Исходные данные:

$l_{OA} := 0.14$ м

$l_{AB} := 0.5$ м

$l_{BO1} := 0.34$ м

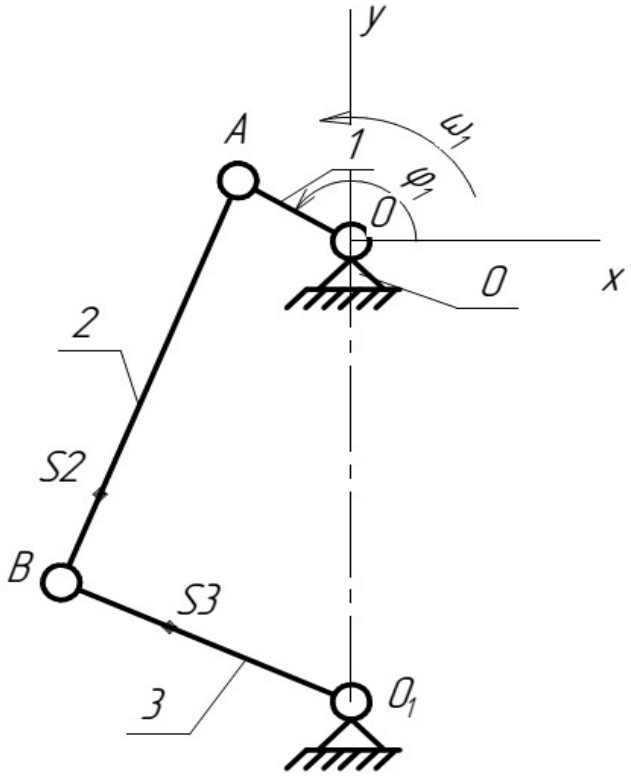
$Y_{O1} := -0.53$ м $\quad X_{O1} := 0$ м

