Nedelcu D., Campian C.V.

Determine The Correlation Between Wicket Gates Angles and Servomotors Strokes

The paper presents a description of the wicket gates kinematics calculated by Microstation Software and offer comparative experimental and theoretical results.

1. Introduction

The Kaplan turbine is a machine with double adjustment of the discharge: the adjustment of the wicket gates opening "a_o" from a maximal value to the complete closing and the adjustment of the runner blades angle "φ" around the zero design position in a range of $-20^o \div +20^o$. The adjustment of the wicket gates and runner blades position is made by servomotors and kinematics mecanism. Figure 1 presents on overview of a Kaplan hydraulic turbine, drawn with Micostation CAD software.

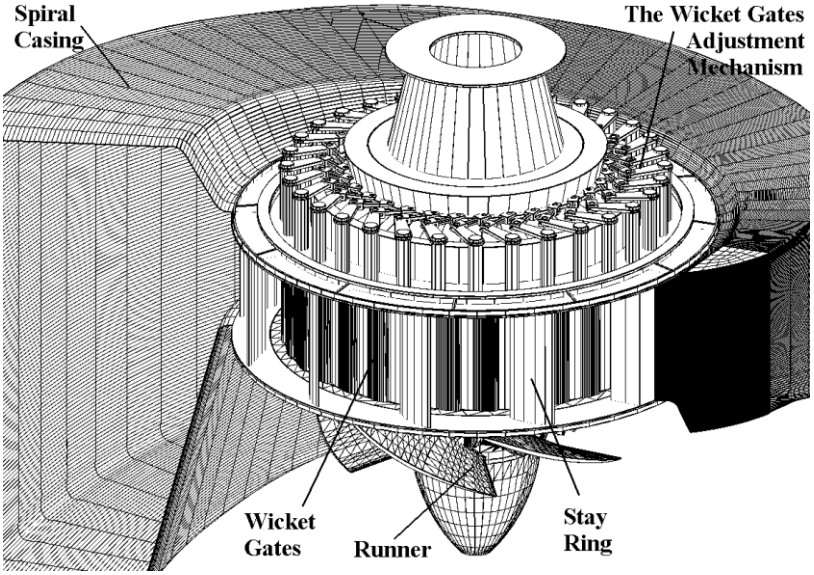

Figure 1. Overview of a Kaplan hydraulic turbine.

The adjustment of the wicket gates is made by two servomotors fixed on the spiral casing and an adjustment mechanism composed from gates, lever, link and discharge ring. The following theoretical and experimental correlation are determined for the kinematics of the wicket gates:

$$a_o = f(\alpha) \quad ; \quad a_o = f(S_{AD}) \quad ; \quad S_{AD} = f(\alpha), \text{ where:}$$

- a_o [mm] – the opening of the wicket gates, defined by the maximum diameter value of the circle which pas between two adjacent gates, fig. 4;
- α [grade] – the rotation angle of the blade gates, the 0^o value is for complete closing position, when the profile chord form the angle δ with tangent line to the characteristic diameter of the wicket gates D_o, fig. 3, , fig. 4;
- S_{AD} [mm] – the stroke of the wicket gates servomotors, fig. 4.

For theoretical determination of these correlation, the values of the main dimensions are needed:

- the theoretical symmetrical profile contour of the wicket gates, fig. 2;
- the characteristic diameter of the wicket gates D_o;
- the diameter of the bolt's link disposition on the adjustment ring D_c;
- the diameter of the bolt's servomotors disposition D_y;
- the length of the lever L_b;
- the length of the link L_C;
- the rigid angle between the chord of the gates profile and the lever α_R;
- the maximum stroke of the servomotors S_{ADmax}.

These dimension are shown in figure 4.

2. Correlation $a_o = f(\alpha)$

The calculus and graphical representations were made with Microstation CAD software, for 3 variant: wicket gates with 20, 24 and 32 blade number, following the purpose to obtain analitical formula for $a_o = f(\alpha)$ correlation.

