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Effect of additional cylinders on power-extraction performance of a Savonius vertical-axis wind turbine

Yangyang YAN, Jintao ZHANG, Junao SHE, Wenhao LIU, Jianghong DENG, Jianyang ZHU

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Physical model

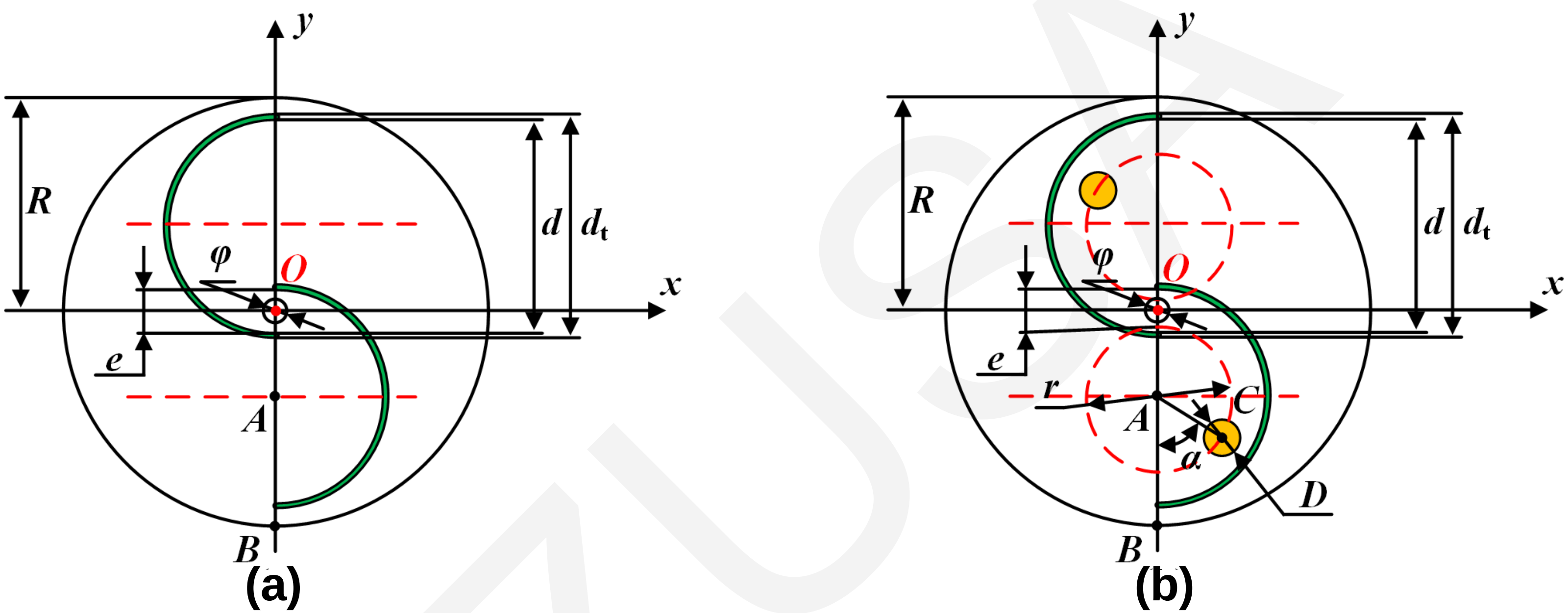

Fig. 1. Top view of wind-turbine structure of (a) a conventional S-VAWT (b) a S-VAWT with additional cylinders.

Taguchi experimental design

Table 1 The factors and levels

Factors	Levels 1	2	3	4	5	6
D (mm)	10	20	30			
r (mm)	20	40	60			
α (°)	0	45	90	135	270	315

$$S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$$

The greater the signal-to-noise (S/N) ratio, the greater the average power coefficient of the wind turbine.

Table 2 Mixed orthogonal experiment array for $L_{18}(6^1\,3^2)$

Case number	α (°)	D (mm)	r (mm)
1	0	10	20
2	0	20	40
3	0	30	60
4	45	10	20
5	45	20	40
6	45	30	60
7	90	10	40
8	90	20	60
9	90	30	20
10	135	10	60
11	135	20	20
12	135	30	40
13	270	10	40
14	270	20	60
15	270	30	20
16	315	10	60
17	315	20	20
18	315	30	40