$l_{AS2} := 0.39035$ м

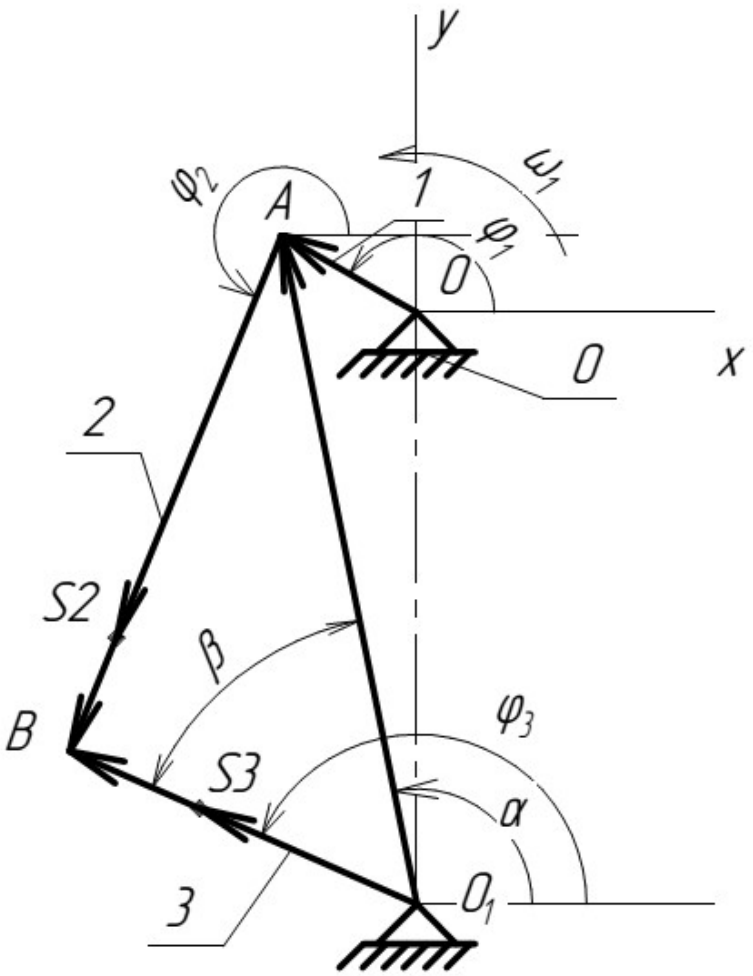
$l_{O1S3} := 0.2129$ м

$\omega_1 := 20 \ \frac{\text{рад}}{\text{с}}$

Структурная схема механизма



Расчетная схема механизма



1. Первичный механизм звено 1

Зададим произвольный начальный угол поворота звена 1

$f := 150deg$ (маткад по стандартам со знаком + задает направление против часовой стрелке)

$\varphi_1(\varphi) := \varphi$

$X_A(\varphi) := l_{OA} \cdot \cos(\varphi_1(\varphi))$ $X_A(f) = -0.121$

$Y_A(\varphi) := l_{OA} \cdot \sin(\varphi_1(\varphi))$ $Y_A(f) = 0.07$

2. Двухповодковая группа Ассура - звенья 2, 3 (ВВВ)

Вводим дополнительный вектор О1А

$l_{O1A}(\varphi) := \sqrt{(Y_{O1} - Y_A(\varphi))^2 + (X_{O1} - X_A(\varphi))^2}$ $l_{O1A}(f) = 0.612$

По теореме косинусов из треугольника ВАО1

$\beta\beta(\varphi) := \dfrac{l_{O1A}(\varphi)^2 + l_{BO1}{}^2 - l_{AB}{}^2}{2 \cdot l_{O1A}(\varphi) \cdot l_{BO1}}$ $\beta\beta(f) = 0.577$

$\beta(\varphi) := \operatorname{acos}(\beta\beta(\varphi))$ $\dfrac{\beta(f)}{deg} = 54.739$

Возспользуемся функцией angle для определения угла альфа:

$\alpha(\varphi) := \operatorname{angle}(X_A(\varphi) - X_{O1}, Y_A(\varphi) - Y_{O1})$ $\dfrac{\alpha(f)}{deg} = 101.424$

$\varphi_3(\varphi) := \alpha(\varphi) + \beta(\varphi)$ $\dfrac{\varphi_3(f)}{deg} = 156.163$

$X_B(\varphi) := X_{O1} + l_{BO1} \cdot \cos(\varphi_3(\varphi))$ $X_B(f) = -0.311$

$Y_B(\varphi) := Y_{O1} + l_{BO1} \cdot \sin(\varphi_3(\varphi))$ $Y_B(f) = -0.393$

$\varphi_2(\varphi) := \operatorname{angle}(X_B(\varphi) - X_A(\varphi), Y_B(\varphi) - Y_A(\varphi))$ $\dfrac{\varphi_2(f)}{deg} = 247.697$

$X_{S2}(\varphi) := X_A(\varphi) + l_{AS2} \cdot \cos(\varphi_2(\varphi))$ $X_{S2}(f) = -0.269$

