CALCULATION OF AERODYNAMICAL EFFICIENCY AND OF THE POWER AT THE LEVEL OF THE BLADES AND THE AXLE OF THE WIND TURBINE

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Abstract
This paper outlines the calculation of aerodynamical and average efficiency of the wind turbine, as well as the calculation of powers at the level of the blades and the axle of the turbine. We make an assessment of the turbine performances based on calculations of the geometry of the blade profile. The values used in the mathematical calculation have been taken from the design calculations of the turbine.

Key words: wind turbine, aerodynamical efficiency, power at the axle of the turbine, power at the level of the blades.,

INTRODUCTION

In order to make an appreciation, in terms of energy, of the performances of the turbine, based on the calculations characteristic of the geometry of the blade profile, we calculate the aerodynamical efficiency and the average efficiency, as well as the calculation of power at the level of the blades and the axle. The power at the axle P_{axle} is a chief component of the wind systems and is yielded by the multiplication of the power absorbed by the turbine and its aerodynamical efficiency. Taking into consideration that the wind turbine is integrated into a structure that is supposed to turn wind power to account, it is necessary to mention the level of power for which the calculations are made.

MATERIAL AND METHODS

1. The calculation of the aerodynamical efficiency: $Rand = 1 - \frac{tg\,\theta}{tg\,\beta_\infty}$
2. The calculation of the average efficiency: $Rand_{mediu} = \frac{\sum(\Delta P \cdot Rand)}{(P_t)_{total}}$

We have used the values determined from the kinematical calculation of turbine design, where the values used have been taken from a variant which was chosen as solution.

3. The calculation ofpower at the level of the blades: $P_{paletaj} = (P_t)_{total} \cdot \eta_{aerod}$

The values used for the calculation of power in blades($P_{paletaj}$) are$(P_t)_{total}$ = 8723,03, and the values for the aerodynamical efficiency have been previously determined.

4. The calculation of power at the axle: $P_{arbore} = P_{paletaj} - P_{pm}$ $(z = 5/6)$

This relation describes the power at the axle, where $P_{paletaj}$ has been previously determined, and the mechanically lost power (P_{pm}) depends on the power lost in the bearings and the loss in the disc. $P_{pm} = P_{pd} + P_{pl}$

5. The calculation of efficiency at the level of the axle:

$$\text{Rand}_{arb} = \frac{P_{arb}}{(P_t)_{total}}$$

RESULTS AND DISCUSSION

1) The calculation of the aerodynamical efficiency:

a) <u>Aerodynamical efficiency</u> (z=5/6)

$$\text{Rand} = \frac{\Delta T_{total}}{\Delta T_P} = \frac{C_y \sin\beta_\infty - C_x \cos\beta_\infty}{C_y \sin\beta_\infty} = 1 - \frac{C_x / C_y}{\text{tg}\,\beta_\infty}$$

$$\frac{C_x}{C_y} = \text{tg}\theta \qquad \text{Rand} = 1 - \frac{\text{tg}\,\theta}{\text{tg}\,\beta_\infty}$$

Obs.: Values C_x and C_y, respectively angle β_∞, which have been used in the calculation of efficiency, have beed determined analytically in the design calculations of the turbine.

Variant 4424 (9)	0,990	0,986	0,982	0,977	0,972	0,967	0,966
Variant 4415 (9)	0,992	0,990	0,987	0,982	0,979	0,975	0,975

Through the insertion of these results, because of the variation of the profile type along the blade, we obtain the following values of the aerodynamical efficiency:

effic_{aerod}	0,990	0,986	0,982	0,977	0,979	0,975	0,975

2. The calculation of average efficiency:

b) Average efficiency (z=5/6)

For the calculation of the average efficiency we have used the values determined through the kinematical calculation from the variant chosen as solution, where the calculation values are as follows:

$\Delta P = f(r)$	103,22	569,37	1225,75	1893,63	2596,72	1988,51	345,84

$(P_t)_{total}$ = 8723,03; Effic. – are the values determined above under a)

$$Rand_{mediu} = \frac{\sum(\Delta P \cdot Rand)}{(P_t)_{total}}$$

Variant 4424 (9)	0,975
Variant 4415 (9)	0,980

Obs.: Because of the variation of the profile type along the blade we can make a mediation of the average efficiency as one single final value: $effic_{aver}$ = 0,9775

3. Calculation of power at the level of the blades:

c) Calculation of power $P_{paletaj} = (P_t)_{total} \cdot \eta_{aerod}$

The values used for the calculation of power at the level of the blades ($P_{paletaj}$) are as follows: $(P_t)_{total}$ = 8723,03, and the values for the aerodynamical efficiency have been previously determined.