Taguchi experimental results

Table 3 Simulation results of Taguchi experiment

Case number	J (kg·m²)	$\overline{C_P}$	S/N(dB)	INCR(%)
1	0.003924	0.230993	-12.7280	14.1010
2	0.006316	0.216700	-13.2828	7.0408
3	0.012355	0.127529	-17.8878	-37.0059
4	0.003877	0.232567	-12.6690	14.8785
5	0.005945	0.220608	-13.1276	8.9712
6	0.011103	0.149655	-16.4982	-26.0765
7	0.003825	0.222237	-13.0637	9.7759
8	0.005445	0.210541	-13.5333	3.9985
9	0.006655	0.188856	-14.4774	-6.7129
10	0.003588	0.215407	-13.3348	6.4022
11	0.004364	0.189386	-14.4530	-6.4511
12	0.005174	0.145992	-16.7134	-27.8859
13	0.003825	0.210804	-13.5224	4.1285
14	0.005445	0.216272	-13.3000	6.8294
15	0.006655	0.172010	-15.2889	-15.0341
16	0.004260	0.219776	-13.1604	8.5603
17	0.005260	0.219198	-13.1833	8.2747
18	0.009205	0.227507	-12.8601	12.3791

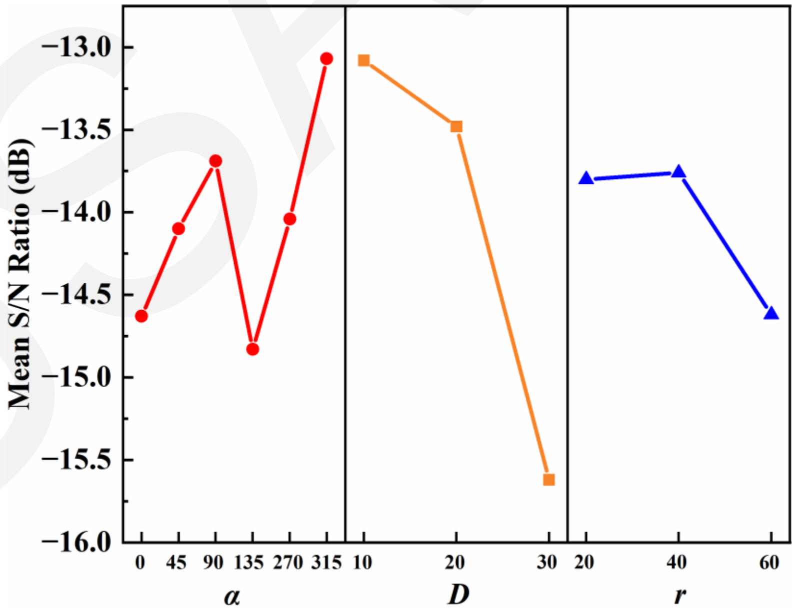

Fig. 2. The mean S/N ratio of various factors at different levels.

Performance comparison

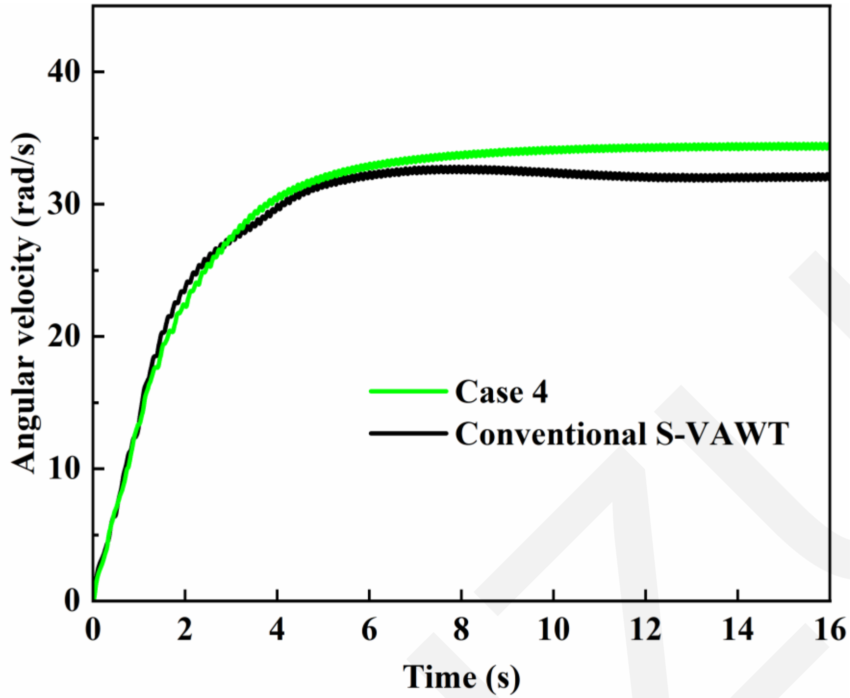

Fig. 3. The angular velocity with time of Case 4 and a conventional S-VAWT.

