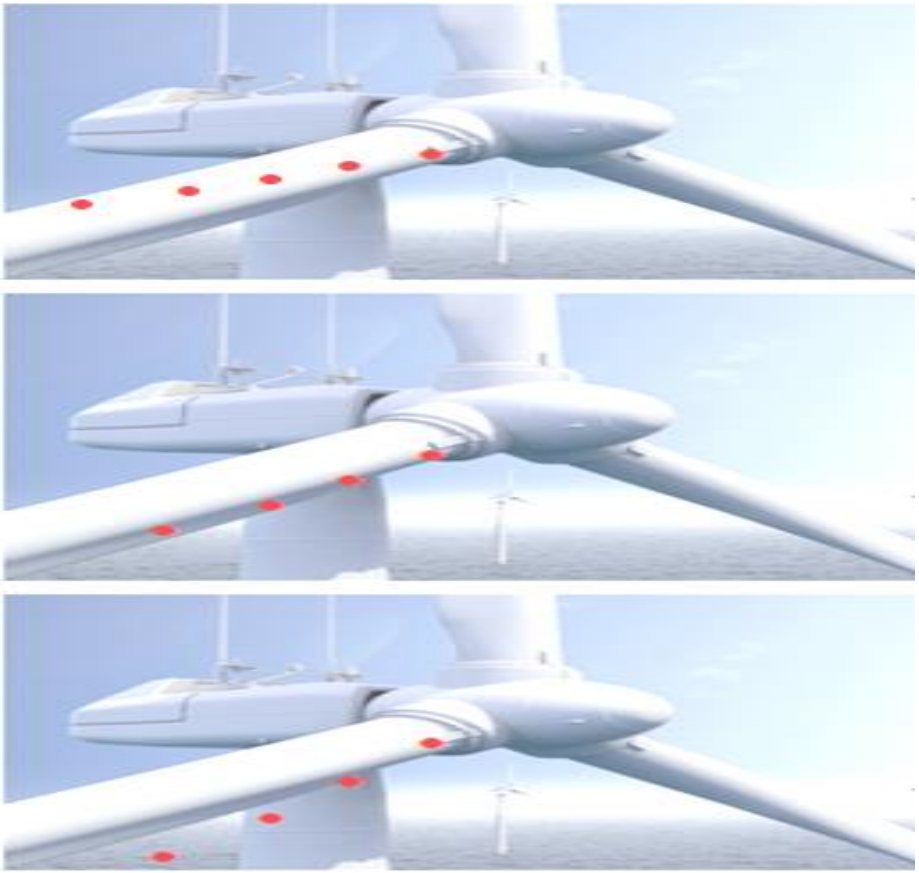
- **OPTIMUM ANGLE OF ATTACK 위치 및 각도 변화에 따른 발전기 효율 산정**

OPTIUM ANGLE OF ATTACK 位置和 根据角度变化估算发电机效率

(OPTIMUM ANGLE OF ATTACK location and Estimation of Generator Efficiency According to Angle Change)

OPTIMUM ANGLE OF ATTACK Position and Angle Change

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12



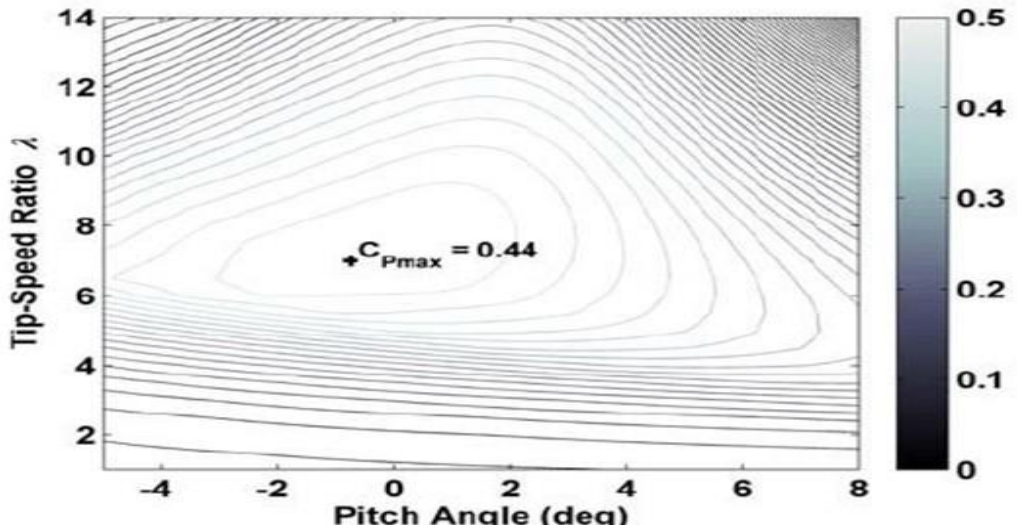
OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

Betz Law

风力涡轮机的发电效率由叶片旋转和风速的比率以及风力涡轮机的叶片角确定。

在下图中，当TSR为7且俯仰角约为-0.5时，效率变为最高 Cpmax = 0.44。

The power generation efficiency of wind turbines is determined by the ratio of blade rotation and wind speed and the blade angle of the wind turbine.
In the figure below, when the TSR is 7 and the pitch angle is about -0.5, the efficiency becomes the highest Cpmax = 0.44.



