THE AERODYNAMIC DESIGN OF A 10 TO 20 KW PROPELLER-TYPE WIND-MACHINE ROTOR

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ABSTRACT

The paper deals with the detailed aerodynamic design and performance as well as the calculation of the energy-output of a three-bladed propeller-type rotor of a 10 to 20 kW wind machine. The aimed-at wind machine is designed to best suit manufacturing technologies and wind energy climatology of Egypt. The in-hand detailed information, obtained through a comprehensive survey and evaluation process reported by the present author in two preceding published works, in addition to the results of a series of computer-runs carried-out to evaluate the performance of a number of internationally-successful wind-machine rotors, have been used to determine the geometric and the aerodynamic parameters of the rotor-design A1. The rotor is designed to operate, when adjusted at the determined performance-setting (speed of rotation & blade pitching angle), at four possible options having rated power of 10, 12.5, 16 and 20 kW; each of them best suits a corresponding annual-average wind-speed level. The computer code used in the design is an addition to the Rockwell-International program to give it the full advantages of use on a modern personal computer.

1. INTRODUCTION

Aiming at designing a small propeller-type wind machine that best suits manufacturing technologies and wind energy climatology of Egypt, the present author has presented in two preceding published works a comprehensive investigation on the design trade-offs of commercially-available units (of rated power P_r between 4 and 100 kW), in [1], as well as a technical evaluation for the performance-effective design parameters adopted in the surveyed group of 87 wind machines, in [2]. The main arrived-at results, on which the aerodynamic design of the candidate wind-machine rotor is to be based, are summarized hereinafter:

- (a) The wind machine shall have four options designated by I/1, I/2, II/1 and II/2 having P_r of 10, 12.5, 16 and 20 kW respectively.
- (b) Only one rotor is to be designed for the four options. It will be capable of operating at each of the four P_r -values when adjusted at the appropriate performance-setting, determined by rotor rotational-speed ω and blade pitching angle $\Delta\beta$:

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- (c) The candidate rotor will be a horizontal-axis, propeller-type, three-bladed, free-yawing, down-wind, fixed-pitch rotor.
- (d) 18-m-high tower is to be used in the aerodynamic-design process. This means a hub-height air density, at a standard day, of 1.185 kg/m^3 .
- (e) Regarding the wind climatology of Egypt, [3], the midvalue of the band of annual average wind speed $\bar{V}$, at a height of 18 m, for the best performance of options I/1, I/2, II/1 and II/2, shall be 4.8, 5.15, 5.6 and 6 m/s respectively.
- (f) The rotor blades shall have a NACA 4415 airfoil section from root to tip. The use of thicker sections up to 4424 or 4426 at the root, is to be left to the structural-design stage and according to the construction considerations and the distributions of thrust load and bending moment (that are to be calculated through the present process).
- (g) The load factor LF for the most economic performance of similar wind machines ranges between 0.20 and 0.30.
- (h) The rated power as extracted by the rotor, PD_r , is directly calculated by dividing the required P_r by a reasonably chosen overall electro-mechanical efficiency for the wind machine, η_o . Based on η_o of 65%, [1,2,4,5&6], the aimed-at values of PD_r of the four options are 15.4, 19.2, 24.6 and 30.8 kW.

2. ROTOR DESIGN A1

The geometric and aerodynamic characteristics of rotor-design A1 have been determined through the following sources and activities:

- (a) In-hand detailed technical information obtained through the comprehensive survey, study and evaluation processes reported in [1 & 2].
- (b) Thorough examination of technical data provided by manufacturers of a number of successful and world-wide recognized wind machines, of about the same size and/or power as the present rotor.
- (c) A series of computer-runs carried-out to evaluate the performance, and consequently the adopted design-parameters, of the rotors indicated in (b).

