168.3	69.6		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	296.2	200.6	337.3	198.4	340.3	186.5	333.1	181.1	328.8	175.4	323.2	172.8	311.6	177.8	303.2	181.3	297.4	182.7			

$u^T =$

	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	260.4	274.2	286.7	292.8	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6						
2	359.5	359.5	359.5	359.5	359.5	355.7	352.0	349.1	346.3	344.0	341.8	340.0	338.3	337.1	336.0	335.2	334.4	333.1	331.7						
3	436.7	428.1	419.9	415.6	411.5	404.8	398.3	393.2	388.2	384.1	380.1	376.9	373.8	371.7	369.6	368.2	366.8	364.3	361.8						

$c_{a_{st(Z,3), av(N_r)}} = 55.00$ $\quad c_{a_{st(Z,3), av(N_r)}} \le 130 = 1$ $\quad$ Для КС

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	86.9	93.6	89.9	87.2	84.5	81.3	78.3	75.5	72.8	70.3	67.9	65.7	63.5	61.5	59.5	57.6	55.7	55.4	55		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	36.8	182.1	34.4	181.3	29.9	187.8	28.3	184.5	25.7	183.4	25.8	180.2	33.3	170.3	38.6	163.3	42.3	159	42.6		

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	283.2	177.4	325.1	178.2	329.6	167.9	323.8	164.6	320.7	160.7	316	159.8	305	166.9	297.3	171.9	292.1	174.1	289.1		

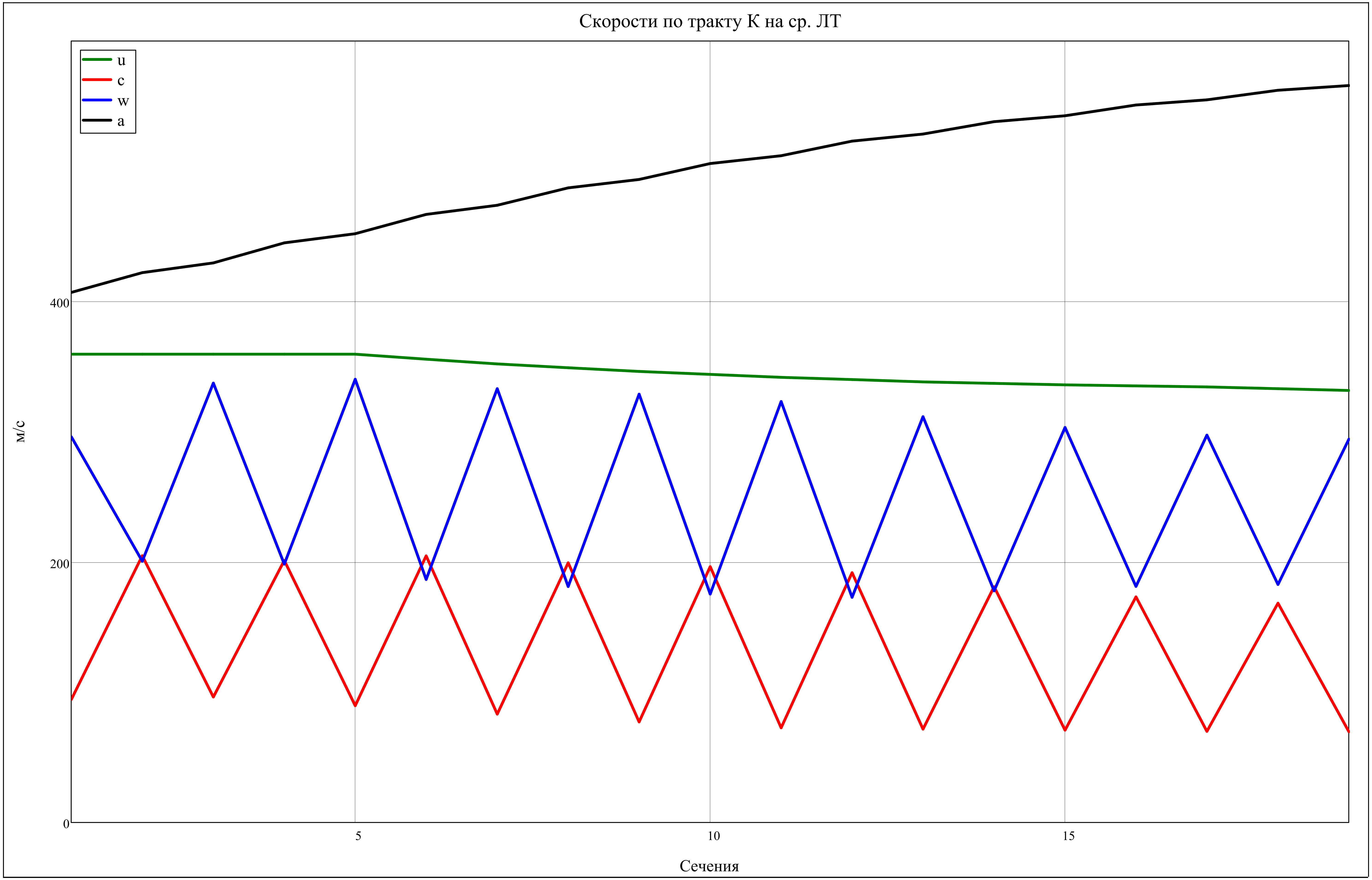
$$\Delta c_{a_{i, av(N_r)}} = \left(c_{a_{st(i,2), av(N_r)}} - c_{a_{st(i,1), av(N_r)}}\right)$$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	6.67	-2.76	-3.18	-2.76	-2.48	-2.24	-2.01	-1.86	-0.38												

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1	1	1	1	1	1	1	1	1																					



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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	67.06	27.21	69.09	25.68	70.51	23.41	70.14	22.26	70.59	20.99	69.18	20.02	62.32	19.84	56.98	19.43	52.78	19.20	52.22		

$\cdot ^\circ$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	17.07	27.82	15.46	26.08	14.38	25.84	13.59	24.63	12.79	23.64	12.13	22.33	11.75	20.22	11.31	18.53	10.81	17.64	10.77		

$\cdot ^\circ$

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

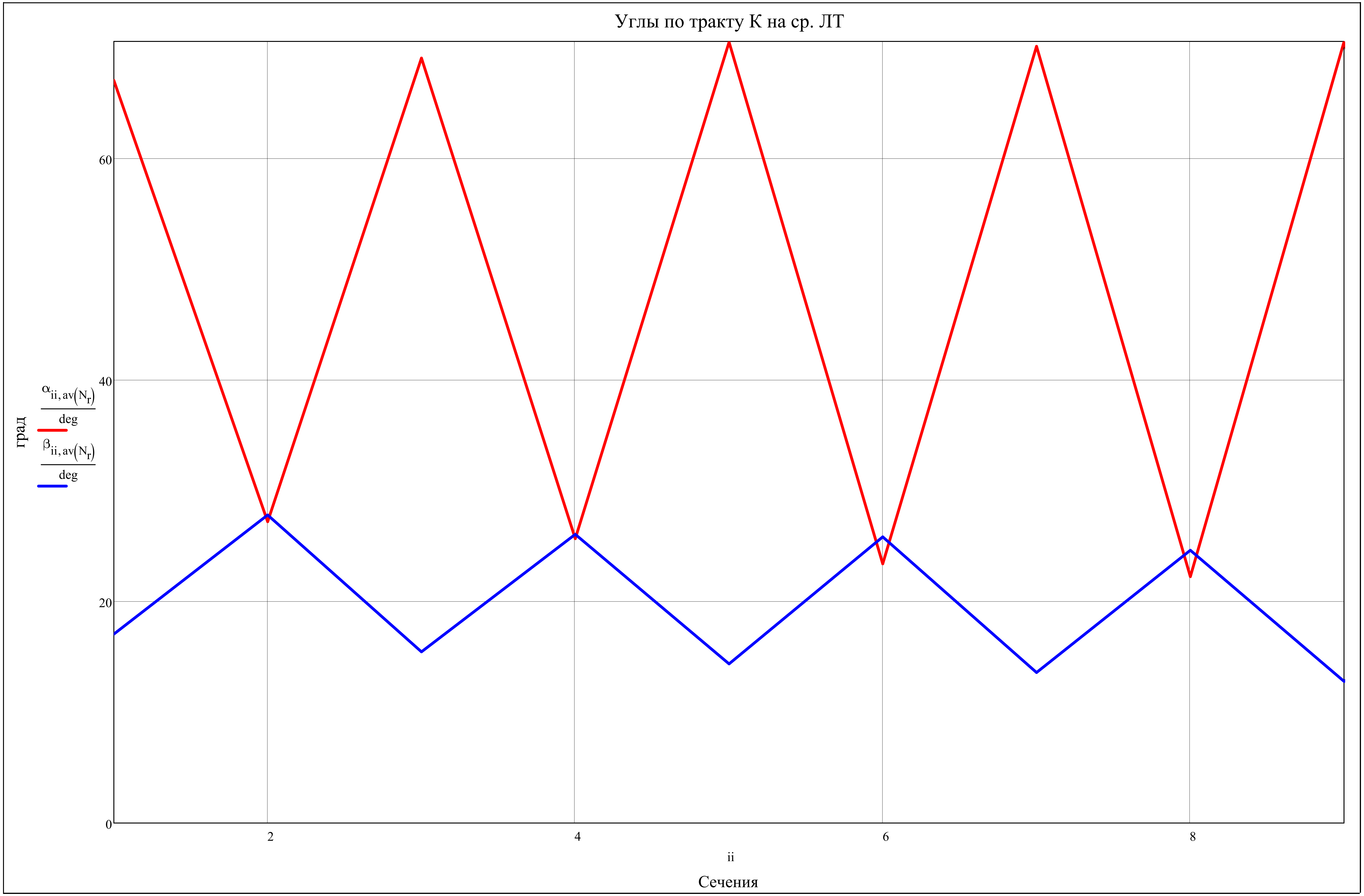
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	10.75	10.61	11.47	11.04	10.85	10.2	8.46	7.22	6.84												

$\cdot ^\circ$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	41.88	44.83	46.73	48.33	48.19	42.29	37.14	33.35	33.02												

$\cdot ^\circ$



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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.2524	0.5183	0.2438	0.4842	0.2157	0.4696	0.1909	0.4388	0.1700	0.4166	0.1541	0.3937	0.1471	0.3617	0.1417	0.3382	0.1367	0.3221	0.1332

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

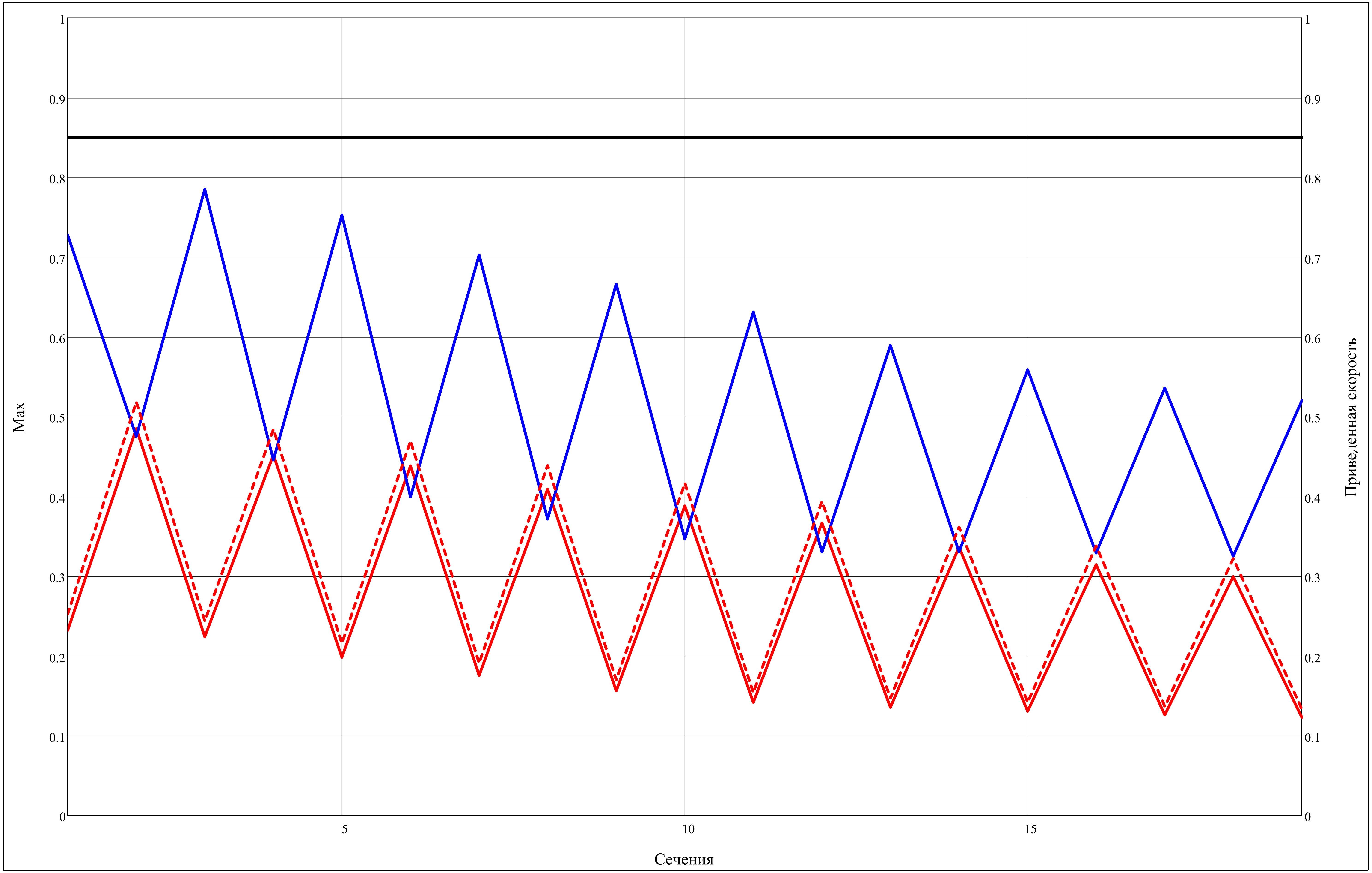
	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	...

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.7278	0.4751	0.7851	0.4457	0.7528	0.3995	0.7028	0.3718	0.6661	0.3467	0.6313	0.3303	0.5894	0.3305	0.5588	0.3291	0.5359	0.325	

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.2320	0.4850	0.2241	0.4521	0.1983	0.4383	0.1756	0.4091	0.1564	0.3881	0.1419	0.3666	0.1356	0.3365	0.1307	0.3144	0.1262	0.2994	0.1230



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

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]

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

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

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

$m^T =$

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.482	0.914	1.000	1.000	1.000	1.000	1.000	1.000	1.000			

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

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

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

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

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

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

if $m_i = 0$

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

otherwise

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

for $r \in 1..N_r$

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

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

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

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

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

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

$$c_{u3BHA} = \begin{pmatrix} 36.79 \\ 36.79 \\ 36.79 \end{pmatrix}$$

$$c_{a1BHA} = \begin{pmatrix} 96.94 \\ 96.94 \\ 96.94 \end{pmatrix}$$

$$c_{a3BHA} = \begin{pmatrix} 86.94 \\ 86.94 \\ 86.94 \end{pmatrix}$$

$$\alpha_{1BHA} = \begin{pmatrix} 90.00 \\ 90.00 \\ 90.00 \end{pmatrix} \cdot ^\circ$$

$$\alpha_{3BHA} = \begin{pmatrix} 67.06 \\ 67.06 \\ 67.06 \end{pmatrix} \cdot ^\circ$$

$$\varepsilon_{BHA} = \begin{pmatrix} 22.94 \\ 22.94 \\ 22.94 \end{pmatrix} \cdot ^\circ$$

$$c_{u1CA} = \begin{pmatrix} 45.62 \\ 41.07 \\ 37.65 \end{pmatrix}$$

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

$$c_{a1CA} = \begin{pmatrix} 55.00 \\ 55.00 \\ 55.00 \end{pmatrix}$$

$$c_{a3CA} = \begin{pmatrix} 45.00 \\ 45.00 \\ 45.00 \end{pmatrix}$$

$$\alpha_{1CA} = \begin{pmatrix} 50.32 \\ 53.25 \\ 55.61 \end{pmatrix} \cdot ^\circ$$

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

$$\varepsilon_{CA} = \begin{pmatrix} 39.68 \\ 36.75 \\ 34.39 \end{pmatrix} \cdot ^\circ$$

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	418.2	467.3	467.3	517.9	517.9	570.6	570.6	620.9	620.9	669.9	669.9	716.5	716.5	757.1	757.1	793.6	793.6	827.2	827.2						
2	418.2	467.3	467.3	517.9	517.9	570.6	570.6	620.9	620.9	669.9	669.9	716.5	716.5	757.1	757.1	793.6	793.6	827.2	827.2						
3	418.2	467.3	467.3	517.9	517.9	570.6	570.6	620.9	620.9	669.9	669.9	716.5	716.5	757.1	757.1	793.6	793.6	827.2	827.2						

$T^{T} =$

	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	413.8	436.0	464.0	490.3	513.9	544.1	567.4	596.6	618.1	647.0	667.5	695.2	714.3	738.6	755.0	776.8	791.5	811.7	824.9						
2	413.8	446.2	464.0	498.3	513.9	551.0	567.4	602.4	618.1	652.0	667.5	699.6	714.3	742.2	755.0	780.0	791.5	814.5	825.1						
3	413.8	449.6	464.0	502.3	513.9	554.8	567.4	605.7	618.1	655.1	667.5	702.4	714.3	744.5	755.0	782.1	791.5	816.4	825.2						

$P^{*T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	315.7	443.9	443.9	612.3	612.3	835.1	835.1	1099.7	1099.7	1412.8	1412.8	1767.6	1767.6	2124.9	2124.9	2483.1	2483.1	2847.9	2847.9		
2	315.7	443.9	443.9	612.3	612.3	835.1	835.1	1099.7	1099.7	1412.8	1412.8	1767.6	1767.6	2124.9	2124.9	2483.1	2483.1	2847.9	2847.9		
3	315.7	443.9	443.9	612.3	612.3	835.1	835.1	1099.7	1099.7	1412.8	1412.8	1767.6	1767.6	2124.9	2124.9	2483.1	2483.1	2847.9	2847.9		

$\cdot 10^3$

$P^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	304.1	346.8	432.9	502.7	595.5	702.3	817.9	949.5	1081.5	1241.4	1394.0	1578.3	1747.9	1934.0	2102.6	2288.9	2458.5	2648.4	2817.4		
2	304.1	376.5	432.9	532.8	595.5	735.2	817.9	983.9	1081.5	1278.0	1394.0	1616.3	1747.9	1970.2	2102.6	2324.4	2458.5	2683.2	2819.7		
3	304.1	386.9	432.9	548.3	595.5	753.6	817.9	1004.1	1081.5	1300.5	1394.0	1640.4	1747.9	1993.9	2102.6	2348.1	2458.5	2706.8	2821.3		

$\cdot 10^3$

$\rho^{*T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	2.629	3.308	3.308	4.117	4.117	5.096	5.096	6.168	6.168	7.345	7.345	8.592	8.592	9.774	9.774	10.897	10.897	11.990	11.990		
2	2.629	3.308	3.308	4.117	4.117	5.096	5.096	6.168	6.168	7.345	7.345	8.592	8.592	9.774	9.774	10.897	10.897	11.990	11.990		
3	2.629	3.308	3.308	4.117	4.117	5.096	5.096	6.168	6.168	7.345	7.345	8.592	8.592	9.774	9.774	10.897	10.897	11.990	11.990		

$\rho^{T} =$

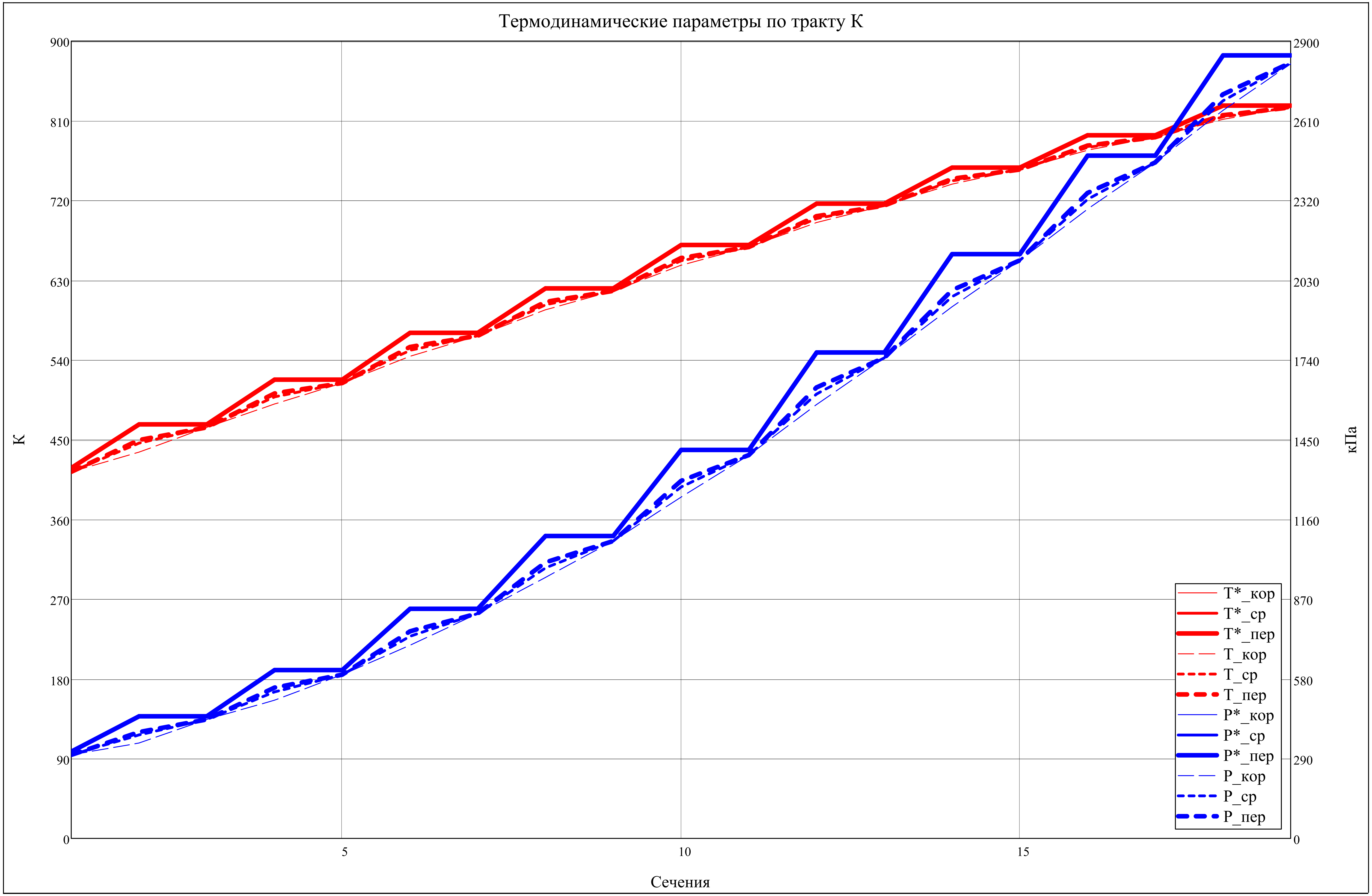
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	2.559	2.770	3.249	3.571	4.035	4.495	5.020	5.543	6.094	6.683	7.274	7.907	8.522	9.119	9.698	10.261	10.817	11.362	11.895		
2	2.559	2.939	3.249	3.724	4.035	4.647	5.020	5.688	6.094	6.826	7.274	8.046	8.522	9.245	9.698	10.378	10.817	11.473	11.902		
3	2.559	2.997	3.249	3.802	4.035	4.731	5.020	5.773	6.094	6.914	7.274	8.134	8.522	9.327	9.698	10.456	10.817	11.547	11.907		

$Cp^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1016	1025	1025	1034	1034	1045	1045	1057	1057	1068	1068	1079	1079	1088	1088	1096	1096	1104	1104						
2	1016	1025	1025	1034	1034	1045	1045	1057	1057	1068	1068	1079	1079	1088	1088	1096	1096	1104	1104						
3	1016	1025	1025	1034	1034	1045	1045	1057	1057	1068	1068	1079	1079	1088	1088	1096	1096	1104	1104						

$k^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1.394	1.389	1.389	1.384	1.384	1.379	1.379	1.373	1.373	1.368	1.368	1.363	1.363	1.359	1.359	1.355	1.355	1.352	1.352						
2	1.394	1.389	1.389	1.384	1.384	1.379	1.379	1.373	1.373	1.368	1.368	1.363	1.363	1.359	1.359	1.355	1.355	1.352	1.352						
3	1.394	1.389	1.389	1.384	1.384	1.379	1.379	1.373	1.373	1.368	1.368	1.363	1.363	1.359	1.359	1.355	1.355	1.352	1.352						


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

$a^{*T}_{c} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	373.9	395.0	395.0	415.5	415.5	435.8	435.8	454.2	454.2	471.4	471.4	487.2	487.2	500.5	500.5	512.1	512.1	522.5	522.5						
2	373.9	395.0	395.0	415.5	415.5	435.8	435.8	454.2	454.2	471.4	471.4	487.2	487.2	500.5	500.5	512.1	512.1	522.5	522.5						
3	373.9	395.0	395.0	415.5	415.5	435.8	435.8	454.2	454.2	471.4	471.4	487.2	487.2	500.5	500.5	512.1	512.1	522.5	522.5						

$a_{зв}^{T} =$

	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	407.0	417.1	430.2	441.5	452.0	464.1	473.9	485.0	493.7	504.1	512.0	521.6	528.7	536.8	542.7	549.7	554.9	561.3	565.8						
2	407.0	421.9	430.2	445.0	452.0	467.0	473.9	487.4	493.7	506.1	512.0	523.2	528.7	538.1	542.7	550.9	554.9	562.2	565.9						
3	407.0	423.5	430.2	446.8	452.0	468.6	473.9	488.7	493.7	507.2	512.0	524.3	528.7	538.9	542.7	551.6	554.9	562.9	565.9						

$c^{T} =$

	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	94.4	252.9	81.9	238.9	90.7	235.4	82.5	226.6	77.1	221.1	71.8	214.3	67.8	201.1	67.6	191.7	67.4	184.9	71.5						
2	94.4	207.8	81.9	201.4	90.7	202.5	82.5	197.7	77.1	195.1	71.8	190.8	67.8	180.4	67.6	172.7	67.4	167.6	68.6						
3	94.4	190.2	81.9	179.8	90.7	182.2	82.5	178.9	77.1	177.5	71.8	174.4	67.8	165.6	67.6	159.1	67.4	154.8	66.7						

$w^{T} =$

	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	239.9	146.6	259.1	117.4	277.3	112.5	283.6	113.7	282.9	113.4	283.6	115.2	281.9	123.5	273.1	129.3	266.6	134.2	258.9						
2	334.2	211.2	329.7	198.6	335.8	188.6	335.3	182.7	329.2	176.7	325.7	173.8	320.7	178.5	309.6	181.7	301.7	183.5	295.8						
3	409.2	290.3	388.8	271.5	386.3	255.1	380.5	243.0	370.2	232.0	363.3	225.1	355.5	226.4	342.7	227.3	333.6	226.6	328.8						

$u^{T} =$

	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	260.4	274.2	286.7	292.8	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6	298.6						
2	359.5	359.5	359.5	359.5	359.5	355.7	352.0	349.1	346.3	344.0	341.8	340.0	338.3	337.1	336.0	335.2	334.4	333.1	331.7						
3	436.7	428.1	419.9	415.6	411.5	404.8	398.3	393.2	388.2	384.1	380.1	376.9	373.8	371.7	369.6	368.2	366.8	364.3	361.8						

$c_{a}^{T} =$

	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	86.9	133.9	72.6	92.4	84.0	81.3	78.3	75.5	72.8	70.3	67.9	65.7	63.5	61.5	59.5	57.6	55.7	55.4	55.0						
2	86.9	107.6	72.6	87.7	84.0	81.3	78.3	75.5	72.8	70.3	67.9	65.7	63.5	61.5	59.5	57.6	55.7	55.4	55.0						
3	86.9	106.1	72.6	85.7	84.0	81.3	78.3	75.5	72.8	70.3	67.9	65.7	63.5	61.5	59.5	57.6	55.7	55.4	55.0						

$c_{u}^{T} =$

	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	36.8	214.6	37.9	220.3	34.4	220.9	26.0	213.6	25.3	209.6	23.3	204.0	24.0	191.5	32.1	182.8	37.9	176.4	45.6						
2	36.8	177.8	37.9	181.3	34.4	185.5	26.0	182.7	25.3	182.0	23.3	179.1	24.0	169.6	32.1	162.9	37.9	158.1	41.1						
3	36.8	157.9	37.9	158.0	34.4	163.0	26.0	162.2	25.3	163.0	23.3	161.6	24.0	153.8	32.1	148.3	37.9	144.6	37.7						

$w_{u}^{T} =$

	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	223.6	59.7	248.8	72.5	264.3	77.7	272.6	85.0	273.3	89.0	275.4	94.7	274.6	107.2	266.5	115.8	260.7	122.2	253.0						
2	322.7	181.7	321.6	178.2	325.1	170.2	326.0	166.4	321.0	162.1	318.5	160.9	314.3	167.6	303.9	172.3	296.6	174.9	290.7						
3	399.9	270.2	382.0	257.6	377.1	241.8	372.3	230.9	362.9	221.1	356.8	215.3	349.8	217.9	337.5	219.9	328.9	219.7	324.2						

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

$\Delta c_a{}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.00	46.94	-61.29	19.79	-8.40	-2.67	-3.06	-2.76	-2.68	-2.48	-2.42	-2.24	-2.20	-2.01	-1.99	-1.86	-1.85	-0.38	-0.37		
2	0.00	20.70	-35.05	15.09	-3.70	-2.67	-3.06	-2.76	-2.68	-2.48	-2.42	-2.24	-2.20	-2.01	-1.99	-1.86	-1.85	-0.38	-0.37		
3	0.00	19.19	-33.55	13.11	-1.72	-2.67	-3.06	-2.76	-2.68	-2.48	-2.42	-2.24	-2.20	-2.01	-1.99	-1.86	-1.85	-0.38	-0.37		

