Design and parametric performance of a rotating helical coil pump

V.J.MODI* and A.NOURBAKSH**
 Department of Mechanical Engineering
 The University of British Columbia
 Vancouver, B.C., Canada V6T 1Z4

ABSTRACT

Parametric performance of a helical coil pump, developed for operation in conjunction with wind turbines for farm irrigation, is studied experimentally. The results suggest rather promising behaviour with a wide variety of applications ranging from pumping water to chemical transport and fire-fighting. Economic considerations as well as the simplicity of design, operation and maintenance make the system particularly attractive.

KEYWORDS

Helical pump, irrigation, wind energy

NOMENCLATURE

d	=	diameter of the tube	ω	=	angular speed
D	=	base diameter of the drum, 2R	θ	=	inclination of the shaft
L	=	length of the drum	ϕ_a	=	air intake angle
n	=	number of turns	ϕ_w	=	water intake angle
p	=	pitch of the coil	γ	=	drum divergence angle

* Professor, Fellow ASME, AIAA; presently visiting Professor, Institute of Space and Astronautical Science, 3-1-1 Sagamihara, Kanagawa, Japan 229

** Visiting Professor, Tehran University, Tehran, Iran

INTRODUCTION

The concept of helical or coil type devices for generating mechanical effort dates back to the days of Archimedes (287-212 B.C.) and Leonardo da Vinci (1452-1519 A.D.). The design of a rotating coil pump was reported in the Encyclopedia of Arts and Science in 1745 and was credited to a Swiss scientist in Zurich named Andrew Wirtz. The concept seems to have remained essentially dormant until the preliminary study at the Civil Engineering Department of the Loughborough University in 1979 and reported later in the Journal of the Chartered Mechanical Engineer of the U.K. [1].

The design and performance evaluation of a wind energy operated irrigation system, for use in rural environment, has been in progress at the University of British Columbia for more than a decade (FIGURE 1). A number of Savonius rotor models have been tested systematically to arrive at an optimum blade configuration [2-4]. A prototype has been designed and field tested under a variety of wind conditions. A boundary element based numerical method has also been developed to predict the rotor performance [5, 6].

Together with the design of the Savonius wind turbine, the attention was also focused on the development of a simple, inexpensive, yet efficient pump, which may be suitable for farm application. To that end, the concept of helical pump appeared to be quite attractive.

The paper describes in some details design of the helical pump whose performance is governed by a large number of parameters as apparent from FIGURE 2. Of course, in addition, operation of the pump will be governed by the flow rate (Q) and the head (H), which will also depend on the fluid characteristics, i.e. density and viscosity, together with the internal roughness of the tube.

TEST ARRANGEMENT

A simple analysis provided the dimensionless Pi-numbers governing the pump performance. This helped in planning the tests to assess their effect on the pump operation. The test arrangement is schematically shown in FIGURE 3. Essentially it con-

sists of a Plexiglas tank, which served as a reservoir for pumping water from, with the helical coil pump installed in it. The pump itself comprises of a polyethylene tube, of desired size, wound around a drum and driven by a variable speed 1.5 H.P. d.c. motor. The arrangement provides desired control of the system variables, over a range, including those associated with the tube diameter, pitch, rpm, and intake angles. The pumped water is either raised to a desired head before return to the reservoir or delivered to a separate pressurized tank located at the ground level. A system of regulators permit directing of the flow as desired and taps help monitor pressure in the line.

RESULTS AND DISCUSSION

As can be expected, the amount of information obtained through a planned variation of system parameters is literally enormous. For conciseness, only a small sample of typical results, useful in establishing trends, is presented here.

Effect of the coil pitch, i.e. the number of helical coil turns, on the dimensionless head coefficient is presented in FIGURE 4 as a function of the intake angle ratio ϕ_w/ϕ_a . It is apparent that doubling the number of turns, i.e. halving the pitch, roughly doubles the discharge head. On the other hand, the flow rate was found to be essentially independent of the pitch (FIGURE 5). Note, in general, the flow rate increases with a larger value of the water intake angle ϕ_w . This is clearly indicated in FIGURE 6. The water to air angle ratio represents the volume fraction of water to air in one complete coil. The flow rate peaks at 45 rpm in the present operating condition followed by a stall. Based on similar results it can be concluded that an increase in tube diameter results in higher Q .

CONCLUDING REMARKS

The helical coil pump represents a rather simple and economical device for delivery of liquids. Through an appropriate design and selection of operating conditions, the desired performance in terms of head and flow rate can be achieved. It is particularly suited for irrigation of farms with the power derived from wind energy. As it pumps both liquid and gaseous phases simultaneously, the receiving tank can be pressurized and used as a propulsive force to at-

tain a higher head, thus eliminating construction of a costly elevated tank. Furthermore, in conjunction with water and carbon dioxide, it can be used, rather effectively, for fire-fighting operations.

ACKNOWLEDGEMENT

The investigation reported here was supported by the Natural Sciences and Engineering Research Council of Canada, Grant No. A-2181.

REFERENCES

1. Martin, J.H. and Annable, R.J., Rotating coil pump. Chartered Mech. Engrs., 1981, **28**, 43-4.
2. Modi, V.J., Fernando, M.S.U.K. and Roth, N.J., Model and prototype performance of a Savonius rotor based irrigation system. Proc. Euro Wind Energy Conf., Ed.: W. Palz, H.S. Stephens and Associates Publisher, London, 1984, 740-5.
3. Modi, V.J., Roth, N.J. and Fernando, M.S.U.K., Optimum configuration studies and prototype design of a wind-energy-operated irrigation system. J. Wind Engg. and Indust. Aero., 1984, **16**, 85-96.
4. Modi, V.J. and Fernando, M.S.U.K., On the performance of the Savonius wind turbine. Trans. of the ASME, J. Solar Energy, 1989, **111**, 71-81.
5. Fernando, M.S.U.K. and Modi, V.J., A numerical analysis of the unsteady flow past a Savonius wind turbine. J. Wind Engg. and Indust. Aero., 1989, **32**, 303-27.
6. Fernando, M.S.U.K. and Modi, V.J., A numerical analysis of the unsteady flow past bluff bodies. Computational Mechanics, 1990, **6**, 11-34.

Figure 1. Schematic diagram of the wind-energy operated irrigation system. The project aims at replacement of a conventional commercially available centrifugal, axial flow or similar pump with a simple, inexpensive helical coil type device.

Figure 2. Geometric parameters associated with the helical coil pump which affect its performance.

Figure 3 Test arrangement showing the oil pump with its drive system, flow regulators, reservoir and the flow receiving tank. System parameters, such as the rpm(N), head(H), number of turns(n), and water/air input angles were systematically varied to evaluate the pump performance.

Figure 4 Variation of the head parameter with the pitch and water/air input angle ratio.

Figure 5 Effect of the input angle ratio on the flow rate. Note, an increase in the number of turns does not affect the discharge but increases the head for a given N .

Figure 6 Plots showing the variation of the discharge rate with the pump rpm for two values of the water/air intake ratio.