An idea of the characteristics of rotor A1 is given by Fig.(1). A complete list of the key figures is introduced hereinafter:

- Rotor radius is 4750 mm; based on an assumed system-efficiency of 27.5% and a correlation, determined in [2], between rated wind speed of rotor and annual average wind speed.
- Rotor-hub radius is 8% of rotor radius.
- Blade-spar equivalent diameter is 2% of rotor radius.
- Rotor solidity is 0.0775.
- Blade taper ratio is 0.41.
- Blade twist angle β , as illustrated in Fig.(2), has a value at the root of 14.7° and at the tip of 1.7° , giving a blade twist T_w of 13° .
- The blade has a trapezoidal planform, i.e., linear chord-variation, while the variation of β is non-linear; with the highest twist-gradient near the root and the lowest one near the tip, as shown in Fig.(1).

3. COMPUTER-CODE USED

The computer program used in the present work is the most recent generation of a respected family of windmill performance programs that arose from the works carried out by Wilson, et al, [7 & 8]. Their method of calculation is now most often referred to as the "blade element / momentum method", or

sometimes as strip theory. The best known program in the family is the one used by NASA-Lewis Research Center, and developed to its highest perfection by Aerovironment Corporation. A modified version of this code was adopted for analysis of small horizontal-axis wind machines by Rockwell International at the Rocky Flats Test Center in Colorado, U.S.A. It has undergone further improvement and experimental verification. This latter computer-code is presently the most generally accepted and reliable method for predicting the performance of horizontal-axis wind turbines, but it was not developed for use on personal computers. The program used in the present work is an addition to the Rockwell-International program to give it the full advantages of use on a modern personal computer.

To run the program, the following data have to be entered (values between brackets are adopted in the present design):

- Rotational speed - Number of blades - Rotor radius - Hub radius - Blade coning angle (3°) - Tilting angle of rotor shaft (0°) - Hub height - Wind-shear exponent (0.1429) - Number of segments to which the blade is to be divided for the strip-theory calculations (16) - Number of rotational positions in the vertical plane at which the calculations are to be carried out for each blade segment (4) - Table for blade chord and twist data including: segment number, midvalue radius percentage of segment location, midvalue-chord of segment normalized w.r.t. rotor radius, midvalue β of segment, and airfoil section of segment - Tables of aerodynamic lift and drag coefficients as function of angle of attack for the chosen section(s) - Wind speeds V_0 at which the aerodynamic performance and loading are to be calculated including: first V_0 , step size, and loop counter - Blade pitching angles $\Delta\beta$ at which the above calculations are to be made including: first $\Delta\beta$, step size, and loop counter.

The output results of each run (confined to a certain ω) may have optionally either a concise form or a detailed segment-by-segment form. In concise form, the results at each V_0 value include: tip speed ratio X , rotor thrust coefficient TC , rotor torque coefficient QC , rotor power coefficient PC , rotor performance-index Eta , rotor thrust TD , blade bending-moment at the hub MD , rotor torque QD , and power extracted by rotor PD . A single page of this type of output is given in an Appendix sheet. In the detailed form, the results include, in addition to the above ones, details of flow angles, coefficients and forces of each segment.

4. AERODYNAMIC PERFORMANCE OF ROTOR A1

Several computer-runs have been carried out to determine the detailed aerodynamic performance of rotor A1 at the different operation conditions. The results of only five of these runs are introduced in this work. These runs are at ω of 70, 80, 90, 100, and 110 rpm. In each run, $\Delta\beta$ has taken the values from -2° to 8° with a step size of 1° . At each value of $\Delta\beta$, V_0 has taken the values from 3 m/s to 20 m/s with a step of 1 m/s. Figs.(3) to (7) display samples of power and power-coefficient curves, plotted directly from the computation results. Fig.(3) shows the effect of blade pitching on the power curve (at a fixed ω of 90 rpm). While Fig.(4) shows the effect of ω on the power curve (with a fixed $\Delta\beta$ of 0°). Figs.(5) and (6) are corresponding to Figs.(3) and (4) respectively, but for power-coefficient curves. The single plot of C_p versus X , in Fig.(7), is obtained from the results of the five rpm runs; P all of them at the same $\Delta\beta$ of 0° .