The results can be seen in the following table:

Variant 4424 (9)	8634,37	8604,90	8568,05	8526,21	8480,80	8436,60	8427,73
Variant 4415 (9)	8656,61	8632,39	8606,49	8569,62	8538,28	8506,10	8500,97

Through the insertion of these results, because of the variation of the profile type along the blade, we obtain the following values of power at the level of the blades:

$P_{paletaj}$	8634,37	8604,90	8568,05	8526,21	8538,28	8506,10	8500,97

4. Calculation of power at the axle:

d) Calculation of the power at the axle

$$P_{arbore} = P_{paletaj} - P_{pm}\ (z = 5/6);$$

This relation describes the power at the axle, where $P_{paletaj}$ has been previously determined, and the mechanically lost power (P_{pm}) depends on the power lost in the bearings and the loss in the disc. The mathematical formulae for the calculation of the mechanically lost power are presented in the following relations:

$$P_{pm} = P_{pd} + P_{pl}$$

d – disc
l – bearing

- $P_{pd} = M \cdot \omega$; where $M = C_M \cdot \rho \cdot \omega^2 \cdot \frac{R^5}{2}$

$C_M = 0{,}01$

$\rho =$ 1,225 kg/m^3

n = 250 rot/min ; $\omega = \frac{2\pi n}{60}$ [rad/s]

R = 0,23 m

We obtain *power loss in the disc* value $P_{pd} = 0{,}0027$, where the values used in the mathematical calculations have been taken from the design calculation of the turbine.

- $P_{pl} = M_{f_r} \omega$; where $\omega = \frac{2\pi n}{60}$ [rad/s]; n = 250 rot/min

$G = m \cdot g$

$F_{f_r} = \mu \cdot m \cdot g$

$M_{f_r} = \mu \cdot m \cdot g \cdot r_1$

where g = 9,81 m/s^2;

m = 545 kg;

μ = 0,01;

r_1 = 0,14 m;

Power loss in the bearings has the calculation value $P_{pl} = 195{,}957$.

The values used in the mathematical calculation have been taken from the design calculations of the turbine.

Finally, we obtain the following values for the mechanically lost power:

$$P_{pm} = 0{,}0027 + 195{,}957 = 195{,}96$$

$$P_{arbore} = P_{paletaj} - P_{pm}:$$

Variant 4424 (9)	8438,41	8408,94	8372,09	8330,25	8284,84	8240,64	8231,77
Variant 4415 (9)	8460,65	8436,43	8410,53	8373,66	8342,32	8310,14	8305,01

Through the insertion of these results, because of the variation of the profile type along the blade, we obtain the following values of power at the level of the axle:

P_{arbore}	8438,41	8408,94	8372,09	8330,25	8342,32	8310,14	8305,01

5. Calculation of efficiency at the axle of the turbine:

$$P_{arbore} = P_{paletaj} - P_{pm}$$

Finally, the calculation of efficiency at the axle of the turbine is yielded through the relation:

$$Rand_{arb} = \frac{P_{arb}}{(P_t)_{total}}$$

$Effic_{blades}$:

Variant 4424 (9)	0,967	0,964	0,960	0,955	0,950	0,945	0,944
Variant 4415 (9)	0,970	0,967	0,964	0,960	0,956	0,953	0,952

Through the insertion of these results, because of the variation of the profile type along the blade, we obtain the following values of power at the level of the axle:

$Effic_{blad}$	0,967	0,964	0,960	0,955	0,956	0,953	0,952

CONCLUSIONS

1. Following this calculation, because of the variation of the profile type along the blade, we obtain the following values of the aerodynamical efficiency:

$effic_{aerod}$	0,990	0,986	0,982	0,977	0,979	0,975	0,975

2. Because of the variation of the profile type along the blade we can make a mediation of the average efficiency as one single final value: $effic_{aver}$ = 0,9775

3. Because of the variation of the profile type along the blade, we obtain the following values of power at the level of the blades:

$P_{paletaj}$	8634,37	8604,90	8568,05	8526,21	8538,28	8506,10	8500,97

4. Through the insertion of these results, because of the variation of the profile type along the blade, we obtain the following values of power at the level of the axle:

P_{arbore}	8438,41	8408,94	8372,09	8330,25	8342,32	8310,14	8305,01

5. Through the insertion of these results, because of the variation of the profile type along the blade, we obtain the following values of efficiency at the level of the axle:

$Rand_{arb}$	0,967	0,964	0,960	0,955	0,956	0,953	0,952

It can be noticed that we have obtained elevated values of efficiency, both aerodynamically and at the level of the axle of the turbine, values which are similar to the results published internationally.

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