COMPARATIVE ANALYSIS OF Cyl/t=f(r) CURVES FOR A HORIZONTAL-AXIS WIND TURBINES (HAWT) IN AN GRAPHICAL DISPLAY FROM THE HUB TO PERIPHERY

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Abstract

The summaries presented reflect the impact of a series of parameters used in our analysis based on a new computational model on the achievable power coefficient. Analyze power coefficients are maximum theoretical values. It is noticeable that the higher degrees of reaction are very effective in achieving increased power coefficients. The values are crest indicators and show that the new evaluation method of the possibilities is substantiated

Additional parameters influencing the power coefficient are λ_0, k_{V_3}

Key words: turbine, power coefficient, degree of reaction, summaries, $C_y l/t = f(r)$ curves.

INTRODUCTION

The calculation was done for two wind speeds within the area of interest of turbine surveyed. These speeds have a direct impact on the theoretical power that can be generated by wind, and they are also depending on the area exposed to the wind. The two speeds classes of 5 m/s and 12 m/s, respectively, lead us to the following power categories.

Table 1.

Speed-power correlation

5 m/s	$(P_t)_{total}$	338 ... to 516 W	for $\lambda_0 = 2$
		395 ... to 865 W	for $\lambda_0 = 3$
12 m/s	$(P_t)_{total}$	4679 ... to 7135 W	for $\lambda_0 = 2$
		5470 ... to 8723 W	for $\lambda_0 = 3$

One may observe that powers increase in the $\left(\frac{12}{5}\right)^3$ ratio.

The 0.6 Bent's limit on the maximum power efficiency coefficient will translate the indicators as follows:

$P_t = 344.531$ for $v = 5$ m/s

$P_t = 4762.8$ for $v = 12$ m/s.

MATERIAL AND METHOD

The calculation model does not show the scale effects of v1 velocities (speeds). Thus the conclusions are identical for the two speeds (5 and 12 m/s, respectively). This means that the effects on power are manifested through the third speed of power, which is confirmed by analyzing powers based on summaries presented.

The chart for the summary 2a shows the dependency of C_y l/t values derived from calculation software depending on range. In charts one may notice the influence of radius as the curves have the same rate for all parameters analyzed, and the later' effect is somewhat secondary. By using the same grouping of variations by power fields, the graphs for variant group are showed for comparative analysis purposes (see Graphs 2/1, 2/2, 2/3, 2/4).

The impact of the degree of reaction in power coefficient analysis showed that through higher degrees of reaction the coefficient values get higher. This trend, however, requires higher values of t C_y l/t term.

RESULTS AND DISSCUSIONS

Corresponding results for the 16 variants submitted for analysis, for the parameter $C_y = \frac{l}{t} =$ f (r) are presented in the following table which highlights the correlation between these parameters.

Table 2.

Calcul of *SUMMARY 2a*

Variants	$C_y \frac{l}{t}$						
r =	*0.3*	*0.5*	*0.75*	*1*	*1.25*	*1.5*	*1.55*
1-1-1-1	0.950	0.767	0.587	0.454	0.358	0.286	0.274
1-1-1-2	1.004	0.840	0.673	0.545	0.449	0.374	0.362
1-1-2-1	0.660	0.522	0.388	0.292	0.223	0.175	0.167
1-1-2-2	0.715	0.595	0.471	0.375	0.303	0.248	0.239
1-2-1-1	0.950	0.767	0.587	0.454	0.358	0.286	0.274
1-2-1-2	1.004	0.840	0.673	0.545	0.449	0.374	0.362
1-2-2-1	0.660	0.522	0.388	0.292	0.223	0.175	0.167
1-2-2-2	0.715	0.595	0.471	0.375	0.303	0.248	0.239
2-1-1-1	0.809	0.587	0.402	0.286	0.211	0.161	0.153
2-1-1-2	0.879	0.673	0.494	0.374	0.292	0.234	0.224
2-1-2-1	0.554	0.388	0.255	0.175	0.125	0.093	0.088
2-1-2-2	0.624	0.471	0.336	0.248	0.189	0.147	0.141
2-2-1-1	0.809	0.587	0.402	0.286	0.211	0.161	0.153
2-2-1-2	0.879	0.673	0.494	0.374	0.292	0.234	0.224
2-2-2-1	0.554	0.388	0.255	0.175	0.125	0.093	0.088
2-2-2-2	0.624	0.471	0.336	0.248	0.189	0.147	0.141

In the summary 2b the C_y l/t values for hub and periphery are shown. This graphical and tabular ordering allows for an analysis which will substantiate the selection method of the solution considered optimal. In this way one will examine the development of geometries associated to kinematic study of a horizontal-axis wind turbine.

Table 3.