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

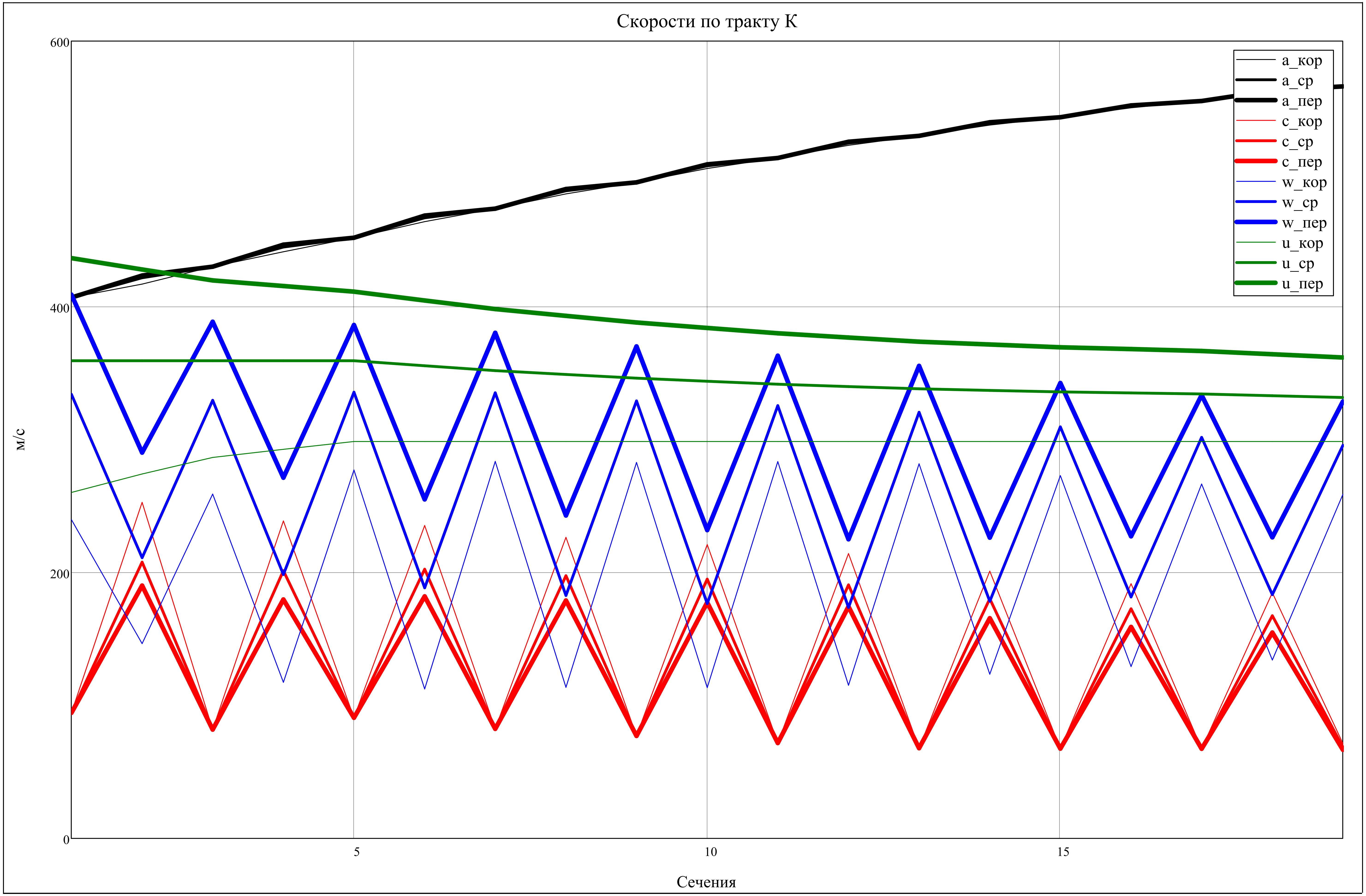
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
2	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
3	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		

$R_L{}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.5298	0.5544	0.5725	0.5988	0.6066	0.6195	0.6393	0.6401	0.6412			
2	0.7015	0.6951	0.6926	0.7023	0.6998	0.7032	0.7134	0.7095	0.7063			
3	0.7749	0.7655	0.7582	0.7622	0.7562	0.7558	0.7615	0.7555	0.7504			

$R_L{}^T \geq 0 =$

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


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

$\alpha^T =$

	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	67.06	31.96	62.43	22.75	67.74	20.21	71.62	19.46	70.85	18.55	71.09	17.85	69.30	17.80	61.62	17.49	55.80	17.43	50.32						
2	67.06	31.19	62.43	25.81	67.74	23.67	71.62	22.45	70.85	21.13	71.09	20.13	69.30	19.92	61.62	19.48	55.80	19.30	53.25						
3	67.06	33.91	62.43	28.47	67.74	26.51	71.62	24.95	70.85	23.34	71.09	22.12	69.30	21.78	61.62	21.23	55.80	20.95	55.61						

$\cdot^\circ$

$\beta^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	21.25	65.98	16.27	51.88	17.63	46.30	16.02	41.61	14.92	38.33	13.85	34.75	13.01	29.83	12.58	26.45	12.07	24.37	12.26		
2	15.08	30.64	12.72	26.20	14.48	25.54	13.50	24.40	12.78	23.46	12.04	22.20	11.42	20.14	11.07	18.48	10.65	17.56	10.71		
3	12.27	21.44	10.76	18.40	12.55	18.59	11.87	18.10	11.34	17.64	10.78	16.96	10.28	15.75	9.99	14.68	9.62	14.15	9.63		

$\cdot^\circ$

$\beta^T \le 91\cdot^\circ =$

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

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

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

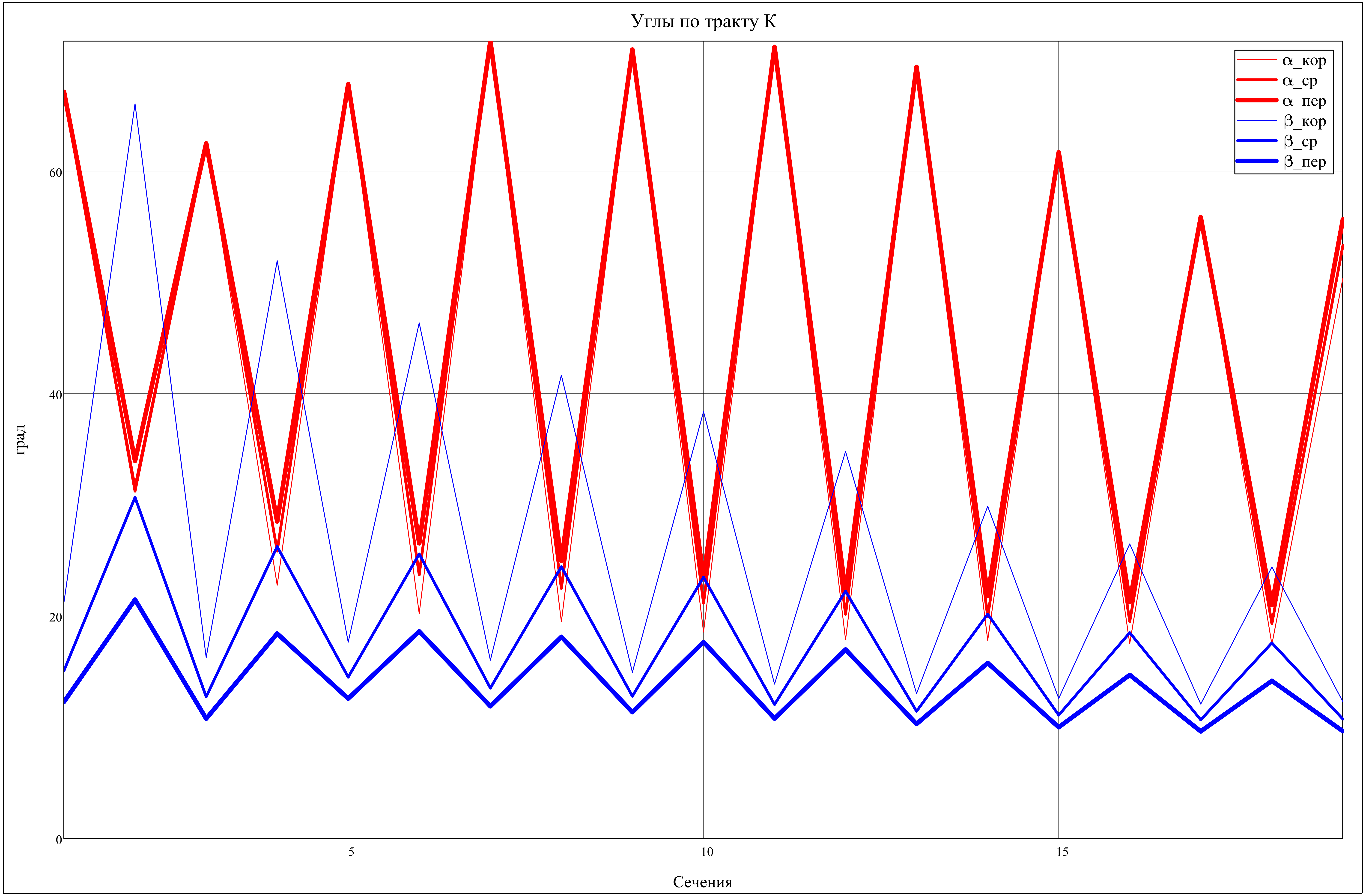
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	44.74	35.61	28.67	25.60	23.41	20.90	16.82	13.87	12.30						
2	15.56	13.48	11.06	10.91	10.68	10.17	8.73	7.41	6.92						
3	9.18	7.64	6.03	6.23	6.30	6.18	5.47	4.69	4.53						

$\cdot^\circ$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	35.61	42.38	48.40	48.60	50.04	48.97	40.91	35.24	32.90						
2	31.24	41.94	47.95	48.40	49.96	49.16	41.70	36.32	33.95						
3	12.58	40.97	47.12	47.84	49.54	49.00	42.07	36.99	34.65						

$\cdot^\circ$



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

λ_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	0.2524	0.6403	0.2073	0.5749	0.2184	0.5402	0.1892	0.4988	0.1697	0.4691	0.1523	0.4399	0.1393	0.4018	0.1350	0.3743	0.1316	0.3538	0.1368				
2	0.2524	0.5262	0.2073	0.4847	0.2184	0.4647	0.1892	0.4353	0.1697	0.4139	0.1523	0.3916	0.1393	0.3604	0.1350	0.3374	0.1316	0.3207	0.1314				
3	0.2524	0.4816	0.2073	0.4326	0.2184	0.4180	0.1892	0.3940	0.1697	0.3766	0.1523	0.3581	0.1393	0.3310	0.1350	0.3107	0.1316	0.2963	0.1276				

[16, c. 87] $\lambda_c^T \le 0.85$ =

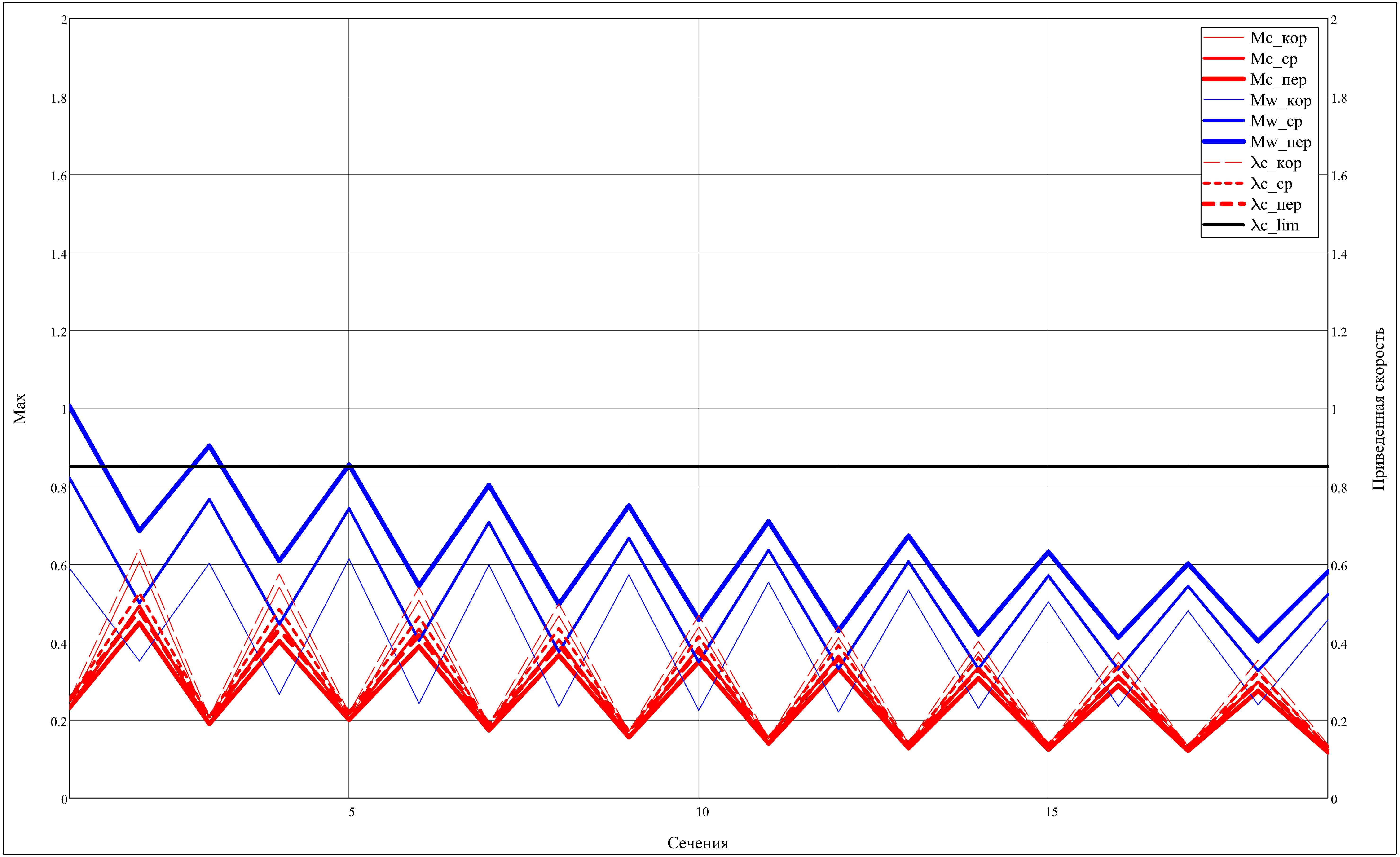
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

M_c^T =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.2320	0.6064	0.1903	0.5411	0.2008	0.5072	0.1740	0.4672	0.1561	0.4387	0.1402	0.4108	0.1283	0.3746	0.1245	0.3487	0.1215	0.3294	0.1263				
2	0.2320	0.4926	0.1903	0.4526	0.2008	0.4336	0.1740	0.4057	0.1561	0.3855	0.1402	0.3646	0.1283	0.3352	0.1245	0.3136	0.1215	0.2980	0.1213				
3	0.2320	0.4492	0.1903	0.4023	0.2008	0.3887	0.1740	0.3662	0.1561	0.3500	0.1402	0.3327	0.1283	0.3074	0.1245	0.2884	0.1215	0.2751	0.1178				

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	0.5895	0.3514	0.6023	0.2660	0.6135	0.2423	0.5985	0.2344	0.5730	0.2250	0.5539	0.2209	0.5331	0.2302	0.5031	0.2353	0.4805	0.2391	0.4576				
2	0.8212	0.5006	0.7663	0.4462	0.7430	0.4038	0.7075	0.3749	0.6669	0.3491	0.6361	0.3322	0.6065	0.3317	0.5705	0.3299	0.5438	0.3264	0.5228				
3	1.0055	0.6855	0.9037	0.6076	0.8548	0.5443	0.8028	0.4972	0.7498	0.4575	0.7095	0.4294	0.6725	0.4200	0.6314	0.4121	0.6011	0.4025	0.5811				



Результаты расчета параметров потока по высоте Л

Вывод результатов расчета параметров потока по высоте Л

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

Построение треугольников скоростей в 3х сечениях

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

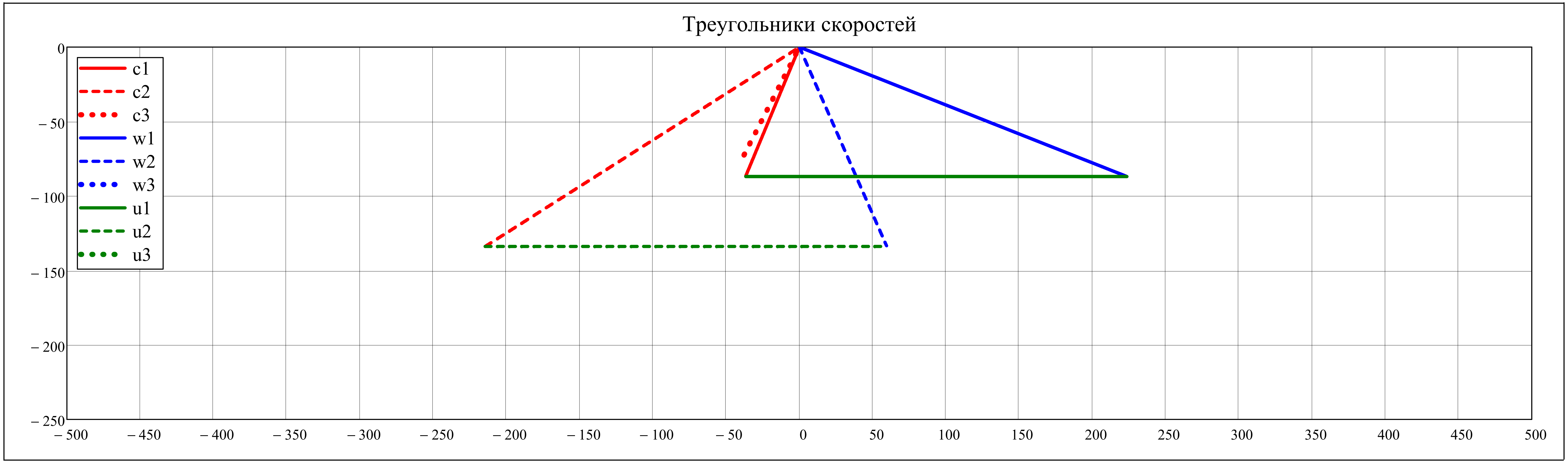
$$v_{lim} := \mathrm{ceil}\left(\frac{\max(c,w,u)}{10^2}\right)\cdot 10^2 = 500$$

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

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

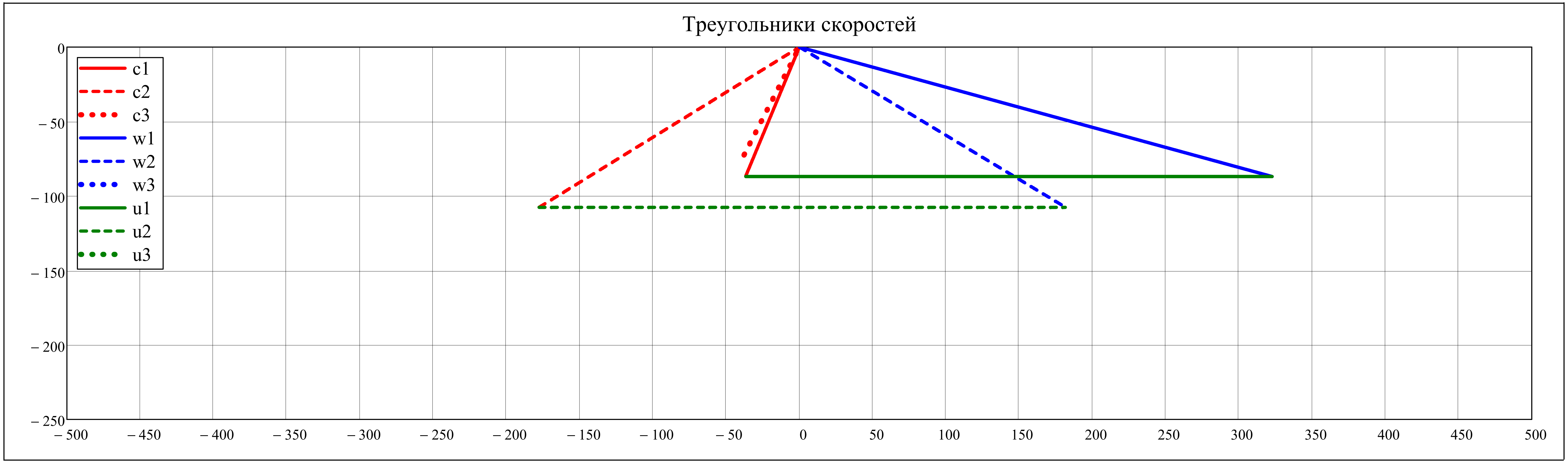
Дискретизация скорости: $v := -v_{lim}, -v_{lim} + \frac{v_{lim}}{3000} .. v_{lim}$

r = 1



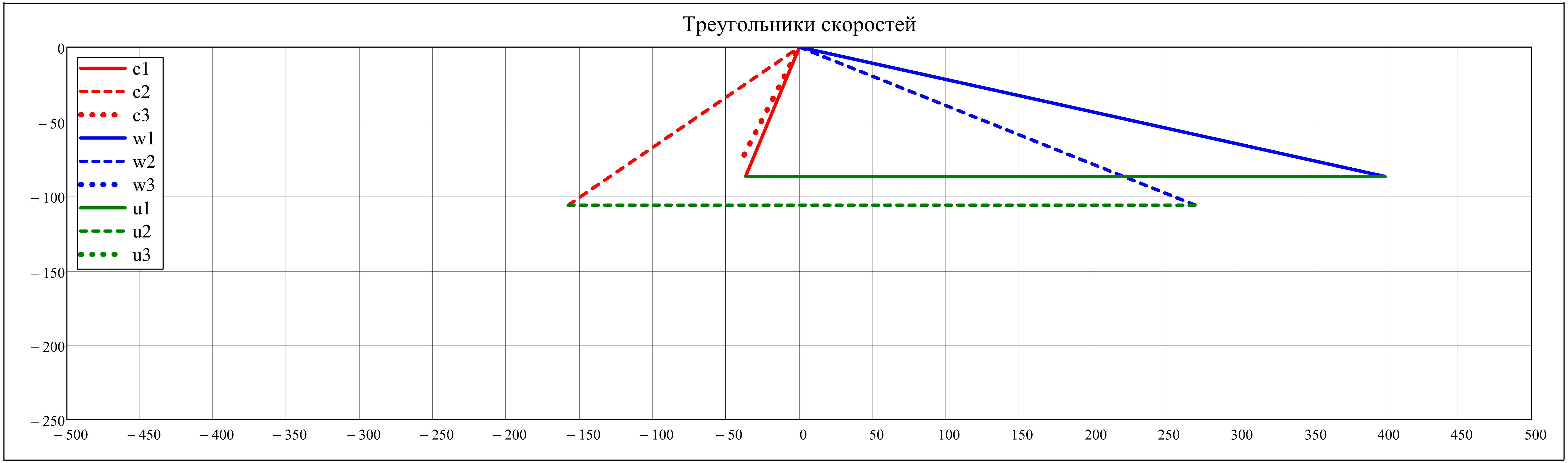
Треугольники скоростей
c1
c2
c3
w1
w2
w3
u1
u2
u3
0
− 50
− 100
− 150
− 200
− 250
− 500
− 450
− 400
− 350
− 300
− 250
− 200
− 150
− 100
− 50
0
50
100
150
200
250
300
350
400
450
500

$r = av(N_r)$



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

$r = N_r$



Построение треугольников скоростей в 3х сечениях

Определение степени повышения полного давлеия по 2ум контурам

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

Кольцевые площади (м^2):

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

	1	2	3	4	5	6	7	8
1	0.0223	0.0197	0.0171	0.0158	0.0146	0.0136	0.0126	0.0119
2	0.1341	0.1180	0.1027	0.0950	0.0874	0.0815	0.0758	0.0714
3	0.1564	0.1261	0.1198	0.1072	0.1020	0.0923	0.0885	...

Радиус и диаметр двухконтурности (м):

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

	1	2	3	4	5	6	7	8	9
1	186.0	191.7	196.9	199.5	201.9	201.2	200.4	199.8	199.3
2	372.0	383.3	393.7	398.9	403.9	402.3	400.8	399.6	...

$\cdot 10^{-3}$

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

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

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.406	1.379	1.364	1.317	1.285	1.251	1.202	1.169	1.147			
2	1.406	1.379	1.364	1.317	1.285	1.251	1.202	1.169	1.147			

$$\prod_{i=1}^{Z} \pi^*_{I_i} = 9.022 \qquad \prod_{i=1}^{Z} \pi^*_{II_i} = 9.022$$

Определение степени повышения полного давлеия по 2ум контурам

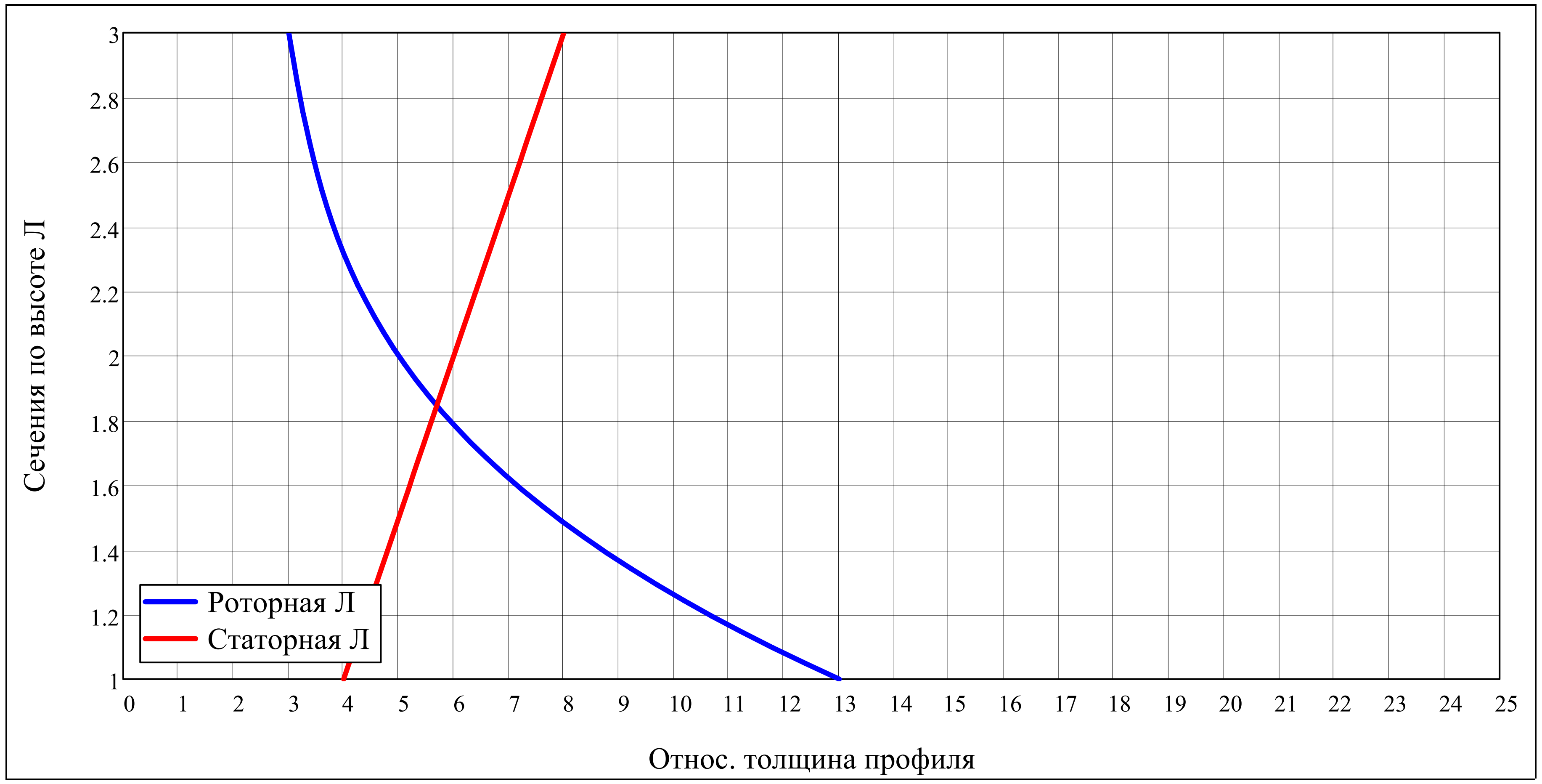
Относ. толщины и радиусы профилей

Относ. толщины Л РК и СА:

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

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

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



$$\bar{c}_{BHA} = \left| \begin{array}{l} \text{for } r \in 1..N_r \\ \quad \bar{c}_{BHA_r} = \bar{c}_{stator.}{}^{\langle r \rangle} \\ \bar{c}_{BHA} \end{array} \right.$$

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

	1
1	4.00
2	6.00
3	8.00

$\cdot\%$

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

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

	1	2	3	4	5	6	7	8	9
1	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
2	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
3	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00

$\cdot\%$

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

	1	2	3	4	5	6	7	8	9
1	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
2	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
3	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

$\cdot\%$

$$\bar{c}_{CA} = \left| \begin{array}{l} \text{for } r \in 1..N_r \\ \quad \bar{c}_{CA_r} = \bar{c}_{stator.}{}^{\langle r \rangle} \\ \bar{c}_{CA} \end{array} \right.$$

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

	1
1	4.00
2	6.00
3	8.00

$\cdot\%$

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

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

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

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

	1
1	0.800
2	1.200
3	1.600

$\cdot\%$

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

	1
1	0.800
2	1.200
3	1.600

$\cdot\%$

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

	1	2	3	4	5	6	7	8	9
1	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
2	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
3	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600

$\cdot\%$

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

	1	2	3	4	5	6	7	8	9
1	2.600	2.600	2.600	2.600	2.600	2.600	2.600	2.600	2.600
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600

$\cdot\%$

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

	1	2	3	4	5	6	7	8	9
1	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
2	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
3	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800

$\cdot\%$

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

	1	2	3	4	5	6	7	8	9
1	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300	1.300
2	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
3	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300

$\cdot\%$

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

	1
1	0.400
2	0.600
3	0.800

$\cdot\%$

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

	1
1	0.400
2	0.600
3	0.800

$\cdot\%$

Относ. толщины и радиусы профилей

Распределение параметров по высоте Л

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

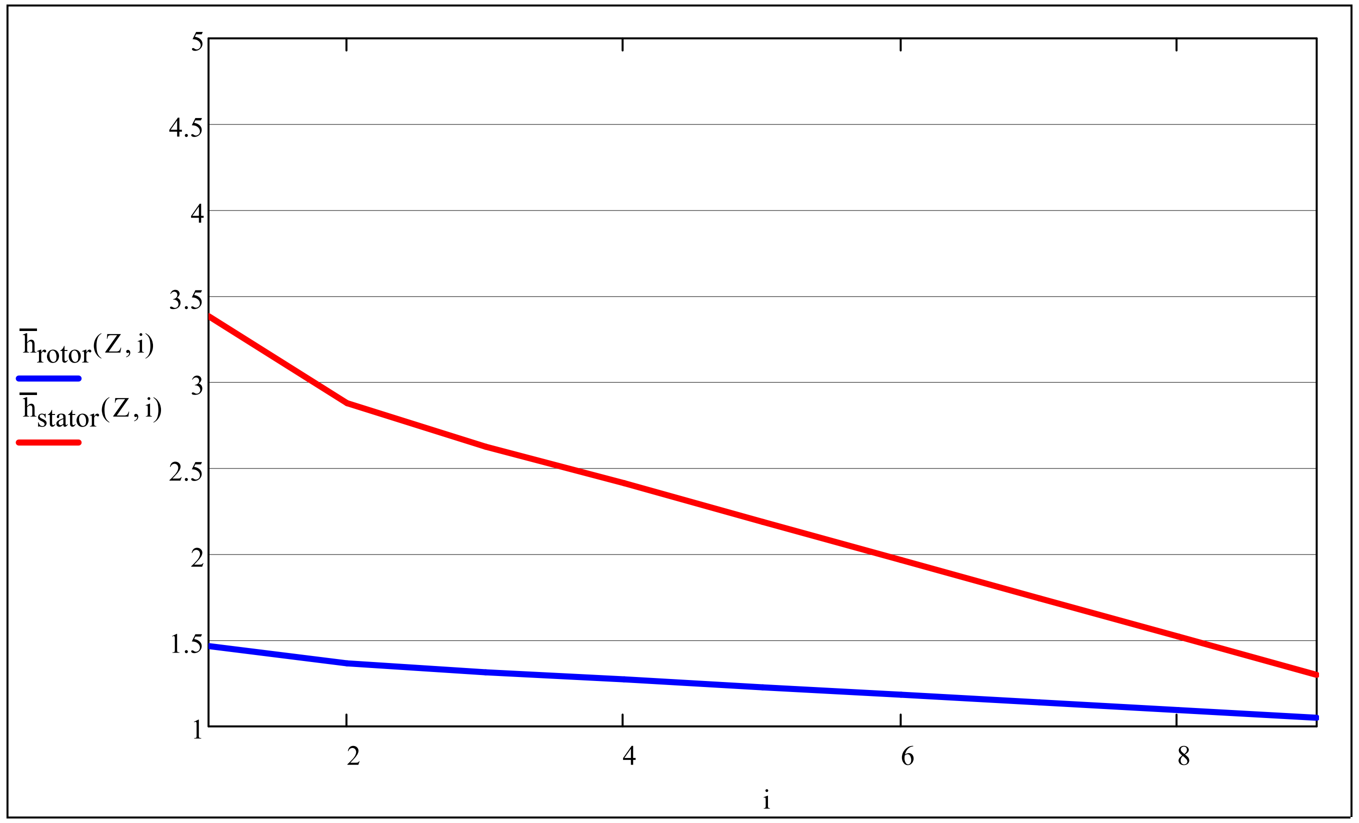
$$\overline{h}_{\sim rotor} = (2\ \ 1.9\ \ 1.85\ \ 1.8\ \ 1.75\ \ 1.7\ \ 1.65\ \ 1.6)^{T} + \begin{cases} 1.1 & \text{if compressor = "Вл"} \\ -0.1 & \text{if compressor = "КНД"} \\ -0.55 & \text{if compressor = "КВД"} \end{cases}$$