It can be noticed in Fig.(3) that increasing $\Delta\beta$ decreases PD at low V_0

Fig. (2): Notations of Wind/
Blade Geometry Fig. (3): Power Curves of Rotor A1
at 90 rpm and Different
Pitching Angles Fig. (4): Power Curves of Rotor A1
at 0° Pitching Angle and
Different Rotational Speeds

and increases it at high V_o . The same result is obtained too with increasing ω , as shown in Fig.(4). These results are confirmed by the C_p curves in Figs.(5) and (6). Furthermore, Fig.(5) shows the relative merits of the different $\Delta\beta$ regarding C_p , for the speed-range considered. As it was expected, the shape of the C_p curve, being dependent on $\Delta\beta$ as shown in Fig.(5), does not depend on ω as indicated in Fig.(6). The curves have the same shape, but shifted towards higher V_o for higher ω . This fact explains why the C_p values fall on a single curve, when they are plotted versus tip speed ratio, Fig.(7), rather than wind speed V_o .

5. ENERGY OUTPUT OF ROTOR A1

In order to calculate the annual energy output of the rotor at a certain performance setting ($\omega, \Delta\beta$) when erected at a site having a certain $\bar{V}$, the rotor extracted-power at each V_o value, $PD(V_o)$, must be multiplied by the number of hours per year of the wind-speed occurrence, $n(V_o)$, at that site. This product is to be calculated for the considered spectrum of V_o between 3 and 20 m/s. The summation takes the form:

$$E \text{ (kWh/Yr)} = \sum_{V_o=3}^{V_o=20} PD(V_o) \cdot n(V_o) \quad (1)$$

The list of values $PD(V_o)$ is a direct output of the computation, as given in the last column in the Appendix and as shown in Figs.(3) and (4). It is worth to mention that the negative $PD(V_o)$ values, if any, are not included in the above summation, since this means that the rotor is not yet extracting power from the wind. The list of values $n(V_o)$ depends on $\bar{V}$ of the site. Values of $n(V_o)$ have been calculated using the widely-accepted Rayleigh wind-speed distribution function, [3, 5 & 6]. Fig.(8) shows the curves of $n(V_o)$ and $E_{av}(V_o)$ for the four $\bar{V}$ values at each of which one of the rotor options will best perform. It can be noticed that $E_{av}(V_o)$ is the same as $E(V_o)/C_p$.

A very clear picture about the performance and energy production of rotor A1 is presented in Figs.(9) to (12) for the four sites considered. In each one of these figures, two sets of curves are introduced. The first set of PD_r as function of $\Delta\beta$ for different values of ω , is identical in the four figures. Here PD_r is simply the largest value of PD for a certain setting ($\omega, \Delta\beta$). In Fig.(9), the PD_r curves intersect with the value of 15.4 kW (the aimed-at value for option 1/1) giving the pitching angles required to let the rotor operating at this option at the corresponding rotational speeds. The same thing is shown in Figs.(10), (11), and (12) for the other options.

The second set of curves, representing the rotor energy-output at the different performance-settings, is not identical in Figs.(9) to (12) since each set represents E at a different $\bar{V}$, as indicated in the captions of the figures. The use of the two sets of curves (of PD_r and E) together on the same figure, made it possible to show how the best performance-setting ($\omega, \Delta\beta$) of a certain option at a certain site, can be determined. For example, point 1 on Fig.(9) represents E of the rotor with PD_r of option 1/1 at $\bar{V}$ of 4.8 m/s, which can be obtained with the setting (70 rpm, 5.3°). While point 2 indicates a higher E obtained with a better performance-setting of (80 rpm, 0.4°). Point 3, however representing the setting (90 rpm, -3.2°), is not as good as point 2. In this way, Figs.(9) to (12) can show how the relative merits of the different possible settings for each option, have been determined.