Variation of the power coefficient C_p as a function of the blade pitch angle β and tip speed ratio

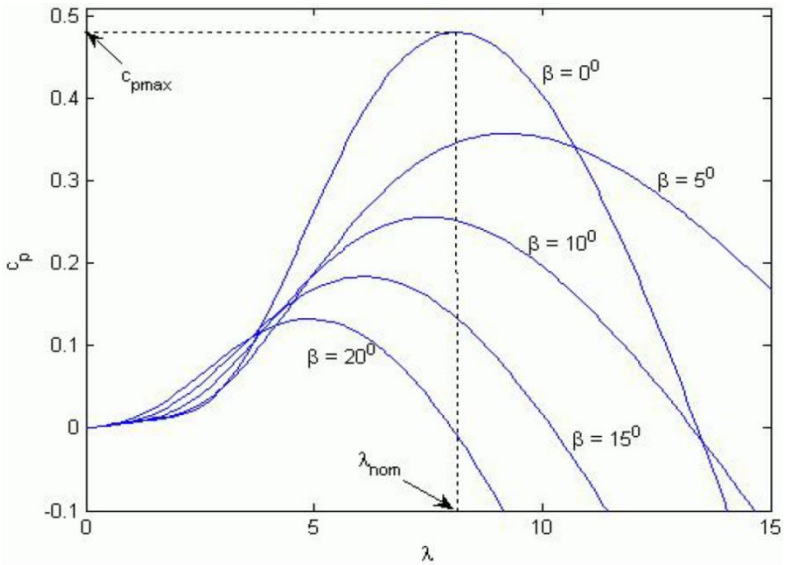
OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

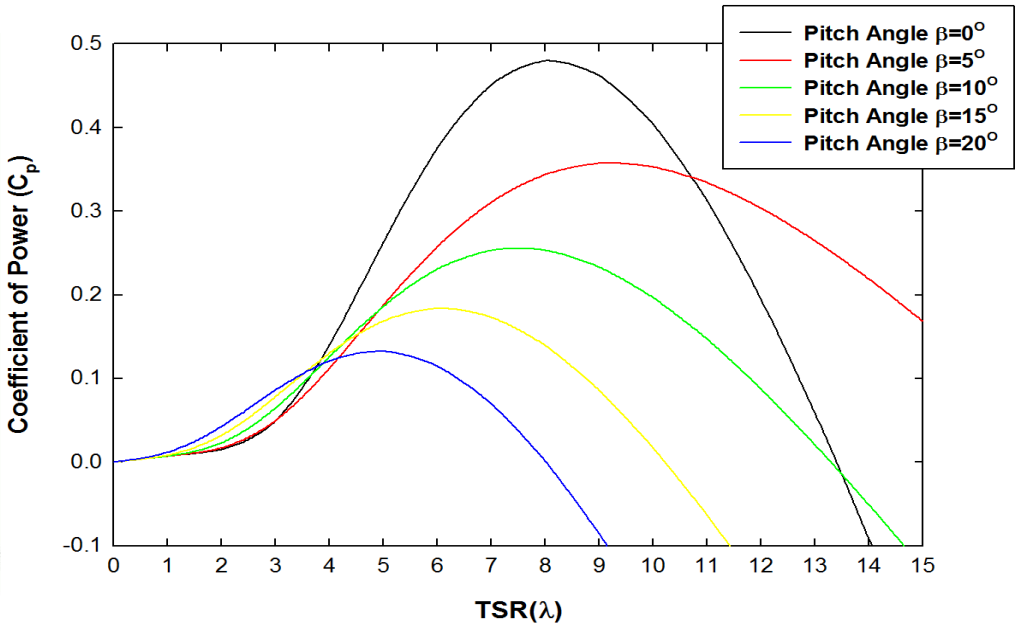
A generic equation is used to model c (λ,β). This equation, based on the modeling turbine characteristics of [1], is:

$$c_p(\lambda,\beta) = c_1\left(c_2/\lambda_i - c_3\beta - c_4\right)e^{-c_5/\lambda_i} + c_6\lambda$$

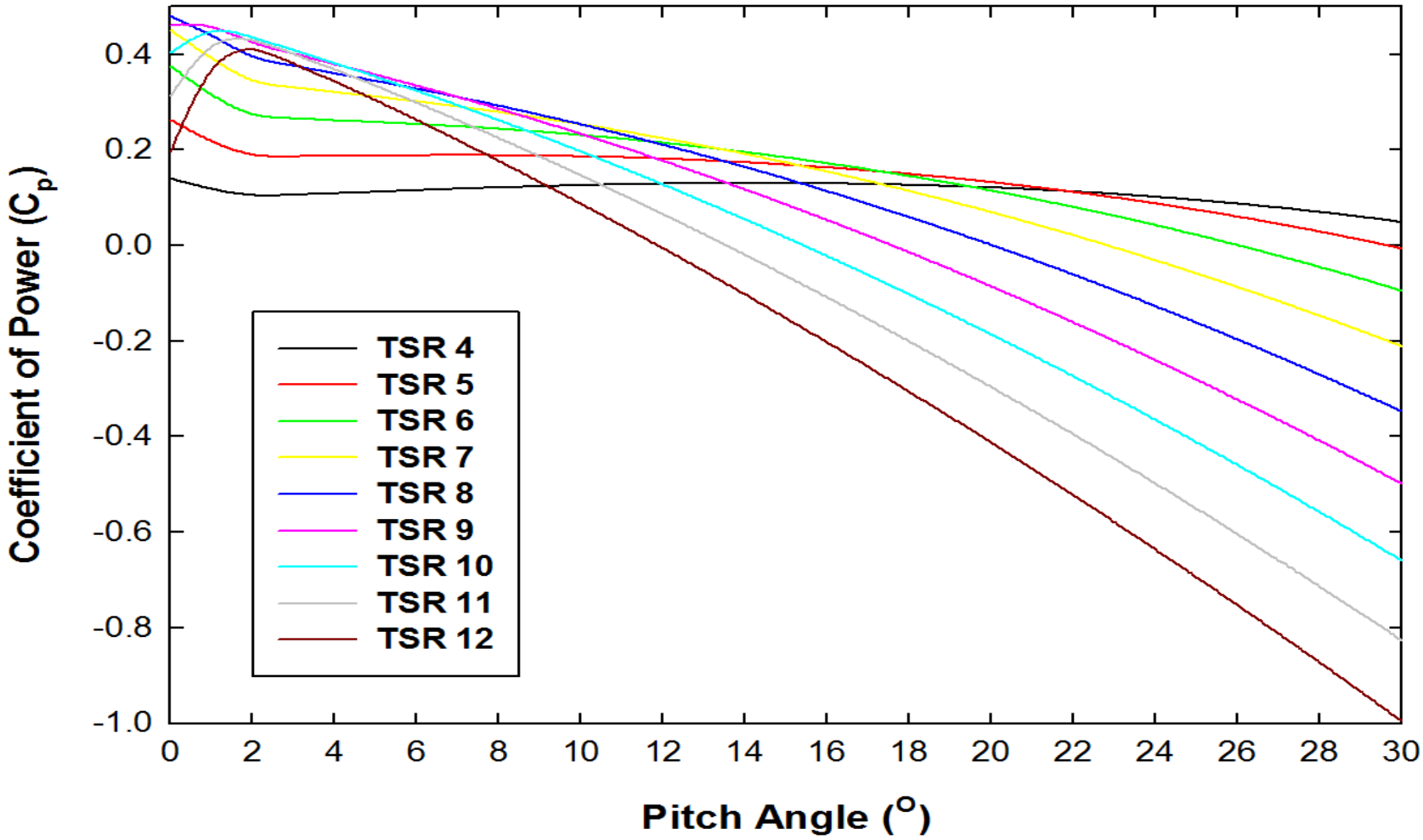
$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}$$