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

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

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

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



Для компрессора газогенератора

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

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

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

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

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

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

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

Расчет длин хорд по высоте Л

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

$\bar{x}_f = 0.5$

Определение количества Л РК и НА

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Определение количества Л РК и НА

Результаты расчета количества Л и параметров решеток РК и НА

Длина хорды Л (м):

$chord_{BHA} =$

	1
1	30.57
2	34.01
3	36.68

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	61.43	51.32	45.64	41.88	39.16	37.10	35.78	35.30	35.05						
2	71.64	59.68	53.00	48.59	45.40	42.98	41.44	40.87	40.57						
3	79.86	66.72	59.34	54.44	50.91	48.23	46.51	45.89	45.57						

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	24.31	23.51	22.54	21.94	21.96	22.47	23.78	26.05	28.56						
2	27.00	26.06	24.96	24.29	24.29	24.84	26.28	28.80	31.56						
3	29.17	28.21	27.04	26.33	26.35	26.96	28.53	31.27	34.27						

$\cdot 10^{-3}$

$chord_{CA} =$

	1
1	27.83
2	30.96
3	33.40

$\cdot 10^{-3}$

Радисы входных и выходных кромок профилей Л (мм):

$r\_inlet_{BHA} =$

	1
1	0.24
2	0.41
3	0.59

$\cdot 10^{-3}$

$r\_outlet_{BHA} =$

	1
1	0.12
2	0.20
3	0.29

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	1.60	1.33	1.19	1.09	1.02	0.96	0.93	0.92	0.91
2	0.72	0.60	0.53	0.49	0.45	0.43	0.41	0.41	0.41
3	0.48	0.40	0.36	0.33	0.31	0.29	0.28	0.28	0.27

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	0.80	0.67	0.59	0.54	0.51	0.48	0.47	0.46	0.46
2	0.36	0.30	0.27	0.24	0.23	0.21	0.21	0.20	0.20
3	0.24	0.20	0.18	0.16	0.15	0.14	0.14	0.14	0.14

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	0.19	0.19	0.18	0.18	0.18	0.18	0.19	0.21	0.23
2	0.32	0.31	0.30	0.29	0.29	0.30	0.32	0.35	0.38
3	0.47	0.45	0.43	0.42	0.42	0.43	0.46	0.50	0.55

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	0.10	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.11
2	0.16	0.16	0.15	0.15	0.15	0.15	0.16	0.17	0.19
3	0.23	0.23	0.22	0.21	0.21	0.22	0.23	0.25	0.27

$\cdot 10^{-3}$

$r\_inlet_{CA} =$

	1
1	0.22
2	0.37
3	0.53

$\cdot 10^{-3}$

$r\_outlet_{CA} =$

	1
1	0.11
2	0.19
3	0.27

$\cdot 10^{-3}$

Угол поворота потока:

$\varepsilon_{BHA(b/t)=1_{av(N_r)}} = 23.31\cdot°$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	8.16	7.12	6.98	6.76	6.58	6.35	6.02	5.78	5.66						

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	21.01	23.64	25.50	25.14	25.25	24.39	20.60	17.78	16.52						

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

Густота решетки:

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

	1
1	3.873
2	3.120
3	2.771

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.781	1.639	1.643	1.578	1.541	1.522	1.528	1.507	1.555						
2	1.544	1.536	1.593	1.559	1.545	1.544	1.564	1.553	1.611						
3	1.431	1.477	1.563	1.548	1.549	1.561	1.591	1.586	1.652						

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

	1	2	3	4	5	6	7	8	9
1	2.037	1.829	1.774	1.727	1.691	1.655	1.632	1.614	1.626
2	1.765	1.667	1.658	1.641	1.629	1.611	1.601	1.591	1.614
3	1.617	1.569	1.583	1.584	1.586	1.580	1.578	1.574	1.605

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

	1
1	3.660
2	3.665
3	3.625

Количество Л:

$Z_{BHA} = 42$

$Z_{rotor}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	31	37	43	45	47	49	51	51	53						

$Z_{stator}^T =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	94	92	94	94	92	88	82	74	68						

$Z_{CA} = 50$

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

$t_{BHA} =$

	1
1	7.89
2	10.90
3	13.24

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	34.49	31.32	27.78	26.54	25.41	24.38	23.42	23.42	22.54						
2	46.39	38.86	33.26	31.16	29.38	27.83	26.49	26.32	25.19						
3	55.79	45.16	37.96	35.18	32.87	30.90	29.24	28.93	27.59						

$\cdot 10^{-3}$

Шаг решетки (м):

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	11.93	12.86	12.71	12.71	12.98	13.57	14.57	16.14	17.57						
2	15.30	15.63	15.06	14.80	14.91	15.42	16.42	18.10	19.55						
3	18.04	17.98	17.09	16.63	16.61	17.06	18.08	19.86	21.36						

$\cdot 10^{-3}$

$t_{CA} =$

	1
1	7.60
2	8.45
3	9.21

$\cdot 10^{-3}$

$i_{BHA} =$

	1
1	4.682
2	2.801
3	1.928

$\cdot ^{\circ}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.953	1.596	1.608	1.444	1.352	1.304	1.319	1.268	1.388						
2	1.361	1.339	1.484	1.398	1.363	1.361	1.411	1.382	1.526						
3	1.078	1.193	1.408	1.369	1.372	1.402	1.478	1.465	1.629						

$\cdot ^{\circ}$

Угол атаки:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.092	-0.429	-0.566	-0.683	-0.772	-0.862	-0.919	-0.965	-0.935						
2	-0.587	-0.831	-0.856	-0.897	-0.927	-0.972	-0.998	-1.022	-0.965						
3	-0.958	-1.077	-1.043	-1.041	-1.035	-1.050	-1.055	-1.065	-0.988						

$\cdot ^{\circ}$

$i_{CA} =$

	1
1	4.150
2	4.162
3	4.061

$\cdot ^{\circ}$

$m_{BHA} =$

	1
1	0.2759
2	0.2759
3	0.2759

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	0.2780	0.3062	0.3174	0.3268	0.3333	0.3405	0.3503	0.3571	0.3613						
2	0.3487	0.3576	0.3589	0.3612	0.3631	0.3656	0.3697	0.3730	0.3749						
3	0.3671	0.3732	0.3728	0.3738	0.3747	0.3761	0.3785	0.3806	0.3817						

$m_{stator}{}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.2851	0.2745	0.2668	0.2683	0.2678	0.2714	0.2868	0.2984	0.3094						
2	0.2851	0.2745	0.2668	0.2683	0.2678	0.2714	0.2868	0.2984	0.3035						
3	0.2851	0.2745	0.2668	0.2683	0.2678	0.2714	0.2868	0.2984	0.2988						

$m_{CA} =$

	1
1	0.2300
2	0.2300
3	0.2300

$\theta_{BHA} =$

	1
1	21.23
2	23.86
3	25.18

$\cdot{}^{\circ}$

Угол изгиба ср. линии профиля:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	54.04	44.71	35.97	32.65	30.16	27.06	21.63	17.77	15.36						
2	19.74	17.07	13.38	13.38	13.16	12.47	10.38	8.60	7.65						
3	11.68	9.30	6.59	6.95	7.05	6.84	5.70	4.61	4.12						

$\cdot{}^{\circ}$

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	44.38	53.71	61.24	61.93	64.00	63.16	53.94	47.31	44.67						
2	40.53	54.31	61.56	62.36	64.40	63.77	55.21	48.92	45.88						
3	17.45	53.84	61.13	62.12	64.23	63.83	55.88	49.93	46.64						

$\cdot{}^{\circ}$

$\theta_{CA} =$

	1
1	40.38
2	37.04
3	34.50

$\cdot{}^{\circ}$

$\delta_{BHA} =$

	1
1	2.976
2	3.726
3	4.173

$\cdot°$

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

	1	2	3	4	5	6	7	8
1	11.259	10.697	8.907	8.493	8.098	7.470	6.131	5.168
2	5.540	4.926	3.803	3.870	3.845	3.670	3.069	2.575
3	3.585	2.857	1.966	2.089	2.123	2.060	1.711	...

$\cdot°$

Угол отставания:

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

	1	2	3	4	5	6	7	8
1	8.867	10.904	12.266	12.645	13.179	13.325	12.107	11.113
2	8.698	11.546	12.755	13.060	13.512	13.634	12.513	11.572
3	3.914	11.800	12.961	13.244	13.659	13.783	12.755	...

$\cdot°$

$\delta_{CA} =$

	1
1	4.855
2	4.450
3	4.168

$\cdot°$

$\upsilon_{BHA} =$

	1
1	105.30
2	104.73
3	104.52

$\cdot°$

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

	1	2	3	4	5	6	7	8	9
1	50.22	40.22	37.22	33.78	31.35	28.69	25.15	22.73	21.14
2	26.31	22.59	22.65	21.58	20.72	19.63	18.02	16.75	16.00
3	19.19	16.60	17.26	16.71	16.24	15.60	14.61	13.77	13.31

$\cdot°$

Угол установки Л:

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

	1	2	3	4	5	6	7	8	9
1	54.24	49.18	50.26	49.74	49.77	48.56	43.85	40.18	38.83
2	50.87	52.13	53.59	52.73	52.40	51.05	46.53	42.91	41.27
3	41.68	54.32	56.03	54.97	54.42	52.98	48.66	45.13	43.29

$\cdot°$

$\upsilon_{CA} =$

	1
1	74.66
2	75.93
3	76.92

$\cdot°$

$R_{СЛ.ВНА} = \cdot 10^{-3}$

	1
1	82.97
2	82.25
3	84.14

$R_{СЛ.rotor}^{T} = \cdot 10^{-3}$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	67.61	67.46	73.91	74.50	75.27	79.27	95.34	114.29	131.10						
2	208.94	201.06	227.57	208.56	198.03	197.82	228.97	272.52	304.04						
3	392.29	411.33	515.94	448.88	413.91	404.06	467.54	569.97	633.85						

Радиус дуги ср. линии (м):

$R_{СЛ.stator}^{T} = \cdot 10^{-3}$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	32.18	26.02	22.12	21.32	20.72	21.45	26.21	32.47	37.58						
2	38.98	28.55	24.39	23.45	22.79	23.52	28.36	34.77	40.49						
3	96.12	31.15	26.59	25.52	24.78	25.50	30.45	37.04	43.29						

$R_{СЛ.СА} = \cdot 10^{-3}$

	1
1	40.32
2	48.74
3	56.31

$K_{ВНА} =$

	1
1	0.8968
2	0.8968
3	0.8968

$K_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.5399	1.2726	0.9682	0.9648	0.9660	0.9670	0.9683	0.9687	0.9932						
2	1.2381	1.2079	0.9682	0.9648	0.9660	0.9670	0.9683	0.9687	0.9932						
3	1.2208	1.1806	0.9682	0.9648	0.9660	0.9670	0.9683	0.9687	0.9932						

Фактор диффузорности решетки:

$K_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.5422	0.9091	0.9624	0.9645	0.9656	0.9664	0.9676	0.9679	0.9933						
2	0.6744	0.9578	0.9624	0.9645	0.9656	0.9664	0.9676	0.9679	0.9933						
3	0.6839	0.9800	0.9624	0.9645	0.9656	0.9664	0.9676	0.9679	0.9933						

$K_{СА} =$

	1
1	0.8182
2	0.8182
3	0.8182

D_{BHA} =

	1
1	-0.0228
2	-0.0346
3	-0.0423

D_{rotor}^{T} =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.5809	0.7545	0.7991	0.8088	0.8105	0.8031	0.7562	0.7094	0.6637						
2	0.5047	0.5393	0.5831	0.6077	0.6196	0.6231	0.5897	0.5499	0.5170						
3	0.4012	0.4100	0.4518	0.4815	0.4968	0.5051	0.4799	0.4448	0.4199						

Диффузорность решетки:

D_{stator}^{T} =

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.8477	0.8330	0.8832	0.9005	0.9245	0.9371	0.9066	0.8826	0.8310						
2	0.7967	0.7683	0.8304	0.8527	0.8817	0.8967	0.8633	0.8372	0.8068						
3	0.7647	0.7144	0.7849	0.8109	0.8437	0.8607	0.8248	0.7967	0.7847						

D_{CA} =

	1
1	0.4575
2	0.4260
3	0.4028

$D_{BHA} \le 0.6$ =

	1
1	1
2	1
3	1

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

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

[18, с. 71]

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

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

$D_{CA} \le 0.6$ =

	1
1	1
2	1
3	1

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.1018	0.1956	0.2457	0.2647	0.2783	0.2923	0.2900	0.2745	0.2623						
2	0.1203	0.1564	0.1944	0.2164	0.2321	0.2474	0.2446	0.2289	0.2215						
3	0.1071	0.1320	0.1607	0.1817	0.1971	0.2127	0.2127	0.2000	0.1975						

Коэф. потерь полного давления:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.2881	0.2370	0.2602	0.2677	0.2804	0.2875	0.2765	0.2713	0.2519						
2	0.2137	0.1768	0.2079	0.2212	0.2388	0.2495	0.2390	0.2337	0.2230						
3	0.1769	0.1398	0.1725	0.1880	0.2077	0.2201	0.2098	0.2042	0.2010						

$\mathrm{quality}_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	18.423	10.287	6.380	6.152	6.033	5.911	6.067	6.463	7.099						
2	18.537	15.659	8.148	7.619	7.336	7.070	7.192	7.624	8.341						
3	23.595	19.909	9.319	8.688	8.334	7.961	7.905	8.157	8.854						

Качество профилей решеток РК и НА:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3.028	5.851	5.709	5.633	5.468	5.417	5.680	5.840	6.418						
2	4.681	7.704	6.833	6.544	6.186	6.023	6.320	6.508	6.951						
3	5.364	9.419	7.919	7.433	6.893	6.624	6.956	7.170	7.445						

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	70.55	75.23	69.85	68.36	66.92	65.53	65.19	65.46	66.79						
2	78.87	79.44	71.57	69.45	67.76	66.08	65.60	65.94	67.02						
3	81.09	80.88	71.43	69.30	67.65	65.87	65.00	64.98	65.85						

$\cdot\%$

Результаты расчета количества Л и параметров решеток РК и НА

Вывод параметров решеток

Подключение симметричного профиля

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

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

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

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

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

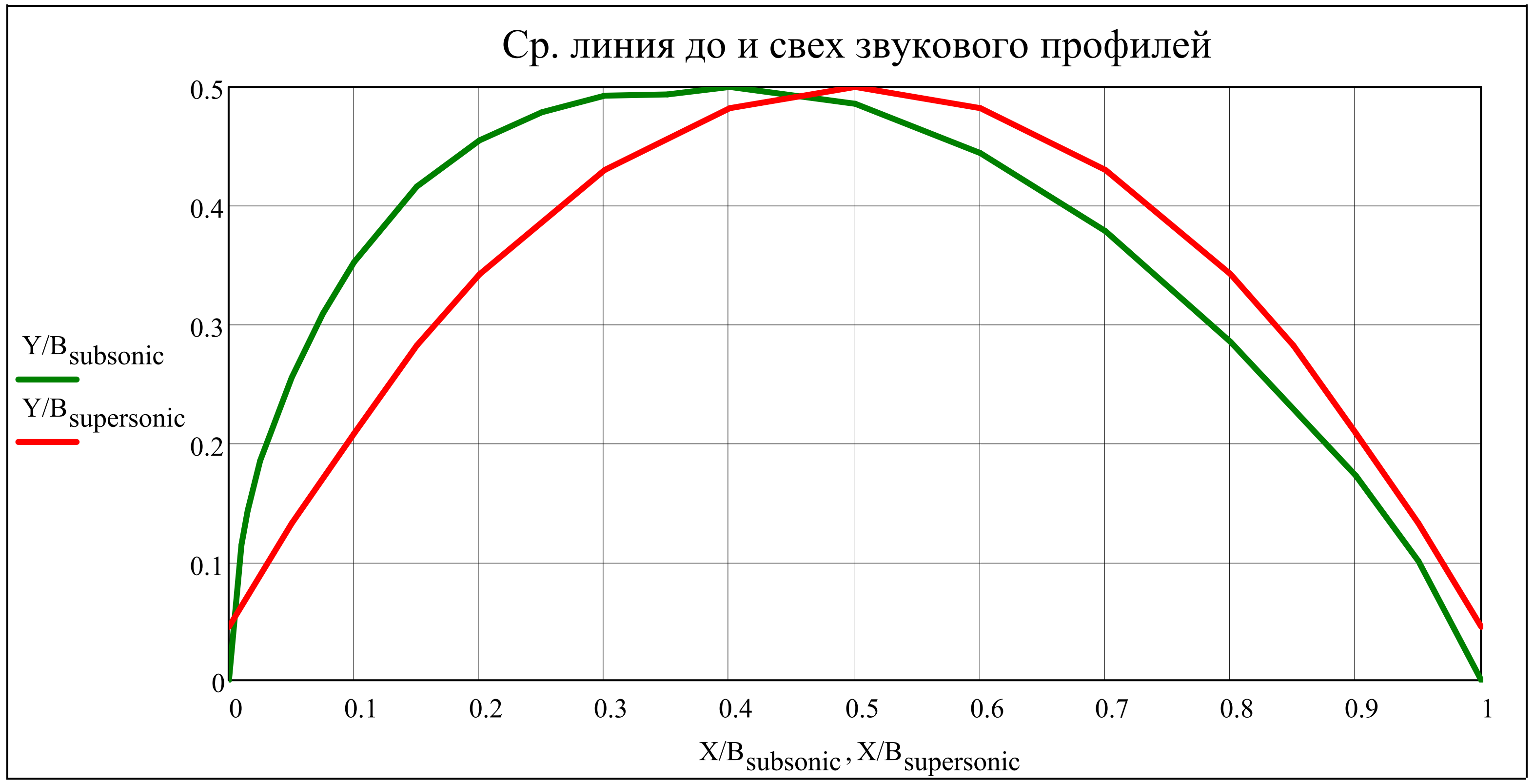
$Y/B_{supersonic} = submatrix\left(EXCEL_{AIRFOIL.supersonic}, 2, rows\left(EXCEL_{AIRFOIL.supersonic}\right), ORIGIN + 1, ORIGIN + 1\right)$

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

	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

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

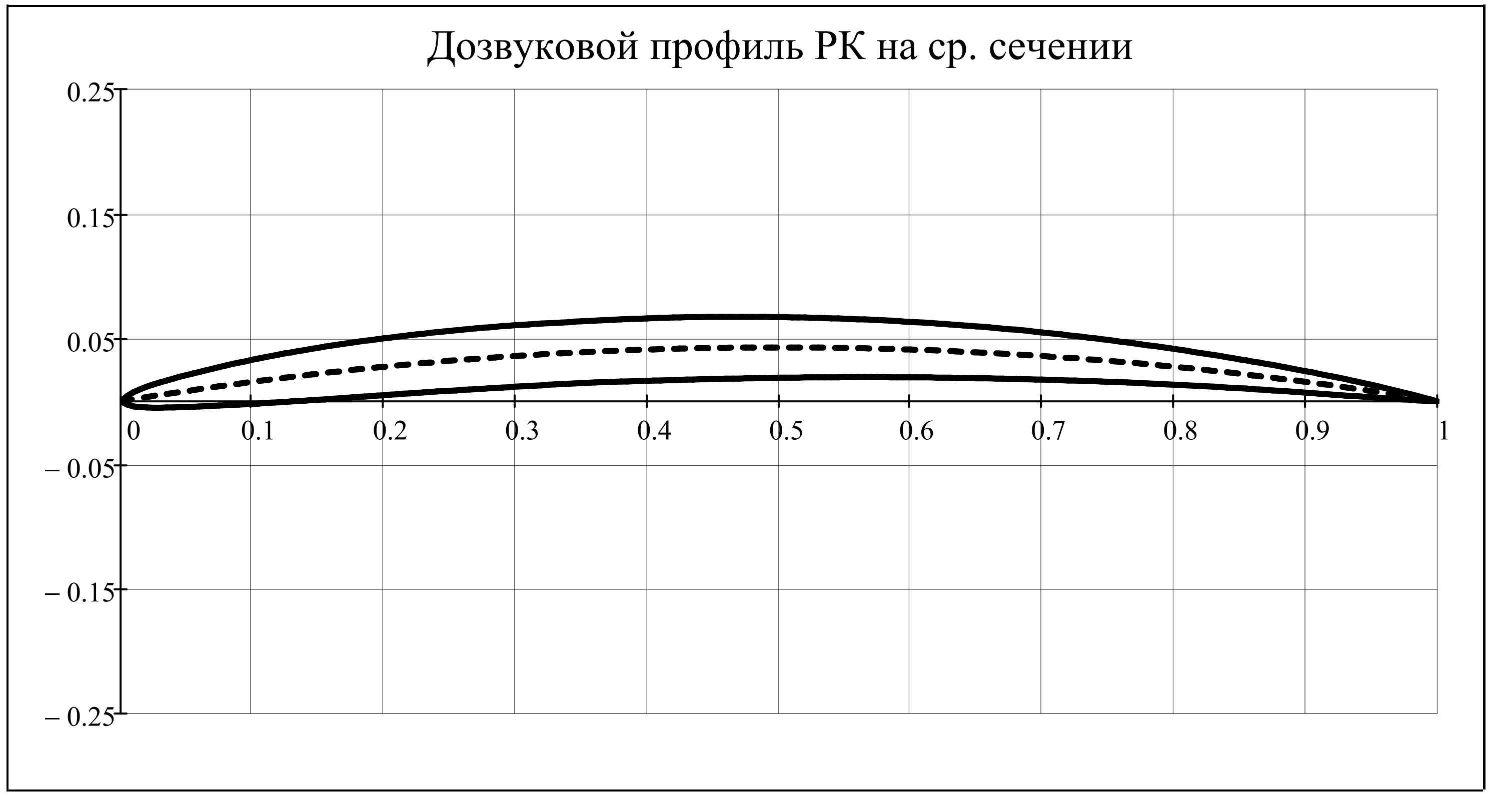
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.000	0.050	0.100	0.150	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.850	0.900	0.950	1.000
2	0.045	0.132	0.208	0.282	0.342	0.430	0.482	0.500	0.482	0.430	0.342	0.282	0.208	0.132	0.045

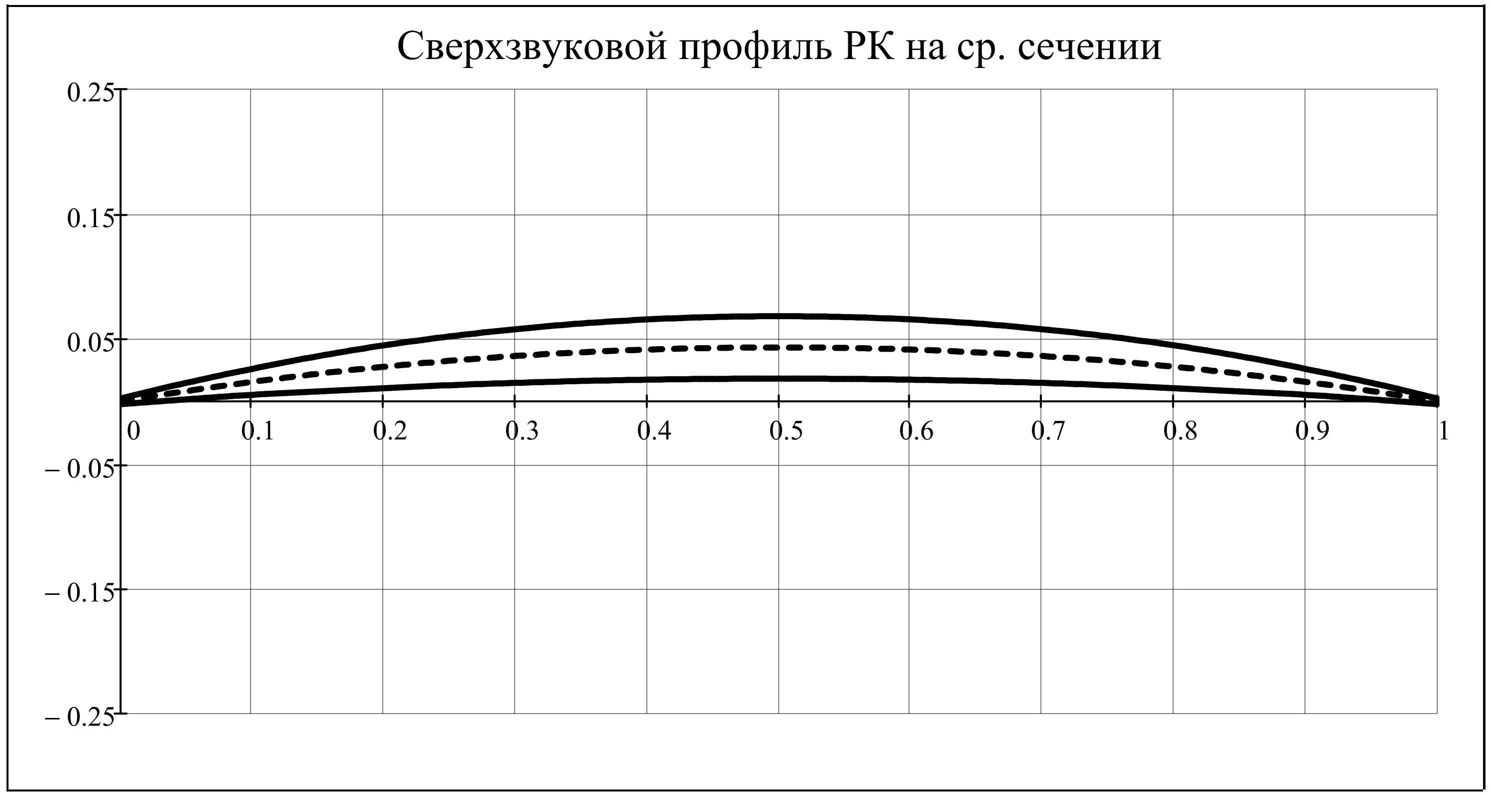


$$AIRFOIL_{subsonic}(x, line, \bar{c}, \theta) = \begin{cases} \begin{cases} interp\left(cspline\left(X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right) + Y/B_{subsonic} \cdot \bar{c}\right), X/B_{subsonic}, y/b_{ср.л}\left(X/B_{subsonic}, \theta\right) + Y/B_{subsonic} \cdot \bar{c}, x\right)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

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

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





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	4	5	6	7	8	9
1	24.96	24.34	23.53	22.91	22.98	23.47	24.57	26.75	29.24
2	27.76	27.15	26.23	25.54	25.61	26.16	27.38	29.78	32.55
3	29.63	29.57	28.61	27.88	27.98	28.60	29.95	32.59	35.62

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	66.11	54.44	47.94	43.81	40.85	38.59	37.04	36.43	36.12
2	72.43	60.26	53.44	48.98	45.76	43.31	41.72	41.12	40.81
3	80.10	66.94	59.50	54.60	51.05	48.36	46.63	46.00	45.67

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	24.53	23.85	22.99	22.39	22.44	22.93	24.09	26.29	28.78
2	27.14	26.36	25.36	24.69	24.73	25.27	26.57	29.02	31.76
3	29.27	28.46	27.39	26.68	26.74	27.34	28.80	31.48	34.48

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	62.02	51.71	45.99	42.21	39.48	37.42	36.14	35.70	35.47
2	71.74	59.76	53.07	48.65	45.46	43.04	41.50	40.93	40.63
3	79.87	66.75	59.37	54.47	50.93	48.25	46.54	45.92	45.59

$\cdot 10^{-3}$

$area_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	17.28	16.17	14.86	14.08	14.11	14.77	16.54	19.86	23.87
2	31.99	29.81	27.34	25.88	25.89	27.08	30.32	36.39	43.71
3	49.78	46.57	42.80	40.56	40.63	42.52	47.63	57.20	68.73

$\cdot 10^{-6}$

$area_{rotor}^{T} =$

	1	2	3	4	5	6	7	8
1	358.79	250.43	198.09	166.75	145.80	130.84	121.72	118.48
2	187.69	130.26	102.74	86.33	75.37	67.56	62.80	61.08
3	134.04	97.67	77.25	65.03	56.86	51.03	47.47	...

$\cdot 10^{-6}$

$Sx_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	25.2	27.3	27.6	25.6	26.4	27.7	27.2	30.7	37.7
2	45.3	55.1	55.6	51.8	53.5	56.3	56.2	64.1	78.8
3	30.4	91.0	92.7	86.9	90.3	95.6	96.7	111.5	137.4

$\cdot 10^{-9}$

$Sx_{rotor}^{T} =$

	1	2	3	4	5	6	7	8
1	1672.1	770.8	434.7	299.3	223.5	169.5	122.2	96.7
2	349.0	174.7	100.3	76.2	60.9	49.2	37.8	30.8
3	167.7	82.9	46.0	36.7	30.4	25.3	20.1	...

$\cdot 10^{-9}$

$Sy_{stator}^{T} =$

	1	2	3	4	5	6	7	8
1	189.7	171.7	151.3	139.6	139.9	149.8	177.6	233.7
2	390.1	350.9	308.2	283.9	284.1	303.8	359.9	473.2
3	655.7	593.3	522.7	482.4	483.5	517.7	613.8	...

$\cdot 10^{-9}$

$Sy_{rotor}^{T} =$

	1	2	3	4	5	6	7	8
1	9953.9	5804.7	4083.4	3153.9	2578.4	2192.1	1966.9	1888.8
2	6072.8	3511.1	2459.4	1894.5	1545.4	1311.5	1175.2	1127.5
3	5352.0	2943.0	2070.3	1599.1	1307.3	1111.4	997.2	...