We will consider the relative adimensional value of the opening of the wicket gates, described by relation (1):

$$a_{or} = \frac{a_o}{D_o}, \tag{1}$$

We assume that $a_{or} = f(\alpha)$ correlation is a unique function, for a given number of blade number.

The method for determine the correlation $a_{or} = f(\alpha)$ of the wicket gates has the following algorithm:

- the placement of the symmetrical profile (fig. 2) of the wicket gates on the characteristic diameter D_o;
- the calculus of the complete closing position of the wicket gates, fig. 3;
- the rotation of the gates at the imposed angle α, fig. 4;
- the determine of the wicket gates opening a_o, for each imposed angle α, fig. 4.
- the calculus of the value a_{or}.

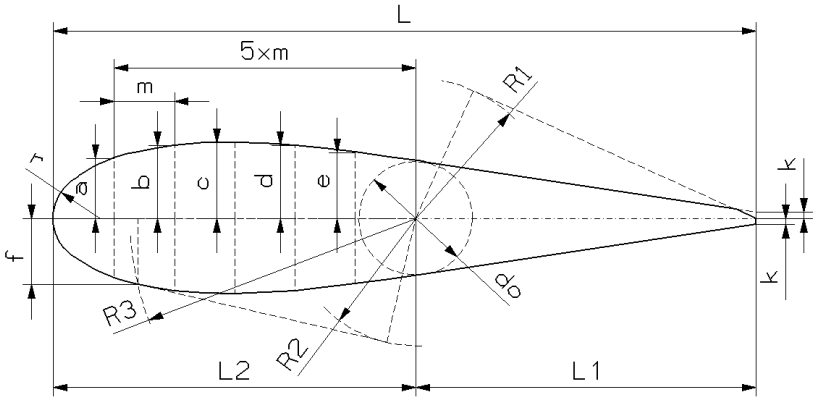

Figure 2. The theoretical symmetrical contour profile of wicket gates.

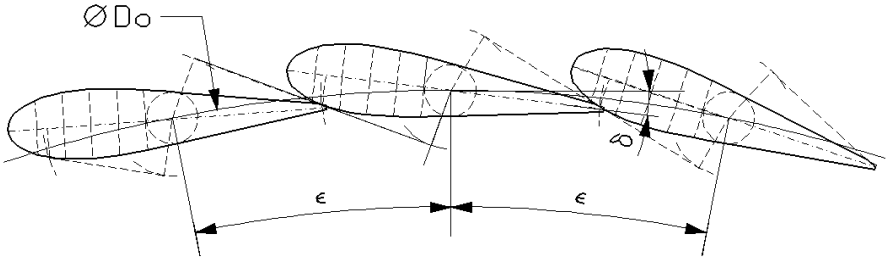

Figure 3. The closing position of the wicket gates.

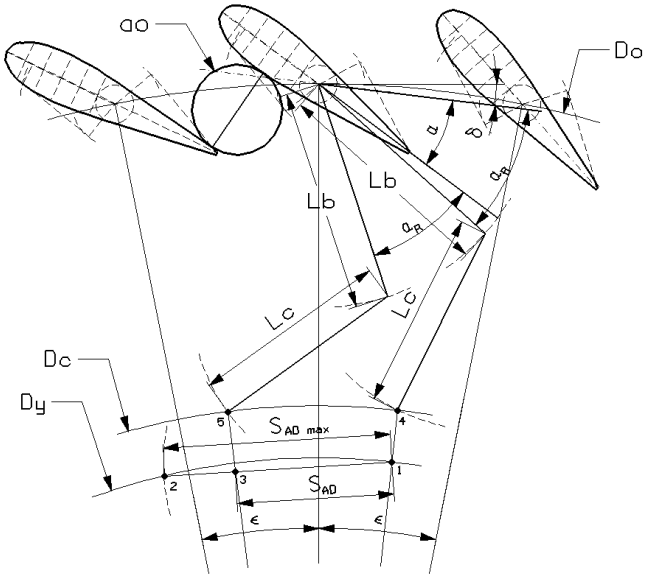

Figure 4. The position of the wicket gates for α.