Fig. (5): Power-Coefficient Curves of Rotor A1 at 90 rpm for Different Pitching Angles

Fig. (7): The Power-Coefficient Curve of Rotor A1 at 0° Pitching Angle

Fig. (6): Power-Coefficient Curves of Rotor A1 at 0° Pitching Angle for Different Rotational Speeds

Fig. (8): Number of Hours of Wind-Speed Occurrence (n) and the Energy Available in the Area Swept by Rotor A1 (E_{av}) at the Four V Values based on Rayleigh Distribution

Fig.(9): Performance of Rotor A1 at $\bar{V}$ of 4.8 m/s for Wind-Machine Option I/1

Fig.(10): Performance of Rotor A1 at $\bar{V}$ of 5.15 m/s for Wind-Machine Option I/2

Fig.(11): Performance of Rotor A1 at $\bar{V}$ of 5.6 m/s for Wind-Machine Option II/1

Fig.(12): Performance of Rotor A1 at $\bar{V}$ of 6.0 m/s for Wind-Machine Option II/2

The results obtained from Figs.(9) to (12) are combined together in Fig.(13), where E is replaced by the dimensionless performance-parameter load-factor LF which can be expressed by the relation:

$$LF = (E / 8760) / PD_r \quad (2)$$

In fact, LF represents ratio of average power-output of the rotor to its rated power-output. Adopting LF instead of E brings the numerical results of the four options to the same level, which will facilitate the comparison. The major result, as shown by Fig.(13), is that the peak value of LF is almost the same for the four options. This is namely 0.223. Also, the peak value occurs at a higher ω as the option rated-power is greater. This latter point is directly related to the effect of ω on C_p curves shown before in Fig.(6). It is also related to the power curves, as those of Fig.(4), and to E_{av} curves of Fig.(8). It is worth to mention that the final performance settings, that make the rotor to best operate at the four aimed-at options, have been determined using the results of other several additional runs with smaller increments of ω and $\Delta\beta$, in addition to the present ones.

6. ENERGY OUTPUT OF ROTOR A1 WITH VARIABLE-PITCH BLADES

The present section presents the results of a trial which has been made to evaluate the influence of allowing $\Delta\beta$ to be varied according to the variation of V_o , searching for operating always at the highest PD, i.e. with the highest C_p , as long as PD is less or equal to PD_r of the aimed-at option. In this way, the rotor energy-output E can be maximized. An example to show this procedure is given in Table(1). The values of PD that are used to calculate E, are the underlined (largest) ones up to V_o of 10 m/s, followed by PD of 15.4 kW for the rest of V_o values. This is for option 1/1. While for option 1/2, the underlined values are used up to V_o of 11 m/s, followed by PD of 19.2 kW as a constant. The same thing has been done for the other two options and for the five rpm-runs considered in the present work.

Fig.(14) presents the results of the above-described procedure. It shows LF of each option at its corresponding $\bar{V}$ level. Comparison of Figs.(13) and (14) indicates that the peak value of LF with variable-pitch blades of 0.229 is only 2.7% higher than that of the fixed-pitch blades. This result agrees with the conclusion derived by the present author in [1] that fixed-pitch blades can extract as much energy as variable-pitch ones, after accounting for the discrepancies and the response time of the control mechanism used in the latter.

7. CONCLUSIONS

Summing-up the work and the results presented in this paper, concerning the aerodynamic design of rotor A1, the following points can be derived:

- The computer-code in-hand is a very powerful and accurate one that takes into account the most-recent developments in the aerodynamic theory of the flow over a propeller-type horizontal-axis wind-machine rotor.
- The first-configured rotor-design A1 is a very good one that has a power coefficient which peaks up to 0.495. This makes the designed rotor competitive with the most-successful rotor designs now in the international market.
- The aerodynamic performance and the energy output of rotor A1, have been comprehensively calculated and analysed for the four aimed-at options at