$\cdot 10^{-9}$

$x0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	10.98	10.62	10.18	9.91	9.92	10.15	10.74	11.77	12.90
2	12.19	11.77	11.27	10.97	10.97	11.22	11.87	13.01	14.25
3	13.17	12.74	12.21	11.89	11.90	12.18	12.89	14.12	15.48

$\cdot 10^{-3}$

$x0_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	27.74	23.18	20.61	18.91	17.69	16.75	16.16	15.94	15.83
2	32.36	26.95	23.94	21.94	20.50	19.41	18.71	18.46	18.32
3	39.93	30.13	26.80	24.59	22.99	21.78	21.01	20.73	20.58

$\cdot 10^{-3}$

$y0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	1.46	1.69	1.86	1.81	1.87	1.87	1.64	1.55	1.58
2	1.42	1.85	2.04	2.00	2.07	2.08	1.85	1.76	1.80
3	0.61	1.95	2.17	2.14	2.22	2.25	2.03	1.95	2.00

$\cdot 10^{-3}$

$y0_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	4.66	3.08	2.19	1.79	1.53	1.30	1.00	0.82	0.72
2	1.86	1.34	0.98	0.88	0.81	0.73	0.60	0.50	0.47
3	1.25	0.85	0.60	0.56	0.53	0.50	0.42	0.36	0.34

$\cdot 10^{-3}$

$Jx_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	41	51	57	51	55	57	50	53	67
2	76	116	128	117	125	132	119	131	165
3	37	209	232	215	231	248	231	260	333

$\cdot 10^{-12}$

$Jy_{stator}^{T} =$

	1	2	3	4	5	6	7	8
1	2665	2332	1970	1769	1775	1945	2440	3518
2	6086	5284	4445	3983	3987	4361	5465	7874
3	11052	9672	8169	7339	7361	8065	10119	...

$\cdot 10^{-12}$

$Jxy_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	287	301	292	263	272	292	304	375	505
2	574	674	652	590	610	656	693	867	1167
3	417	1205	1176	1074	1117	1210	1296	1636	2210

$\cdot 10^{-12}$

$Jx0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	4.58	5.32	5.64	5.11	5.39	5.69	5.25	5.95	7.73
2	11.41	14.31	14.60	13.27	13.92	14.87	14.69	17.64	23.43
3	18.34	31.65	31.45	28.79	30.17	32.60	34.10	42.96	58.29

$\cdot 10^{-12}$

$Jy0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	582	509	430	386	388	425	533	768	1109
2	1329	1154	971	870	871	952	1193	1719	2480
3	2414	2112	1784	1603	1608	1761	2210	3187	4602

$\cdot 10^{-12}$

$Jxy0_{stator}^{T} =$

	1	2	3	4	5	6	7	8	9
1	10.93	11.39	11.00	9.92	10.25	10.99	11.50	14.28	19.24
2	21.89	25.54	24.59	22.24	22.95	24.74	26.27	32.94	44.41
3	15.98	45.59	44.33	40.43	42.01	45.52	48.99	62.16	84.08

$\cdot 10^{-12}$

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

	1	2	3	4	5	6	7	8	9
1	1.08	1.29	1.48	1.49	1.54	1.50	1.25	1.07	1.00
2	0.95	1.28	1.47	1.49	1.53	1.51	1.28	1.11	1.04
3	0.38	1.25	1.45	1.47	1.52	1.51	1.29	1.13	1.06

$\cdot \circ$

$Jx_{rotor}^{T} =$

	1	2	3	4	5	6	7	8	9
1	9935	3282	1472	891	606	426	295	238	214
2	860	328	152	105	78	58	41	33	30
3	273	101	45	33	26	20	15	12	11

$\cdot 10^{-12}$

$Jy_{rotor}^{T} =$

	1	2	3	4	5	6	7
1	353315	172137	107695	76321	58341	46989	40665
2	251377	121079	75321	53185	40537	32571	28138
3	260264	113452	70979	50301	38451	30969	...

$\cdot 10^{-12}$

$Jxy_{rotor}^{T} =$

	1	2	3	4	5	6	7	8
1	48209	18571	9317	5885	4110	2952	2053	1603
2	11742	4897	2496	1739	1298	992	736	591
3	6698	2597	1283	939	726	574	439	...

$\cdot 10^{-12}$

$Jx0_{rotor}^{T} =$

	1	2	3	4	5	6	7
1	2142.12	909.35	517.89	353.49	263.66	206.83	172.35
2	210.97	93.86	53.63	37.68	28.51	22.54	18.67
3	62.65	30.81	17.62	12.62	9.68	7.75	...

$\cdot 10^{-12}$

$Jy0_{rotor}^{T} =$

	1	2	3	4	5	6	7	8
1	77161	37593	23520	16668	12741	10262	8881	8414
2	54892	26439	16447	11614	8852	7112	6144	5814
3	46564	24774	15499	10984	8396	6763	5852	...

$\cdot 10^{-12}$

$Jxy0_{rotor}^{T} =$

	1	2	3	4	5	6	7
1	1819.57	704.88	354.80	224.39	156.84	112.93	78.63
2	449.80	187.67	95.72	66.67	49.77	38.06	28.22
3	-0.02	99.62	49.22	36.03	27.84	22.01	...

$\cdot 10^{-12}$

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

	1	2	3	4	5	6	7	8	9
1	1.39	1.10	0.88	0.79	0.72	0.64	0.52	0.43	0.38
2	0.47	0.41	0.33	0.33	0.32	0.31	0.26	0.22	0.21
3	-0.00	0.23	0.18	0.19	0.19	0.19	0.17	0.14	0.14

$\cdot \circ$

$Ju_{stator}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7	8	9
1	4.37	5.06	5.36	4.85	5.12	5.40	5.00	5.68	7.39
2	11.05	13.74	13.97	12.69	13.31	14.22	14.10	17.00	22.63
3	18.23	30.65	30.33	27.75	29.06	31.41	33.00	41.73	56.73

$Jv_{stator}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7	8	9
1	582	510	430	387	388	425	533	769	1110
2	1329	1154	971	870	871	953	1194	1720	2481
3	2414	2113	1785	1604	1609	1763	2211	3188	4603

$Juv_{stator}^{T} = \cdot 10^{-12}$

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

$Jp_{stator}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7	8	9
1	586	515	436	391	393	430	538	774	1117
2	1340	1168	985	883	885	967	1208	1737	2504
3	2432	2144	1815	1631	1638	1794	2244	3230	4660

$Wp_{stator}^{T} = \cdot 10^{-9}$

	1	2	3	4	5	6	7	8	9
1	43.7	39.6	34.9	32.2	32.2	34.5	40.9	53.9	71.0
2	90.1	81.1	71.2	65.6	65.6	70.2	83.1	109.3	143.9
3	151.9	137.5	121.1	111.8	112.0	120.0	142.2	187.2	246.5

$stiffness_{stator}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7	8
1	3.97	3.48	2.94	2.64	2.65	2.90	3.64	5.25
2	20.42	17.73	14.92	13.37	13.38	14.63	18.34	26.42
3	65.93	57.70	48.73	43.78	43.91	48.11	60.37	...

$Ju_{rotor}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7
1	2098.02	895.81	512.42	350.40	261.68	205.56	171.64
2	207.27	92.52	53.07	37.30	28.23	22.33	18.54
3	62.65	30.41	17.47	12.50	9.59	7.68	...

$Jv_{rotor}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7	8
1	77205	37607	23525	16671	12743	10263	8882	8414
2	54895	26440	16448	11614	8852	7113	6144	5814
3	46564	24774	15499	10984	8396	6763	5853	...

$Juv_{rotor}^{T} = \cdot 10^{-12}$

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

$Jp_{rotor}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7	8
1	79303	38503	24038	17021	13005	10469	9053	8573
2	55103	26533	16501	11651	8880	7135	6163	5831
3	46626	24804	15517	10997	8406	6770	5859	...

$Wp_{rotor}^{T} = \cdot 10^{-9}$

	1	2	3	4	5	6	7	8
1	2332.0	1360.0	956.7	738.9	604.1	513.6	460.8	442.5
2	1401.0	810.0	567.4	437.1	356.5	302.6	271.1	260.1
3	1167.2	677.8	476.8	368.3	301.1	256.0	229.7	...

$stiffness_{rotor}^{T} = \cdot 10^{-12}$

	1	2	3	4	5	6	7
1	5565.78	2711.68	1696.52	1202.28	919.04	740.21	640.60
2	585.81	282.16	175.53	123.94	94.47	75.90	65.57
3	177.61	95.18	59.55	42.20	32.26	25.98	...

$CPx_{stator}{}^{T} =$

	1	2	3	4	5	6	7	8
1	8.507	8.228	7.888	7.680	7.685	7.863	8.322	9.119
2	9.450	9.122	8.736	8.500	8.502	8.695	9.199	10.079
3	10.209	9.874	9.466	9.216	9.223	9.436	9.986	...

$\cdot 10^{-3}$

$CPx_{rotor}{}^{T} =$

	1	2	3	4	5	6	7	8
1	21.500	17.963	15.975	14.658	13.706	12.984	12.523	12.355
2	25.074	20.889	18.551	17.006	15.890	15.044	14.504	14.305
3	27.950	23.352	20.768	19.055	17.817	16.879	16.280	...

$\cdot 10^{-3}$

$CPy_{stator}{}^{T} =$

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

$\cdot 10^{-3}$

$CPy_{rotor}{}^{T} =$

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

$\cdot 10^{-3}$

Результат расчета абсолютных геометрических характеристик сечений Л

Вывод результатов расчета геометрических хар-к сечений Л

Профилирование решеток

Абс. координаты профиля:

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

Профилирование решеток

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

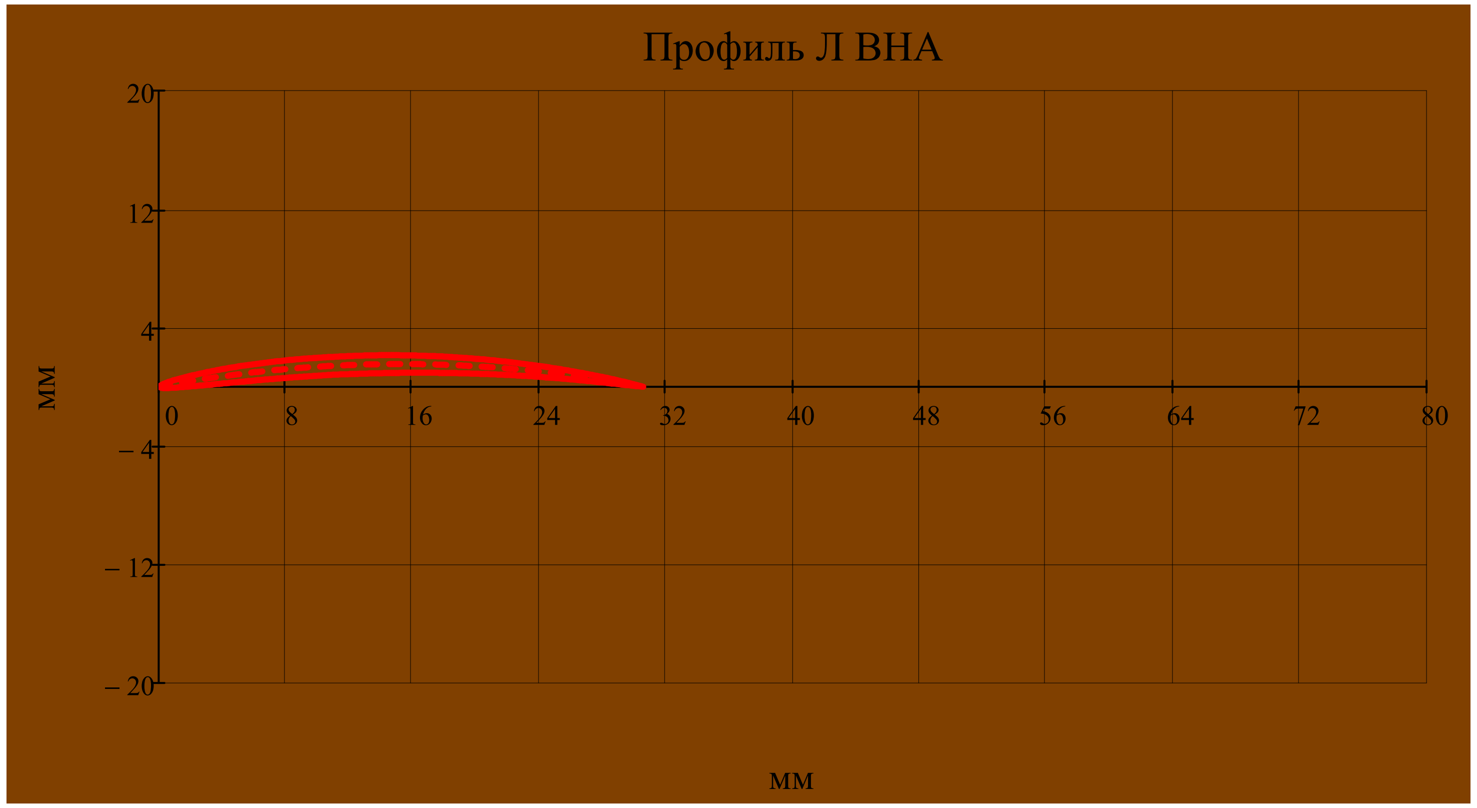
Построение профилей Л РК и НА

$$\mathrm{AXLE0}(type, x, i, r) = \left| \begin{array}{ll} \dfrac{y0rotor_{i,r}}{chord_{rotor_{i,r}}} + \tan\left(\alpha\_major_{rotor_{i,r}}\right)\cdot\left(x - \dfrac{x0rotor_{i,r}}{chord_{rotor_{i,r}}}\right) & \text{if } type = \text{"rotor"} \\ \dfrac{y0_{stator_{i,r}}}{chord_{stator_{i,r}}} + \tan\left(\alpha\_major_{stator_{i,r}}\right)\cdot\left(x - \dfrac{x0_{stator_{i,r}}}{chord_{stator_{i,r}}}\right) & \text{if } type = \text{"stator"} \\ \mathrm{NaN} & \text{otherwise} \end{array} \right.$$

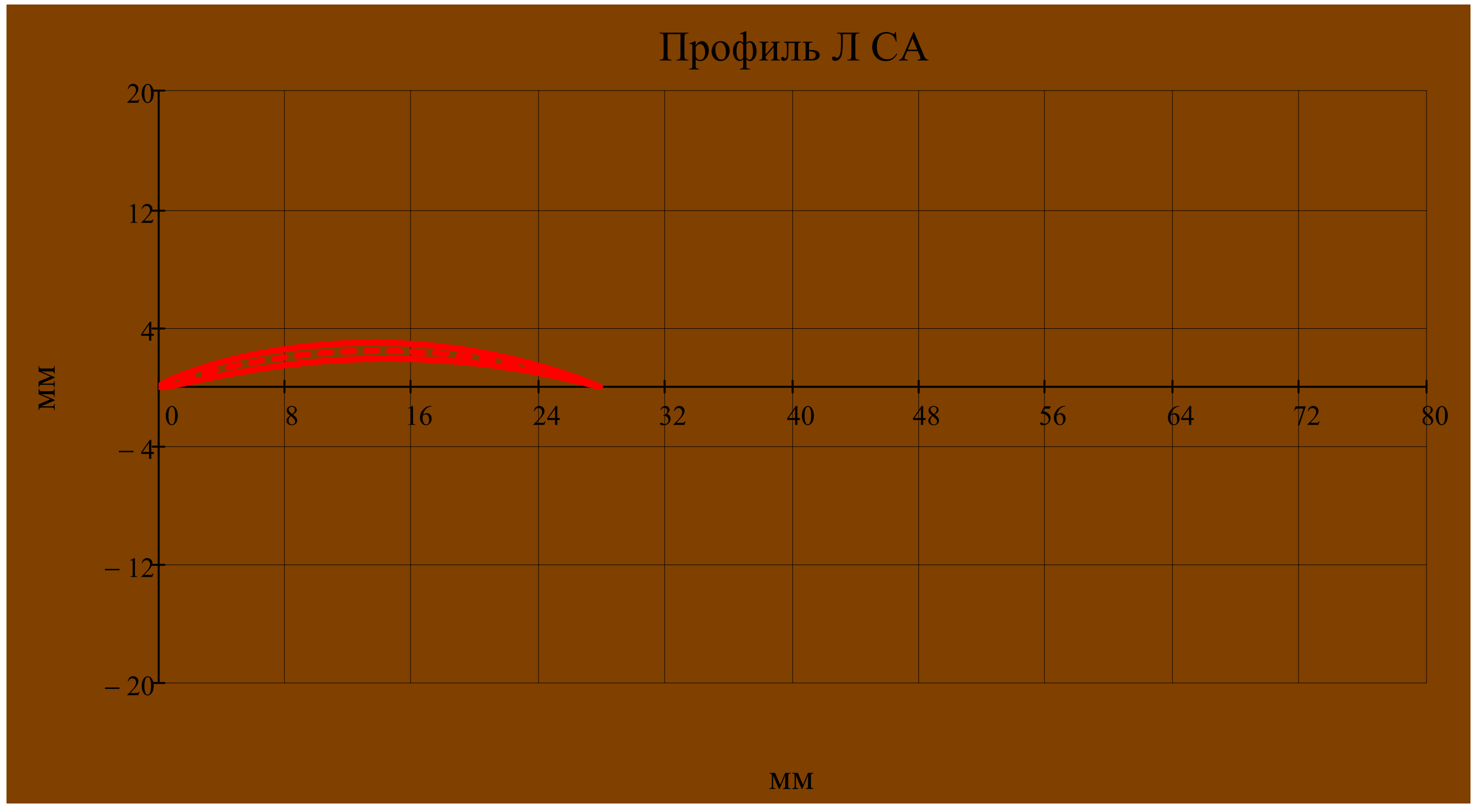
$$b_{lim} = \frac{\mathrm{ceil}\left(\max\left(chord_{rotor_{j,N_r}}, chord_{stator_{j,N_r}}\right)\cdot 10^2\right)}{10^2} = 80\cdot 10^{-3}$$

$$\mathrm{AXLE90}(type, x, i, r) = \left| \begin{array}{ll} \dfrac{y0_{rotor_{i,r}}}{chord_{rotor_{i,r}}} + \tan\left(\alpha\_major_{rotor_{i,r}} + \dfrac{\pi}{2}\right)\cdot\left(x - \dfrac{x0_{rotor_{i,r}}}{chord_{rotor_{i,r}}}\right) & \text{if } (type = \text{"rotor"}) \wedge \left|\alpha\_major_{rotor_{i,r}}\right| \ge 1\cdot^\circ \\ \dfrac{y0_{stator_{i,r}}}{chord_{stator_{i,r}}} + \tan\left(\alpha\_major_{stator_{i,r}} + \dfrac{\pi}{2}\right)\cdot\left(x - \dfrac{x0_{stator_{i,r}}}{chord_{stator_{i,r}}}\right) & \text{if } (type = \text{"stator"}) \wedge \left|\alpha\_major_{stator_{i,r}}\right| \ge 1\cdot^\circ \\ \mathrm{NaN} & \text{otherwise} \end{array} \right.$$

$r = 1$

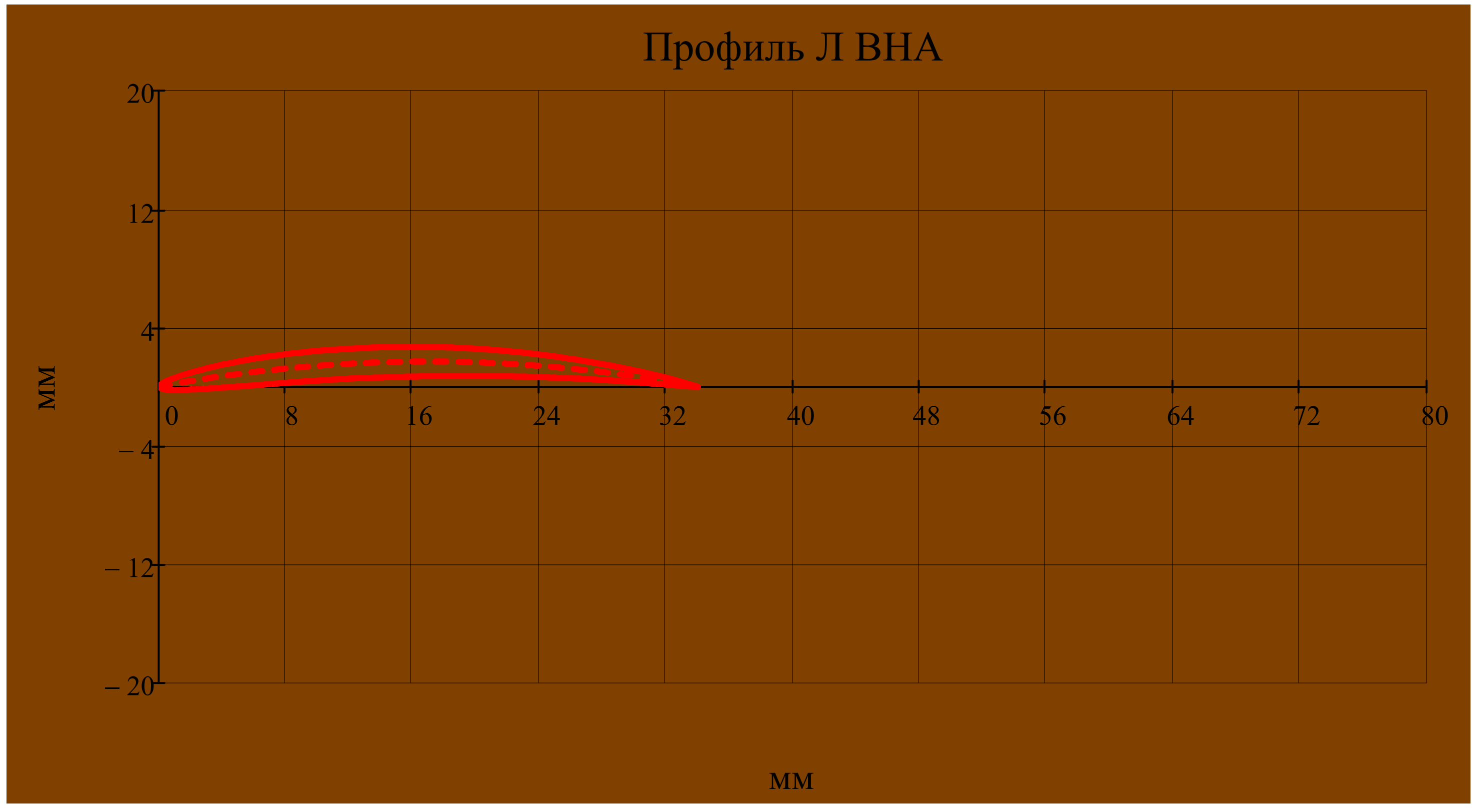


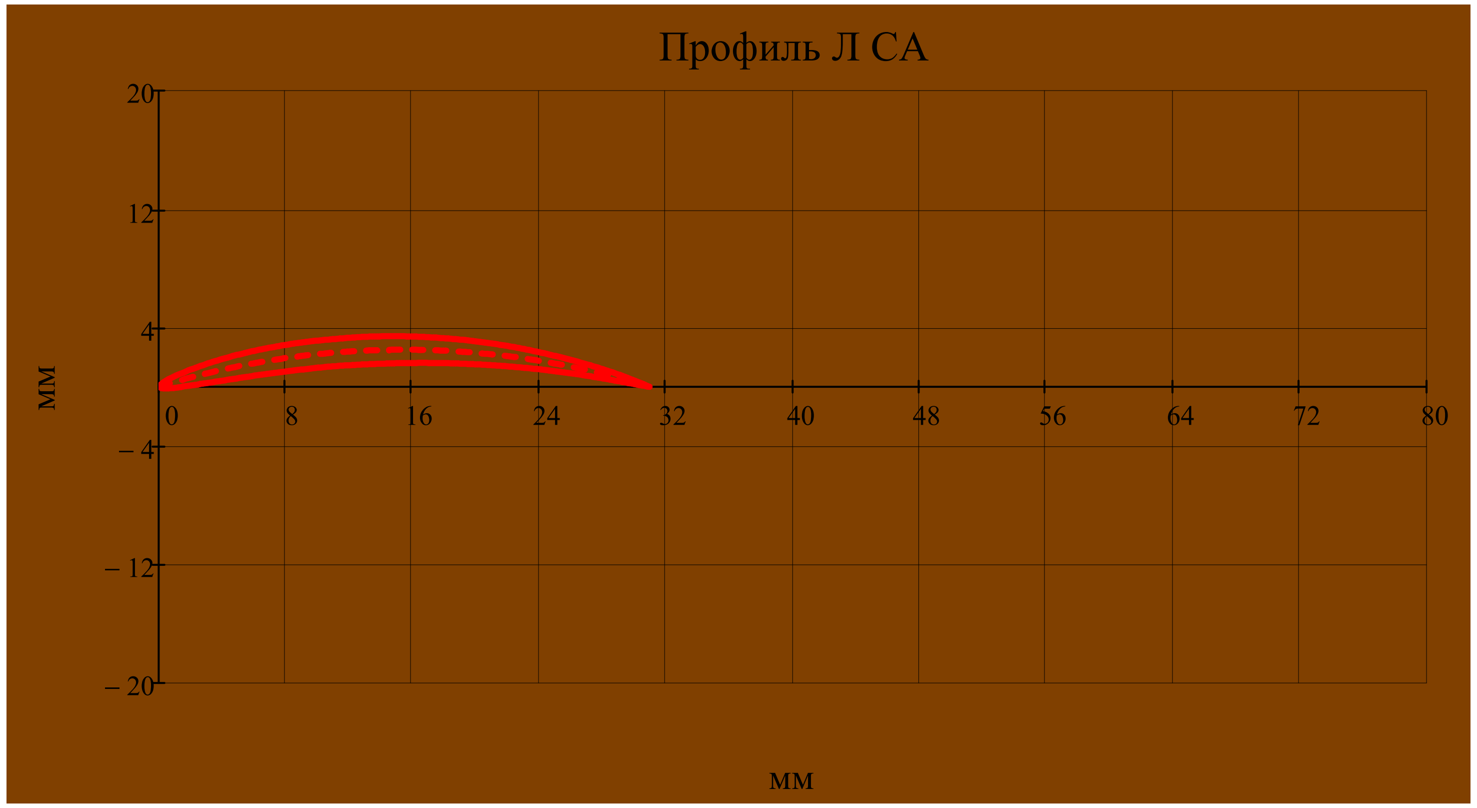
Профиль Л ВНА
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм



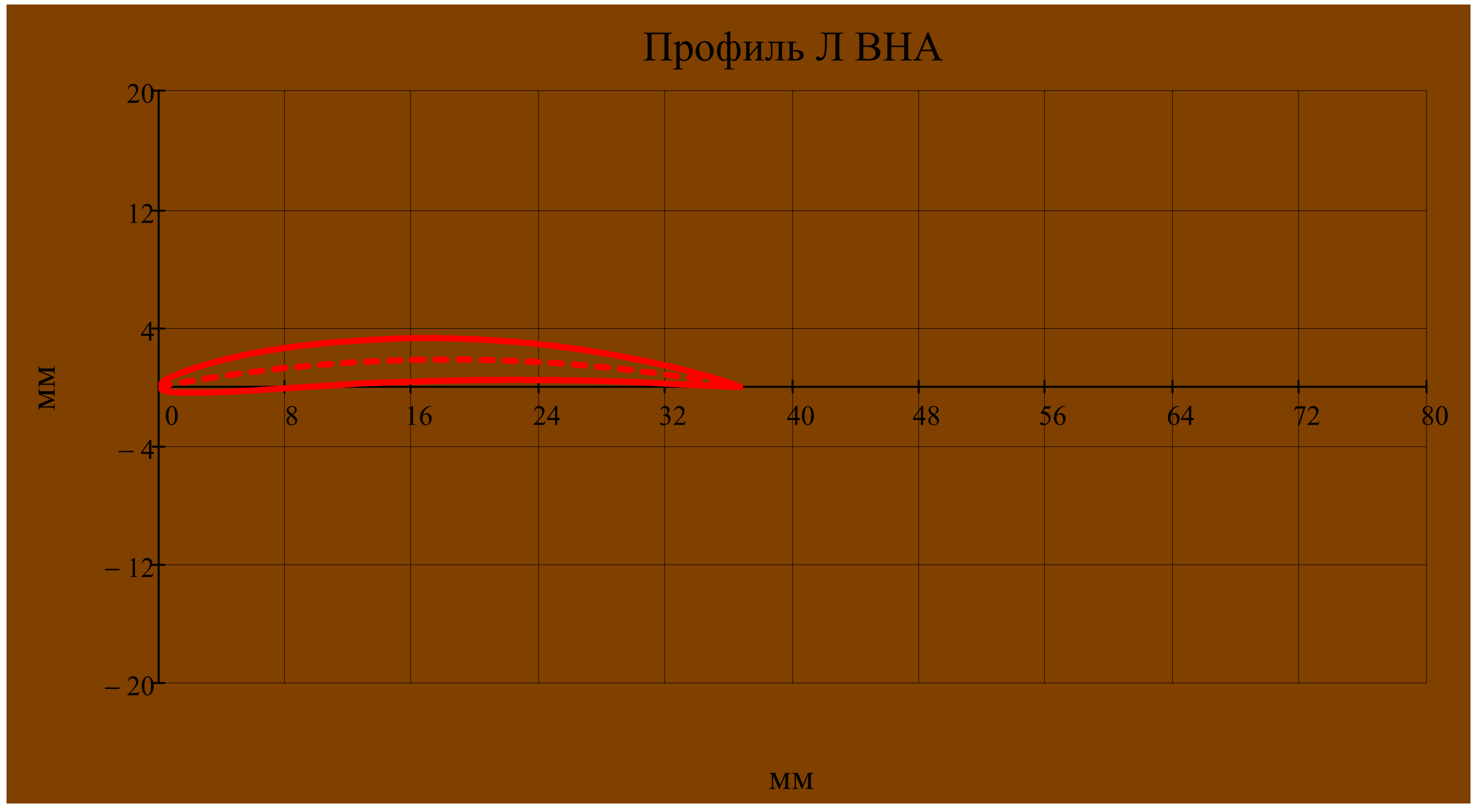
Профиль Л СА
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм