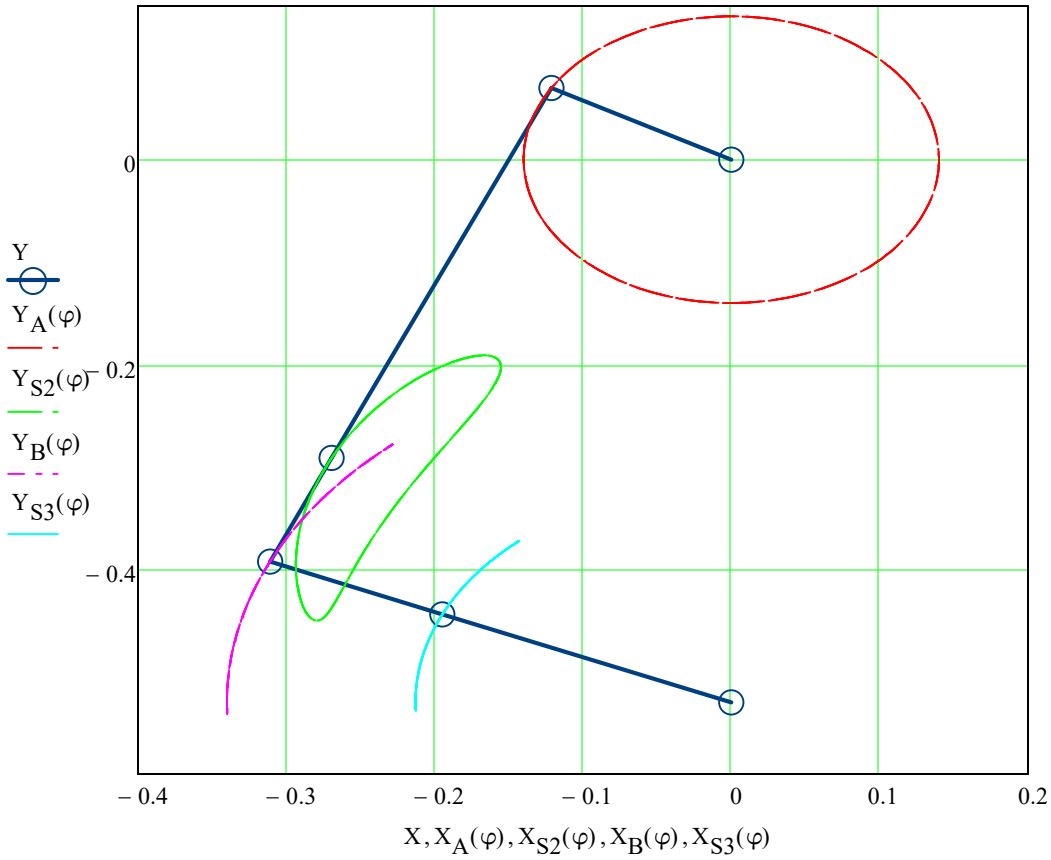
$Y_{S2}(\varphi) := Y_A(\varphi) + l_{AS2} \cdot \sin(\varphi_2(\varphi))$ $Y_{S2}(f) = -0.291$

$$X_{S3}(\varphi) := X_{O1} + l_{O1S3}\cdot\cos\left(\varphi_3(\varphi)\right) \qquad X_{S3}(f) = -0.195$$

$$Y_{S3}(\varphi) := Y_{O1} + l_{O1S3}\cdot\sin\left(\varphi_3(\varphi)\right) \qquad Y_{S3}(f) = -0.444$$

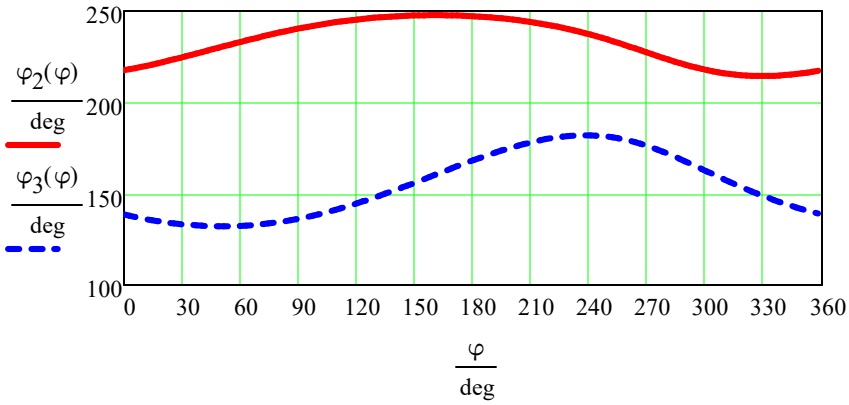
Проверим правильность сборки механизма:

$$X := \begin{pmatrix} 0 \\ X_A(f) \\ X_{S2}(f) \\ X_B(f) \\ X_{S3}(f) \\ X_{O1} \end{pmatrix} \qquad Y := \begin{pmatrix} 0 \\ Y_A(f) \\ Y_{S2}(f) \\ Y_B(f) \\ Y_{S3}(f) \\ Y_{O1} \end{pmatrix}$$