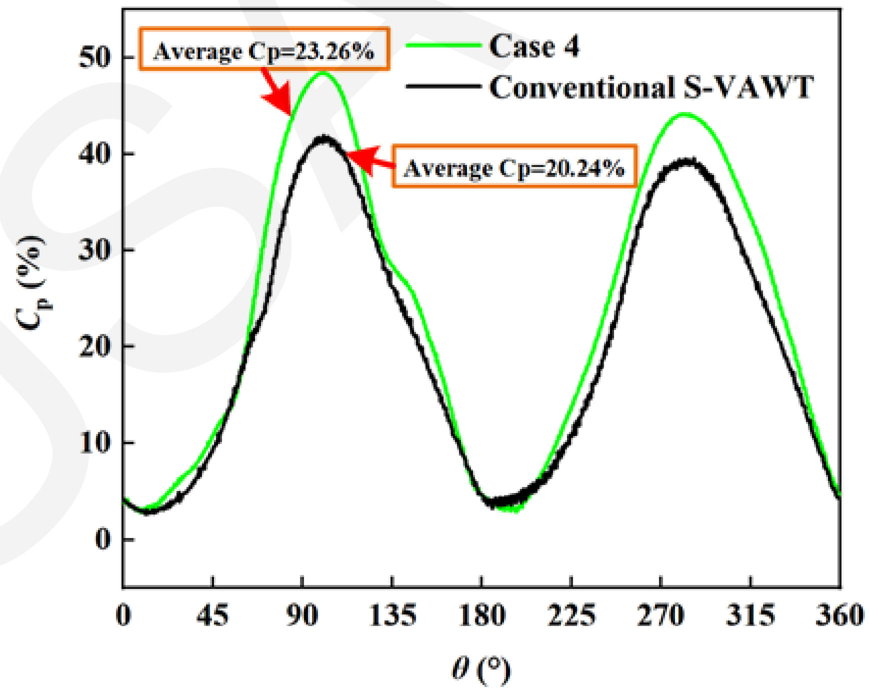

Fig. 4. The power coefficients of a single cycle for Case 4 and a con-ventional S-VAWT.

pressure contours

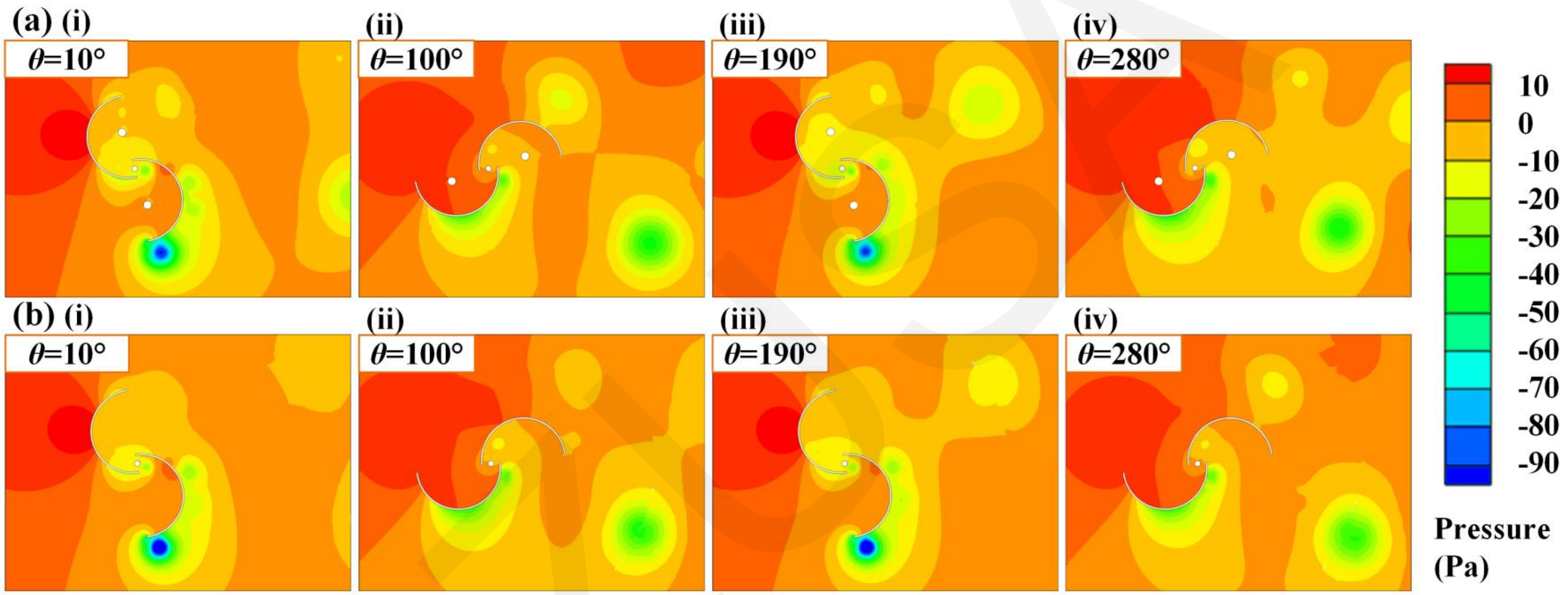

Fig. 5. Comparison of pressure contours between Case 4 and a conventional S-VAWT at θ = 10°, θ = 100°, θ = 190°, and θ = 280° (a) Case 4 (b) Conventional S-VAWT.

