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DESIGN AND PERFORMANCE OF WIND DRIVEN RECIPROCATING LIFT PUMPS

BY

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بسم الله الرحمن الرحيم

PREFACE.

This thesis is submitted to Ain Shams University for the degree of Ph.D. in Mechanical Engineering. The work included in this thesis was carried out by the author at the laboratory of fluid mechanics, Mechanical Engineering Department, Reading University in the U.K.

No part of this thesis has been submitted for a degree or qualification at any other university or institution.

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ABSTRACT.

Experimental and theoretical investigations were carried out on a specially designed reciprocating wind pump. The tests were performed using an electric motor as a pump driver. The study was concerned with two main topics in particular, the first one regarding the design and testing of a piston pump with hydro-dynamic (non-contact) seals; for better performance of the pump and for minimizing the rate of maintenance due to wear and tear. The second topic was concerned with the design and testing of a spring valve with the aim of reducing the pump starting torque.

Regarding the first topic, some preliminary tests were run in order to get the best dimensions and shape of seals which offer the minimum leakage flow. Then, the designed seals were manufactured around the piston outer surface with two different clearances; one of them was 1.25 mm and the other was 0.69 mm.

The pump was tested under different values of static head and rotational speed. The results showed that although having the mentioned clearances which may increase the leakage flow, more benefits were obtained such as increasing the speed at which the pump will begin delivering water (depending on the static head). Also, it reduces the peak force required to drive the pump by about 50%. At the same time, the pump is still having a relatively good overall efficiency reaching about 50% at 40 rpm when working against

a static head of 1.0 bar.

A theoretical model was built to simulate the experimental results. An excellent agreement between them was obtained at different seal clearances and static heads.

Concerning the second point, a spring valve was designed and tested using the same reciprocating pump indicated before. The tests were run at different static heads and pump rotational speeds.

The results showed that, at a low speed (around 8 rpm), regardless of the static head, the spring valve delays the valve closure about half the stroke. In other words, this delay leads to reduction of the starting torque.

Furthermore, two theoretical models were designed one for the floating valve designed by the Dutch (CWD) and the second for the newly designed spring valve. These two models were built in order to understand the valve behavior and also to compare between the two types of valves. The obtained results showed that the valve closes at about middle of the stroke when the pump runs at 8 rpm. The same result was found experimentally which indicates a remarkable agreement between the theoretical and experimental results.

CONTENTS.

CHAPTER (3). Theoretical work.

CHAPTER (4). Experimental equipments.

NOMENCLATURES.

A	: Cross section area	m^2
a	: Acceleration.	m/sec^2
A_r	: Rotor area.	m^2
A_p	: Piston cross section area.	m^2
A_v	: Valve area.	m^2
B	: Blade pitch	mm
C_d	: Drag coefficient.	
C_g	: Gap flow coefficient.	
C_p	: Power coefficient.	
C_{p_o}	: Maximum power coefficient.	
C_f	: Force coefficient.	
C_T	: Torque coefficient.	
$C_{non-st.}$	: Non-steady force coefficient.	
D	: Pump diameter.	m
D_v	: Valve diameter.	m
d	: Pump rod diameter.	m
F	: Static force.	N
F_b	: Buoyancy force.	N
F_{total}	: Total force.	N
F_f	: Friction force.	N
g	: Gravitational acceleration.	m/sec^2
H	: Water static head.	m
h	: Valve gap height.	mm
K	: Spring stiffness.	N/mm
K_L	: Blade velocity coefficient.	

L	:	Piston length.	m
M	:	Mass.	Kg
n	:	Rotational speed.	rps
N	:	Rotational speed.	rpm
N_{sd}	:	Sommerfeld number.	
P	:	Power.	Watt
P_h	:	Hydraulic power.	Watt
Q	:	Discharge.	m^3/sec
Q_i	:	Ideal discharge.	m^3/sec
$Q_{act.}$	:	Actual discharge.	m^3/sec
Q_{total}	:	Total discharge.	m^3/sec
Q_{net}	:	Net discharge.	m^3/sec
Q_L	:	Leakage discharge.	m^3/sec
R	:	Crank radius.	mm
R_n	:	Reynolds number.	
S	:	Pump stroke.	mm
T	:	Torque.	N.m
T_{av}	:	Average torque.	N.m
T_i	:	Ideal torque.	N.m
T_s	:	Starting torque.	N.m
T_n	:	Normal torque.	N.m
t	:	Time.	Sec
U	:	Volume.	m^3
U_s	:	Stroke volume.	m^3
U_v	:	Valve volume.	m^3
V	:	Velocity.	m/sec
V_d	:	Design wind velocity.	m/sec
V_g	:	Flow velocity in the gap.	m/sec.