THE FORMULATION OF EXPLOITATION CURVES FOR THE TURBINE WITH A VERTICAL AXIS

Dubau Calin*, Derecichei Laura

*University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048 Oradea; Romania, e-mail: calin_dubau@yahoo.com

Abstract

Formulation of exploitation curves with the turbine with vertical axis requires employment of an original method to maximize the energy obtained starting from experimental data. Considering the constant values of revolution and the values of wind speed as reference point, the following values have been calculated: λ, C_P, P_{arb}. Following calculation, certain numerical values have resulted, which have been determined in order to generate a reference point in the subsequent calculations regarding the assessment of energy production for the vertical turbine which analyzed

Key words: vertical turbine, exploitation curves, wind speed, the power value, revolution

INTRODUCTION

The exploitation curves for the turbine with a vertical axis, are formulated in relation to the wind speed v=3...19m/s, the peripheral speed u, the air density ρ, and the exposed area S, materialized in the formula of unitary power at axis of the turbine:.

$$P_{arb} = C_P \cdot \rho \cdot \frac{v^3}{2} \cdot S$$

MATERIAL AND METHODS

The calculation algorithm for the tables below is:

1. speed v - within the interval v=3...19m/s (all the value in the interval)
2. revolution n – for each table the revolution has been made constant (n=50, 100,150, 200, 250)
3. the characteristic number λ:

$$\lambda = \frac{u}{v} = \frac{R \cdot \omega}{v}; \quad \omega = \frac{\pi \cdot n}{30}; \quad \lambda = \frac{R \cdot \pi \cdot n}{30 \cdot v}$$

4. the power value C_P is calculated using the relation:

$$C_{P\,arb} = a \cdot \lambda^{\alpha} - b \cdot \lambda^{\beta}$$

For the vertical turbine we use the following values:

α=2; a=0,11666

β=3,5; b=0,01283

5. power at the axis of the turbine P_{arb} is calculated using the relation:

$$P_{arb} = C_P \cdot \rho \cdot \frac{v^3}{2} \cdot S$$

For the vertical turbine we calculate the area exposed to the air using the relation $S = D \cdot H$, where D = 2,5m, H = 3 m

Obs.1: We have taken in to consideration the limitation of the power at the axis as P_{arb}=3500 W. As a result the figures have been recalculated in the following sequence:

P_{arb}=3500→C_P→λ→n, using the following formula of calculation:

For the power value we have:

$$C_P = \frac{P_{arb}}{\rho \cdot \frac{v^3}{2} \cdot S}$$

The characteristic number λ has been determined from the graph C_{Parb} = f(λ) using a graphical method (for each calculated C_P, the correspondence of the characteristic number λ has been determined, by reading the graph.

6. revolution n – for the power values at the axis P_{arb} > 3500 we have calculated the revolution in relation to λ determined from the graph, using the relation $n = \frac{30 \cdot \lambda \cdot v}{\pi \cdot R}$.

The results of the calculation P_{arb} under constant n = 50...250 rpm. The vertical turbine: λ = 3, C_{Pmax} = 0,45.

RESULTS AND DISCUSSION

The vertical turbine

Table 1

The results of the calculation P_{arb} under constant rotations n=50

v	n = 50		P_{arb}
	λ	C_P	
3	2,18	0,36	46,82
4	1,64	0,24	74,44
5	1,31	0,17	100,96
6	1,09	0,12	126,87
7	0,93	0,09	152,40
8	0,82	0,07	177,66
9	0,73	0,06	202,73
10	0,65	0,05	227,67
11	0,59	0,04	252,50
12	0,55	0,03	277,24
13	0,50	0,03	301,92
14	0,47	0,02	326,55
15	0,44	0,02	351,13
16	0,41	0,02	375,67
17	0,38	0,02	400,17
18	0,36	0,02	424,65
19	0,34	0,01	449,11

Table 2

The results of the calculation P_{arb} under constant rotations n=100

v	n = 100		P_{arb}
	λ	C_P	
3	4,36	-0,01	-0,69
4	3,27	0,44	134,97
5	2,62	0,43	258,25
6	2,18	0,36	374,58
7	1,87	0,29	486,53
8	1,64	0,24	595,52
9	1,45	0,20	702,40
10	1,31	0,17	807,72
11	1,19	0,14	911,83
12	1,09	0,12	1014,99
13	1,01	0,11	1117,39
14	0,93	0,09	1219,17
15	0,87	0,08	1320,44
16	0,82	0,07	1421,26
17	0,77	0,06	1521,72
18	0,73	0,06	1621,86
19	0,69	0,05	1721,73