Experimentation

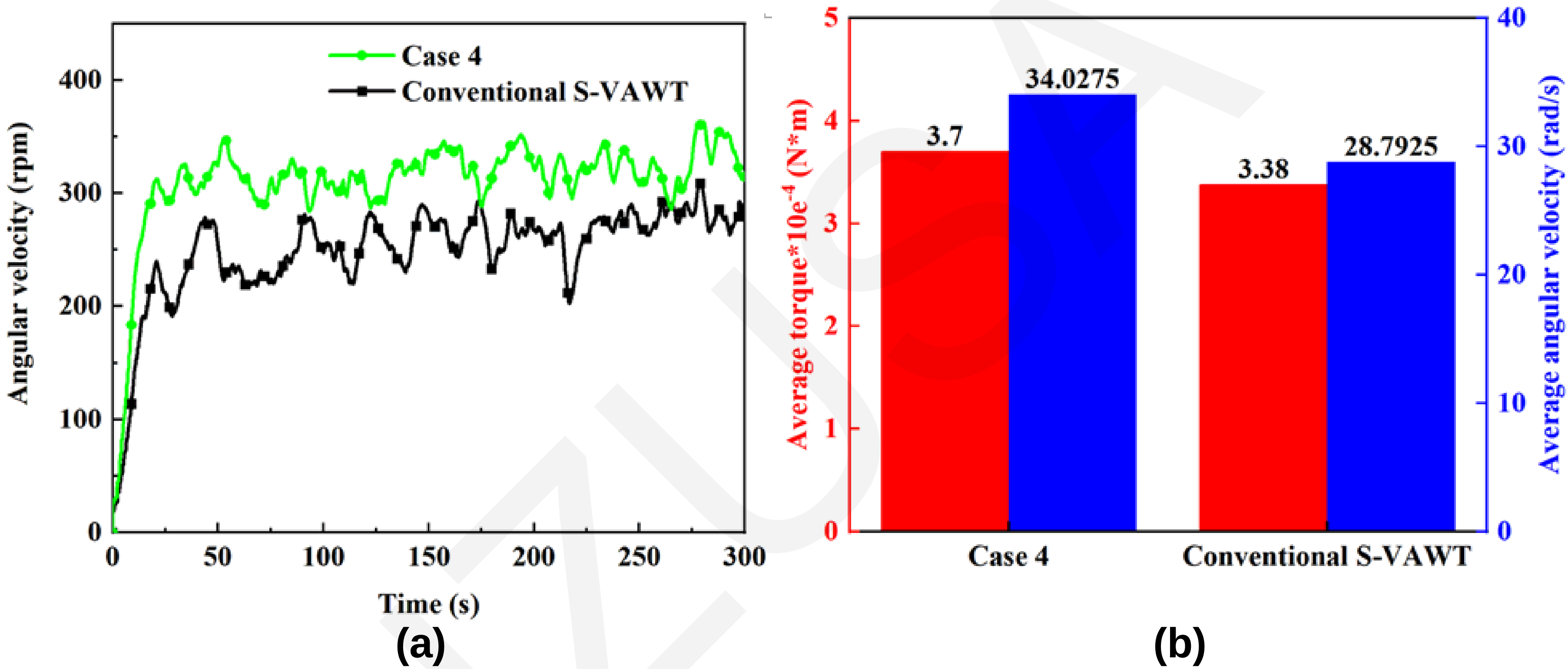

Fig. 6. Comparison of the conventional S-VAWT and Case 4 (a) angular velocity (b) average torque and average angular velocity in the range of 200s – 300s.

Conclusions

- When α = 45°, D = 10 mm, and r = 20 mm, compared with the conventional S-VAWT, the average torque coefficient and average power coefficient of the S-VAWT with additional cylinders are about 7% and 15% higher, respectively.
- The influence of three characteristic parameters of the S-VAWT with additional cylinders on the average power coefficient is ranked as $D > \alpha > r$.
- The main reason for the better average power coefficient of the S-VAWT with additional cylinders is that they accelerate the shedding speed of the vortex.
- Compared with a conventional S-VAWT, the output power was 8% higher for an S-VAWT with additional cylinders under the same particular conditions, which is consistent with the simulation results.