Функции положения

$\varphi := 0, 0.05 .. 2\pi$



3. Вычислим аналоги скоростей точек и звеньев механизма

$v_{qAx}(\varphi) := \frac{d}{d\varphi} X_A(\varphi)$

$v_{qAy}(\varphi) := \frac{d}{d\varphi} Y_A(\varphi)$

$v_{qA}(\varphi) := \sqrt{\left(v_{qAx}(\varphi)\right)^2 + \left(v_{qAy}(\varphi)\right)^2}$

$v_{qAx}(f) = -0.07$

$v_{qAy}(f) = -0.121$

$v_{qBx}(\varphi) := \frac{d}{d\varphi} X_B(\varphi)$

$v_{qBy}(\varphi) := \frac{d}{d\varphi} Y_B(\varphi)$

$v_{qB}(\varphi) := \sqrt{\left(v_{qBx}(\varphi)\right)^2 + \left(v_{qBy}(\varphi)\right)^2}$

$v_{qBx}(f) = -0.056$

$v_{qBy}(f) = -0.127$

$v_{qS2x}(\varphi) := \frac{d}{d\varphi} X_{S2}(\varphi)$

$v_{qS2y}(\varphi) := \frac{d}{d\varphi} Y_{S2}(\varphi)$

$v_{qS2}(\varphi) := \sqrt{\left(v_{qS2x}(\varphi)\right)^2 + \left(v_{qS2y}(\varphi)\right)^2}$

$v_{qS2x}(f) = -0.059$

$v_{qS2y}(f) = -0.126$

$v_{qS3x}(\varphi) := \frac{d}{d\varphi} X_{S3}(\varphi)$

$v_{qS3y}(\varphi) := \frac{d}{d\varphi} Y_{S3}(\varphi)$

$v_{qS3}(\varphi) := \sqrt{\left(v_{qS3x}(\varphi)\right)^2 + \left(v_{qS3y}(\varphi)\right)^2}$