$c_1 = 0.5176$, $c_2 = 116$, $c_3 = 0.4$, $c_4 = 5$, $c_5 = 21$ and $c_6 = 0.0068$





OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12



[Coefficients of Power vs. Pitch angle according to TSR(Tip Speed Ratio)]

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
4	0	0	0.5176	116	0.4	5	21	0.0068	4.651163	0.140148336	100
4	1	0.017444444	0.5176	116	0.4	5	21	0.0068	4.393711	0.118507389	84.55854176
4	2	0.034888889	0.5176	116	0.4	5	21	0.0068	4.228406	0.105225502	75.08152103
4	3	0.052333333	0.5176	116	0.4	5	21	0.0068	4.262592	0.106068917	75.68332248
4	4	0.069777778	0.5176	116	0.4	5	21	0.0068	4.330072	0.109022851	77.79104236
4	5	0.087222222	0.5176	116	0.4	5	21	0.0068	4.405384	0.112318147	80.14233357
4	6	0.104666667	0.5176	116	0.4	5	21	0.0068	4.48324	0.11556378	82.45818956
4	7	0.122111111	0.5176	116	0.4	5	21	0.0068	4.562117	0.118622933	84.64098576
4	8	0.139555556	0.5176	116	0.4	5	21	0.0068	4.641469	0.121424583	86.64004633
4	9	0.157	0.5176	116	0.4	5	21	0.0068	4.721068	0.123919346	88.42013362
4	10	0.174444444	0.5176	116	0.4	5	21	0.0068	4.800806	0.126066414	89.95213066
4	11	0.191888889	0.5176	116	0.4	5	21	0.0068	4.880626	0.127829017	91.20980007
4	12	0.209333333	0.5176	116	0.4	5	21	0.0068	4.960498	0.129172647	92.16852034
4	13	0.226777778	0.5176	116	0.4	5	21	0.0068	5.040405	0.130064318	92.80475357
4	14	0.244222222	0.5176	116	0.4	5	21	0.0068	5.120334	0.13047223	93.09581138
4	15	0.261666667	0.5176	116	0.4	5	21	0.0068	5.20028	0.130365633	93.01975143
4	16	0.279111111	0.5176	116	0.4	5	21	0.0068	5.280238	0.12971476	92.55533371
4	17	0.296555556	0.5176	116	0.4	5	21	0.0068	5.360205	0.128490804	91.68200486
4	18	0.314	0.5176	116	0.4	5	21	0.0068	5.440178	0.126665919	90.37989544
4	19	0.331444444	0.5176	116	0.4	5	21	0.0068	5.520155	0.124213221	88.62982246
4	20	0.348888889	0.5176	116	0.4	5	21	0.0068	5.600137	0.121106793	86.41329354
4	21	0.366333333	0.5176	116	0.4	5	21	0.0068	5.680122	0.11732169	83.71251064
4	22	0.383777778	0.5176	116	0.4	5	21	0.0068	5.760109	0.112833947	80.51037245
4	23	0.401222222	0.5176	116	0.4	5	21	0.0068	5.840098	0.107620573	76.79047494
4	24	0.418666667	0.5176	116	0.4	5	21	0.0068	5.920089	0.101659552	72.53711001
4	25	0.436111111	0.5176	116	0.4	5	21	0.0068	6.000081	0.094929843	67.73526211
4	26	0.453555556	0.5176	116	0.4	5	21	0.0068	6.080074	0.087411362	62.37060303
4	27	0.471	0.5176	116	0.4	5	21	0.0068	6.160067	0.079084984	56.429485
4	28	0.488444444	0.5176	116	0.4	5	21	0.0068	6.240062	0.069932523	49.89893216
4	29	0.505888889	0.5176	116	0.4	5	21	0.0068	6.320057	0.059936721	42.76663067
4	30	0.523333333	0.5176	116	0.4	5	21	0.0068	6.400053	0.049081233	35.02091756