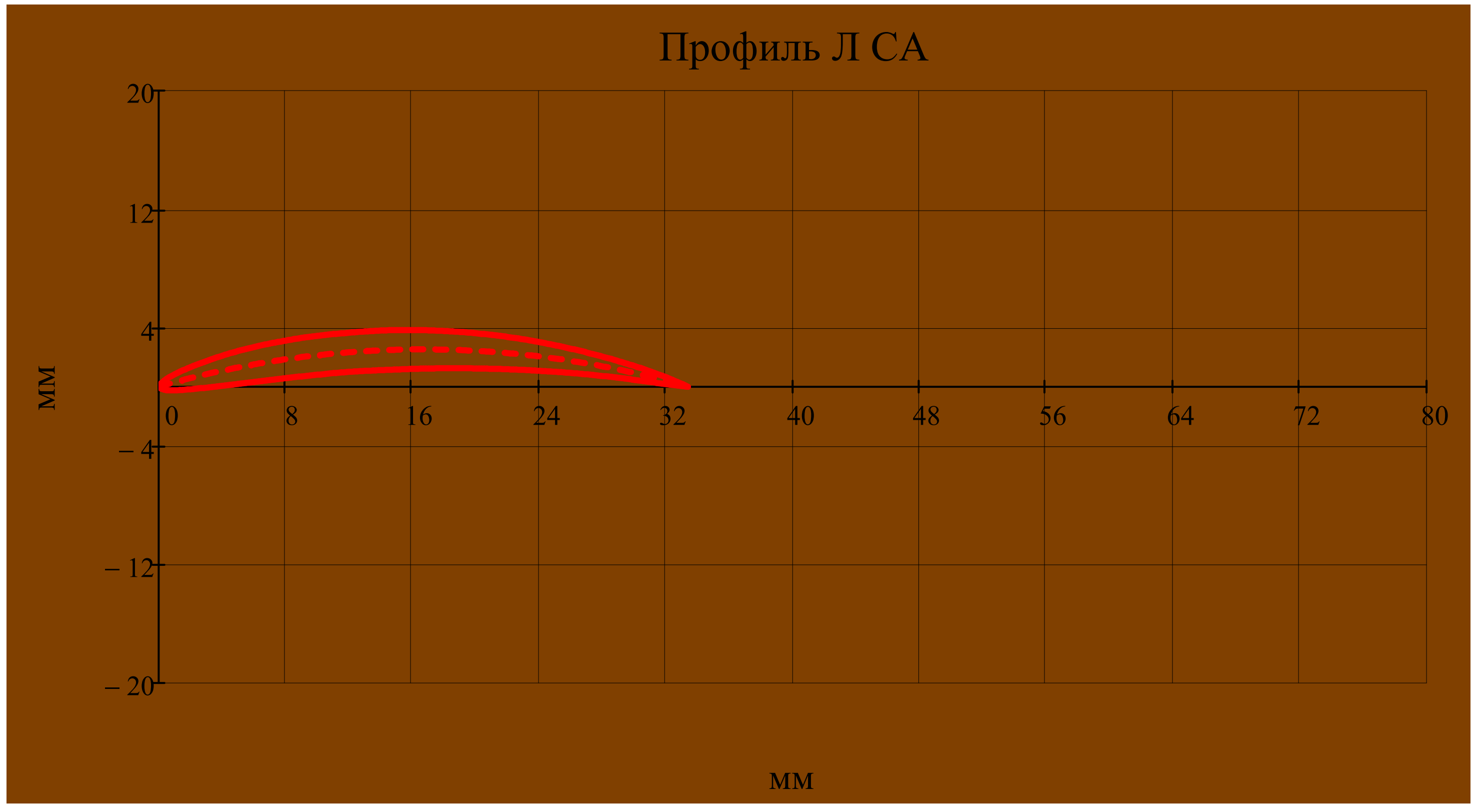
$r = av(N_r)$


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

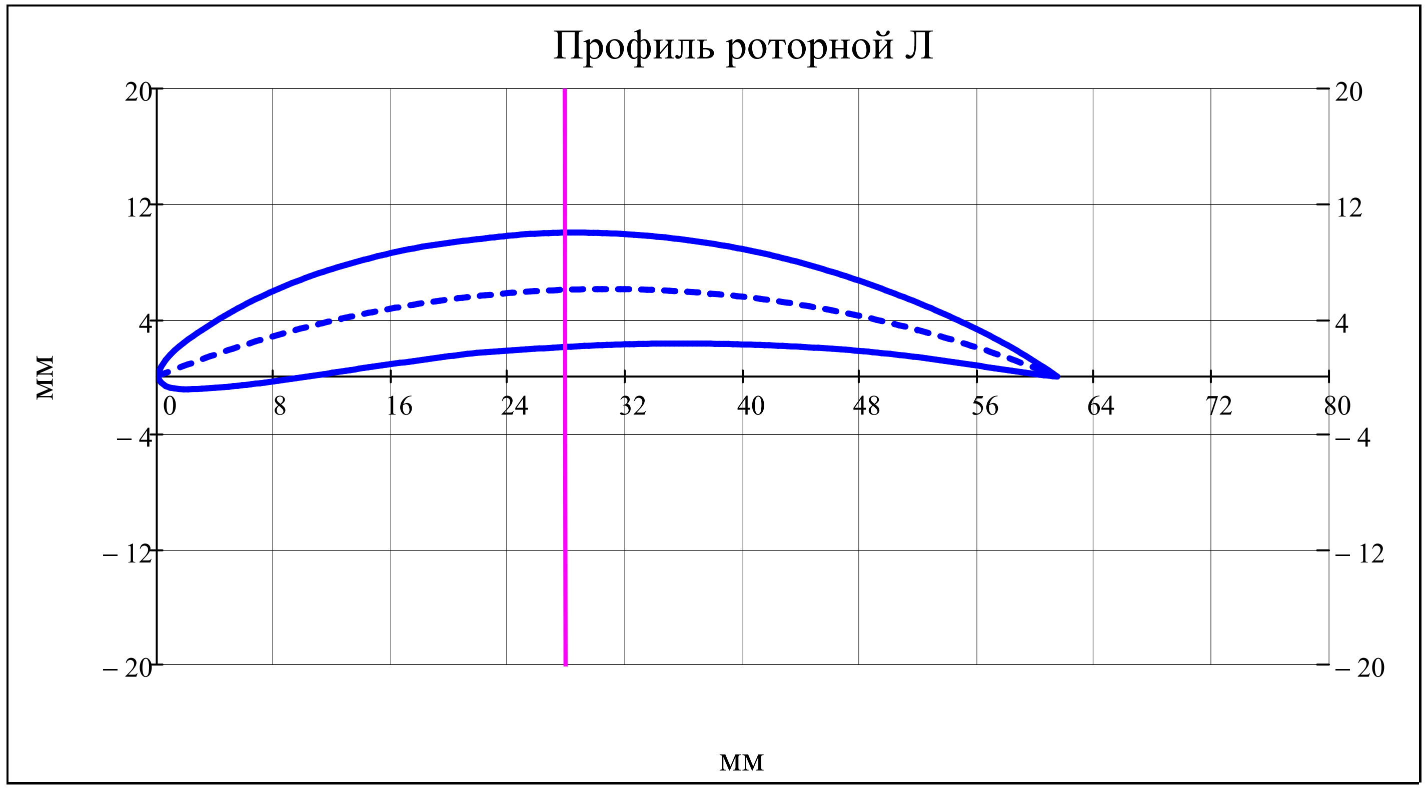

Профиль Л СА
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм

$r = N_r$

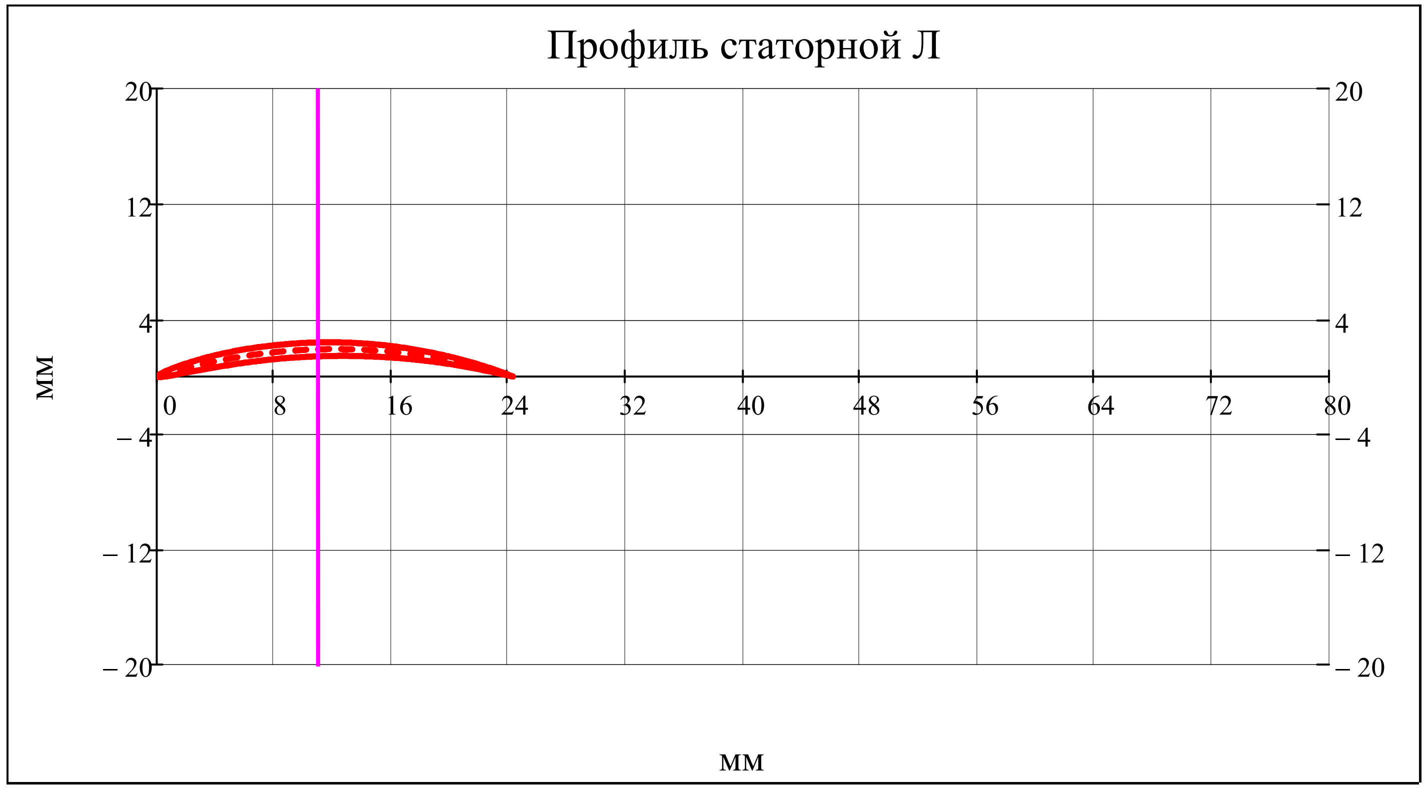

Профиль Л ВНА
20
12
4
0
8
16
24
32
40
48
56
64
72
80
– 4
– 12
– 20
мм
мм


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

$r = 1$

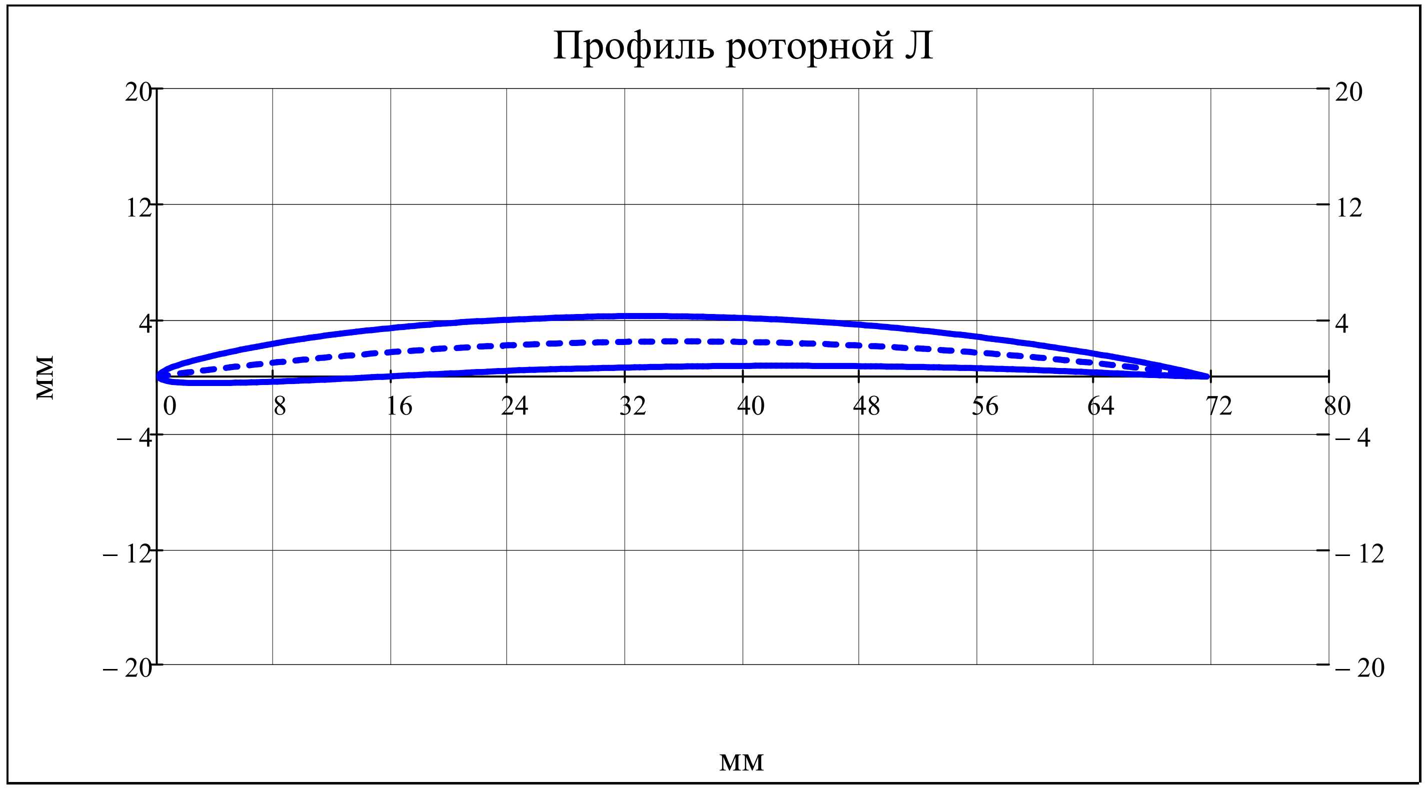


Профиль роторной Л
20
12
4
0
8
16
24
32
40
48
56
64
72
80
− 4
− 12
− 20
мм
мм

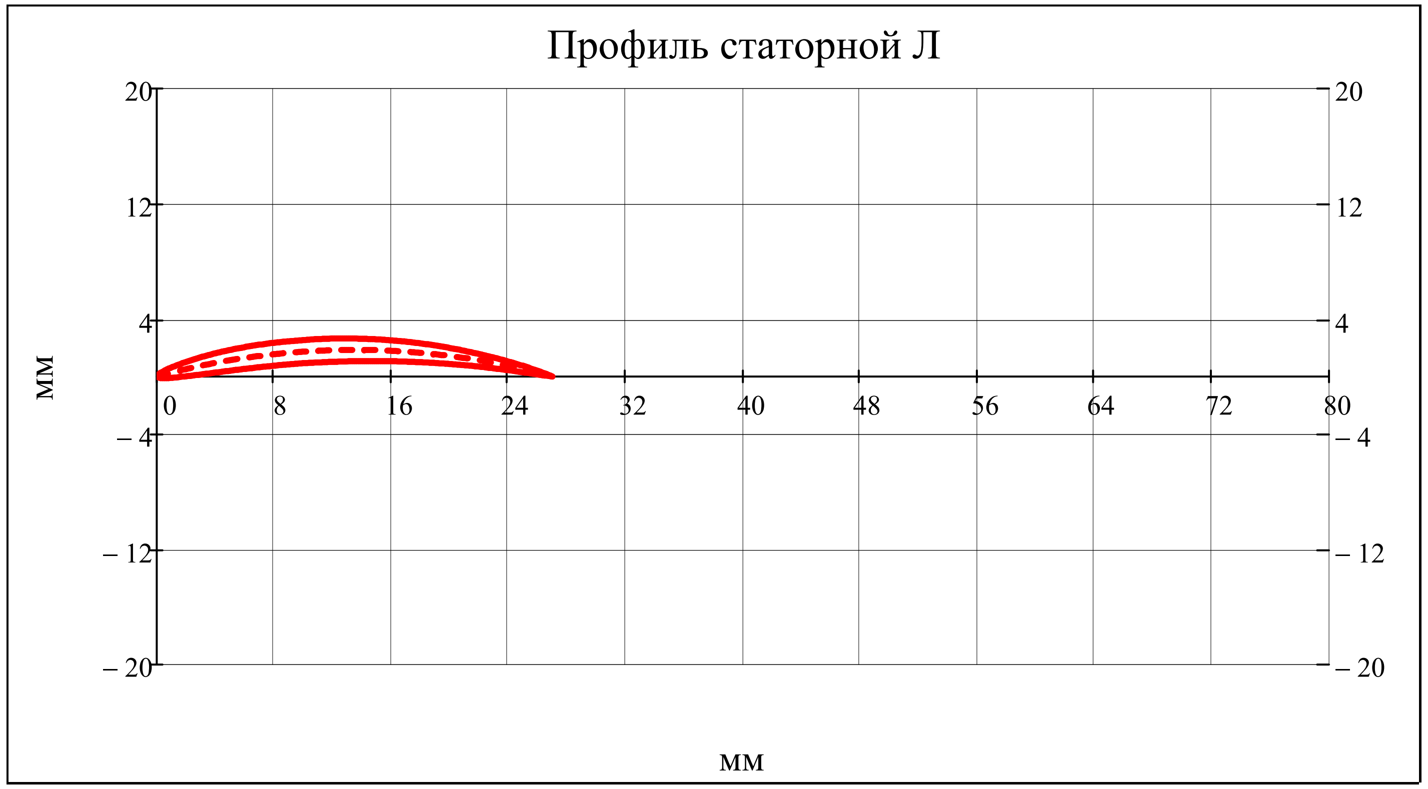


Профиль статорной Л
20
12
4
0
8
16
24
32
40
48
56
64
72
80
− 4
− 12
− 20
мм
мм

$r = av(N_r)$

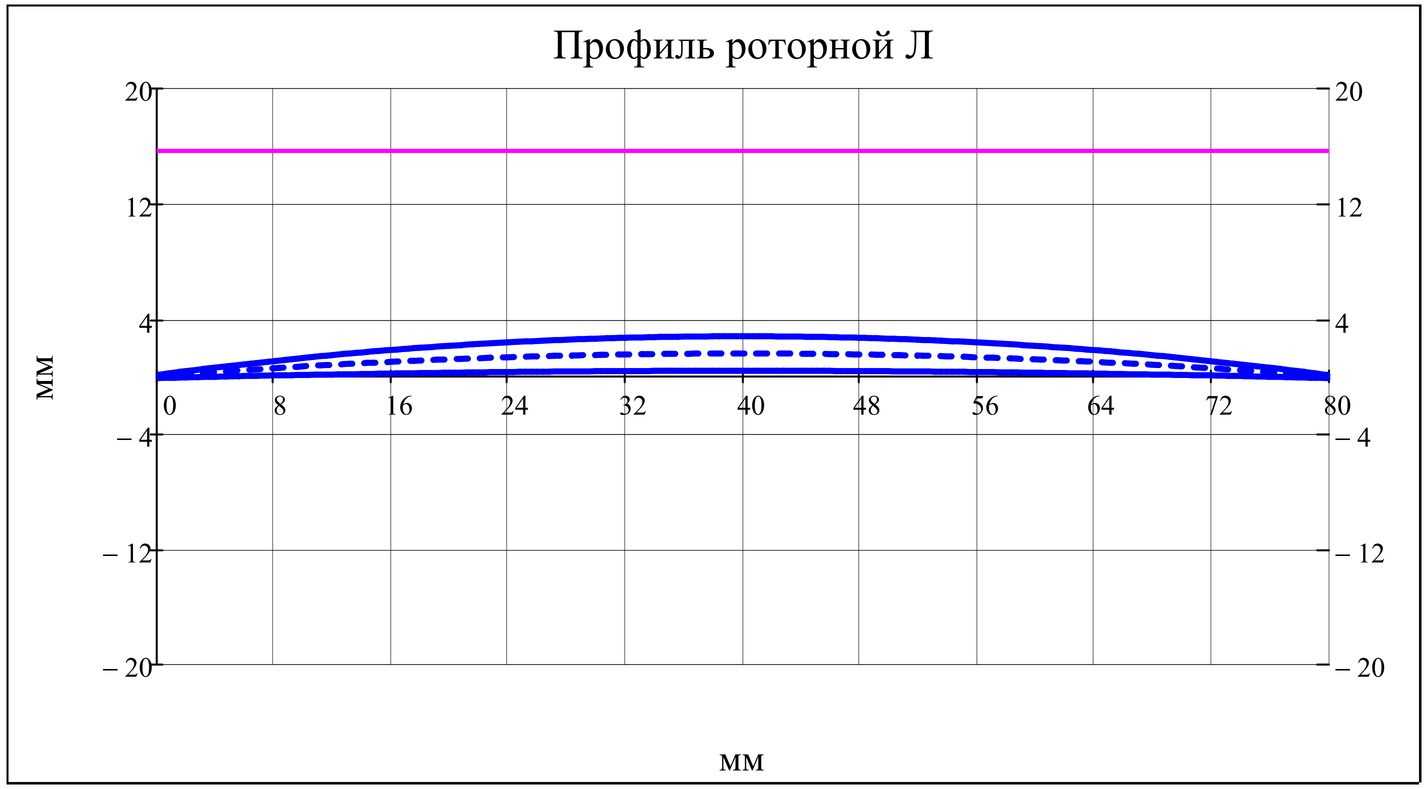


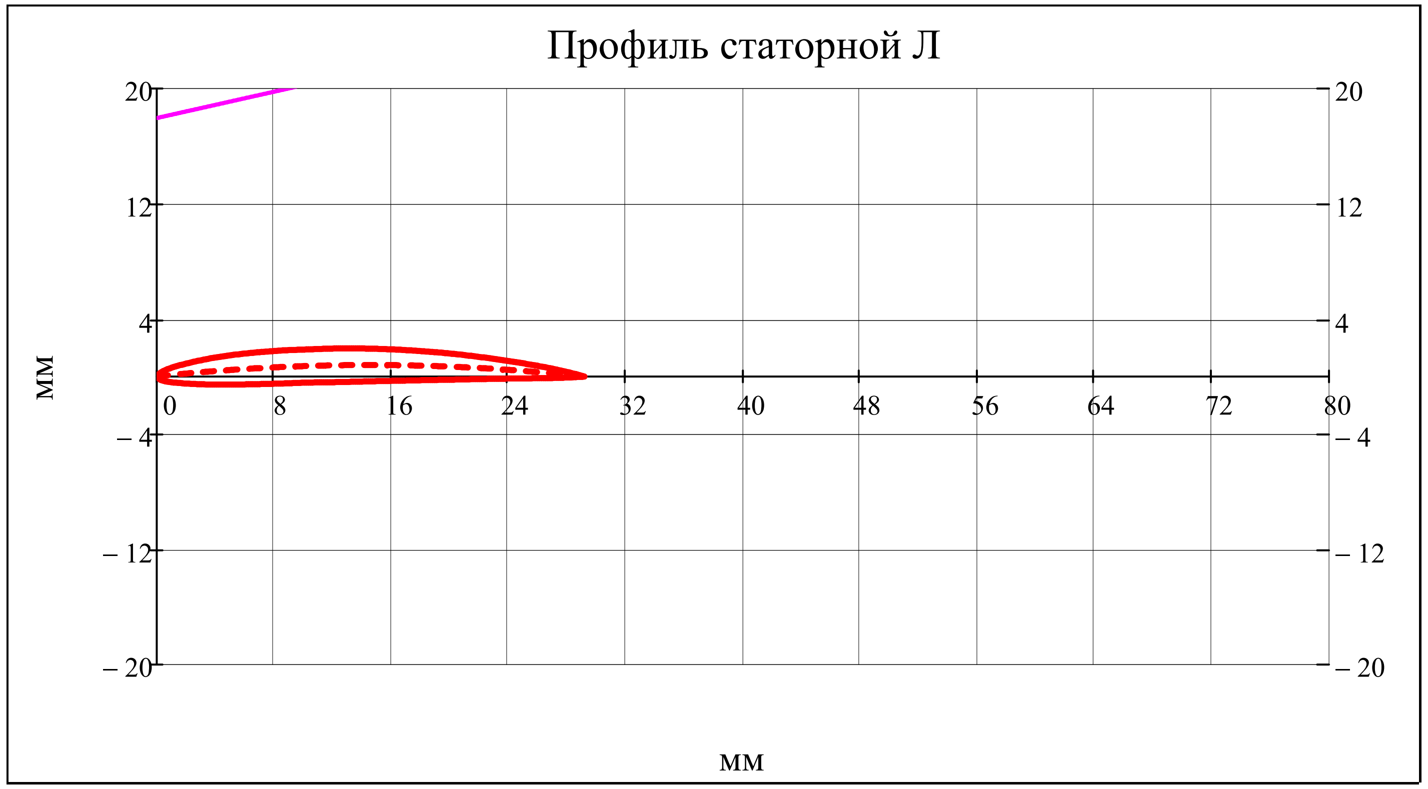
Профиль роторной Л
20
12
4
– 4
– 12
– 20
0
8
16
24
32
40
48
56
64
72
80
мм
мм



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

$r = N_r$





Построение профилей Л РК и НА

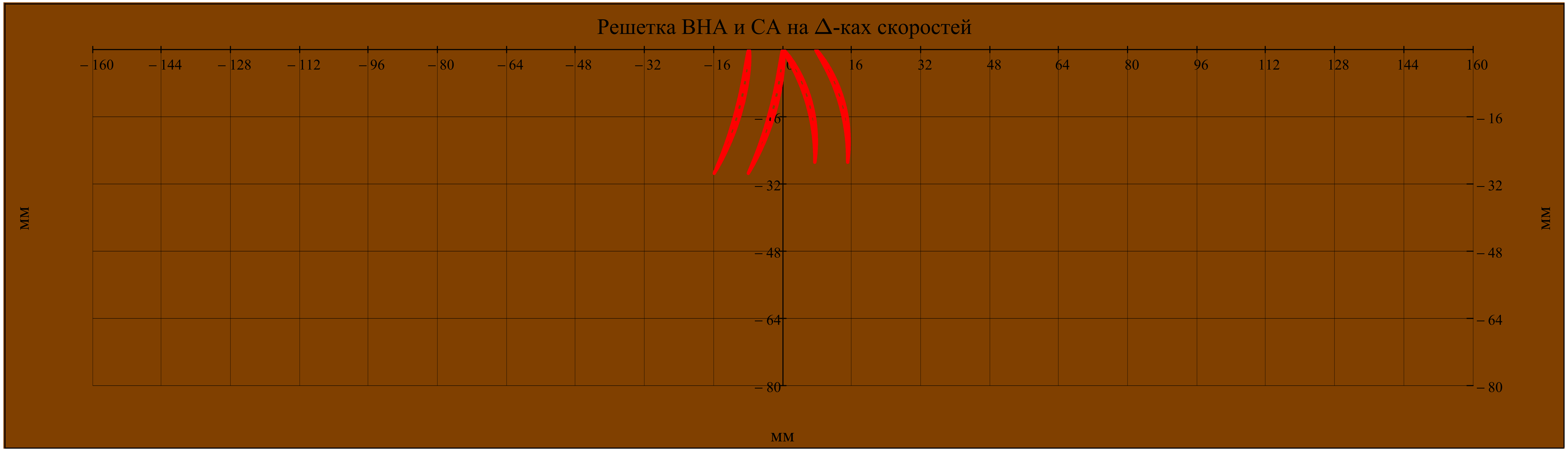
Вывод координат для построения профиля Л

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

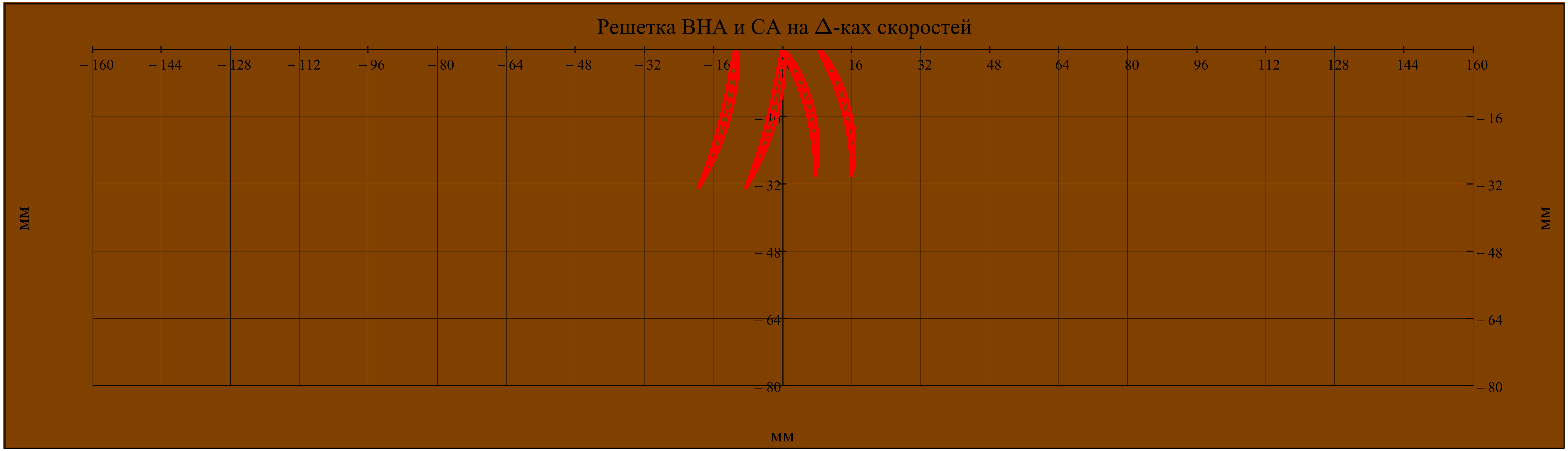
$$b_{lim} := \frac{\mathrm{ceil}\left(\max\left(\mathrm{chord}_{rotor_{j,N_r}}, \mathrm{chord}_{stator_{j,N_r}}\right)\cdot 10^2\right)}{10^2} = 80\cdot 10^{-3}$$