- their corresponding wind levels. The results presented are only few samples that give an idea about the in-hand complete and fully-analysed ones.
- The energy output of the fixed-pitch blades has shown more sensitivity to the chosen rotational speed, compared to the variable-pitch ones. However, the difference in the peak value of the load factor is only 2.7%.
 - The arrived-at peak values of the load factor of 0.223, for the fixed-pitch blades of rotor A1, seem somewhat low w.r.t. the aimed-at level between 0.2 and 0.3 (with an average of 0.25). So, further work still needs to be done to evaluate the aerodynamic design of other rotor-design alternatives that incorporate variations of the rotor solidity, the blade twist, the blade taper-ratio, and the rotor radius, aiming at determining the best entry to increase the energy output (and consequently the load factor) at the least additional weight and/or cost.

Fig. (13): Load-Factor Curves of Rotor A1 for the Four Wind-Machine Options

Fig. (14): Load-Factor Curves of Rotor A1 with Variable-Pitch Operation for the Four Wind-Machine Options

Table (1): Computation Results for the Output Power PD (kW)
of Rotor A1 at 80 rpm Rotational Speed

$\Delta\beta^\circ$ $V_o(m/s)$	-2	-1	0	1	2	3	4	5	6	7	8
3	-0.147	-0.030	0.059	0.122	<u>0.159</u>	0.155	0.064	-0.107	-0.344	-0.636	-0.979
4	0.642	0.762	0.865	0.956	<u>1.028</u>	1.024	0.918	0.729	0.468	0.145	-0.235
5	1.966	2.112	2.256	2.384	<u>2.428</u>	2.365	2.215	1.991	1.693	1.330	0.907
6	4.017	4.213	4.380	<u>4.439</u>	4.385	4.241	4.020	3.732	3.382	2.971	2.497
7	6.912	7.064	<u>7.108</u>	7.049	6.905	6.677	6.377	6.006	5.578	5.096	4.561
8	9.923	10.038	<u>10.050</u>	9.958	9.789	9.534	9.197	8.777	8.281	7.725	7.115
9	11.874	12.415	<u>12.685</u>	12.759	12.692	12.499	12.212	11.815	11.324	10.758	10.102
10	12.214	13.426	14.336	14.900	15.190	<u>15.238</u>	15.111	14.850	14.466	13.953	13.350
11	11.799	13.475	14.814	15.984	16.818	17.349	<u>17.612</u>	17.591	17.434	17.096	16.613
12	10.947	12.850	14.655	16.191	17.528	18.615	19.358	19.839	20.021	19.953	19.698
13	9.937	11.987	14.013	15.880	17.690	19.136	20.394	21.360	21.989	22.363	22.461
14	8.912	11.104	13.183	15.253	17.244	19.102	20.782	22.200	23.328	24.202	24.768
15	7.945	10.159	12.318	14.527	16.656	18.736	20.710	22.534	24.047	25.410	26.362
16	7.159	9.342	11.508	13.789	16.006	18.191	20.401	22.396	24.392	26.016	27.480
17	6.465	8.669	10.838	13.121	15.353	17.701	19.883	22.148	24.231	26.317	28.201
18	5.948	8.128	10.321	12.506	14.841	17.188	19.494	21.862	24.054	26.377	28.364
19	5.585	7.713	9.908	12.163	14.473	16.717	19.139	21.443	23.943	26.121	28.541
20	5.401	7.470	9.611	11.818	14.161	16.496	18.787	21.263	23.747	26.146	28.391