$v_{qS3x}(f) = -0.035$

$v_{qS3y}(f) = -0.079$

$\omega_{q2}(\varphi) := \frac{d}{d\varphi}\left(\varphi_2(\varphi)\right)$

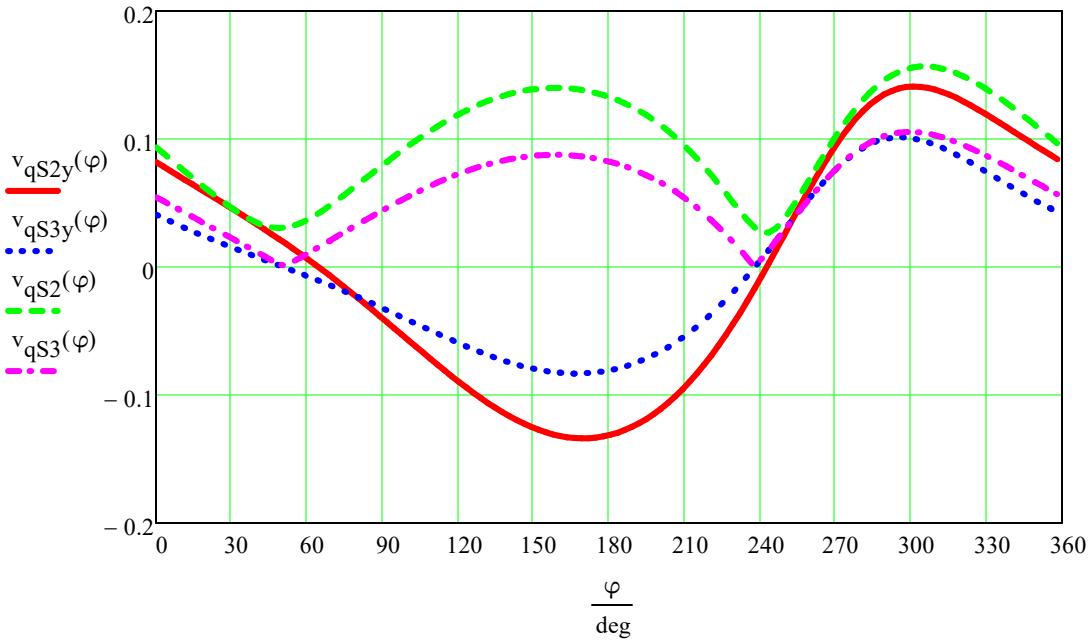
$\omega_{q2}(f) = 0.03$

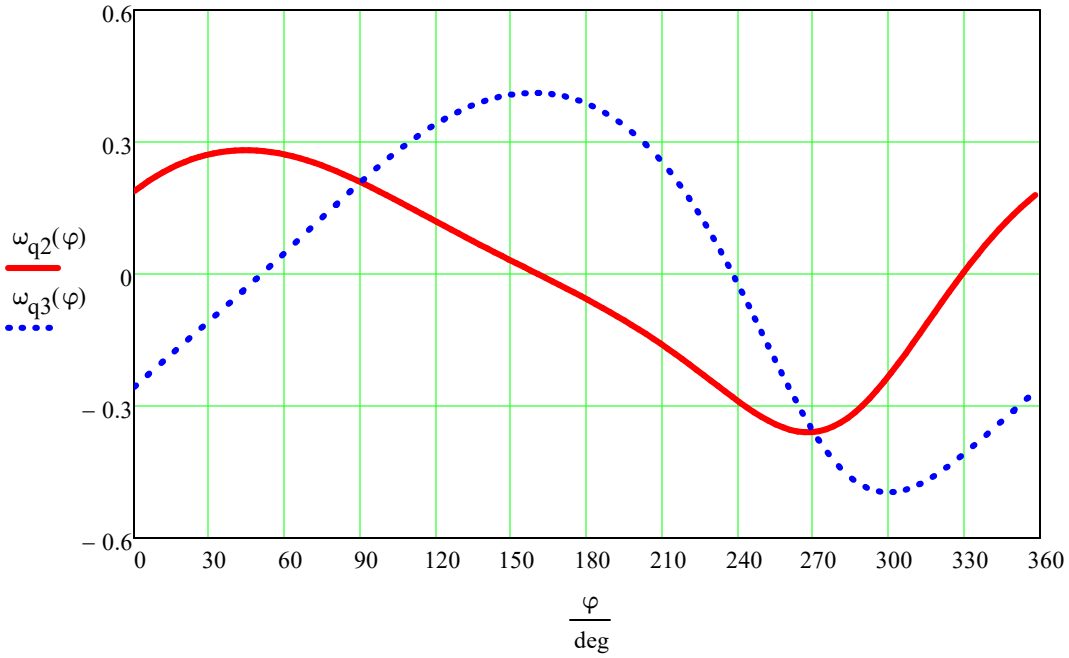
$\omega_{q3}(\varphi) := \frac{d}{d\varphi}\left(\varphi_3(\varphi)\right)$

$\omega_{q3}(f) = 0.408$

построим график аналогов скоростей точек, характерзующие положение центров масс:

$\varphi := 0, 0.05 .. 2\pi$





4. Вычислим аналоги ускорений точек и звеньев механизма

$a_{qAx}(\varphi) := \frac{d}{d\varphi} v_{qAx}(\varphi)$ $a_{qAx}(f) = 0.121$

$a_{qAy}(\varphi) := \frac{d}{d\varphi} v_{qAy}(\varphi)$ $a_{qAy}(f) = -0.07$

$a_{qBx}(\varphi) := \frac{d}{d\varphi} v_{qBx}(\varphi)$ $a_{qBx}(f) = 0.045$

$a_{qBy}(\varphi) := \frac{d}{d\varphi} v_{qBy}(\varphi)$ $a_{qBy}(f) = -0.038$

$a_{qS2x}(\varphi) := \frac{d}{d\varphi} v_{qS2x}(\varphi)$ $a_{qS2x}(f) = 0.062$