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
5	0	0	0.5176	116	0.4	5	21	0.0068	6.060606	0.262882874	100
5	1	0.017444444	0.5176	116	0.4	5	21	0.0068	5.575678	0.218474936	83.10732953
5	2	0.034888889	0.5176	116	0.4	5	21	0.0068	5.265664	0.189700315	72.16153414
5	3	0.052333333	0.5176	116	0.4	5	21	0.0068	5.274548	0.186528011	70.9547976
5	4	0.069777778	0.5176	116	0.4	5	21	0.0068	5.335284	0.187027499	71.14480176
5	5	0.087222222	0.5176	116	0.4	5	21	0.0068	5.408112	0.187975013	71.5052338
5	6	0.104666667	0.5176	116	0.4	5	21	0.0068	5.484848	0.188694432	71.77889903
5	7	0.122111111	0.5176	116	0.4	5	21	0.0068	5.563147	0.188975116	71.88567037
5	8	0.139555556	0.5176	116	0.4	5	21	0.0068	5.642171	0.188725586	71.79074962
5	9	0.157	0.5176	116	0.4	5	21	0.0068	5.721569	0.187893169	71.47410056
5	10	0.174444444	0.5176	116	0.4	5	21	0.0068	5.801176	0.186440421	70.92147855
5	11	0.191888889	0.5176	116	0.4	5	21	0.0068	5.880909	0.184336921	70.12131248
5	12	0.209333333	0.5176	116	0.4	5	21	0.0068	5.960719	0.181556044	69.06347372
5	13	0.226777778	0.5176	116	0.4	5	21	0.0068	6.040581	0.178073542	67.73873857
5	14	0.244222222	0.5176	116	0.4	5	21	0.0068	6.120478	0.173866877	66.13853335
5	15	0.261666667	0.5176	116	0.4	5	21	0.0068	6.200399	0.168914876	64.25480429
5	16	0.279111111	0.5176	116	0.4	5	21	0.0068	6.280337	0.163197547	62.07994626
5	17	0.296555556	0.5176	116	0.4	5	21	0.0068	6.360288	0.156695966	59.60676089
5	18	0.314	0.5176	116	0.4	5	21	0.0068	6.440249	0.149392209	56.8284298
5	19	0.331444444	0.5176	116	0.4	5	21	0.0068	6.520217	0.141269302	53.738496
5	20	0.348888889	0.5176	116	0.4	5	21	0.0068	6.600191	0.132311184	50.3308498
5	21	0.366333333	0.5176	116	0.4	5	21	0.0068	6.680169	0.122502676	46.59971717
5	22	0.383777778	0.5176	116	0.4	5	21	0.0068	6.76015	0.111829453	42.53964951
5	23	0.401222222	0.5176	116	0.4	5	21	0.0068	6.840135	0.100278024	38.14551424
5	24	0.418666667	0.5176	116	0.4	5	21	0.0068	6.920121	0.087835703	33.41248578
5	25	0.436111111	0.5176	116	0.4	5	21	0.0068	7.00011	0.074490588	28.33603682
5	26	0.453555556	0.5176	116	0.4	5	21	0.0068	7.0801	0.060231539	22.9119297
5	27	0.471	0.5176	116	0.4	5	21	0.0068	7.160091	0.045048156	17.13620791
5	28	0.488444444	0.5176	116	0.4	5	21	0.0068	7.240084	0.028930753	11.00518763
5	29	0.505888889	0.5176	116	0.4	5	21	0.0068	7.320077	0.011870343	4.51544927
5	30	0.523333333	0.5176	116	0.4	5	21	0.0068	7.400071	-0.006141393	-2.336170827

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
6	0	0	0.5176	116	0.4	5	21	0.0068	7.594937	0.375673981	100
6	1	0.017444444	0.5176	116	0.4	5	21	0.0068	6.803939	0.316130225	84.15015181
6	2	0.034888889	0.5176	116	0.4	5	21	0.0068	6.311188	0.274465672	73.05953718
6	3	0.052333333	0.5176	116	0.4	5	21	0.0068	6.289055	0.265589605	70.69683264
6	4	0.069777778	0.5176	116	0.4	5	21	0.0068	6.341581	0.261461049	69.59785931
6	5	0.087222222	0.5176	116	0.4	5	21	0.0068	6.411398	0.257839708	68.63390095
6	6	0.104666667	0.5176	116	0.4	5	21	0.0068	6.48678	0.253856774	67.57369068
6	7	0.122111111	0.5176	116	0.4	5	21	0.0068	6.564381	0.249257178	66.34933224
6	8	0.139555556	0.5176	116	0.4	5	21	0.0068	6.643009	0.243941169	64.9342731
6	9	0.157	0.5176	116	0.4	5	21	0.0068	6.722166	0.237858759	63.3152071
6	10	0.174444444	0.5176	116	0.4	5	21	0.0068	6.801617	0.230979027	61.48390336
6	11	0.191888889	0.5176	116	0.4	5	21	0.0068	6.881244	0.223279544	59.43439142
6	12	0.209333333	0.5176	116	0.4	5	21	0.0068	6.960981	0.214742229	57.16185837
6	13	0.226777778	0.5176	116	0.4	5	21	0.0068	7.040789	0.205351551	54.66217017
6	14	0.244222222	0.5176	116	0.4	5	21	0.0068	7.120646	0.195093679	51.93164525
6	15	0.261666667	0.5176	116	0.4	5	21	0.0068	7.200537	0.183956049	48.96693905
6	16	0.279111111	0.5176	116	0.4	5	21	0.0068	7.280453	0.171927124	45.76498058
6	17	0.296555556	0.5176	116	0.4	5	21	0.0068	7.360386	0.158996255	42.32293503
6	18	0.314	0.5176	116	0.4	5	21	0.0068	7.440332	0.145153589	38.63818007
6	19	0.331444444	0.5176	116	0.4	5	21	0.0068	7.520289	0.130390013	34.70828945
6	20	0.348888889	0.5176	116	0.4	5	21	0.0068	7.600253	0.114697102	30.53102091
6	21	0.366333333	0.5176	116	0.4	5	21	0.0068	7.680223	0.098067088	26.10430664
6	22	0.383777778	0.5176	116	0.4	5	21	0.0068	7.760198	0.080492828	21.42624513
6	23	0.401222222	0.5176	116	0.4	5	21	0.0068	7.840177	0.061967777	16.49509413
6	24	0.418666667	0.5176	116	0.4	5	21	0.0068	7.920159	0.042485963	11.30926416
6	25	0.436111111	0.5176	116	0.4	5	21	0.0068	8.000143	0.022041967	5.86731253
6	26	0.453555556	0.5176	116	0.4	5	21	0.0068	8.08013	0.000630898	0.167937625
6	27	0.471	0.5176	116	0.4	5	21	0.0068	8.160118	-0.021751623	-5.79002649
6	28	0.488444444	0.5176	116	0.4	5	21	0.0068	8.240108	-0.045109486	-12.00761531
6	29	0.505888889	0.5176	116	0.4	5	21	0.0068	8.320099	-0.069446111	-18.48573891
6	30	0.523333333	0.5176	116	0.4	5	21	0.0068	8.400091	-0.094764464	-25.22518688

