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Energy Procedia 16 (2012) 651 – 655
Energy Procedia

2012 International Conference on Future Energy, Environment, and Materials

Hydraulic Characteristic of Cooling Tower Francis Turbine with Different Spiral Casing and Stay Ring

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Abstract

Cooling tower Francis turbine stands between heat exchanger and sprayer of cooling water system in cooling tower, so the level dimension of spiral casing is small and the flow rate coefficient is high to 1.42. Its flow rate limits to cooling water discharge, output to fan, and head to energy-saving of cooling water system, so its specific speed is very low, hydraulic loss of spiral casing and stay ring is high to reduce hydraulic efficiency of water turbine. To increase the hydraulic efficiency, a pump casing and stay ring with no stay vane is designed. Through CFD simulation and test, hydraulic efficiency of water turbine with that spiral casing and stay ring is improved to 5%, hydraulic loss of casing and stay ring reduces from 13.7% to 3.41%, hydraulic loss of runner increases from 7.93% to 11.57%, and simulation result coincides with test. If that spiral casing and stay ring links to runner with no angle of blade attack, hydraulic loss of runner is about 7% and hydraulic efficiency reaches to 82%.

Key words: cooling tower; hydraulic turbine; hydraulic characteristic; spiral casing and stay ring

1. Introduction

Francis turbine replaces the motor to run the fan, so that saves energy of motor and its output equals to output of fan. Driven by energy-saving of recycling water [1], the head and flow rate of turbine is lower than surplus energy and discharge of recycling water separately. Exactly, the rotating speed, output and head is separately the power of 1, 3 and 2 [2]. Standing in tower, the level dimension of spiral casing of that turbine limits to the tower diameter, shown on Fig. 1. This special work environment makes this water turbine have a very low special speed, being about 50 m.kW. The geometry parameters is similar [3],

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1876-6102 © 2011 Published by Elsevier B.V. Selection and/or peer-review under responsibility of International Materials Science Society .
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such as $D_1 / D_2 = 2$, $\beta_2 = 2\alpha_0$, and $\alpha_0 \approx 13^0$. And guide vane is canceled, shown on Fig. 2. The hydraulic characteristic is common too. For example, the hydraulic loss of stay ring reaches to 14%, calculated by hydraulic loss theory of blade cascades [4], and the loss of spiral casing is about 5%, computed by hydraulic loss of circle pipe, and those are much higher than normal hydraulic turbine one.

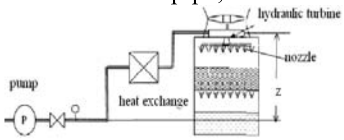

Fig.1. water recycle system

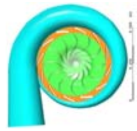

Fig.2. computing geometry

To decrease hydraulic loss of stay ring, a new spiral casing section and a stay ring with no stay vanes is designed for a hydraulic turbine with a 50 m.kW special speed. CFD is used to simulate the flow to calculate their hydraulic loss and efficiency.

Nomenclature

Q	computing discharge, m^3/s
n	rotating speed, r/min
H	computing head, m
H_{test}	test head, m
P	output, kW
η_h	hydraulic efficiency of water turbine, %
η_t	test efficiency of water turbine, %
h_{sp}	relative hydraulic loss of spiral casing, %
h_{sr}	relative hydraulic loss of stay ring, %
h_r	relative hydraulic loss of runner, %
h_d	relative hydraulic loss of draft tube, %
v_u	circumferential velocity, m/s
φ	nose angle of spiral casing, °

2. Spiral casing section and stay ring introduction

The new spiral casing section and stay ring is shown on Fig. 3(a). The traditional spiral casing section and stay ring does on Fig. 3(b). The traditional spiral casing section is circle section, and stay ring has stay vanes, recorded by No. a. The new spiral casing section is integral section similar to pump's, and stay ring has no stay vane, recorded by No. b. To make up circulation formed by stay vane, the section of new spiral casing is smaller than traditional one to generate more circulation.

Fig. 3. (a) new spiral casing and stay ring; (b) traditional spiral casing and stay ring

The other flow passages are same. Their parameters are following. The rated discharge equals $0.139m^3/s$. The rotation speed does 240r/min. The diameter of runner does 0.42m. The height of guide vane does 0.042m. The blade number is 12 and its aerofoil does single.