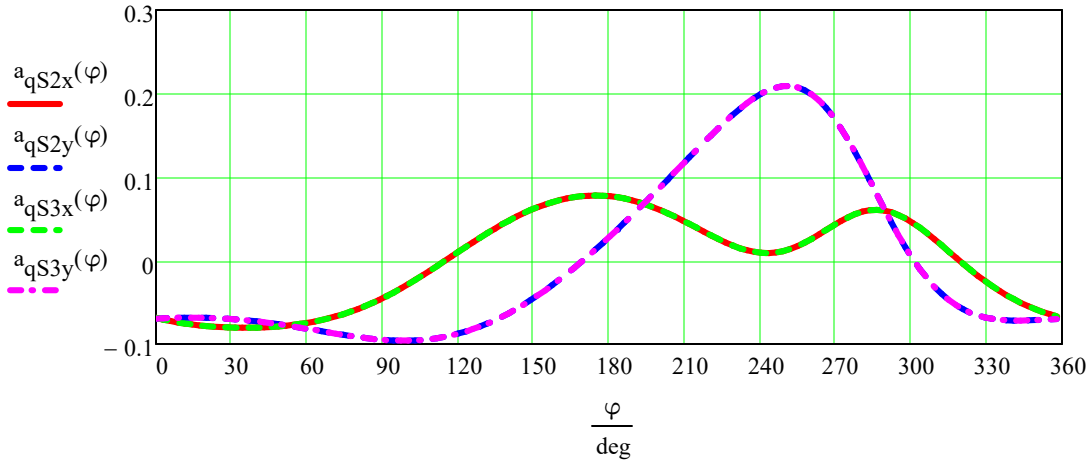
$a_{qS2y}(\varphi) := \frac{d}{d\varphi} v_{qS2y}(\varphi)$ $a_{qS2y}(f) = -0.045$

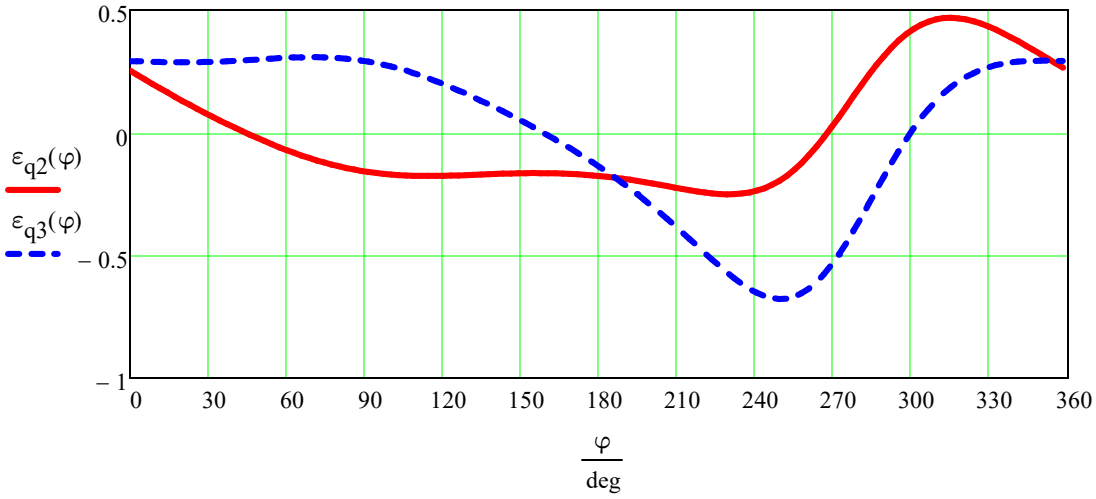
$a_{qS3x}(\varphi) := \frac{d}{d\varphi} v_{qS2x}(\varphi)$ $a_{qS3x}(f) = 0.062$