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
7	0	0	0.5176	116	0.4	5	21	0.0068	9.271523	0.451282393	100
7	1	0.017444444	0.5176	116	0.4	5	21	0.0068	8.081269	0.392316245	86.9336474
7	2	0.034888889	0.5176	116	0.4	5	21	0.0068	7.365076	0.345120072	76.47541251
7	3	0.052333333	0.5176	116	0.4	5	21	0.0068	7.30612	0.330378094	73.2087267
7	4	0.069777778	0.5176	116	0.4	5	21	0.0068	7.348966	0.320520038	71.0242727
7	5	0.087222222	0.5176	116	0.4	5	21	0.0068	7.415242	0.311086056	68.93378965
7	6	0.104666667	0.5176	116	0.4	5	21	0.0068	7.489035	0.301171759	66.7368734
7	7	0.122111111	0.5176	116	0.4	5	21	0.0068	7.56582	0.290521224	64.37681332
7	8	0.139555556	0.5176	116	0.4	5	21	0.0068	7.643984	0.279040841	61.8328668
7	9	0.157	0.5176	116	0.4	5	21	0.0068	7.722859	0.26668816	59.09562712
7	10	0.174444444	0.5176	116	0.4	5	21	0.0068	7.802128	0.253439901	56.15993542
7	11	0.191888889	0.5176	116	0.4	5	21	0.0068	7.881632	0.239281064	53.0224683
7	12	0.209333333	0.5176	116	0.4	5	21	0.0068	7.961283	0.224200725	49.68080488
7	13	0.226777778	0.5176	116	0.4	5	21	0.0068	8.041029	0.20819023	46.13302747
7	14	0.244222222	0.5176	116	0.4	5	21	0.0068	8.120841	0.191242357	42.37753553
7	15	0.261666667	0.5176	116	0.4	5	21	0.0068	8.200697	0.17335089	38.41295223
7	16	0.279111111	0.5176	116	0.4	5	21	0.0068	8.280586	0.1545104	34.23807414
7	17	0.296555556	0.5176	116	0.4	5	21	0.0068	8.360498	0.134716108	29.85184218
7	18	0.314	0.5176	116	0.4	5	21	0.0068	8.440427	0.113963803	25.25332357
7	19	0.331444444	0.5176	116	0.4	5	21	0.0068	8.52037	0.092249792	20.44169976
7	20	0.348888889	0.5176	116	0.4	5	21	0.0068	8.600324	0.069570857	15.41625773
7	21	0.366333333	0.5176	116	0.4	5	21	0.0068	8.680285	0.045924226	10.17638333
7	22	0.383777778	0.5176	116	0.4	5	21	0.0068	8.760252	0.02130755	4.721555715
7	23	0.401222222	0.5176	116	0.4	5	21	0.0068	8.840225	-0.004281123	-0.948657308
7	24	0.418666667	0.5176	116	0.4	5	21	0.0068	8.920201	-0.030843362	-6.834603513
7	25	0.436111111	0.5176	116	0.4	5	21	0.0068	9.000181	-0.058380373	-12.93655009
7	26	0.453555556	0.5176	116	0.4	5	21	0.0068	9.080164	-0.086893013	-19.25468724
7	27	0.471	0.5176	116	0.4	5	21	0.0068	9.160149	-0.11638181	-25.78913151
7	28	0.488444444	0.5176	116	0.4	5	21	0.0068	9.240136	-0.146846971	-32.53992904
7	29	0.505888889	0.5176	116	0.4	5	21	0.0068	9.320125	-0.1782884	-39.50705862
7	30	0.523333333	0.5176	116	0.4	5	21	0.0068	9.400115	-0.210705711	-46.69043462