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

$r := 1$

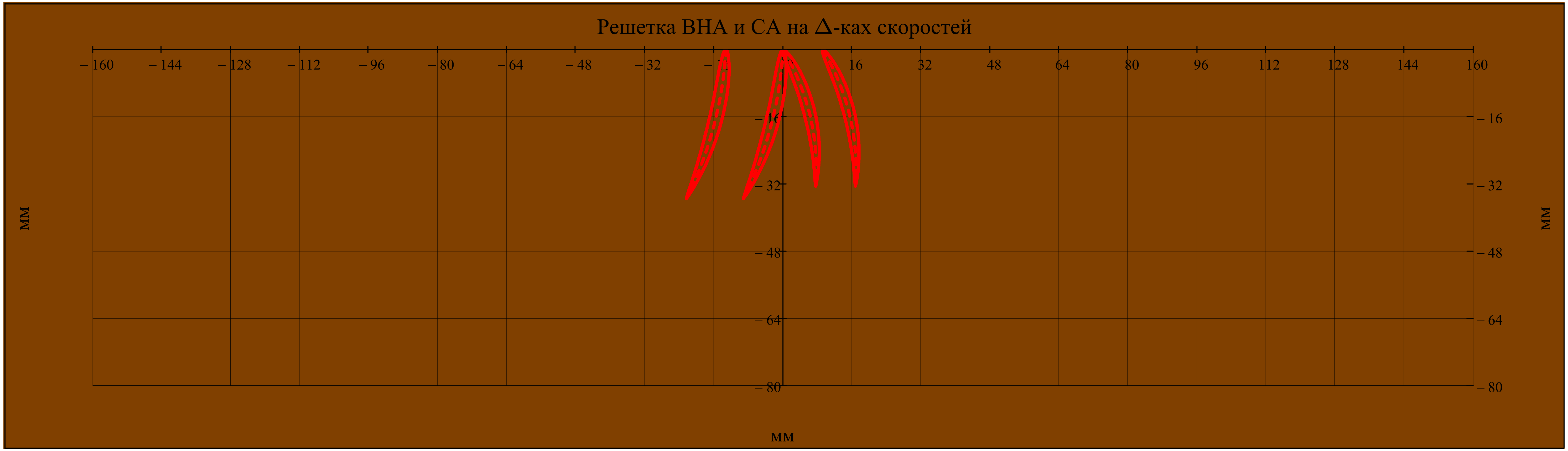


$r = av(N_r)$



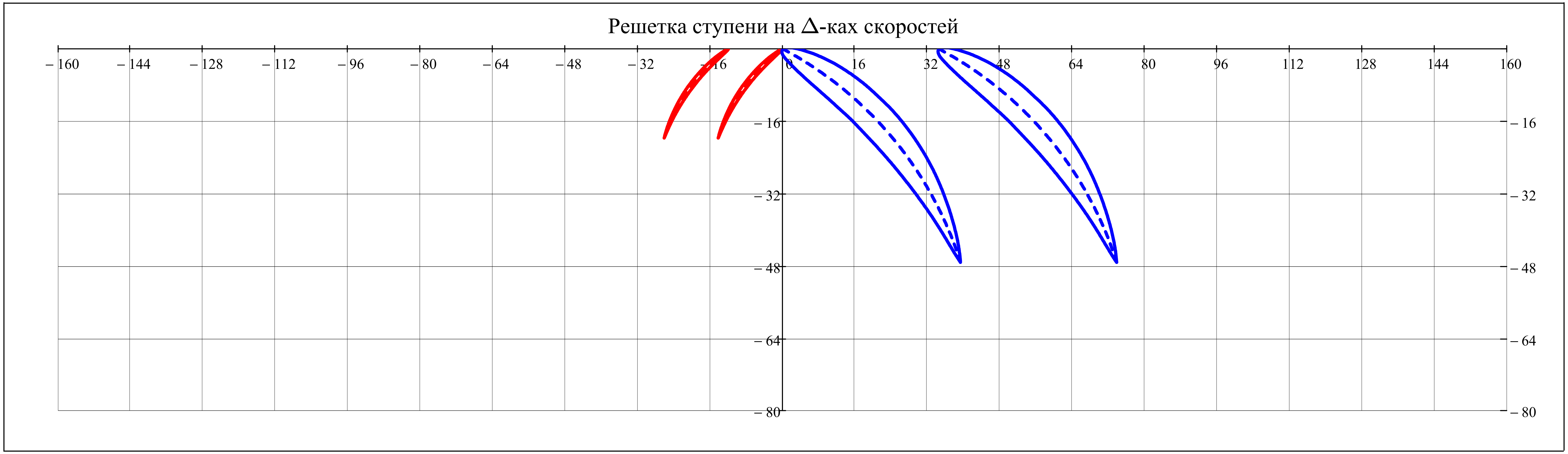
Решетка ВНА и СА на Δ-ках скоростей
– 160
– 144
– 128
– 112
– 96
– 80
– 64
– 48
– 32
– 16
16
32
48
64
80
96
112
128
144
160
– 16
– 32
– 48
– 64
– 80
мм
мм
мм

$r = N_r$



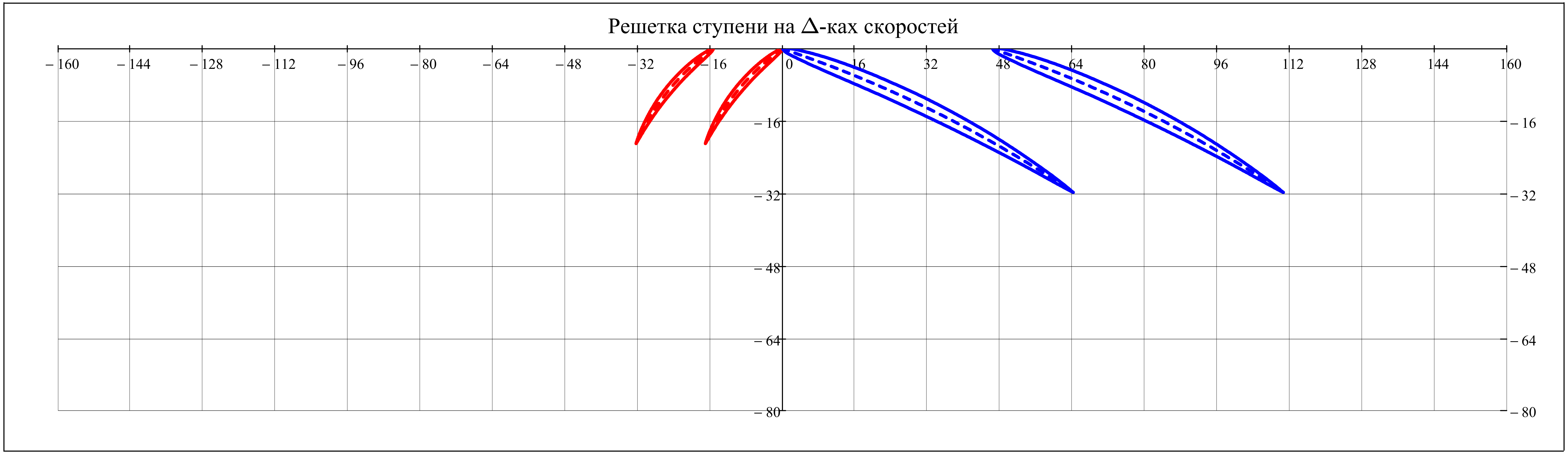
Решетка ВНА и СА на Δ-ках скоростей
– 160
– 144
– 128
– 112
– 96
– 80
– 64
– 48
– 32
16
32
48
64
80
96
112
128
144
160
– 16
– 32
– 48
– 64
– 80
мм
мм
мм

$r = 1$



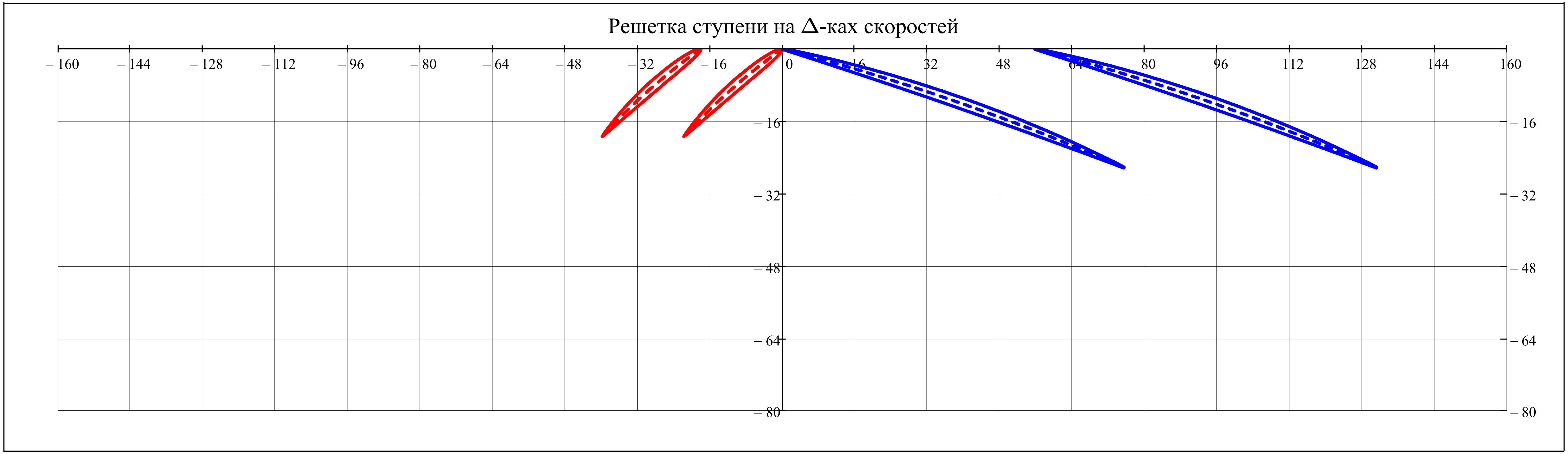
Решетка ступени на Δ-ках скоростей
– 160
– 144
– 128
– 112
– 96
– 80
– 64
– 48
– 32
– 16
0
16
32
48
64
80
96
112
128
144
160
– 16
– 32
– 48
– 64
– 80

$r = av(N_r)$



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

$r = N_r$



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

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]:

$\overline{\Delta}r = 0.0025$

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

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

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

	1	2	3	4	5	6	7	8	9
1	1.36	1.32	1.29	1.25	1.22	1.20	1.18	1.17	1.16

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

$\overline{\Delta}a = 0.17$

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

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

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

	1	2	3	4	5	6	7	8	9
1	12.18	10.15	9.01	8.26	7.72	7.31	7.04	6.95	6.90

Односторонний осевой зазор (м):

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

	1	2	3	4	5	6	7	8	9
1	6.09	5.07	4.51	4.13	3.86	3.65	3.52	3.47	3.45

Длина ОК (м):

$$Length = \left[\Delta a_1 + \begin{vmatrix} chord_{BHA_{av(N_r)}} \cdot \sin\left(\upsilon_{BHA_{av(N_r)}}\right) & \text{if } BHA = 1 \\ 0 & \text{otherwise} \end{vmatrix} \ldots \\ + \sum_{i=1}^{Z} \left(chord_{rotor_{i,av(N_r)}} \cdot \sin\left(\upsilon_{rotor_{i,av(N_r)}}\right)\right) + 2 \cdot \sum_{i=1}^{Z} \Delta a_i + \sum_{i=1}^{Z} \left(chord_{stator_{i,av(N_r)}} \cdot \sin\left(\upsilon_{stator_{i,av(N_r)}}\right)\right) \ldots \\ + \begin{vmatrix} chord_{CA_{av(N_r)}} \cdot \sin\left(\upsilon_{CA_{av(N_r)}}\right) & \text{if } CA = 1 \\ 0 & \text{otherwise} \end{vmatrix} + \Delta a_Z \right] = 571.3 \cdot 10^{-3}$$

Радиальные и осевые зазоры и длина К

Проточная часть

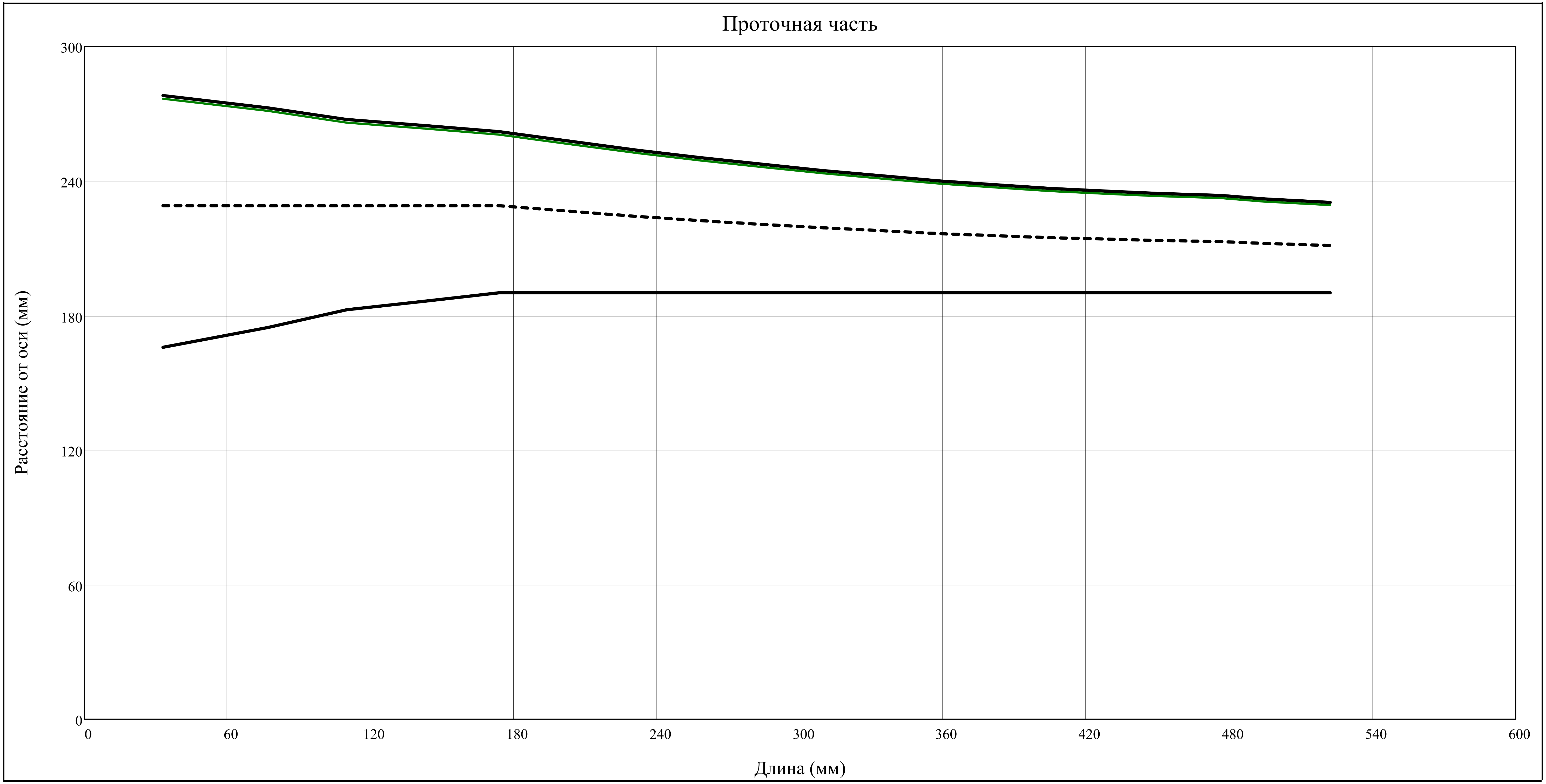
$$\begin{pmatrix} x_{ПЧ} \\ y_{ПЧпер} \\ y_{ПЧср} \\ y_{ПЧкор} \\ y_{Лпер} \end{pmatrix} = \left| \begin{array}{l} c \leftarrow 1 \\ x_{ПЧ_c} \leftarrow \left| \begin{array}{ll} chord_{BHA_{av(N_r)}} \cdot \sin\left(\upsilon_{BHA_{av(N_r)}}\right) & \text{if } BHA = 1 \\ 0 & \text{otherwise} \end{array}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

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

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

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

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



Проточная часть

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

Поперечная часть ступени

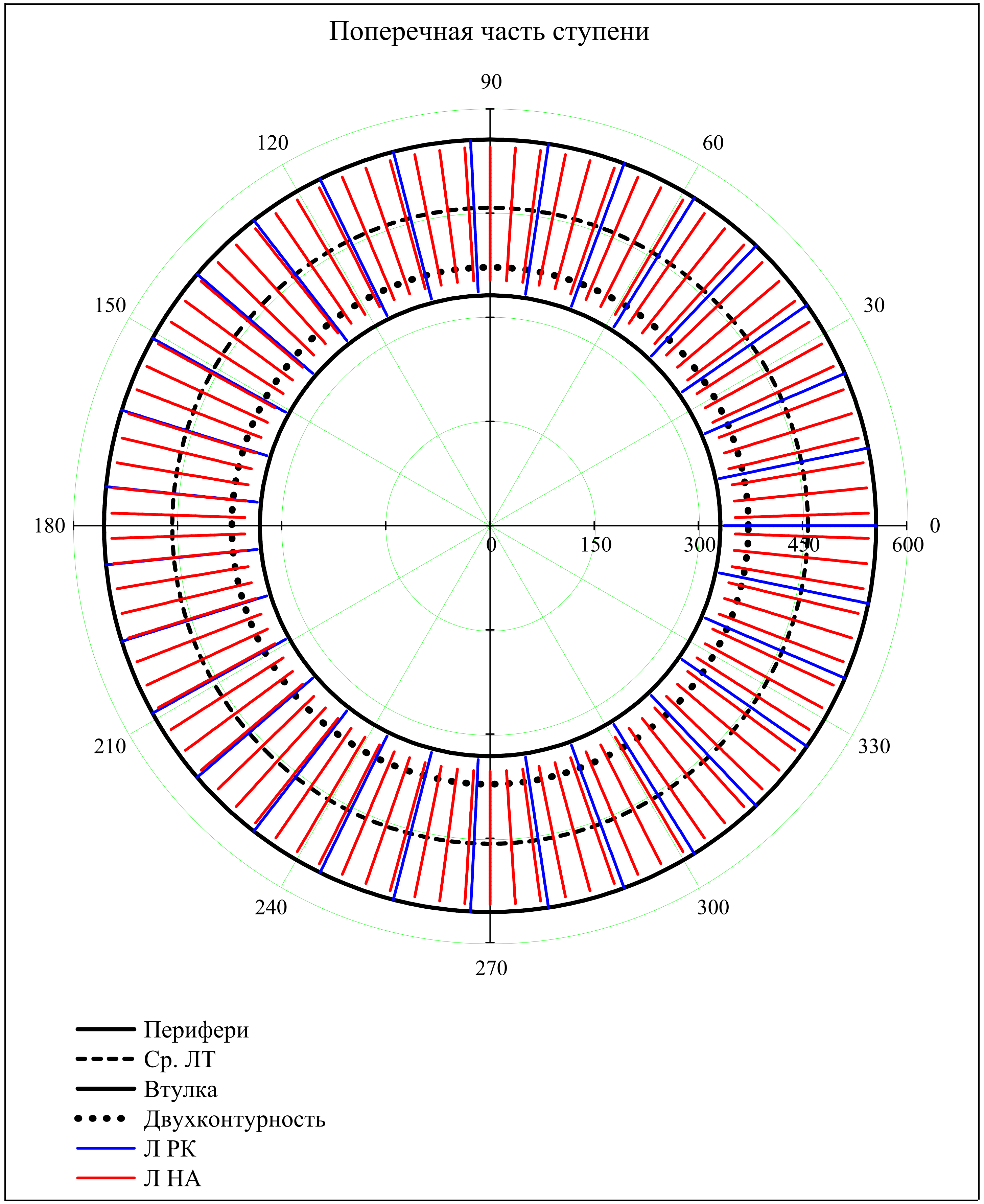
$$r := \min(D), \min(D) + \frac{\max(D) - \min(D)}{N_{dis}} .. \max(D)$$

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

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

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

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



Поперечная часть ступени

Выбор материала Л

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

Выбранный материал Л:

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

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

Плотность материала Л (кг/м^3):

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

Коэф. формы: $k_n = 6.8$

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

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

Предел длительной прочности Л РК (Па):

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

$material\_blade^T =$

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

$\rho\_blade^T =$

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

$\sigma\_blade\_long^T =$

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

$\cdot 10^6$

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]:

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1429	1738	1987	2220	2448	2666	2846	2980	2404	1038	1339	1565	1764	1958	2148	2315	2443	1936
2	4287	5213	5960	6661	7344	7999	8539	8940	7212	3114	4016	4696	5293	5874	6443	6945	7328	5808
3	7145	8688	9934	11102	12241	13332	14232	14901	12020	5190	6693	7827	8822	9790	10739	11575	12213	9679
4	10003	12163	13907	15543	17137	18665	19924	20861	16828	7266	9370	10958	12351	13706	15034	16205	17098	13551
5	12861	15638	17881	19983	22033	23998	25617	26821	21637	9342	12047	14089	15880	17621	19330	20835	21983	17423
6	15719	19113	21854	24424	26929	29331	31309	32781	26445	11418	14724	17220	19409	21537	23625	25464	26868	21294

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

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	269	461	636	778	969	1160	1240	1360	1233	363	484	565	656	752	849	932	1007	827
2	1684	2887	3984	4876	6072	7271	7772	8522	7729	2277	3036	3540	4113	4715	5324	5844	6311	5185
3	4714	8083	11156	13655	17004	20362	21765	23864	21645	6376	8501	9913	11517	13204	14908	16364	17674	14519
4	9245	15852	21879	26778	33347	39932	42683	46799	42447	12503	16670	19440	22585	25894	29236	32091	34659	28473
5	15277	26193	36152	44249	55102	65983	70529	77331	70139	20660	27546	32123	37319	42787	48310	53026	57270	47049
6	22815	39118	53991	66083	82292	98542	105332	115490	104749	30854	41138	47973	55734	63900	72148	79192	85530	70265

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

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	2858	3475	3973	4441	4896	5333	5693	5960	4808	2076	2677	3131	3529	3916	4295	4630	4885	3872
2	5716	6950	7947	8881	9793	10666	11385	11920	9616	4152	5354	6262	7058	7832	8591	9260	9770	7743
3	8574	10425	11920	13322	14689	15999	17078	17881	14424	6228	8031	9393	10587	11748	12886	13890	14655	11615
4	11432	13900	15894	17763	19585	21331	22771	23841	19233	8304	10708	12524	14116	15664	17182	18520	19540	15487
5	14290	17376	19867	22204	24481	26664	28463	29801	24041	10380	13386	15655	17645	19579	21477	23150	24425	19359
6	17148	20851	23841	26644	29378	31997	34156	35761	28849	12456	16063	18786	21173	23495	25773	27779	29311	23230

Расчет собственных частот колебаний Л

Вывод результатов расчета собственных частот колебаний Л

Расчетный узел: $type = "compressor"$

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

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

Расчет Л на прочность

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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	-3.247	-2.277	-2.328	-2.361	-2.386	-2.408	-2.434	-2.454	-2.465
2	-0.805	-0.811	-1.531	-1.531	-1.532	-1.533	-1.535	-1.538	-1.538
3	0.001	-0.922	-0.923	-0.923	-0.923	-0.923	-1.722	-1.723	-1.723

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	5.471	5.107	4.899	4.801	4.730	4.652	4.528	4.437	4.389
2	2.340	2.266	2.181	2.176	2.168	2.149	2.099	2.053	2.035
3	1.546	1.497	1.434	1.442	1.445	1.440	1.412	1.381	1.375

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	33.039	33.430	32.893	31.703	31.113	-15.578	-11.258	-10.016	-10.007
2	39.261	39.268	-23.774	-23.057	-23.057	-22.339	-20.904	-19.470	-18.753
3	39.928	-28.885	-24.891	-25.690	-25.690	-25.689	-24.092	-22.494	-21.695

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	-8.057	-5.547	-4.547	-4.056	-3.722	-3.473	-3.516	-3.574	-3.611
2	-2.329	-1.994	-1.752	-1.748	-1.743	-1.728	-1.691	-1.669	-1.665
3	-1.399	-1.248	-1.170	-1.178	-1.181	-1.177	-1.152	-1.133	-1.130

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	0.222	0.229	-1.717	-1.724	-1.778	-1.738	-1.441	-1.236	-1.152
2	-0.023	-0.009	0.001	0.002	0.004	0.003	-0.009	-0.016	-0.018
3	-0.331	-0.001	0.011	0.013	0.016	0.015	0.001	-0.007	-0.303

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	0.912	0.993	11.026	11.026	11.029	11.027	11.012	11.003	10.999
2	1.224	1.366	1.445	1.450	1.471	1.460	1.363	1.292	1.260
3	1.345	1.752	1.839	1.849	1.873	1.865	1.767	1.695	1.662

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	13.297	13.281	-2.346	-2.356	-2.429	-2.375	-1.971	-1.691	-1.577
2	14.779	14.752	14.731	14.729	14.723	14.726	14.752	14.766	14.772
3	-8.222	15.936	15.912	15.909	15.902	15.904	15.931	15.947	15.954

$\cdot 10^{-3}$

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

	1	2	3	4	5	6	7	8	9
1	-1.724	-2.079	-13.273	-13.272	-13.269	-13.271	-13.289	-13.300	-13.304
2	-1.675	-2.299	-2.660	-2.687	-2.781	-2.734	-2.289	-1.978	-1.844
3	-1.120	-2.444	-2.846	-2.891	-3.003	-2.968	-2.517	-2.197	-2.052

$\cdot 1$

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

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

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

	1	2	3	4	5	6	7	8	9
1	-19.14	-46.15	-70.23	-94.47	-119.79	-140.76	-141.73	-139.24	-130.15
2	-40.62	-68.40	-102.67	-127.72	-153.92	-173.51	-168.19	-161.83	-152.70
3	-0.38	-0.22	-0.98	-0.88	-0.82	-0.65	-0.32	-0.15	-0.48

$\cdot 10^6$

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

	1	2	3	4	5	6	7	8	9
1	1.71	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	144.22	104.51	106.02	104.07	94.86	84.60	74.31	58.82	41.71
3	328.37	203.51	206.83	204.98	189.27	169.01	142.95	109.54	77.43

$\cdot 10^6$

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

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

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

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

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

	1	2	3	4	5	6	7	8	9
1	35.52	60.11	79.05	95.69	111.86	94.07	102.57	106.16	101.94
2	42.92	63.29	79.38	98.92	119.55	135.12	131.72	128.45	122.24
3	0.35	0.18	0.78	0.71	0.66	0.52	0.26	0.12	0.39

$\cdot 10^6$

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

	1	2	3	4	5	6	7	8	9
1	-3.27	-0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	-198.81	-179.97	-200.95	-198.54	-185.04	-163.29	-127.85	-91.88	-62.18
3	-274.20	-292.60	-332.03	-332.61	-315.42	-279.36	-210.23	-146.02	-98.10

$\cdot 10^6$

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

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

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

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

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

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

$\sigma_{rotor}^T =$

	1	2	3	4	5	6	7	8	9
1	179.08	175.01	178.54	182.50	189.04	163.63	166.66	166.63	202.19
2	148.71	147.90	153.94	163.61	176.85	186.51	178.74	172.58	196.18
3	8.62	4.17	6.93	5.29	4.23	3.23	2.04	1.30	3.98

$\cdot 10^6$

$\sigma_{stator}^T =$

	1	2	3	4	5	6	7	8	9
1	1.74	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	144.23	104.53	106.05	104.11	94.90	84.64	74.34	58.84	41.74
3	328.37	203.52	206.85	205.00	189.30	169.04	142.97	109.56	77.45

$\cdot 10^6$

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

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

	1	2	3	4	5	6	7	8	9
1	1.12	1.14	1.12	1.1	1.06	0.92	0.9	0.9	0.61
2	1.34	1.35	1.3	1.22	1.13	0.8	0.84	0.87	0.63
3	23.2	47.93	28.84	37.81	47.25	46.46	73.35	115.57	30.93

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

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

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

	1	2	3	4	5
1	115.24	412.98	0000000000000000000000000000000	0000000000000000000000000000000	0000000000000000000000000000000
2	1.39	1.91	1.89	1.92	2.11
3	0.61	0.98	0.97	0.98	...

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

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

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

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

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

	1	2	3
1	165.8	228.9	278.0
2	174.6	228.9	272.5
3	182.5	228.9	267.3

$\cdot 10^{-3}$

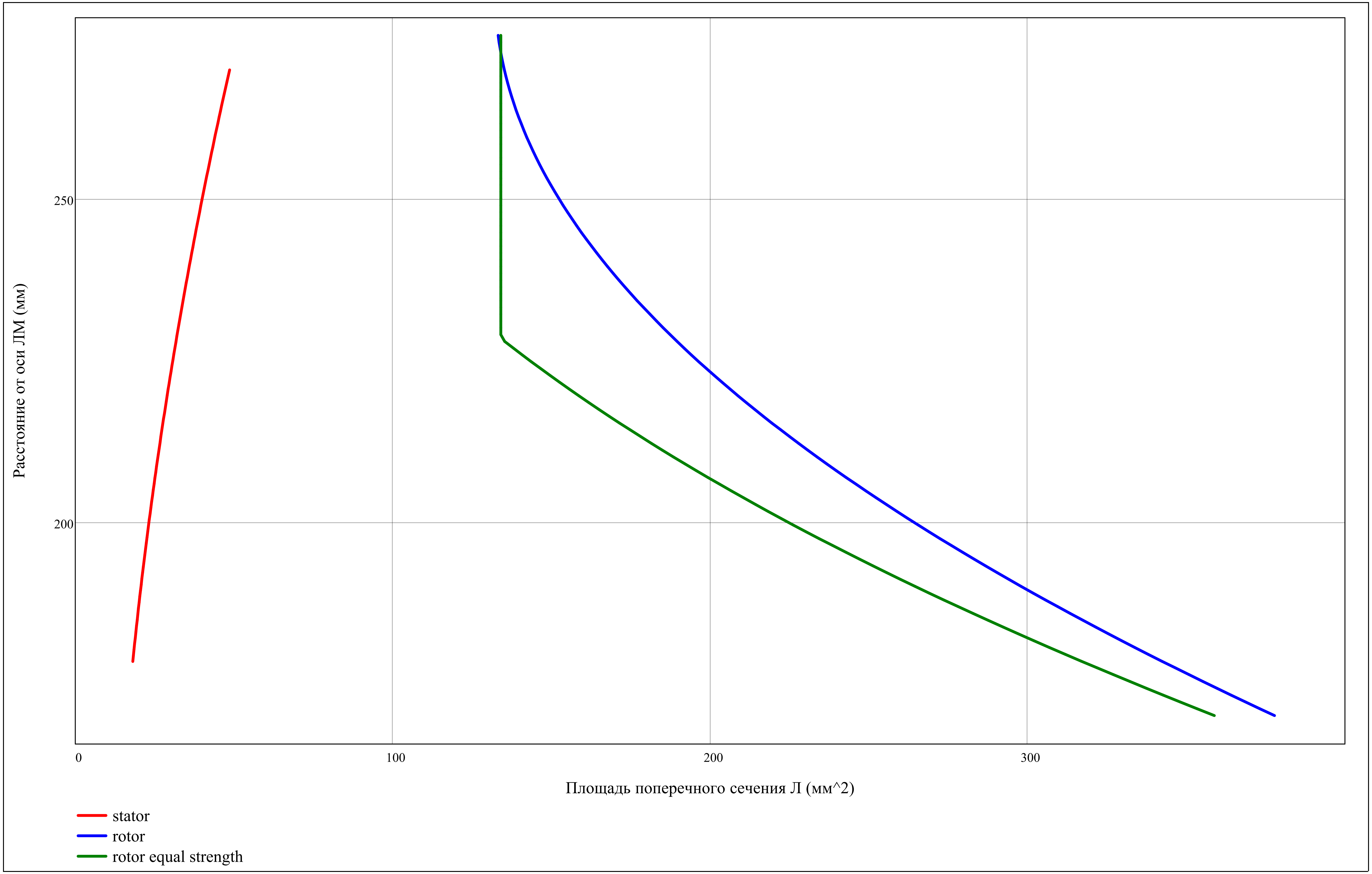
Дискретизация по высоте Л:

