International Journal of Offshore and Polar Engineering
Vol. 10, No. 2, June 2000 (ISSN 1053-5381)

Guide Vanes Effect of Wells Turbine for Wave Power Generator

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ABSTRACT

Guide vanes are installed in the Wells turbine in order to improve its efficiency, self-rotating characteristics and off design performance with stall. This work attempts to explain the role of these guide vanes on the basis of momentum theory. It is shown that the upstream vanes are more effective in enhancing efficiency than the downstream ones. A design method for guide vanes is suggested based on experimental data and potential theory. Experimental studies carried out by the authors do confirm the theory proposed.

NOMENCLATURE

A : section area of annulus passage $=\pi R_t^2(1-\nu^2)$
C_D : drag coefficient
C_L : lift coefficient
C_T : torque coefficient $=T/(\rho U_t^2 A R_t/2)$
C_{T0} : torque coefficient without guide vanes
F_θ : tangential force
P : pressure drop across rotor
P_W : output power
Q : flow rate $=A\,V_a$
Re : Reynolds number
R_t : tip radius of rotor
R_{RMS} : root mean square of radius from hub to tip $=R_t\sqrt{(1+\nu^2)/2}$
S_{RG} : axial spacing between rotor and guide vanes
T : torque
U : rotor blade speed
U_{RMS} : rotor blade speed at R_{RMS}
U_t : rotor blade speed at tip
V : absolute velocity
V_a : axial velocity
W : relative velocity
α : angle of attack
β : inlet or outlet angle in absolute field
η : turbine efficiency $=T\,\omega/(\Delta P\,Q)$
η_0 : efficiency without guide vanes
η_B : efficiency with guide vanes installed at both sides
η_D : efficiency with downstream guide vane
η_U : efficiency with upstream guide vane
θ : camber angle
ν : hub-to-tip ratio
ξ : stagger angle
ρ : density of air
σ : solidity
ϕ : flow coefficient $=V_a/U$
ψ : pressure drop coefficient $=\Delta P/(\rho\,U^2/2)$
ψ_{RMS} : pressure drop coefficient at R_{RMS}
ω : angular velocity
ΔP : stagnation pressure drop between plenum chambers
ΔP_0 : stagnation pressure drop without guide vanes
ΔW : tangential velocity at outlet of rotor without guide vanes
$\Delta\beta$: outlet angle of rotor without guide vanes

Subscripts
θ : tangential
0 : without guide vane
1 : inlet
2 : outlet

INTRODUCTION

A Wells turbine is of the axial flow type and is mainly used by wave energy devices employing an oscillating water column. It drives its unidirectional rotational motion from the reciprocating airflow caused by the wave motion and in this sense it is known as self-rectifying. Guide vanes are used to enhance the performance of the Wells turbine and improve its efficiency and self-starting capability. There have been many studies on efficiency and other features of the guide vanes. These bring out that the downstream guide vane is effective for self-starting (Inoue et al., 1985) and that the upstream guide vane is more effective than the downstream one from efficiency and stall considerations (Arakawa et al., 1987; Setoguchi et al., 1998). In addition, Suzuki and Arakawa (1996) found that the number of guide vane blades has a significant effect on the turbine performance.

Regarding the design of the Wells turbine, one of the approaches has been to use a general formulation of the momentum theory (Grant et al., 1981; Sturge, 1977). On the other hand, Gato and Falcao (1990) use a 2-dimensional potential theory and a flow-through method based on streamline curvature. A shortcoming of these approaches has been that they cannot reveal the role of the guide vanes nor the corresponding physics. It was thought that the primary effect of the guide vanes was to recover the kinetic energy in the swirl induced by rotor blades in the downstream. From this point of view it is desirable to have only the downstream guide vane installed. But the Wells turbine does require that both upstream and downstream guide vanes be installed, as the 2 sides need to be symmetrical to operate in an oscillating airflow. The effects of an upstream guide vane have also been examined in some investigations.

The present work realizes that the upstream guide vane is more

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Received July 3, 1999; revised manuscript received by the editors January 21, 2000. The original version (prior to the final revised manuscript) was presented at the Ninth International Offshore and Polar Engineering Conference (ISOPE-99), Brest, France, May 30-June 4, 1999.
KEY WORDS: Wells turbine, guide vane, wave energy converter, wave power generator, fluid machinery, ocean engineering.