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(° (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cp	generating efficiency(%)
8	0	0	0.5176	116	0.4	5	21	0.0068	11.11111	0.479779539	100
8	1	0.017444444	0.5176	116	0.4	5	21	0.0068	9.410669	0.439321026	91.56726996
8	2	0.034888889	0.5176	116	0.4	5	21	0.0068	8.42743	0.39555728	82.44563334
8	3	0.052333333	0.5176	116	0.4	5	21	0.0068	8.325755	0.37569614	78.30599453
8	4	0.069777778	0.5176	116	0.4	5	21	0.0068	8.357441	0.359787574	74.99018699
8	5	0.087222222	0.5176	116	0.4	5	21	0.0068	8.419646	0.344033145	71.70650608
8	6	0.104666667	0.5176	116	0.4	5	21	0.0068	8.491614	0.327664581	68.29482172
8	7	0.122111111	0.5176	116	0.4	5	21	0.0068	8.567462	0.310471777	64.71134173
8	8	0.139555556	0.5176	116	0.4	5	21	0.0068	8.645096	0.292382315	60.94097207
8	9	0.157	0.5176	116	0.4	5	21	0.0068	8.723647	0.273366184	56.97745772
8	10	0.174444444	0.5176	116	0.4	5	21	0.0068	8.802709	0.253408816	52.8177622
8	11	0.191888889	0.5176	116	0.4	5	21	0.0068	8.882072	0.232502091	48.46019303
8	12	0.209333333	0.5176	116	0.4	5	21	0.0068	8.961625	0.210640938	43.90369338
8	13	0.226777778	0.5176	116	0.4	5	21	0.0068	9.041301	0.187821918	39.1475464
8	14	0.244222222	0.5176	116	0.4	5	21	0.0068	9.121061	0.16404258	34.19124125
8	15	0.261666667	0.5176	116	0.4	5	21	0.0068	9.200878	0.139301148	29.03440774
8	16	0.279111111	0.5176	116	0.4	5	21	0.0068	9.280736	0.113596357	23.67678227
8	17	0.296555556	0.5176	116	0.4	5	21	0.0068	9.360624	0.086927362	18.11818864
8	18	0.314	0.5176	116	0.4	5	21	0.0068	9.440535	0.059293682	12.35852655
8	19	0.331444444	0.5176	116	0.4	5	21	0.0068	9.520462	0.030695163	6.397764033
8	20	0.348888889	0.5176	116	0.4	5	21	0.0068	9.600403	0.001131954	0.235932062
8	21	0.366333333	0.5176	116	0.4	5	21	0.0068	9.680354	-0.029395514	-6.126879533
8	22	0.383777778	0.5176	116	0.4	5	21	0.0068	9.760313	-0.060886545	-12.69052545
8	23	0.401222222	0.5176	116	0.4	5	21	0.0068	9.840279	-0.093340187	-19.45480783
8	24	0.418666667	0.5176	116	0.4	5	21	0.0068	9.920249	-0.126755254	-26.41947885
8	25	0.436111111	0.5176	116	0.4	5	21	0.0068	10.00022	-0.161130327	-33.58424311
8	26	0.453555556	0.5176	116	0.4	5	21	0.0068	10.0802	-0.196463772	-40.9487599
8	27	0.471	0.5176	116	0.4	5	21	0.0068	10.16018	-0.232753746	-48.5126453
8	28	0.488444444	0.5176	116	0.4	5	21	0.0068	10.24017	-0.269998211	-56.27547421
8	29	0.505888889	0.5176	116	0.4	5	21	0.0068	10.32015	-0.308194938	-64.23678229
8	30	0.523333333	0.5176	116	0.4	5	21	0.0068	10.40014	-0.34734152	-72.39606778

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
9	0	0	0.5176	116	0.4	5	21	0.0068	13.13869	0.461992591	100
9	1	0.017444444	0.5176	116	0.4	5	21	0.0068	10.79539	0.456699993	98.85439768
9	2	0.034888889	0.5176	116	0.4	5	21	0.0068	9.498352	0.42498561	91.98970258
9	3	0.052333333	0.5176	116	0.4	5	21	0.0068	9.347969	0.40113127	86.82634268
9	4	0.069777778	0.5176	116	0.4	5	21	0.0068	9.367008	0.379300728	82.10104125
9	5	0.087222222	0.5176	116	0.4	5	21	0.0068	9.424609	0.357166698	77.31004895
9	6	0.104666667	0.5176	116	0.4	5	21	0.0068	9.494517	0.334254421	72.35060218
9	7	0.122111111	0.5176	116	0.4	5	21	0.0068	9.569308	0.31044229	67.19637851
9	8	0.139555556	0.5176	116	0.4	5	21	0.0068	9.646344	0.285692911	61.83928412
9	9	0.157	0.5176	116	0.4	5	21	0.0068	9.724532	0.259993377	56.27652524
9	10	0.174444444	0.5176	116	0.4	5	21	0.0068	9.803359	0.233339068	50.50710176
9	11	0.191888889	0.5176	116	0.4	5	21	0.0068	9.882566	0.205728544	44.53070213
9	12	0.209333333	0.5176	116	0.4	5	21	0.0068	9.962009	0.177161749	38.34731384
9	13	0.226777778	0.5176	116	0.4	5	21	0.0068	10.04161	0.147639313	31.95707384
9	14	0.244222222	0.5176	116	0.4	5	21	0.0068	10.12131	0.117162278	25.36020717
9	15	0.261666667	0.5176	116	0.4	5	21	0.0068	10.20108	0.085731966	18.5570002
9	16	0.279111111	0.5176	116	0.4	5	21	0.0068	10.2809	0.053349927	11.54778839
9	17	0.296555556	0.5176	116	0.4	5	21	0.0068	10.36076	0.020017908	4.33295009
9	18	0.314	0.5176	116	0.4	5	21	0.0068	10.44065	-0.014262159	-3.087096854
9	19	0.331444444	0.5176	116	0.4	5	21	0.0068	10.52056	-0.049488172	-10.71189729
9	20	0.348888889	0.5176	116	0.4	5	21	0.0068	10.60049	-0.085657864	-18.54096046
9	21	0.366333333	0.5176	116	0.4	5	21	0.0068	10.68043	-0.122768809	-26.57376143
9	22	0.383777778	0.5176	116	0.4	5	21	0.0068	10.76038	-0.160818431	-34.80974244
9	23	0.401222222	0.5176	116	0.4	5	21	0.0068	10.84034	-0.199804008	-43.24831428
9	24	0.418666667	0.5176	116	0.4	5	21	0.0068	10.9203	-0.239722677	-51.88885751
9	25	0.436111111	0.5176	116	0.4	5	21	0.0068	11.00027	-0.280571444	-60.73072382
9	26	0.453555556	0.5176	116	0.4	5	21	0.0068	11.08024	-0.322347187	-69.77323729
9	27	0.471	0.5176	116	0.4	5	21	0.0068	11.16022	-0.36504666	-79.01569567
9	28	0.488444444	0.5176	116	0.4	5	21	0.0068	11.2402	-0.408666503	-88.45737162
9	29	0.505888889	0.5176	116	0.4	5	21	0.0068	11.32018	-0.453203246	-98.09751391
9	30	0.523333333	0.5176	116	0.4	5	21	0.0068	11.40017	-0.498653314	-107.9353487