3. Simulation model and boundary

The Navier-Stokes equations and standard κ-ε turbulent closed model are applied to simulate flow of water turbine [5, 6]. The computing geometry is shown on Fig.2, including spiral casing, stay ring, runner and draft cube. The total mesh is 1,100,000. Basing on hydraulic characteristics of this turbine [7], for example, output and head all are functions of discharge, an alone operation condition with rated discharge is chosen to be a computing operation condition. Then, the spiral casing inlet flow is $0.139m^3/s$. The draft outlet pressure is zero. The rotating runner runs at 240 r/min speed.

4. Simulation result

By simulating the flow and analyzing the hydraulic characteristic [8], some results are given, shown on table 1 and Fig. 4-6.

Table 1 Computing results of the water turbine with different spiral casing and stay ring

No.	Q	n	H	H_{test}	h_{sp}	h_{sr}	h_r	h_d	P	η_h	η_t
a	0.139	240	7.44	-	5.32	13.70	7.93	0.97	7.30	72.08	-
b	0.139	240	7.31	7.5	5.93	3.41	11.57	1.3	7.76	77.80	75.21

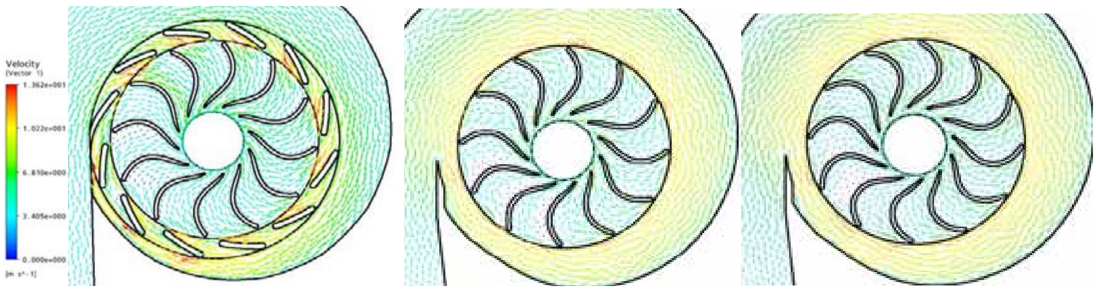

Fig. 4. (a) old spiral casing and stay ring; (b) new spiral casing and stay ring; (c) new spiral casing, stay ring and runner

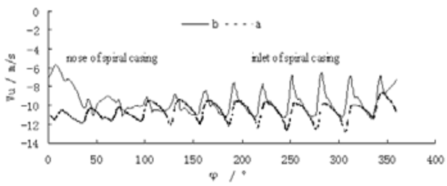

Fig.5. circumferential velocity on runner inlet

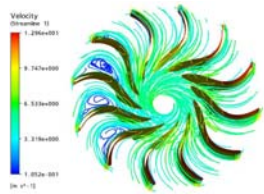

Fig.6. stream line on runner with new spiral and stay ring

4.1. Hydraulic loss analysis

From table 1, hydraulic loss of spiral casing, stay ring, runner and draft tube can be concluded separately.

Hydraulic losses of two spiral-casings are all above 5.3%, because of high velocity. To place turbine in the cooling tower, spiral casing's level dimension is shorten and its section is designed to be smaller. Those dimension and small section result in high velocity coefficient of spiral-casing to produce the high loss. The smaller section of new spiral casing increases velocity to 13.6m/s to a little higher hydraulic loss, shown on Fig. 4.

The hydraulic loss of new stay ring is 3.41%, being lower 10.29% than the loss of stay ring with stay vanes, because the stay vane obstructs flow to increase losses of friction and attack.

The hydraulic loss of the runner with new spiral casing and stay ring is 11.57%, higher 3.64% than the loss of the old runner, caused by three reasons. First, the old stay ring with stay vanes betters the flow of runner. Second, new stay ring with no stay vane improves circulation to increase more loss of attack on runner, shown on Fig. 5. Third, the nose of new spiral casing worsens seriously the runner flow near downstream of that nose. Three blade passages vortex appears, shown on Fig. 6.

In order to decrease loss of attack on runner with new spiral casing and stay ring, a new runner with no angle of attack is designed and simulation result is listed on table 2, numbered by No. c. No. c water turbine makes the total hydraulic efficiency to reach 81.77%, about higher 10% than No. a turbine. The hydraulic of No. c runner is about same to the loss of No. a one. The loss of No. c stay ring is about same to the loss of No. b one. But the loss of spiral casing is higher than the loss of No. a or No. b one.