The final results is presented numerically in table 1 and graphically in fig. 5 and fig. 6. The values $\mathbf{a_{or}}$ were scaled with 1000 coefficient by the numerical reasons.

Table 1

α [°]	1000xa_{or}			α [°]	1000xa_{or}		
	20 blade	**24 blade**	**32 blade**		**20 blade**	**24 blade**	**32 blade**
0	0.00	0.00	0.00	**38**	82.41	69.79	
2	4.75	4.02		**40**	86.01	72.87	55.28
4	9.41	7.97		**42**	89.51	75.84	
5			7.59	**44**	92.88	78.69	
6	14.07	11.89		**45**			60.48
8	18.68	15.83		**46**	96.14	81.41	
10	23.32	19.74	15.04	**48**	99.26	84.00	63.32
12	27.93	23.63		**50**	102.24	86.46	65.08
14	32.50	27.48		**52**		88.79	
15			22.38	**54**		90.97	
16	37.02	31.30		**56**		93.02	
18	41.49	35.08		**58**		94.92	
20	45.91	38.81	29.54	**60**		96.68	72.30
22	50.26	42.50		**62**		98.30	
24	54.56	46.13		**64**		99.75	
25			36.50	**65**			74.87
26	58.78	49.71		**66**		101.05	
28	62.93	53.22		**68**		102.21	
30	67.00	56.68	43.20	**70**		103.21	76.79
32	70.99	60.07		**72**		104.05	
34	74.89	63.39		**75**			78.01
35			49.50	**80**			78.67
36	78.70	66.63					

The values form table 1 were interpolated by polinomial function and the following formulas was generated:

- for 20 blade and symmetrical profiles of wicket gates :

$$a_o = \left(-0.00886213 \cdot \alpha^2 + 2.51220224 \cdot \alpha - 0.059412698\right) \cdot \frac{D_o}{1000} \qquad (2)$$

- for 24 blade and symmetrical profiles of wicket gates:

$$a_o = (-0.00011338 \cdot \alpha^3 + 0.00093687 \cdot \alpha^2 + 1.96274441 \cdot \alpha + 0.088119) \cdot \frac{D_o}{1000} \qquad (3)$$

- for 32 blade and symmetrical profiles of wicket gates

$$a_o = (-0.000072 \cdot \alpha^3 - 0.00135269 \cdot \alpha^2 + 1.55026681 \cdot \alpha - 0.16024079) \cdot \frac{D_o}{1000} \quad (4)$$