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
10	0	0	0.5176	116	0.4	5	21	0.0068	15.38462	0.403749996	90.21535917
10	1	0.017444444	0.5176	116	0.4	5	21	0.0068	12.23895	0.447540197	100
10	2	0.034888889	0.5176	116	0.4	5	21	0.0068	10.57795	0.435263639	97.25688157
10	3	0.052333333	0.5176	116	0.4	5	21	0.0068	10.37277	0.408606788	91.30057827
10	4	0.069777778	0.5176	116	0.4	5	21	0.0068	10.37767	0.381204349	85.17767831
10	5	0.087222222	0.5176	116	0.4	5	21	0.0068	10.43013	0.352875588	78.84779739
10	6	0.104666667	0.5176	116	0.4	5	21	0.0068	10.49774	0.323570472	72.29975623
10	7	0.122111111	0.5176	116	0.4	5	21	0.0068	10.57136	0.293291488	65.53411073
10	8	0.139555556	0.5176	116	0.4	5	21	0.0068	10.64773	0.262047909	58.55293231
10	9	0.157	0.5176	116	0.4	5	21	0.0068	10.72551	0.229847979	51.35806368
10	10	0.174444444	0.5176	116	0.4	5	21	0.0068	10.80408	0.196698257	43.95096982
10	11	0.191888889	0.5176	116	0.4	5	21	0.0068	10.88311	0.162604038	36.3328343
10	12	0.209333333	0.5176	116	0.4	5	21	0.0068	10.96243	0.127569808	28.50465914
10	13	0.226777778	0.5176	116	0.4	5	21	0.0068	11.04194	0.091599555	20.46733583
10	14	0.244222222	0.5176	116	0.4	5	21	0.0068	11.12158	0.054696983	12.22169171
10	15	0.261666667	0.5176	116	0.4	5	21	0.0068	11.2013	0.01686564	3.768519593
10	16	0.279111111	0.5176	116	0.4	5	21	0.0068	11.28109	-0.021890996	-4.891403367
10	17	0.296555556	0.5176	116	0.4	5	21	0.0068	11.36092	-0.061569464	-13.75730364
10	18	0.314	0.5176	116	0.4	5	21	0.0068	11.44079	-0.102166283	-22.82840363
10	19	0.331444444	0.5176	116	0.4	5	21	0.0068	11.52068	-0.143677933	-32.10391683
10	20	0.348888889	0.5176	116	0.4	5	21	0.0068	11.60059	-0.186100841	-41.58304482
10	21	0.366333333	0.5176	116	0.4	5	21	0.0068	11.68052	-0.229431372	-51.26497541
10	22	0.383777778	0.5176	116	0.4	5	21	0.0068	11.76045	-0.273665826	-61.14888171
10	23	0.401222222	0.5176	116	0.4	5	21	0.0068	11.8404	-0.318800434	-71.23392171
10	24	0.418666667	0.5176	116	0.4	5	21	0.0068	11.92036	-0.364831359	-81.51923818
10	25	0.436111111	0.5176	116	0.4	5	21	0.0068	12.00032	-0.411754699	-92.00395889
10	26	0.453555556	0.5176	116	0.4	5	21	0.0068	12.08029	-0.459566484	-102.687197
10	27	0.471	0.5176	116	0.4	5	21	0.0068	12.16026	-0.508262682	-113.5680516
10	28	0.488444444	0.5176	116	0.4	5	21	0.0068	12.24024	-0.557839201	-124.6456082
10	29	0.505888889	0.5176	116	0.4	5	21	0.0068	12.32022	-0.608291889	-135.9189394
10	30	0.523333333	0.5176	116	0.4	5	21	0.0068	12.4002	-0.659616542	-147.3871054

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
11	0	0	0.5176	116	0.4	5	21	0.0068	17.88618	0.312457997	72.78926529
11	1	0.017444444	0.5176	116	0.4	5	21	0.0068	13.74519	0.416190759	96.9545344
11	2	0.034888889	0.5176	116	0.4	5	21	0.0068	11.66632	0.429263842	100
11	3	0.052333333	0.5176	116	0.4	5	21	0.0068	11.40017	0.400905748	93.39378464
11	4	0.069777778	0.5176	116	0.4	5	21	0.0068	11.38942	0.368369401	85.81421623
11	5	0.087222222	0.5176	116	0.4	5	21	0.0068	11.43621	0.334149718	77.84250272
11	6	0.104666667	0.5176	116	0.4	5	21	0.0068	11.5013	0.298724201	69.58988203
11	7	0.122111111	0.5176	116	0.4	5	21	0.0068	11.57361	0.262247335	61.09234212
11	8	0.139555556	0.5176	116	0.4	5	21	0.0068	11.64925	0.22478423	52.36505103
11	9	0.157	0.5176	116	0.4	5	21	0.0068	11.72659	0.186367553	43.41561877
11	10	0.174444444	0.5176	116	0.4	5	21	0.0068	11.80487	0.147016113	34.24842692
11	11	0.191888889	0.5176	116	0.4	5	21	0.0068	11.88371	0.106742109	24.86631731
11	12	0.209333333	0.5176	116	0.4	5	21	0.0068	11.9629	0.065554326	15.27133662
11	13	0.226777778	0.5176	116	0.4	5	21	0.0068	12.04231	0.023459681	5.465095987
11	14	0.244222222	0.5176	116	0.4	5	21	0.0068	12.12187	-0.01953598	-4.551042501
11	15	0.261666667	0.5176	116	0.4	5	21	0.0068	12.20154	-0.06342744	-14.77586357
11	16	0.279111111	0.5176	116	0.4	5	21	0.0068	12.28129	-0.108209859	-25.20823999
11	17	0.296555556	0.5176	116	0.4	5	21	0.0068	12.36109	-0.153878628	-35.84709756
11	18	0.314	0.5176	116	0.4	5	21	0.0068	12.44093	-0.20042927	-46.69139362
11	19	0.331444444	0.5176	116	0.4	5	21	0.0068	12.5208	-0.247857386	-57.74010346
11	20	0.348888889	0.5176	116	0.4	5	21	0.0068	12.60069	-0.296158619	-68.99221173
11	21	0.366333333	0.5176	116	0.4	5	21	0.0068	12.68061	-0.345328624	-80.44670683
11	22	0.383777778	0.5176	116	0.4	5	21	0.0068	12.76054	-0.395363061	-92.10257725
11	23	0.401222222	0.5176	116	0.4	5	21	0.0068	12.84047	-0.446257578	-103.9588093
11	24	0.418666667	0.5176	116	0.4	5	21	0.0068	12.92042	-0.498007808	-116.0143854
11	25	0.436111111	0.5176	116	0.4	5	21	0.0068	13.00038	-0.550609362	-128.2682837
11	26	0.453555556	0.5176	116	0.4	5	21	0.0068	13.08034	-0.604057832	-140.7194769
11	27	0.471	0.5176	116	0.4	5	21	0.0068	13.16031	-0.658348787	-153.3669327
11	28	0.488444444	0.5176	116	0.4	5	21	0.0068	13.24028	-0.713477771	-166.2096133
11	29	0.505888889	0.5176	116	0.4	5	21	0.0068	13.32025	-0.769440308	-179.2464758
11	30	0.523333333	0.5176	116	0.4	5	21	0.0068	13.40023	-0.826231899	-192.4764723