Calcul of *SUMMARY 2b*

v_1 [m/s]	λ_0 [-]	k_{V_3} [-]	$C_y\, l/t$ for hub (r = 0.3 m)		$C_y\, l/t$ for periphery (r = 1.55 m)	
			$C_y\, l/t$ [-]			
			0.8	0.9	0.8	0.9
5	2	0.8	0.95	1.004	0.274	0.362
		0.9	0.66	0.715	0.362	0.239
	3	0.8	0.80	0.879	0.153	0.224
		0.9	0.554	0.624	0.088	0.141
12	2	0.8	0.95	1.004	0.274	0.362
		0.9	0.66	0.715	0.167	0.239
	3	0.8	0.80	0.879	0.153	0.224
		0.9	0.554	0.624	0.088	0.141

The no. 3 centralized summary hereunder corrects information of the two previous summaries here above.

Table 4.

Calcul of *SUMMARY 3*

Variants	λ_0	k_{V_3}	$\bar{R} = 0.8$: P_{arb} [W]	$\bar{R} = 0.8$: C_{Pmax} [–]	$\bar{R} = 0.8$: $(C_y\, l/t)_{hub}$ [–]	$\bar{R} = 0.9$: P_{arb}	$\bar{R} = 0.9$: C_{Pmax}	$\bar{R} = 0.9$: $(C_y\, l/t)_{hub}$
1-2-1-1 ... 2	2	0.8	7135	0.893	0.95	8982	1.124	1.004
1-2-2-1 ... 2		0.9	4679	0.587	0.66	6298	0.788	0.715
2-2-1-1 ... 2	3	0.8	8723	1.092	0.80	11971	1.499	0.879
2-2-2-1 ... 2		0.9	5471	0.685	0.554	8093	1.013	0.624