$a_{qS3y}(\varphi) := \frac{d}{d\varphi} v_{qS2y}(\varphi)$ $a_{qS3y}(f) = -0.045$

$\varepsilon_{q2}(\varphi) := \frac{d}{d\varphi} \omega_{q2}(\varphi)$ $\varepsilon_{q2}(f) = -0.165$

$\varepsilon_{q3}(\varphi) := \frac{d}{d\varphi} \omega_{q3}(\varphi)$ $\varepsilon_{q3}(f) = 0.049$





Теперь по формулам перехода от аналогов к истинным значениям скоростей и ускорений следует посчитать величины скоростей и ускорений для заданного положения механизма и сравнить их с полученными графо-аналитическим методом.

Например Для положения φ1=150 градусов $\omega_1 := 20$ $\varepsilon_1 := 0$

$v_{Ax}(\varphi) := v_{qAx}(\varphi)\cdot\omega_1$ $v_{Ax}(f) = -1.4$

$v_{Ay}(\varphi) := v_{qAy}(\varphi)\cdot\omega_1$ $v_{Ay}(f) = -2.425$

$V_A(\varphi) := \sqrt{v_{Ax}(\varphi)^2 + v_{Ay}(\varphi)^2}$ $V_A(f) = 2.8$

$v_{Bx}(\varphi) := v_{qBx}(\varphi)\cdot\omega_1$ $v_{Bx}(f) = -1.122$

$v_{By}(\varphi) := v_{qBy}(\varphi)\cdot\omega_1$ $v_{By}(f) = -2.539$

$V_B(\varphi) := \sqrt{v_{Bx}(\varphi)^2 + v_{By}(\varphi)^2}$ $V_B(f) = 2.776$

$v_{S2x}(\varphi) := v_{qS2x}(\varphi)\cdot\omega_1$ $v_{S2x}(f) = -1.183$

$v_{S2y}(\varphi) := v_{qS2y}(\varphi)\cdot\omega_1$ $v_{S2y}(f) = -2.514$

$V_{S2}(\varphi) := \sqrt{v_{S2x}(\varphi)^2 + v_{S2y}(\varphi)^2}$ $V_{S2}(f) = 2.778$

$v_{S3x}(\varphi) := v_{qS3x}(\varphi)\cdot\omega_1$ $v_{S3x}(f) = -0.702$

$v_{S3y}(\varphi) := v_{qS3y}(\varphi)\cdot\omega_1$ $v_{S3y}(f) = -1.59$

$V_{S3}(\varphi) := \sqrt{v_{S3x}(\varphi)^2 + v_{S3y}(\varphi)^2}$ $V_{S3}(f) = 1.738$

$a_{Ax}(\varphi) := a_{qAx}(\varphi)\cdot\omega_1^2 + v_{qAx}(\varphi)\cdot\varepsilon_1$ $a_{Ax}(f) = 48.497$

$a_{Ay}(\varphi) := a_{qAy}(\varphi)\cdot\omega_1^2 + v_{qAy}(\varphi)\cdot\varepsilon_1$ $a_{Ay}(f) = -28$

$a_A(\varphi) := \sqrt{a_{Ax}(\varphi)^2 + a_{Ay}(\varphi)^2}$ $a_A(f) = 56$

$a_{Bx}(\varphi) := a_{qBx}(\varphi)\cdot\omega_1^2 + v_{qBx}(\varphi)\cdot\varepsilon_1$ $a_{Bx}(f) = 18.015$

$a_{By}(\varphi) := a_{qBy}(\varphi)\cdot\omega_1^2 + v_{qBy}(\varphi)\cdot\varepsilon_1$ $a_{By}(f) = -15.301$

$a_B(\varphi) := \sqrt{a_{Bx}(\varphi)^2 + a_{By}(\varphi)^2}$ $a_B(f) = 23.635$

$a_{S2x}(\varphi) := a_{qS2x}(\varphi)\cdot\omega_1^2 + v_{qS2x}(\varphi)\cdot\varepsilon_1$ $a_{S2x}(f) = 24.699$

