Lift of a Rotating Circular Cylinder in Unsteady Flows

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ABSTRACT

A cylinder rotating in steady current experiences a lift known as the Magnus effect. In the present study the effect of waves on the Magnus effect has been investigated. This situation is experienced with the novel floating offshore vertical axis wind turbine (VAWT) concept called the DEEPWIND concept, which incorporates a rotating spar buoy and thereby utilizes seawater as a roller-bearing. The a priori assumption and the results suggest that the lift in waves, to a first approximation, may be represented by a formulation similar to the well-known Morison formulation. The force coefficients are experimentally found to primarily depend on the ratio between the surface speed of the cylinder and the outer flow velocity.

KEY WORDS: Rotating cylinder, waves; lift; Magnus effect; floating vertical axis wind turbine; DEEPWIND concept.

INTRODUCTION

The DEEPWIND project is a collaborative research project on future deep sea wind turbine technologies which is partially funded by the European Commission (EC) through the 7th Framework Programme (FP7). The DEEPWIND concept was described in Vita et al. (2009) and is illustrated in Fig. 1. It consists of a VAWT (i.e. Darrieus rotor) as the energy capturing device rigidly fixed on top of a long upright tube connected to the seabed with mooring lines. The submerged part of the tube acts as a rotating spar buoy and utilizes seawater as a roller-bearing instead of having a main bearing between the rotor and the support structure. This solution solves some of the structural problems experienced by VAWT in the past. A correct description of all forces on the rotating spar buoy is paramount in order to be able to simulate the proposed wind turbine concept and to assess the performance.

The flow around the rotating spar buoy may be broken down into two classical topics within hydrodynamics: (1) flow around a circular cylinder in current and waves; and (2) circular cylinder with rotation in steady current. The flow around a circular cylinder in current and waves exerts a resultant in-line force (drag) and cross-flow force (lift) on the cylinder; see e.g. Sumer and Fredsøe (1997). Cylinder diameter, surface roughness and inclination all influence the resultant force as well as current speed and wave motion. A rotating cylinder in steady current experiences an additional force perpendicular to the motion (lift) known as the Magnus effect; see e.g. Batchelor (1967), Hoerner and Borst (1975). Furthermore, the wall shear stress on the cylinder surface exerts a resultant friction opposite the cylinder rotation. Theodorsen and Kegier (1945) give a detailed account of revolving cylinders in stagnant fluid.

![Artist's illustration of the DEEPWIND concept](image-url)