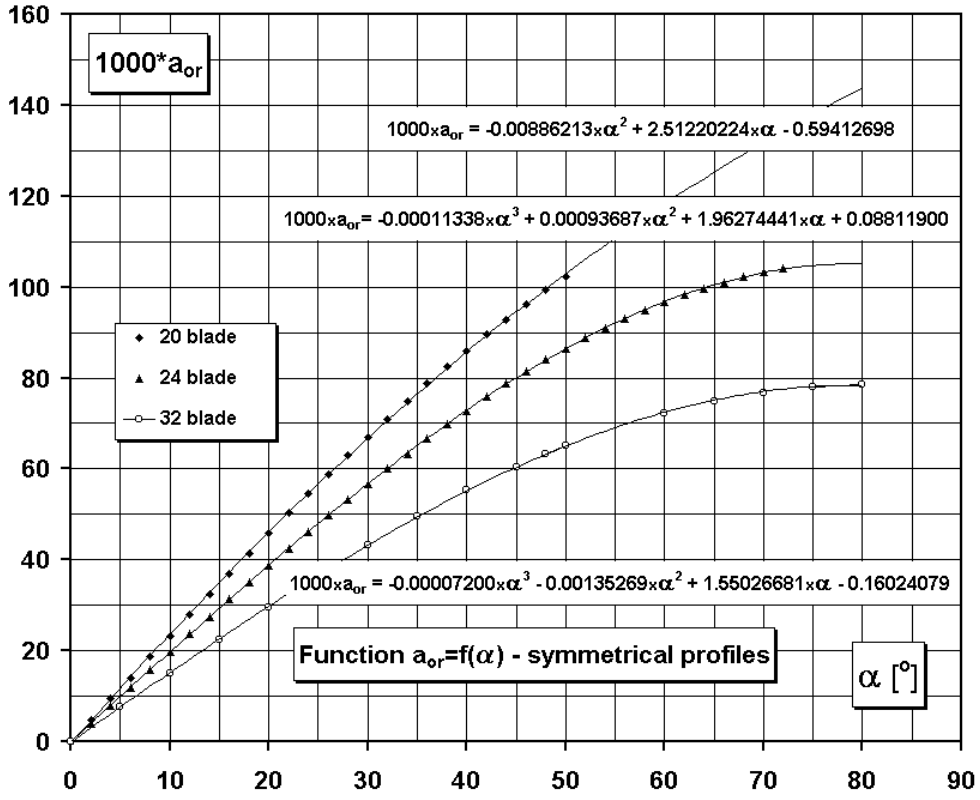

Figure 5. The correlation a_{or} = f (α), for 20,24 and 32 wicket gates blade number.

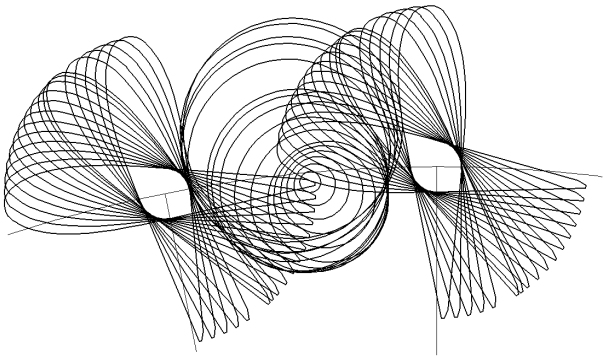

Figure 6. The wicket gates blade successive position.

The formulas (2), (3) and (4) give a quick method for calculus of the wicket gates opening $\mathbf{a_o}$ as a function of the rotation angle of the wicket gates blade α, for 20, 24 and 32 wicket gates blade number and symmetrical profiles.

3. Wicket Gates Kinematics

The calculus and graphical representations were made with Microstation CAD software, for one particular case of hydroelectric power plant, following the purpose to obtain the curves: $S_{AD} = f(\alpha)$ and finally $a_o = f(S_{AD})$. The algorithm from &2 is continued with the calculus of the servomotor stroke S_{AD}, for each imposed angle α. The value S_{AD} is defined as a distance between point 1 and point 3, on the direction of $S_{AD\ max}$ segment, fig. 4. Point 1 is obtained at the closing position of the wicket gates.

Fig. 7 and 8 shows the graphical correlation, compared with experimental results measured in the power station with 32 wicket gates blade number and table 2 shows numerical results. The results were presented adimensionally.

Table 2

α [°]	a_{or} 32 palete	S_{AD}/D_o	
		Experiment	**Microstation**
0	0	0	0
5	7.5909	0.0188	0.0190
10	15.0355	0.0335	0.0329
15	22.3782	0.0456	0.0448
20	29.5427	0.0562	0.0556
25	36.5045	0.0661	0.0656
30	43.1973	0.0756	0.0752
35	49.5018	0.0850	0.0843
40	55.2782	0.0940	0.0930
45	60.4836	0.1021	0.1013
48	63.3155	0.1063	0.1061