$v = 12$ m/s $r_b = 0.3$ m $r_p = 1.55$ m $A_{ext} = 7.5$ m^2

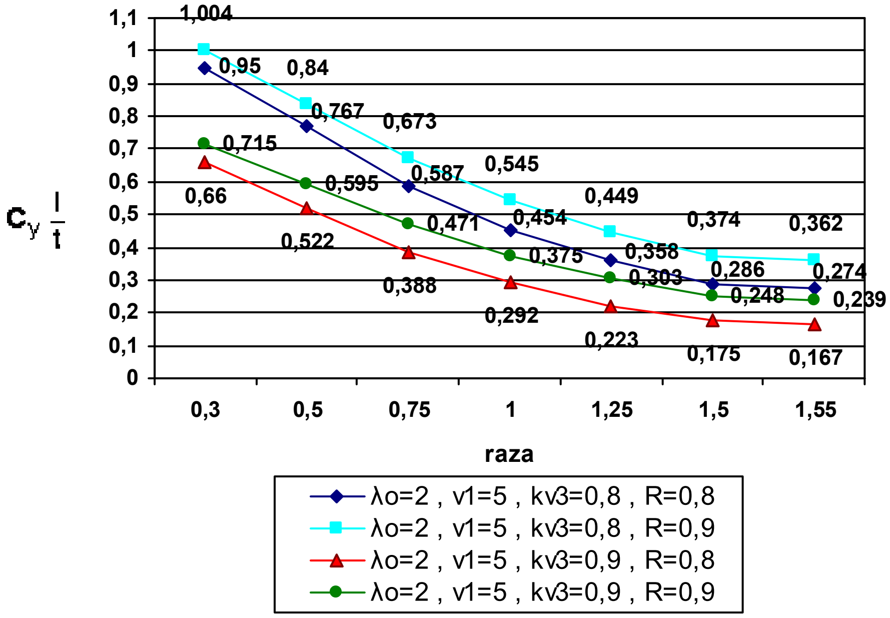

Fig. 1. Overlay graph 2/1 - $C_y l/t = f(r)$

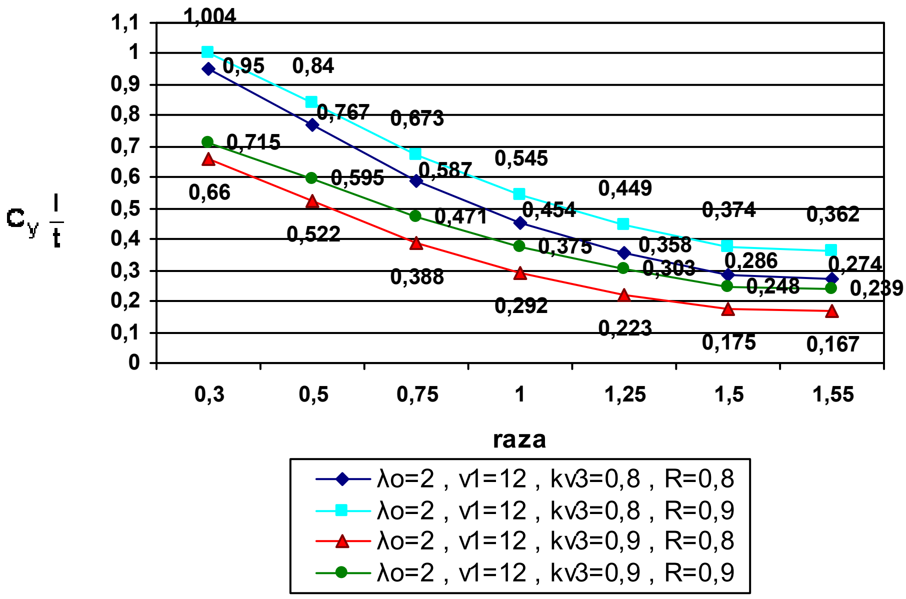

Fig. 2. Overlay graph 2/2 - $C_y l/t = f(r)$

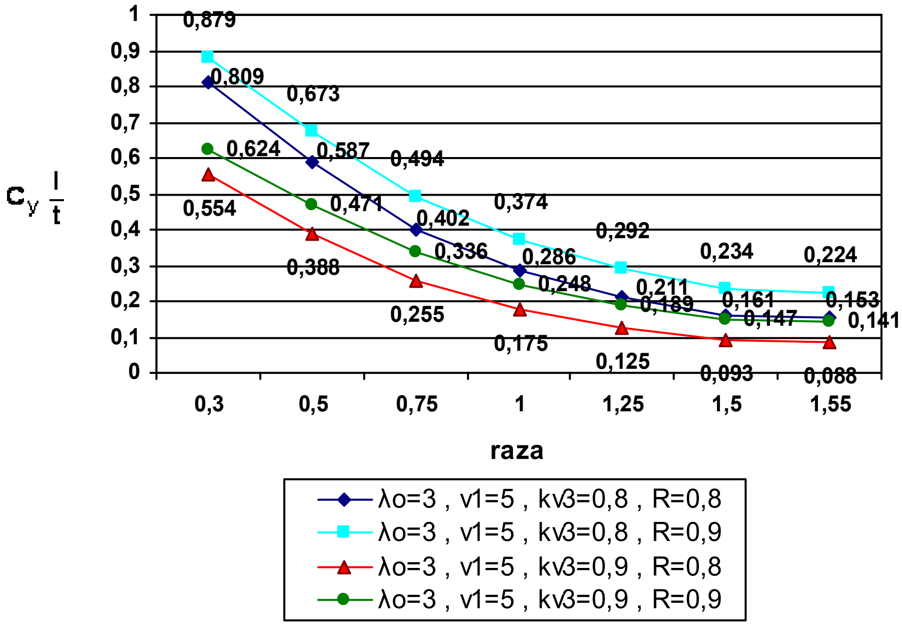

Fig. 3. Overlay graph 2/3 - $C_y l/t = f(r)$

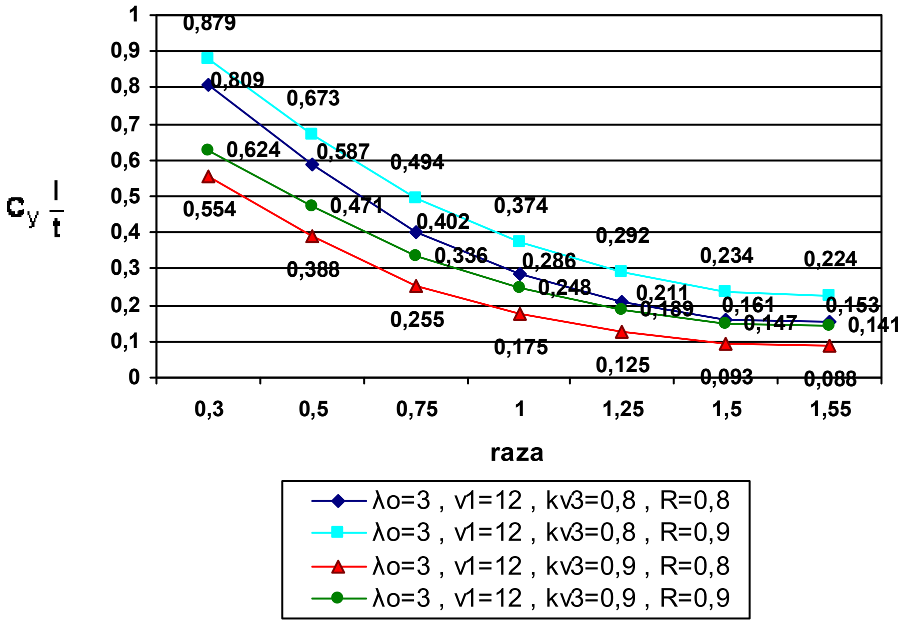

Fig. 4. Overlay graph 2/4 - $C_y l/t = f(r)$

CONCLUSIONS

The k_{v_3} increasing coefficient demand lower values of C_y l/t term. This means that an increase from 0.8 to 0.9 at the $\lambda_0 = 2$ value will allow for a reduction of required bearing areas to the ratio 0.66 / 0.95 hub, and 0.239 / 0.361 at periphery. The influence of the speed goes in the same way: the faster velocities the lower bearing areas are.

Following this calculation we may observe that for C_{Pmax} values in two situations:

- Variant 1 ip. Betz - λ0 = 2, one obtains for $C_{Pmax} = 0.595$
- Variant 2 ip. Betz - λ0 = 3, one obtains for $C_{Pmax} = 0.647$..

These parameters were calculated to be compared with the variants further studied on identifying the impact of the degree of reaction on C_{Pmax} power coefficient.

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