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

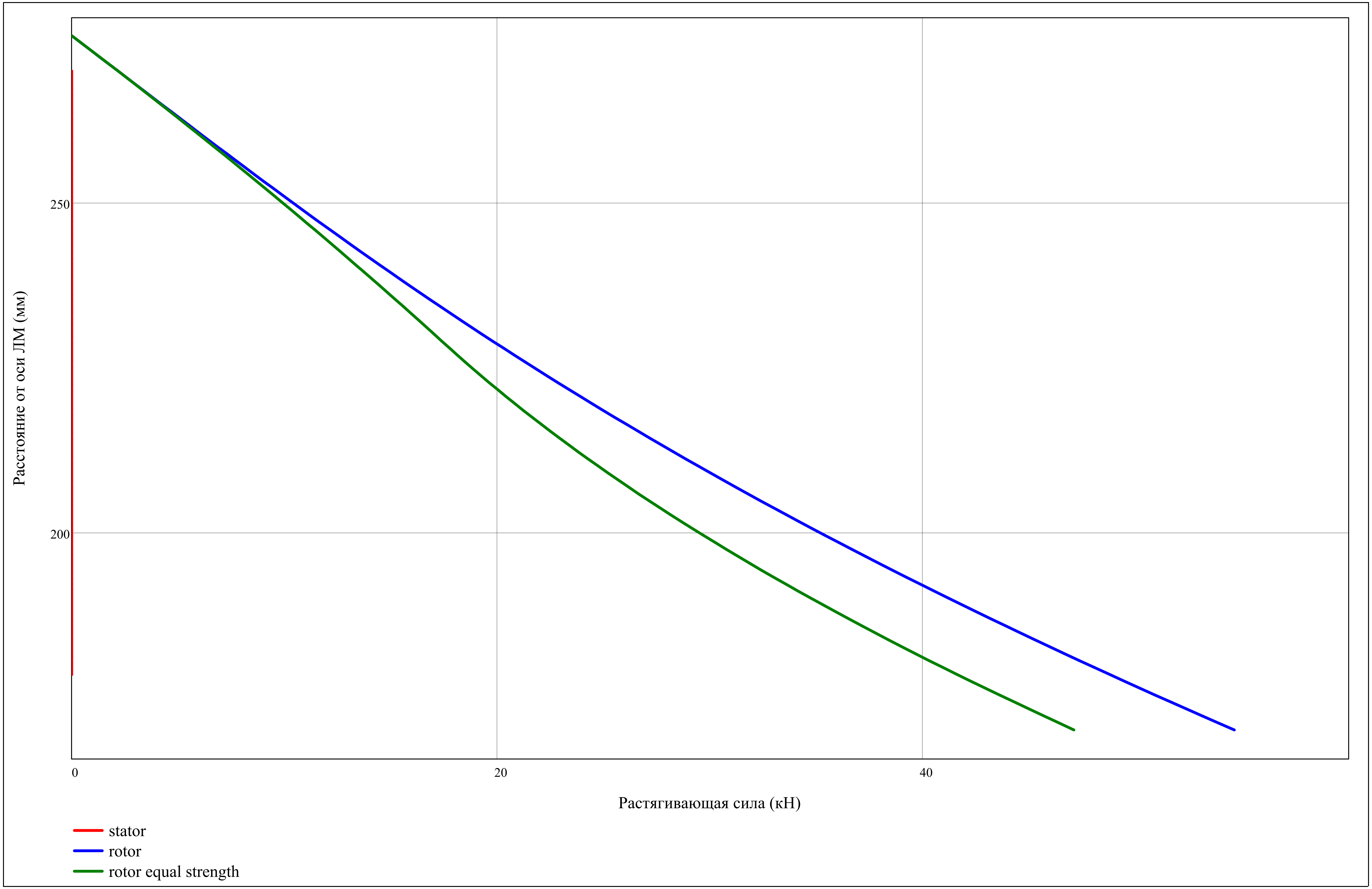
$$z_{rotor} := \left| \begin{array}{l} \mathrm{mean}(Rj_{1,1}, Rj_{2,1}), \mathrm{mean}(Rj_{1,1}, Rj_{2,1}) + \dfrac{\mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) - \mathrm{mean}(Rj_{1,1}, Rj_{2,1})}{100} .. \mathrm{mean}(Rj_{1,N_r}, Rj_{2,N_r}) \text{ if } type = \text{"compressor"} \\ \mathrm{mean}(Rj_{2,1},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

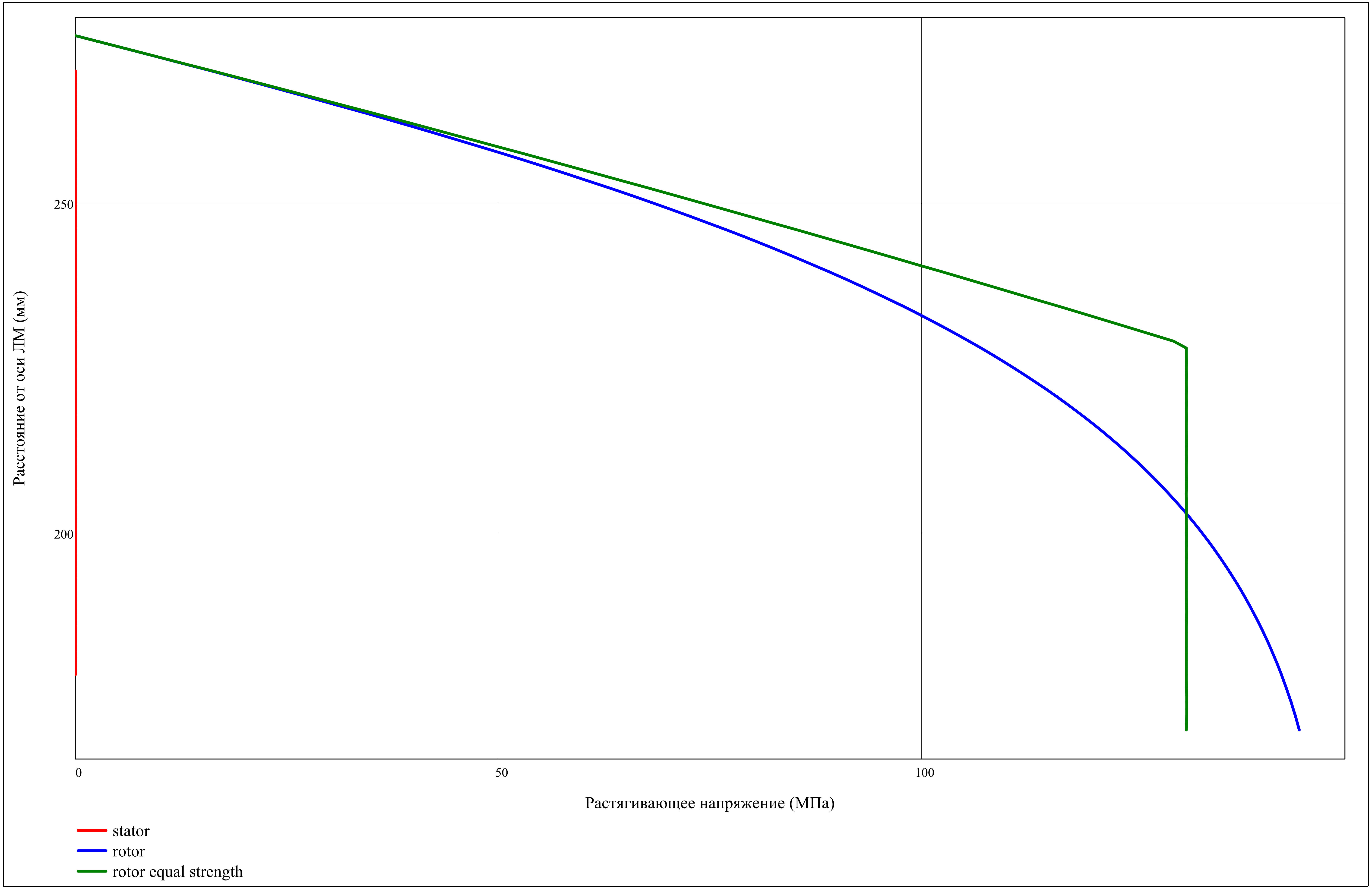
$$z_{stator} := \left| \begin{array}{l} \mathrm{mean}(Rj_{2,1}, Rj_{3,1}), \mathrm{mean}(Rj_{2,1}, Rj_{3,1}) + \dfrac{\mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) - \mathrm{mean}(Rj_{2,1}, Rj_{3,1})}{100} .. \mathrm{mean}(Rj_{2,N_r}, Rj_{3,N_r}) \text{ if } type = \text{"compressor"} \\ \mathrm{mean}(Rj_{1,1},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

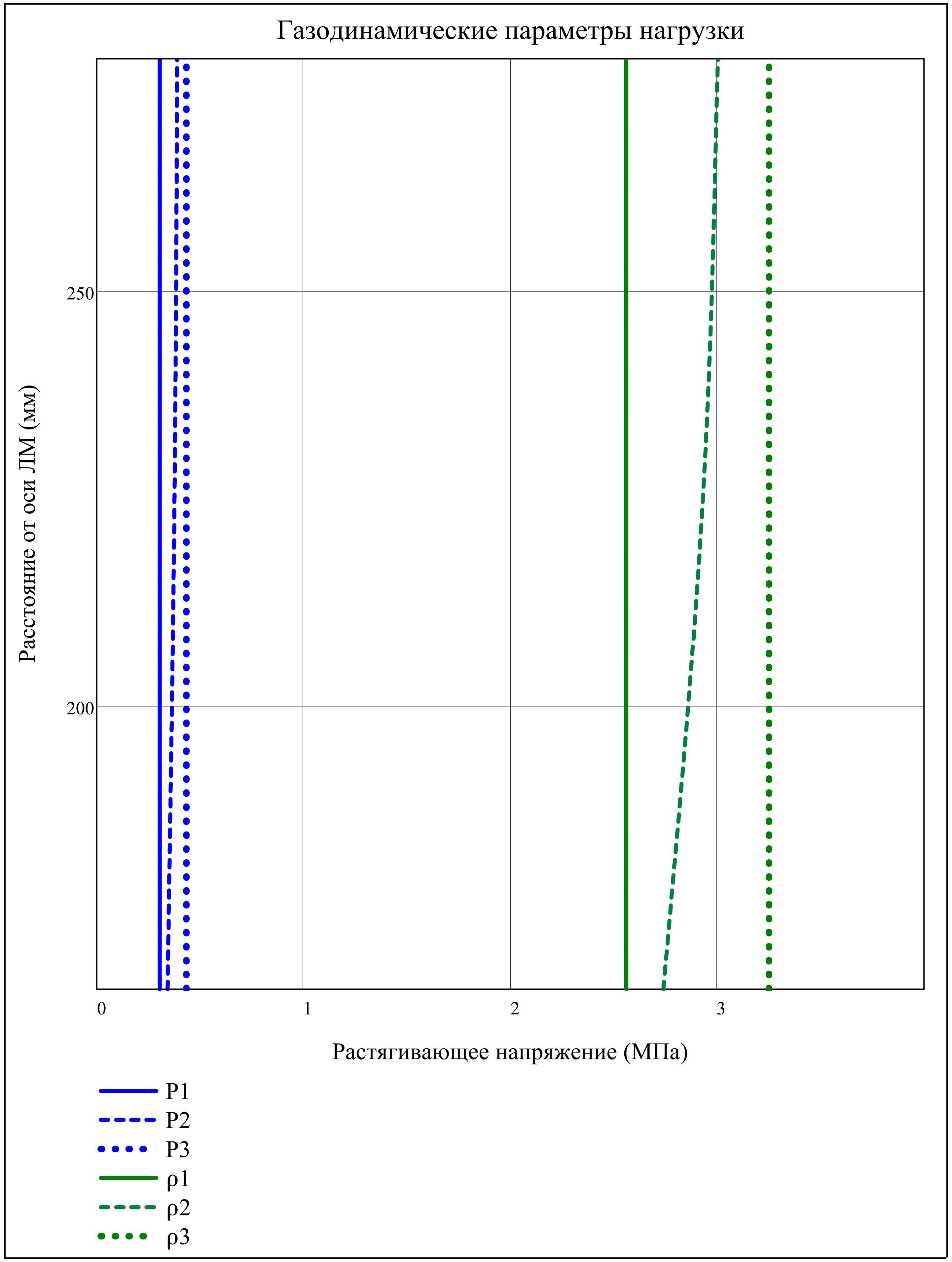
Результаты расчета на прочность Л

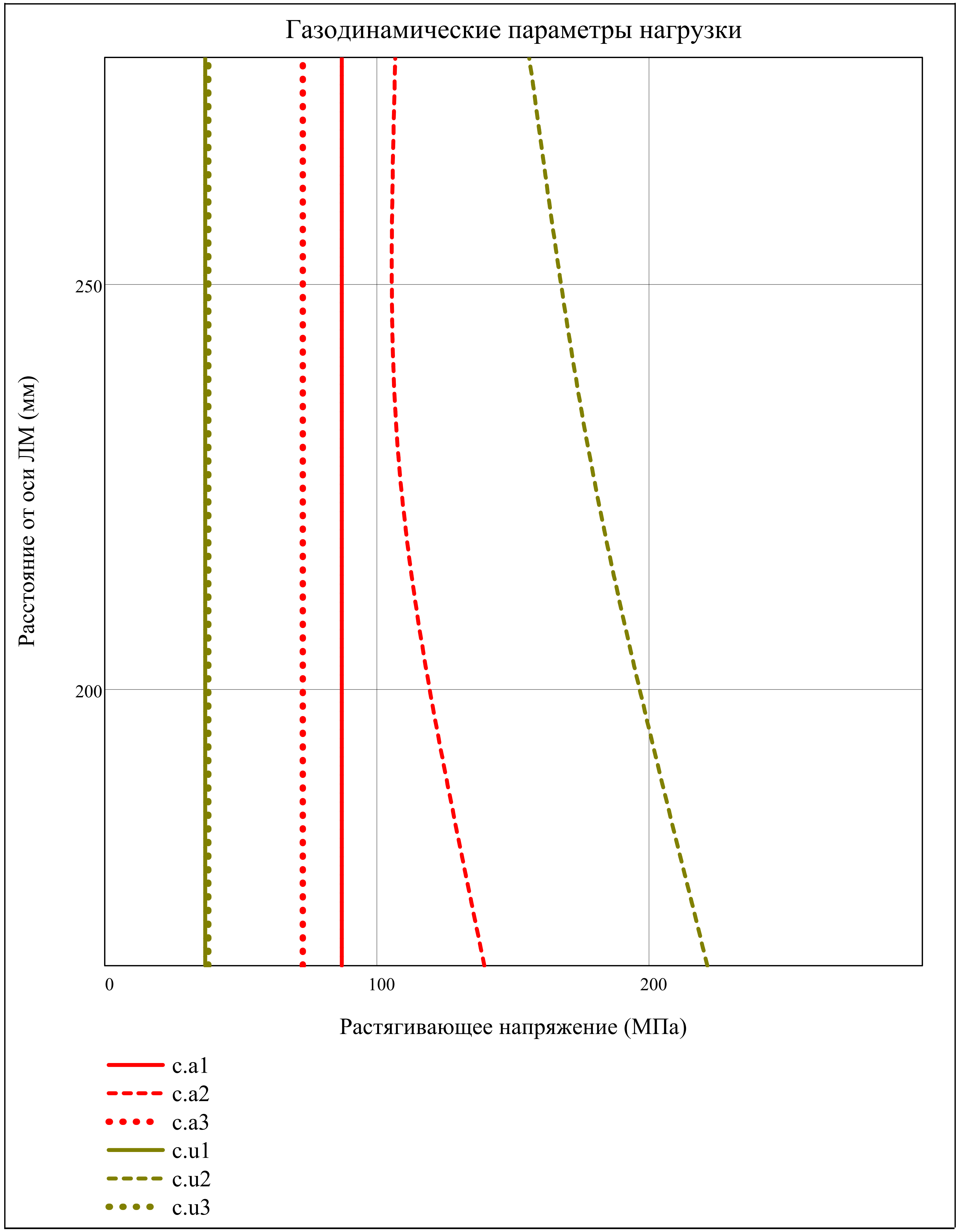


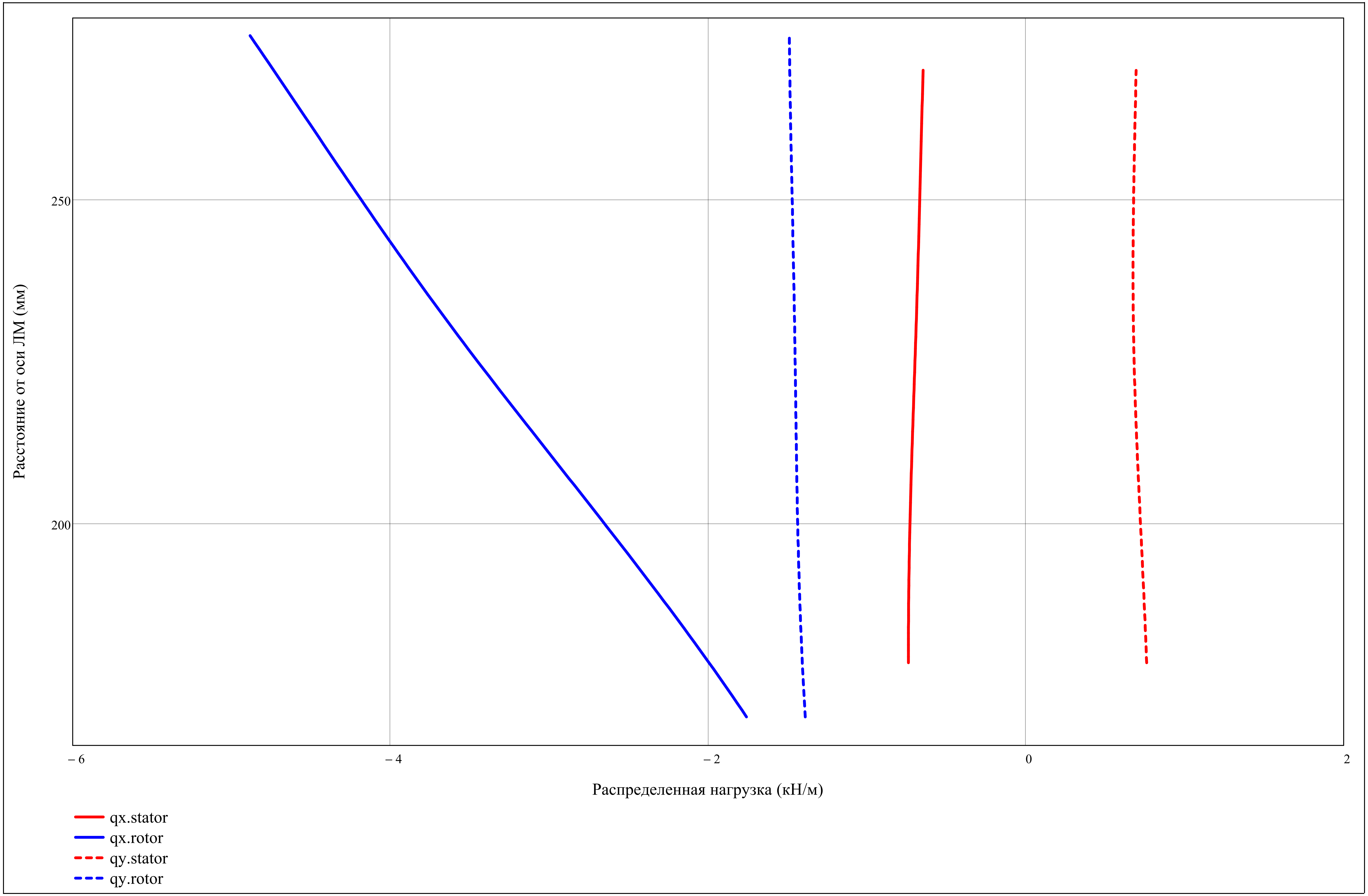
Расстояние от оси ЛМ (мм)
250
200
0
100
200
300
Площадь поперечного сечения Л (мм^2)
stator
rotor
rotor equal strength


Расстояние от оси ЛМ (мм)
250
200
0
20
40
Растягивающая сила (кН)
stator
rotor
rotor equal strength

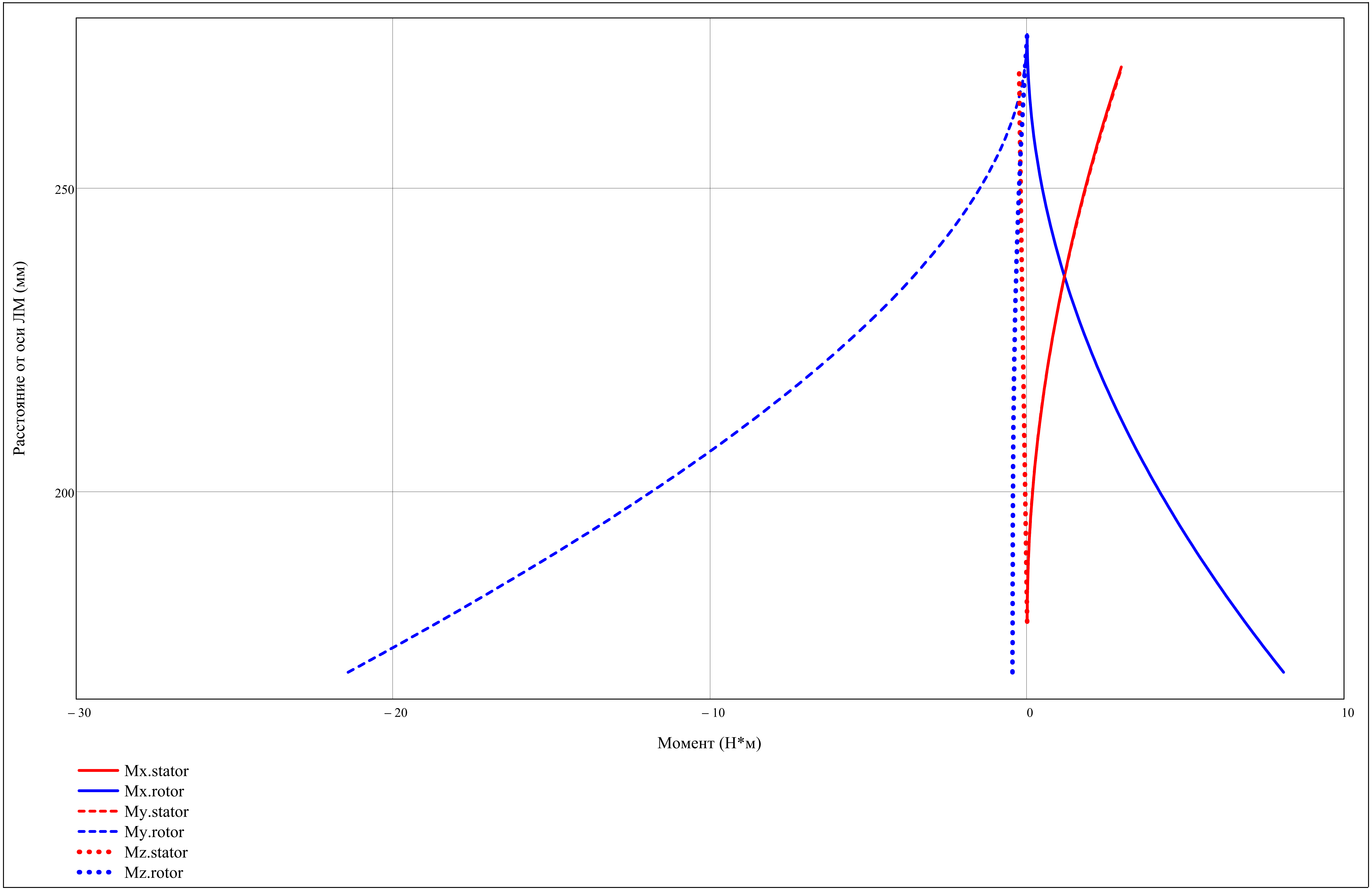

Расстояние от оси ЛМ (мм)
250
200
0
50
100
Растягивающее напряжение (МПа)
stator
rotor
rotor equal strength

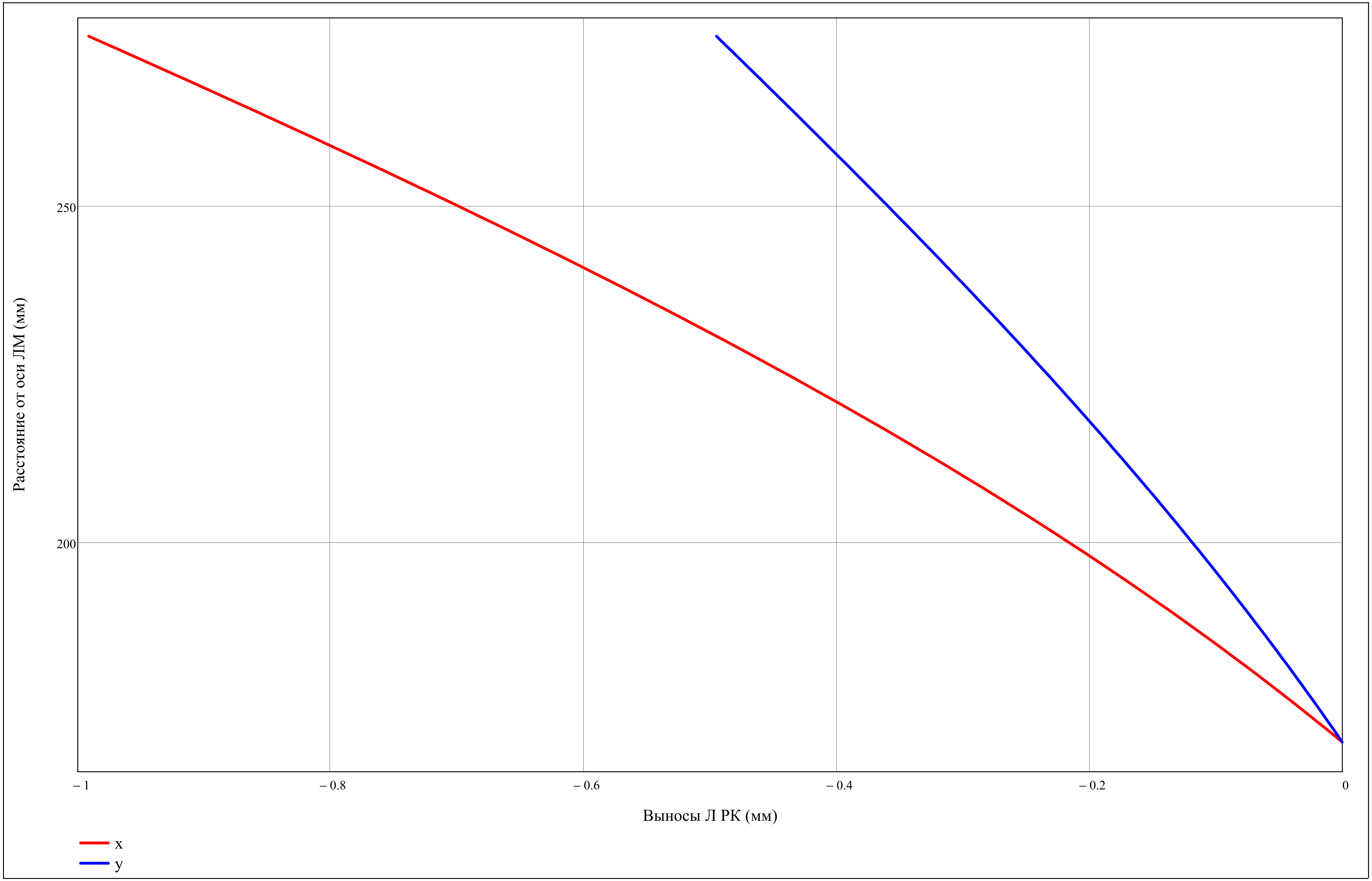

Газодинамические параметры нагрузки
Расстояние от оси ЛМ (мм)
250
200
0
1
2
3
Растягивающее напряжение (МПа)
P1
P2
P3
ρ1
ρ2
ρ3


Газодинамические параметры нагрузки
Расстояние от оси ЛМ (мм)
250
200
0
100
200
Растягивающее напряжение (МПа)
c.a1
c.a2
c.a3
c.u1
c.u2
c.u3

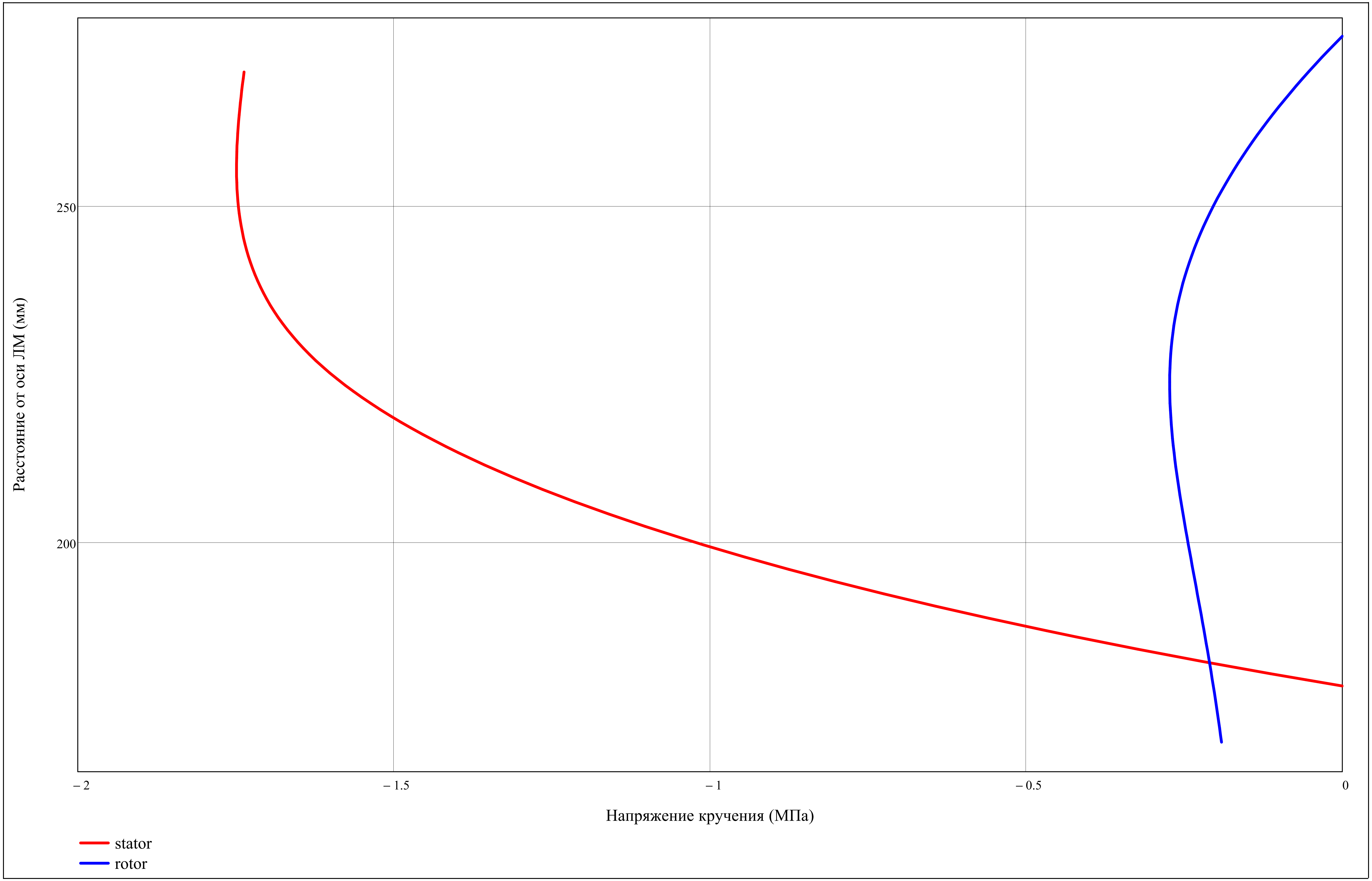


250
200
Расстояние от оси ЛМ (мм)
– 6
– 4
– 2
0
2
Распределенная нагрузка (кН/м)
qx.stator
qx.rotor
qy.stator
qy.rotor