$a_{S2y}(\varphi) := a_{qS2y}(\varphi)\cdot\omega_1^2 + v_{qS2y}(\varphi)\cdot\varepsilon_1$ $a_{S2y}(f) = -18.086$

$a_{S2}(\varphi) := \sqrt{a_{S2x}(\varphi)^2 + a_{S2y}(\varphi)^2}$ $a_{S2}(f) = 30.613$

$a_{S3x}(\varphi) := a_{qS3x}(\varphi)\cdot\omega_1^2 + v_{qS3x}(\varphi)\cdot\varepsilon_1$ $a_{S3x}(f) = 24.699$

$a_{S3y}(\varphi) := a_{qS3y}(\varphi)\cdot\omega_1^2 + v_{qS3y}(\varphi)\cdot\varepsilon_1$ $a_{S3y}(f) = -18.086$

$a_{S3}(\varphi) := \sqrt{a_{S3x}(\varphi)^2 + a_{S3y}(\varphi)^2}$ $a_{S3}(f) = 30.613$

$\omega_2(\varphi) := \omega_{q2}(\varphi)\cdot\omega_1$ $\omega_2(f) = 0.601$

$\varepsilon_2(\varphi) := \varepsilon_{q2}(\varphi)\cdot\omega_1^2 + \omega_{q2}(\varphi)\cdot\varepsilon_1$ $\varepsilon_2(f) = -66.044$

$\omega_3(\varphi) := \omega_{q3}(\varphi)\cdot\omega_1$ $\omega_3(f) = 8.164$

$\varepsilon_3(\varphi) := \varepsilon_{q3}(\varphi)\cdot\omega_1^2 + \omega_{q3}(\varphi)\cdot\varepsilon_1$ $\varepsilon_3(f) = 19.75$

Выведем результаты для двенадцати положений:

$\varphi := 0, \frac{\pi}{6} .. 2\pi$

$V_A(\varphi) =$	$V_B(\varphi) =$	$V_{S2}(\varphi) =$	$V_{S3}(\varphi) =$
2.8	1.745	1.868	1.092
2.8	0.718	0.922	0.449
2.8	0.337	0.737	0.211
2.8	1.421	1.596	0.89
2.8	2.321	2.384	1.453
2.8	2.776	2.778	1.738
2.8	2.632	2.659	1.648
2.8	1.72	1.893	1.077
2.8	0.158	0.559	0.099
2.8	2.441	2.041	1.529
2.8	3.374	3.114	2.113
2.8	2.771	2.778	1.735
2.8	1.745	1.868	1.092

$a_A(\varphi) =$	$a_B(\varphi) =$	$a_{S2}(\varphi) =$	$a_{S3}(\varphi) =$
56	40.674	39.138	39.138
56	39.274	42.621	42.621
56	41.505	44.289	44.289
56	40.219	42.038	42.038
56	31.459	35.326	35.326
56	23.635	30.613	30.613
56	27.669	32.75	32.75
56	53.372	50.597	50.597
56	88.278	79.598	79.598
56	73.942	69.535	69.535
56	33.49	18.728	18.728
56	42.945	29.28	29.28
56	40.674	39.138	39.138

$\omega_2(\varphi)$ =	$\omega_3(\varphi)$ =	$\varepsilon_2(\varphi)$ =	$\varepsilon_3(\varphi)$ =
3.763	-5.131	101.264	116.695
5.451	-2.111	29.631	115.425
5.435	0.992	-28.081	122.07
4.179	4.179	-63.081	116.996
2.384	6.827	-70.217	79.934
0.601	8.164	-66.044	19.75
-1.154	7.74	-70.505	-55.073
-3.229	5.058	-90.03	-154.877
-5.774	-0.464	-95.236	-259.64
-7.179	-7.179	13.053	-211.278
-4.613	-9.923	166.967	2.563
0.136	-8.151	172.268	107.42
3.763	-5.131	101.264	116.695