Table 3

The results of the calculation P_{arb} under constant rotations n=150

v	n = 150		P_{arb}
	λ	C_P	
3	6,54	-4,21	-549,25
4	4,91	-0,55	-170,64
5	3,93	0,26	156,82
6	3,27	0,44	455,51
7	2,80	0,44	736,13
8	2,45	0,41	1004,53
9	2,18	0,36	1264,19
10	1,96	0,31	1517,38
11	1,78	0,27	1765,59
12	1,64	0,24	2009,88
13	1,51	0,21	2251,03
14	1,40	0,19	2489,60
15	1,31	0,17	2726,04
16	1,23	0,15	2960,68
17	1,15	0,13	3193,80
18	1,09	0,12	3425,59
19	1,03	0,11	3656,25

Table 4

The results of the calculation P_{arb} under constant rotations n=200

v	n = 200		P_{arb}
	λ	C_P	
3	8,73	-16,30	-2129,48
4	6,54	-4,21	-1301,92
5	5,24	-1,02	-614,34
6	4,36	-0,01	-5,51
7	3,74	0,33	553,84
8	3,27	0,44	1079,74
9	2,91	0,45	1581,75
10	2,62	0,43	2066,01
11	2,38	0,39	2536,67
12	2,18	0,36	2996,60
13	2,01	0,32	3447,93
14	1,87	0,29	3892,21
15	1,75	0,27	4330,65
16	1,64	0,24	4764,16
17	1,54	0,22	5193,49
18	1,45	0,20	5619,22
19	1,38	0,18	6041,84

Table 5

The results of the calculation P_{arb} under constant rotations n=250

v	n = 250		P_{arb}
	λ	C_P	
3	10,91	-41,12	-5370,83
4	8,18	-12,29	-3804,00
5	6,54	-4,21	-2542,82
6	5,45	-1,39	-1453,61
7	4,67	-0,28	-472,42
8	4,09	0,18	435,69
9	3,64	0,37	1291,65
10	3,27	0,44	2108,86
11	2,97	0,45	2896,34
12	2,73	0,44	3660,43
13	2,52	0,41	4405,71
14	2,34	0,39	5135,61
15	2,18	0,36	5852,74
16	2,05	0,33	6559,13
17	1,92	0,31	7256,37
18	1,82	0,28	7945,76
19	1,72	0,26	8628,35

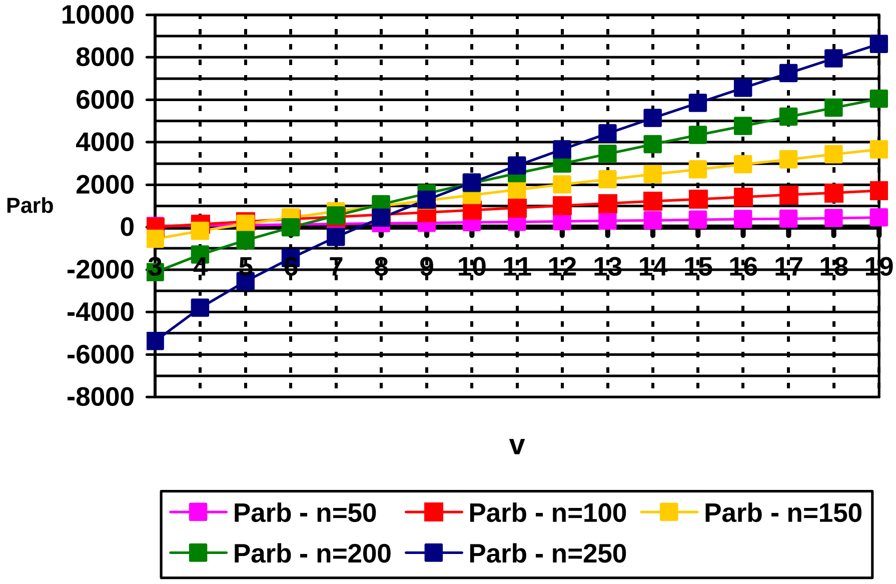

Fig. 1. The correspondence between speed and power at the axis for the rotations presented with colored symbols in the legend above

The graph above displays the correspondence between speed and power at axis for the rotations presented with colored symbols in the legend above. These curves are formulated in relation to wind speed v, peripheral speed u, air density ρ and the exposed area S $(S = D \cdot H)$. The following strategy has been used: at the level of installed power by setting a constant rotation, the power at the axis of the turbine has been limited to the value $P_{arb} = 3500$ W. We have defined the correspondences $P_{arb} = f(v)$ for the rotations analyzed (n = 50...250). These rotations are set in the mode of operation of the vertical assembly.

CONCLUSIONS

It can be noticed that according to the constant revolution which has been analyzed, at a certain value of wind speed it is essential to limit the power at the axis of the turbine mentioned before. For revolutions n = 50, 100, the limitation of power was not necessary, while for the other revolutions which were analyzed, n = 150, 200, 250 it was necessary to limit the power at the respective values of wind speed.

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