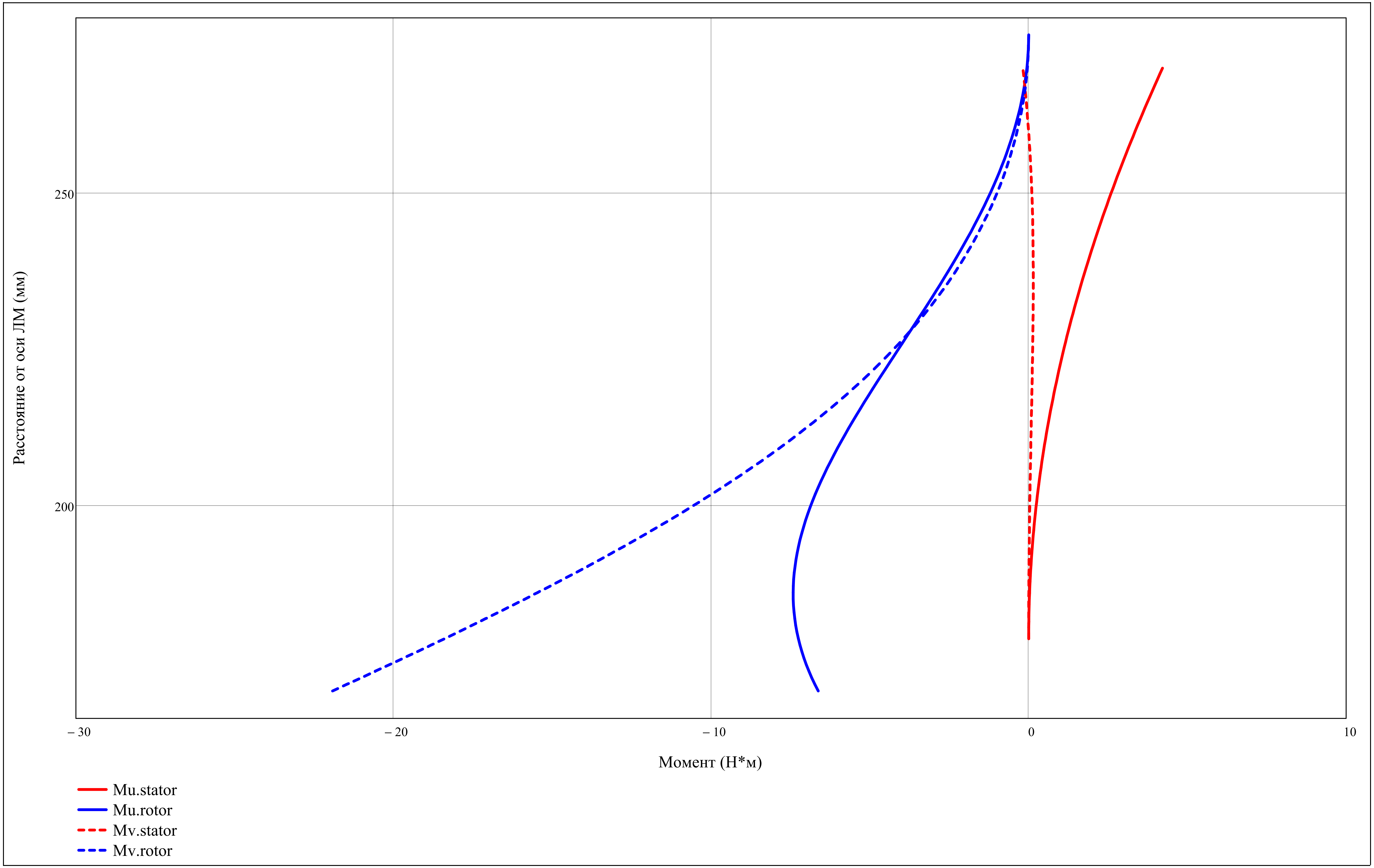

Расстояние от оси ЛМ (мм)
250
200
– 30
– 20
– 10
0
10
Момент (Н*м)
Mx.stator
Mx.rotor
My.stator
My.rotor
Mz.stator
Mz.rotor



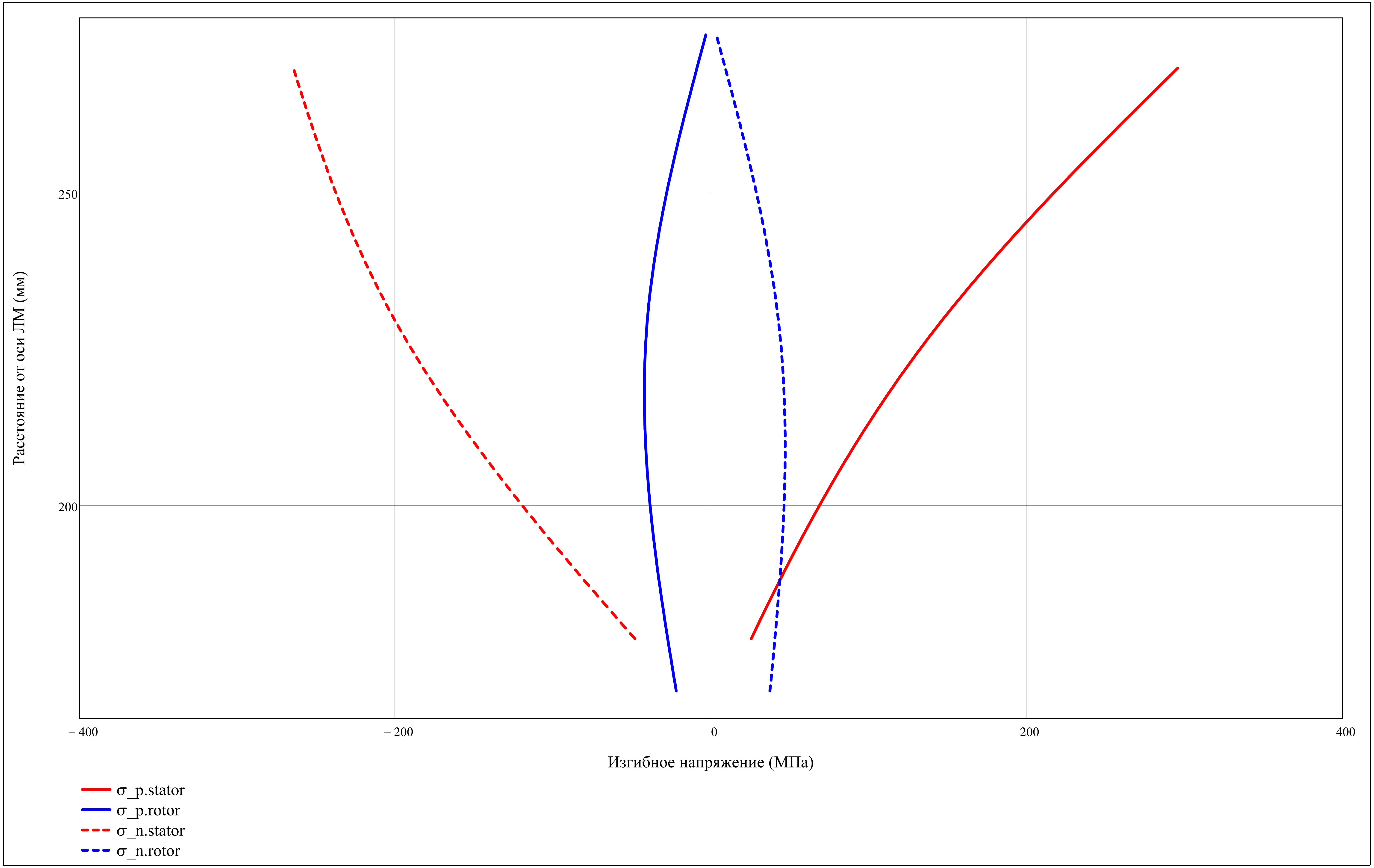
250
200
Расстояние от оси ЛМ (мм)
– 1
– 0.8
– 0.6
– 0.4
– 0.2
0
Выносы Л РК (мм)
x
y



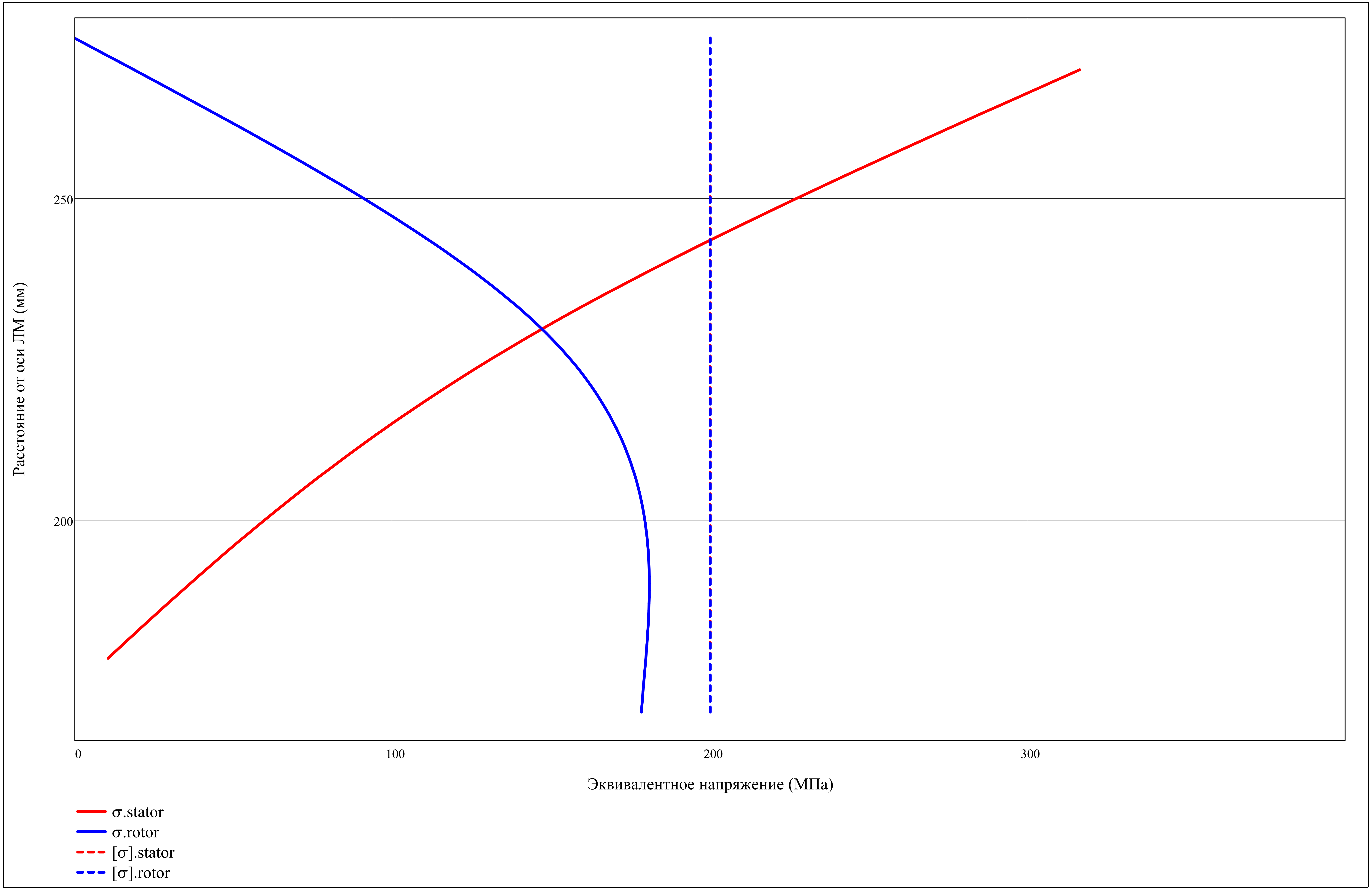
250
200
Расстояние от оси ЛМ (мм)
– 2
– 1.5
– 1
– 0.5
0
Напряжение кручения (МПа)
stator
rotor



250
200
– 30
– 20
– 10
0
10
Расстояние от оси ЛМ (мм)
Момент (Н*м)
Mu.stator
Mu.rotor
Mv.stator
Mv.rotor



Расстояние от оси ЛМ (мм)
250
200
– 400
– 200
0
200
400
Изгибное напряжение (МПа)
σ_p.stator
σ_p.rotor
σ_n.stator
σ_n.rotor


Расстояние от оси ЛМ (мм)
250
200
0
100
200
300
Эквивалентное напряжение (МПа)
σ.stator
σ.rotor
[σ].stator
[σ].rotor

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

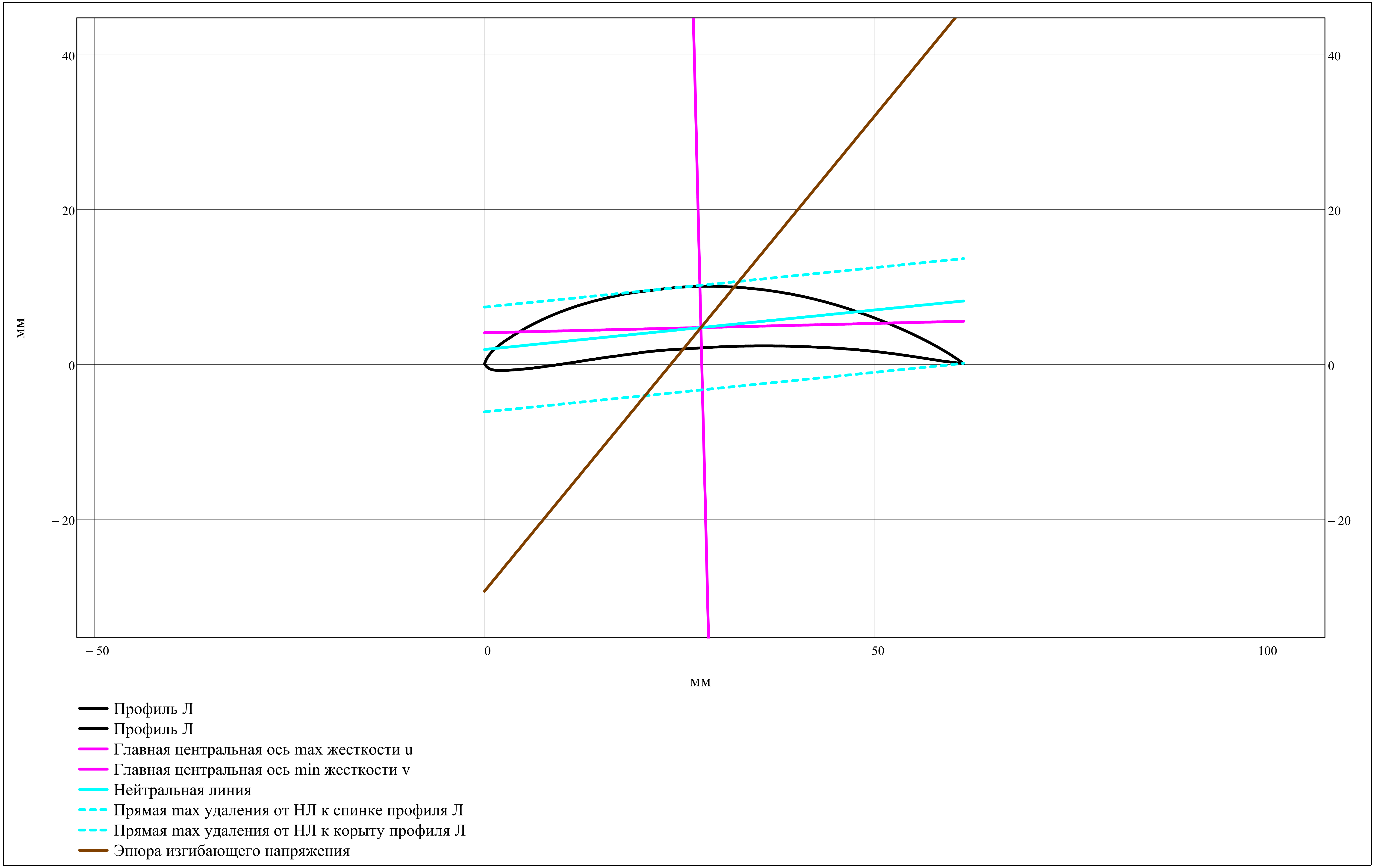
$$\begin{pmatrix} v\_p \\ v\_n \end{pmatrix} = \left| \begin{array}{l} \begin{pmatrix} v\_u_{rotor_{j,r}} \\ v\_l_{rotor_{j,r}} \end{pmatrix} \text{ if } blade = \text{"rotor"} \\ \begin{pmatrix} v\_u_{stator_{j,r}} \\ v\_l_{stator_{j,r}} \end{pmatrix} \text{ otherwise} \end{array} \right. = \begin{pmatrix} 5.471 \\ -8.057 \end{pmatrix} \cdot 10^{-3}$$

	1
1	5.471
2	-8.057

$$\begin{pmatrix} x0 \\ y0 \end{pmatrix} = \left| \begin{array}{l} \begin{pmatrix} x0_{rotor_{j,r}} \\ y0_{rotor_{j,r}} \end{pmatrix} \text{ if } blade = \text{"rotor"} \\ \begin{pmatrix} x0_{stator_{j,r}} \\ y0_{stator_{j,r}} \end{pmatrix} \text{ otherwise} \end{array} \right. = \begin{pmatrix} 27.743 \\ 4.660 \end{pmatrix} \cdot 10^{-3}$$

	1
1	27.743
2	4.660

$$chord = \left| \begin{array}{l} chord_{rotor_{j,r}} \text{ if } blade = \text{"rotor"} \\ chord_{stator_{j,r}} \text{ if } blade = \text{"stator"} \end{array} \right. = 61 \cdot 10^{-3}$$


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

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	-3.25	5.47
2	33.04	-8.06
3	0.22	0.91
4	13.30	-1.72

$\cdot 10^{-3}$

$$\begin{pmatrix} \sigma\_p_{rotor_{j,r}} & \sigma\_p_{stator_{j,r}} \\ \sigma\_n_{rotor_{j,r}} & \sigma\_n_{stator_{j,r}} \end{pmatrix} = \begin{pmatrix} -19.14 & 1.71 \\ 35.52 & -3.27 \end{pmatrix} \cdot 10^{6}$$

$$\begin{pmatrix} \sigma_{stator_{j,r}} \\ \sigma_{rotor_{j,r}} \end{pmatrix} = \begin{pmatrix} 1.74 \\ 179.08 \end{pmatrix} \cdot 10^{6}$$

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

	1
1	115.240
2	1.117

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	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"	"ВТ9"

$\rho\_disk^T =$

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

$\sigma\_disk\_long^T =$

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

$\cdot 10^6$

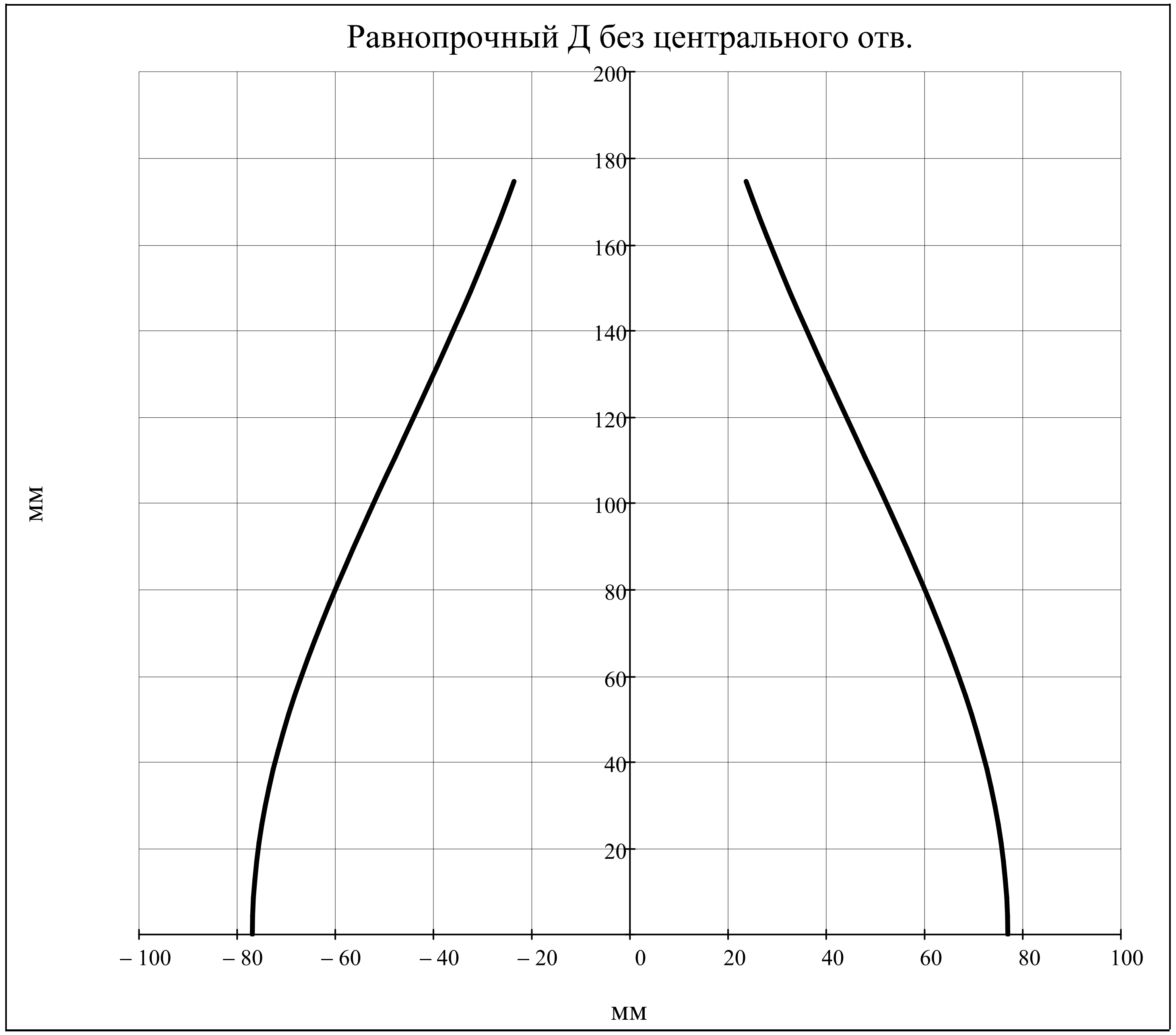
Выбор материала Д

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

Профилирование равнопрочного Д без центрального отв.

$$h(i,z) := \left| \begin{array}{ll} \left(chord_{rotor_{i,ORIGIN}} \cdot \sin\left(\upsilon_{rotor_{i,ORIGIN}}\right)\right) \cdot e^{\frac{\rho\_disk_i \cdot \omega^2}{2} \cdot \frac{1}{\sigma\_z_{rotor}\left(i, R_{st(i,2),ORIGIN}\right)} \cdot \left[\left(R_{st(i,2),ORIGIN}\right)^2 - z^2\right]} & \text{if } z \le R_{st(i,2),ORIGIN} \\ \text{NaN} & \text{otherwise} \end{array} \right.$$

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



Профилирование равнопрочного Д без центрального отв.

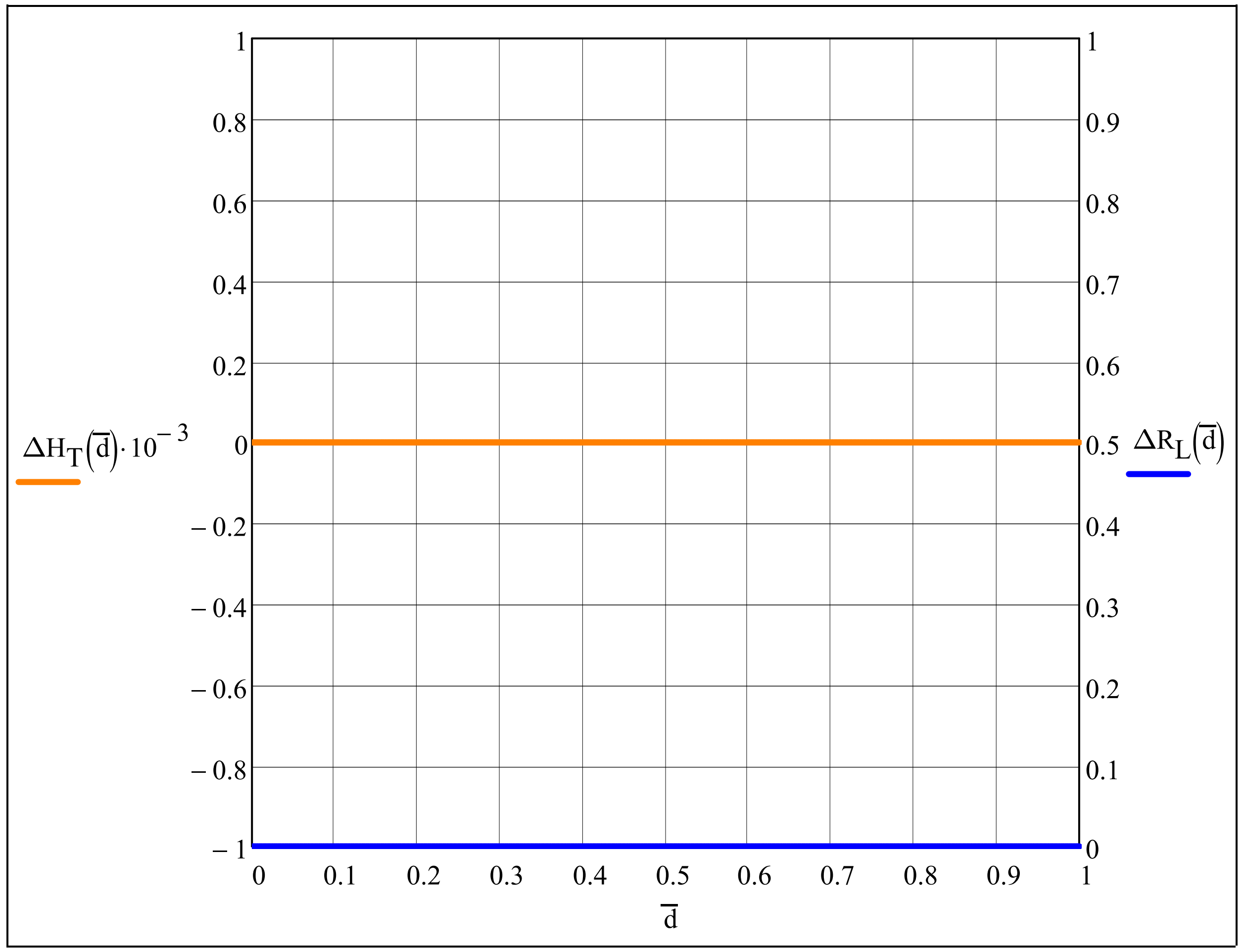
Max разница теор. напора ступени и реактивности от периферии к корню по высоте Л (Дж/кг) [16, с.118-119]:

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

$\Delta R_{Lmax} = 0.0$

$\Delta H_T(\overline{d}) = -\Delta H_{Tmax} \cdot \overline{d} + \Delta H_{Tmax}$

$\Delta R_L(\overline{d}) = -\Delta R_{Lmax} \cdot \overline{d} + \Delta R_{Lmax}$



$$\frac{\ldots{}_{st(i,a),av(N_r)}\Big) - \left(R_{st(i,a),r}\right)^{m_i}\cdot\left(R_{st(i,a),av(N_r)}\right)^{2\cdot m_i+1}\Big] + A_{st(i,a),r}\cdot m_i\cdot\Big[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{st(i,a),av(N_r)}\right) - \left(R_{st(i,a),r}\right)\cdot\left(R_{st(i,a),av(N_r)}\right)^{2\cdot m_i+1}\Big]\Big]}{\ldots\cdot R_{st(i,a),av(N_r)}\Big)^{2\cdot m_i+1}} \quad \text{if } (a = 2)$$

$$\frac{\ldots{}_{st(i,a),av(N_r)}\Big) - \left(R_{st(i,a),r}\right)^{m_i}\cdot\left(R_{st(i,a),av(N_r)}\right)^{2\cdot m_i+1}\Big] + A_{st(i,a),r}\cdot m_i\cdot\Big[\left(R_{st(i,a),r}\right)^{2\cdot m_i+1}\cdot\left(R_{st(i,a),av(N_r)}\right) - \left(R_{st(i,a),r}\right)\cdot\left(R_{st(i,a),av(N_r)}\right)^{2\cdot m_i+1}\Big]\Big]}{\ldots\cdot R_{st(i,a),av(N_r)}\Big)^{2\cdot m_i+1}} \quad \text{if } (a = 3)$$

$$\left.\left.{}_{,1}\right)\right]$$

$$\frac{\ldots_{st(i,a),av(N_r)}}{\ldots_{(i,a),av(N_r)}} - 2\cdot\left[2\cdot A_{st(i,a),r}\cdot\left(B_{st(i,a),r} + \frac{b_{HT}}{\omega}\right) + \frac{k_{HT}^{2}}{\omega^{2}}\right]\cdot\ln\left(\frac{R_{st(i,a),r}}{R_{st(i,a),av(N_r)}}\right) \quad \text{if } (a = 2)$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 94.4 \\ 252.9 \\ 81.9 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 86.9 \\ 133.9 \\ 72.6 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 239.9 \\ 146.6 \\ 259.1 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 67.06 \\ 31.96 \\ 62.43 \end{pmatrix} \cdot {}^\circ$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 260.4 \\ 274.2 \\ 286.7 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 21.25 \\ 65.98 \\ 16.27 \end{pmatrix} \cdot {}^\circ$$

$$\varepsilon_{stator_{j,r}} = 35.61 \cdot {}^\circ$$

$$\varepsilon_{rotor_{j,r}} = 44.74 \cdot {}^\circ$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 94.4 \\ 207.8 \\ 81.9 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 86.9 \\ 107.6 \\ 72.6 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 334.2 \\ 211.2 \\ 329.7 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 67.06 \\ 31.19 \\ 62.43 \end{pmatrix} \cdot ^\circ$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 359.5 \\ 359.5 \\ 359.5 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 15.08 \\ 30.64 \\ 12.72 \end{pmatrix} \cdot ^\circ$$

$$\varepsilon_{stator_{j,r}} = 31.24 \cdot ^\circ$$

$$\varepsilon_{rotor_{j,r}} = 15.56 \cdot ^\circ$$

$$\begin{pmatrix} c_{st(j,1),r} \\ c_{st(j,2),r} \\ c_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 94.4 \\ 190.2 \\ 81.9 \end{pmatrix}$$

$$\begin{pmatrix} c_{a_{st(j,1),r}} \\ c_{a_{st(j,2),r}} \\ c_{a_{st(j,3),r}} \end{pmatrix} = \begin{pmatrix} 86.9 \\ 106.1 \\ 72.6 \end{pmatrix}$$

$$\begin{pmatrix} w_{st(j,1),r} \\ w_{st(j,2),r} \\ w_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 409.2 \\ 290.3 \\ 388.8 \end{pmatrix}$$

$$\begin{pmatrix} \alpha_{st(j,1),r} \\ \alpha_{st(j,2),r} \\ \alpha_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 67.06 \\ 33.91 \\ 62.43 \end{pmatrix} \cdot °$$

$$\begin{pmatrix} u_{st(j,1),r} \\ u_{st(j,2),r} \\ u_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 436.7 \\ 428.1 \\ 419.9 \end{pmatrix}$$

$$\begin{pmatrix} \beta_{st(j,1),r} \\ \beta_{st(j,2),r} \\ \beta_{st(j,3),r} \end{pmatrix} = \begin{pmatrix} 12.27 \\ 21.44 \\ 10.76 \end{pmatrix} \cdot °$$

$$\varepsilon_{stator_{j,r}} = 12.58 \cdot °$$

$$\varepsilon_{rotor_{j,r}} = 9.18 \cdot °$$

$, z\Big)$

$\Big)^{T}, z\Big)$

0^{-3}