OPTIMUM ANGLE OF ATTACK Graphic of development efficiency according to position and angle change TSR4 ~ 12

TSR (ramda)	beta(°) (ANGLE OF ATTCK)	beta(rad)	c1	c2	c3	c4	c5	c6	ramda_i	Cpmax	generating efficiency(%)
12	0	0	0.5176	116	0.4	5	21	0.0068	20.68966	0.195398229	47.65607793
12	1	0.017444444	0.5176	116	0.4	5	21	0.0068	15.31829	0.367099224	89.53258864
12	2	0.034888889	0.5176	116	0.4	5	21	0.0068	12.76358	0.410017435	100
12	3	0.052333333	0.5176	116	0.4	5	21	0.0068	12.43018	0.380909422	92.90078651
12	4	0.069777778	0.5176	116	0.4	5	21	0.0068	12.40227	0.343693377	83.82408819
12	5	0.087222222	0.5176	116	0.4	5	21	0.0068	12.44286	0.303934285	74.12716102
12	6	0.104666667	0.5176	116	0.4	5	21	0.0068	12.50517	0.262713842	64.07382209
12	7	0.122111111	0.5176	116	0.4	5	21	0.0068	12.57607	0.220359315	53.74388879
12	8	0.139555556	0.5176	116	0.4	5	21	0.0068	12.65091	0.17699851	43.16853252
12	9	0.157	0.5176	116	0.4	5	21	0.0068	12.72776	0.132690988	32.36227946
12	10	0.174444444	0.5176	116	0.4	5	21	0.0068	12.80573	0.087468662	21.33291288
12	11	0.191888889	0.5176	116	0.4	5	21	0.0068	12.88436	0.041350815	10.08513564
12	12	0.209333333	0.5176	116	0.4	5	21	0.0068	12.9634	-0.005649586	-1.377889295
12	13	0.226777778	0.5176	116	0.4	5	21	0.0068	13.04271	-0.053522956	-13.05382433
12	14	0.244222222	0.5176	116	0.4	5	21	0.0068	13.1222	-0.102261626	-24.94079933
12	15	0.261666667	0.5176	116	0.4	5	21	0.0068	13.20181	-0.151859063	-37.03722076
12	16	0.279111111	0.5176	116	0.4	5	21	0.0068	13.28151	-0.202309428	-49.34166463
12	17	0.296555556	0.5176	116	0.4	5	21	0.0068	13.36127	-0.253607321	-61.85281377
12	18	0.314	0.5176	116	0.4	5	21	0.0068	13.44108	-0.305747623	-74.56941976
12	19	0.331444444	0.5176	116	0.4	5	21	0.0068	13.52093	-0.358725399	-87.49027919
12	20	0.348888889	0.5176	116	0.4	5	21	0.0068	13.60081	-0.412535838	-100.6142184
12	21	0.366333333	0.5176	116	0.4	5	21	0.0068	13.68071	-0.467174208	-113.9400834
12	22	0.383777778	0.5176	116	0.4	5	21	0.0068	13.76062	-0.522635832	-127.4667335
12	23	0.401222222	0.5176	116	0.4	5	21	0.0068	13.84055	-0.578916068	-141.1930366
12	24	0.418666667	0.5176	116	0.4	5	21	0.0068	13.92049	-0.636010297	-155.1178663
12	25	0.436111111	0.5176	116	0.4	5	21	0.0068	14.00044	-0.693913918	-169.2401
12	26	0.453555556	0.5176	116	0.4	5	21	0.0068	14.08039	-0.752622334	-183.5586171
12	27	0.471	0.5176	116	0.4	5	21	0.0068	14.16036	-0.81213096	-198.0722987
12	28	0.488444444	0.5176	116	0.4	5	21	0.0068	14.24032	-0.872435209	-212.7800267
12	29	0.505888889	0.5176	116	0.4	5	21	0.0068	14.32029	-0.933530498	-227.6806832
12	30	0.523333333	0.5176	116	0.4	5	21	0.0068	14.40027	-0.995412248	-242.7731509