8. REFERENCES

1. Hassanein, Atef M.A., Investigation on the Design Trade-Offs of Propeller Type Wind Machines Under 100 KW, Proceedings of the International Symposium on Applications of Solar & Renewable Energy (ASRE 86), Paper No. 18, Cairo, Egypt, March 1986.
2. Hassanein, Atef M.A., Technical Evaluation of the Performance of Propeller-Type Wind Machines Under 100 KW, Proceedings of the International Symposium on Applications of Solar & Renewable Energy (ASRE 86), Paper No. 103, Cairo, Egypt, March 1986.
3. Hassanein, Atef M.A. and Darwish, A.O., On the Evaluation of Available Wind Energy Using Climatological Wind Data, Proceeding of the First International Alternative Energy Sources and Technology Conference, Mansoura University, Mansoura, Egypt, Vol. 1, pp. 341-363, April 1985.
4. De Renzo, D.J., Ed., Wind Power Recent Development, Noyes Data Corporation, Park Ridge, New Jersey, 1979.
5. Hunt, V.D., Wind Power - A Handbook on Wind Energy Conversion Systems, Van Nostrand Reinhold Company, New York, 1981.
6. Park, J., The Wind Power Book, Cheshire Books, Palo Alto, California, 1981.
7. Wilson, R.E. and Lissman, P.B.S., Applied Aerodynamics of Wind Power Machines, Oregon State University, Oregon, U.S.A., July 1974.
8. Wilson, R.E., Lissman, P.B.S., and Walker, S.N., Aerodynamic Performance of Wind Turbines, Oregon State University, Oregon, U.S.A., June 1976.

9. NOMENCLATURE

c_r	blade-chord at root section
c_t	blade-chord at tip section
C_p	(also PC) power coefficient; ratio of power extracted by rotor to power available in wind-streamtube of same area as the rotor
E	energy extracted by the rotor in kWh/Yr
E_{eta}	rotor-performance index; PC/TC
E_{av}	available wind-energy per year in the area swept by the rotor at a certain wind speed in kWh/Yr
LF	load factor; average power output of an energy system divided by its rated power output
MD	blade bending moment at the hub
n	number of hours per year of the occurrence of a certain wind speed V_0
PD	power extracted by the rotor
P	rated (or maximum) power output of a wind machine
P_D	rated (or maximum) value of PD
QC_r	rotor torque coefficient
QD	rotor torque
r	radial distance from rotor axis
R	rotor radius
TC	rotor thrust coefficient
TD	rotor thrust
Tw	blade twist
$\bar{V}$	annual average wind speed of a site
V	(also V_0) wind speed
X^0	rotor tip speed ratio; blade-tip speed/wind speed
α	angle of attack; Fig.(2)
β	blade twist (or setting) angle; Fig.(2)
$\Delta\theta$	blade pitching angle
η_o	overall electro-mechanical efficiency of the wind machine
ω	rotor rotational-speed in rpm

APPENDIX

Computation Results of the Aerodynamic Performance
and Loading of Rotor A1 at 70 rpm

Wind Turbine: A1

f1

70.000 RPM of Rotor 3 Blades
 15.59 ft Blade Radius 1.25 ft Hub Radius
 3.000 Cone angle 0.000 DEG Shaft Tilt
 60.3 ft Hub Height 0.0000 Wind shear Exponent
 16 Blade Stations 1 Rotational position
 .00230 Slug/Ft³ Air Density
 Prandtl Tip Loss Model Prandtl Hub Loss Model
 Advanced Brake State Model Aerovironment Stall Model
 Swirl Term Included
 Segments 3 to 16 Included in Analysis