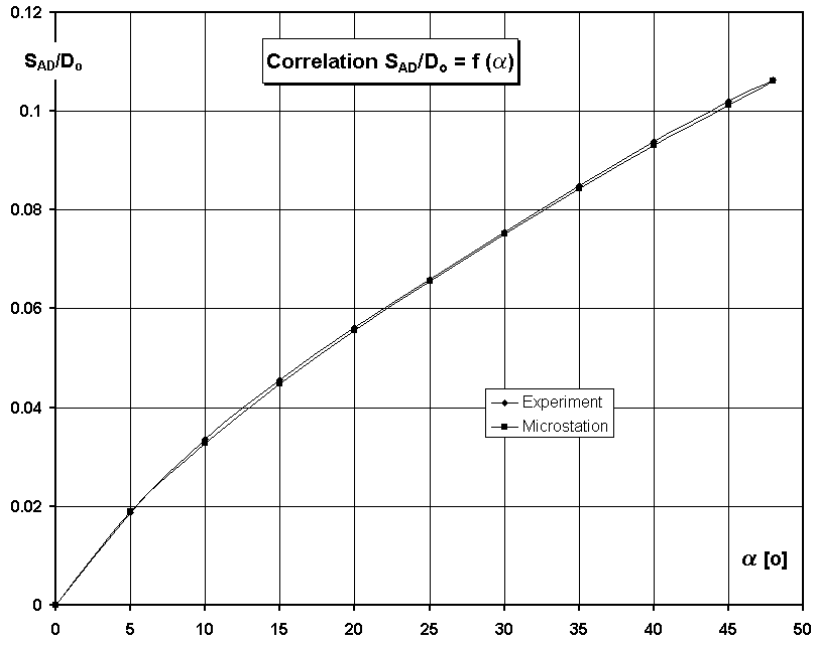

Figure 7. The comparison between theoretical and experimental correlation S_{AD}/D_o= f (α).

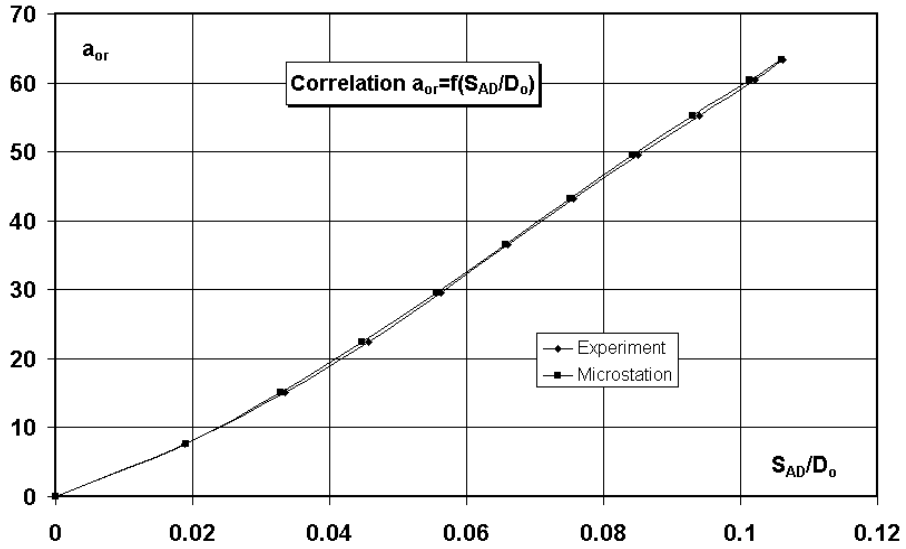

Figure 8. The comparison between theoretical and experimental correlation a_{or}= f (S_{AD}/D_o).

4. Conclusion

The paper describe the algorithm used for theoretical calculus of the kinematics of the wicket gates correlation: $a_o = f(\alpha)$; $a_o = f(S_{AD})$; $S_{AD} = f(\alpha)$ and propose analytical formulas for $a_o = f(\alpha)$ correlation, applicable to 20, 24, 32 wicket gates blade number and symmetrical profiles. Also, present numerical results compared with experimental values.

The CAD software offers the precision and the tools necessary to determine theoretical correlation for the wicket gates kinematics.

References

[1] ********** "International standard. Field acceptance test to determine the hydraulic performance of hydraulic turbines, storage pumps and pump – turbines.", IEC 41, Third Edition, 1991 – 11

- Prof.Dr. Constantin Viorel Câmpian, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, v.campian@uem.ro
- Dr. Dorian Nedelcu, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, d.nedelcu@uem.ro