Table 2 Computing result of the water turbine with different runner

No.	Q	n	H	h_{sp}	h_{sr}	h_r	h_d	P	η_h
b	0.139	240	7.31	5.93	3.41	11.57	1.3	7.76	77.80
c	0.139	240	7.01	6.28	3.26	7.63	1.06	7.82	81.77

4.2. Hydraulic characteristic analysis

From table 1 and table 2, some hydraulic characteristic can be drawn.

The No. a turbine needs 7.44 meter head to produce 7.30 kW output to drive the fan. The No. b turbine does 7.31 meter head to generate 7.76 kW output to drive the fan. The No. c turbine does 7.01 meter head to bring 7.82kW output to drive the fan. Namely, for one fan, lower head can drive fan and save more cycling water energy, if settle No. c water turbine.

The head of No. b water turbine is 7.31 meter, lower 0.19 meter than test head. The hydraulic efficiency of simulation is higher 2.6% than that of test, because of volume and mechanical losses. So simulation result is reliable. The No. c water turbine can be used to improve hydraulic efficiency and the efficiency will be higher 10% than No. a water turbine.

4.3. Flow analysis

From Fig. 4(a), the flow of spiral casing but nose is smooth. The bad flow near nose leads to high loss and deteriorates downstream flow, including stay ring and runner flow. The velocity between stay vanes and near the inlet of stay vanes is high to cause wake of stay vane to result in high loss.

Fig. 4(b) shows the velocity on new spiral casing and stay ring. Canceling stay vanes, spiral casing must produce more circulation to drive the runner. The smaller spiral casing section produce more circumferential velocity that reaches 10.68m/s, higher 1.23 m/s than No. a spiral casing, shown on Fig. 5. That circumferential velocity increases the angle of attack on runner to cause more hydraulic loss. Since the special stay vane near the nose of spiral casing doesn’t extend to stay ring, the blade vortex occurs down nose, shown on Fig. 6. If renew runner blade angle, the better runner flow decreases more hydraulic loss and blade vortex, shown on Fig. 4(c). So, it is important to better flow of stay ring. To do that, enlarge the section near nose of spiral casing and settle better special stay vane, shorten the length of stay vane, even cancel stay vane.

5. Conclusion

From the above analysis, some conclusion can be drawn. First, new spiral casing and stay vane with no stay vane can decrease hydraulic loss itself to 3.42%, lower 10% than common spiral casing and stay ring with stay vane. Second, better flow on spiral casing and stay ring can decrease hydraulic loss, so decreasing stay vane numbers, even cancelling, can benefit hydraulic efficiency if the stay ring’s structure is enough strong. Third, optimizing spiral casing, stay ring and runner together can increase hydraulic efficiency. Fourth, good special stay vane near nose of stay ring, and large section near nose can be used to better flow.

References

[1] Chen Yingxin．Save energy renovation for electric fans of mechanical ventilation cooling tower[J]．Petrochemical Industry Technology.2008，29(1)：41-43．(In Chinese)

[2] Li Yanpin, Nan Haipeng, Chen Dexin. Study on regulation characteristics of special turbine-fan unit in cooling tower[J]. Journal of hydroelectric engineering. 2011，30(3)：187-190．(In Chinese)

[3] Li Yanpin, Wang Kai, Nan Haipen, etc.The Approximate Calculation of the Flow Capacity of Special Turbine in Cooling Tower[J]. Journal of Xi’an University of Technolog.2011，27(1):79-82．(In Chinese)

[4] Guo Qisheng,Qian Hanxin, Peng Guoyi,etc. hydraulic losses model of the diversion components of hydraulic turbine[J].Shuili Xuebao.1996,(10):56-60．(In Chinese)

[5] Launder.N.G.,Spalding D.B.. The Numerical Computation of Turbulent Flows. Computer Methods in Applied Mechanics and Engineering，1974，(3):269-289

[6] Menter, F. R... Two equation eddy-viscosity turbulence models for engineering applications [J]. AIAA-Journal, 1994, 32(8):1598-1605

[7]Li Yanpin, Nan Haipeng, Chen Dexin. Performance and type selection of special hydraulic turbine in cooling tower[J]. Journal of hydroelectric engineering. 2011，42(2):39-43,73．(In Chinese)

[8] Zhang Lanjin, Wang Zhengwei, Chang Jinshi. Flow of Pump-turbine on S-shaped Region of Complete Characteristics. Nongye Jixie Xuebao.2011，42(1):39-43,73．(In Chinese)