Pitch	X	TC	QC	PC	Eta	VO-M/S	TD-Lbs	MD-Ftlbs	QD-Ftlbs	PD-KW
-2.00	11.606	1.392	0.007	0.080	.0576	3.000	118.001	443.812	9.124	0.091
-2.00	8.705	1.148	0.038	0.330	.2872	4.000	173.122	632.624	89.032	0.885
-2.00	6.964	1.010	0.061	0.427	.4230	5.000	237.816	853.293	225.159	2.239
-2.00	5.803	0.909	0.082	0.478	.5260	6.000	308.251	1094.188	435.430	4.329
-2.00	4.974	0.802	0.093	0.462	.5766	7.000	370.095	1309.482	668.629	6.648
-2.00	4.352	0.689	0.086	0.374	.5436	8.000	415.368	1471.594	808.486	8.039
-2.00	3.869	0.584	0.069	0.268	.4586	9.000	445.437	1578.753	822.926	8.182
-2.00	3.482	0.495	0.053	0.183	.3709	10.000	465.931	1640.027	773.536	7.691
-2.00	3.165	0.425	0.039	0.125	.2930	11.000	484.575	1680.872	699.027	6.950
-2.00	2.902	0.374	0.029	0.085	.2282	12.000	507.436	1727.710	621.870	6.183
-2.00	2.678	0.336	0.022	0.059	.1750	13.000	535.236	1785.551	545.083	5.420
-2.00	2.487	0.312	0.017	0.042	.1337	14.000	575.551	1884.638	482.354	4.796
-2.00	2.321	0.290	0.013	0.030	.1046	15.000	615.050	1982.247	431.783	4.293
-2.00	2.176	0.270	0.010	0.023	.0844	16.000	651.466	2067.513	393.727	3.915
-2.00	2.048	0.252	0.009	0.018	.0710	17.000	686.999	2150.935	371.321	3.692
-2.00	1.934	0.237	0.008	0.015	.0626	18.000	723.355	2238.256	364.853	3.628
-2.00	1.833	0.224	0.007	0.013	.0569	19.000	761.082	2330.563	367.994	3.659
-2.00	1.741	0.213	0.007	0.012	.0542	20.000	801.121	2430.785	388.710	3.865
-1.00	11.606	1.253	0.013	0.149	.1191	3.000	106.219	396.924	16.984	0.169
-1.00	8.705	1.068	0.042	0.363	.3396	4.000	160.922	584.603	97.843	0.973
-1.00	6.964	0.959	0.065	0.451	.4701	5.000	225.990	807.682	237.745	2.364
-1.00	5.803	0.873	0.085	0.491	.5623	6.000	296.098	1047.595	447.178	4.446
-1.00	4.974	0.773	0.094	0.468	.6047	7.000	356.950	1257.667	676.350	6.725
-1.00	4.352	0.672	0.091	0.395	.5882	8.000	405.038	1427.514	853.060	8.482
-1.00	3.869	0.574	0.076	0.295	.5143	9.000	437.981	1549.538	907.341	9.021
-1.00	3.482	0.491	0.061	0.211	.4308	10.000	462.330	1629.466	891.530	8.864
-1.00	3.165	0.426	0.047	0.149	.3495	11.000	485.865	1688.968	836.100	8.313
-1.00	2.902	0.374	0.036	0.105	.2806	12.000	507.962	1736.281	765.495	7.611
-1.00	2.678	0.336	0.028	0.075	.2229	13.000	534.693	1792.147	693.396	6.894
-1.00	2.487	0.307	0.022	0.054	.1769	14.000	567.724	1866.869	629.459	6.259
-1.00	2.321	0.287	0.017	0.041	.1417	15.000	607.406	1964.026	578.038	5.747
-1.00	2.176	0.268	0.014	0.031	.1162	16.000	647.009	2060.630	538.229	5.351
-1.00	2.048	0.251	0.012	0.025	.0981	17.000	683.732	2146.922	510.347	5.074
-1.00	1.934	0.236	0.010	0.020	.0859	18.000	720.410	2234.386	498.623	4.958
-1.00	1.833	0.223	0.009	0.017	.0780	19.000	758.609	2327.425	503.180	5.003
-1.00	1.741	0.212	0.009	0.015	.0720	20.000	798.085	2424.934	514.448	5.115
0.00	11.606	1.123	0.018	0.204	.1818	3.000	95.203	352.953	23.243	0.231
0.00	8.705	0.994	0.045	0.393	.3956	4.000	149.829	541.146	106.135	1.055
0.00	6.964	0.912	0.068	0.473	.5185	5.000	214.749	764.504	249.180	2.478