

DESIGN OF SELF-COMPENSATING NOZZLE FOR GATED IRRIGATION PIPES

By

MOHAMED EL-SAYED ABDEL-RAHMAN

B.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2000

M.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2005

**A thesis submitted in partial fulfillment
of
the requirements for the degree of**

**DOCTOR OF PHILOSOPHY
in
Agricultural Science
(Agricultural Mechanization)**

**Department of Agricultural Engineering
Faculty of Agriculture
Ain Shams University**

2010

Approval Sheet

**DESIGN OF SELF-COMPENSATING NOZZLE FOR
GATED IRRIGATION PIPES**

BY

MOHAMED EL-SAYED ABDEL-RAHMAN

B.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2000

M.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2005

This thesis for Ph. D. degree has been approved by:

Prof. Dr. Mohamed Youssif El-Ansary

Prof. Emeritus of Agric. Engineering, Faculty of Agriculture,
Benha University

Prof. Dr. Mahmoud Mohamed Hegazi

Prof. Emeritus of Agric. Engineering, Faculty of Agriculture, Ain
Shams University

Prof. Dr. Abdel-Ghany Mohamed El-Gindy

Prof. Emeritus of Agric. Engineering, Faculty of Agriculture, Ain
Shams University

Date of Examination: 22 /12 / 2009

DESIGN OF SELF-COMPENSATING NOZZLE FOR GATED IRRIGATION PIPES

By

MOHAMED EL-SAYED ABDEL-RAHMAN

B.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2000

M.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2005

Under the supervision of:

Dr. Abdel-Ghany Mohamed El-Gindy

Prof. Emeritus of Agricultural Engineering, Department of
Agricultural Engineering, Faculty of Agriculture, Ain Shams
University (Principal Supervisor)

Dr. Ahmed Mohamed Said El-Kot

Associate Research Prof. of Agricultural Engineering,
Department of Soil Conservation, Desert Research Center

Approval Sheet

**DESIGN OF SELF-COMPENSATING NOZZLE FOR
GATED IRRIGATION PIPES**

By

MOHAMED EL-SAYED ABDEL-RAHMAN

B.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2000

M.Sc. Agric. Sc. (Agric. Mechanization), Ain Shams University, 2005

This thesis for Ph. D. degree has been approved by:

Prof. Dr. Mohamed Youssif El-Ansary

Prof. Emeritus of Agric. Engineering, Faculty of Agriculture,
Benha University

Prof. Dr. Mahmoud Mohamed Hegazi

Prof. Emeritus of Agric. Engineering, Faculty of Agriculture, Ain
Shams University

Prof. Dr. Abdel-Ghany Mohamed El-Gindy

Prof. Emeritus of Agric. Engineering, Faculty of Agriculture, Ain
Shams University

Date of Examination: 22 / 12 / 2009

ACKNOWLEDGEMENTS

The author wishes to thank "**Allah**" for the completion of this work.

He further wishes to express his greatest appreciation and deepest gratitude to Prof. Dr. Abdel- Ghany M. El- Gindy, Prof. of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, for entrenching the principle of scientific research, for kind guidance, encouragement and providing all the required facilities.

Special thanks are due to Dr. Ahmed S. El-kot, Associate Research Professor of Agricultural Engineering, Soil Conservation Department, Desert Research Center, for his support and help to achieve this work.

Thanks to all who had helped to complete this research work.

ABSTRACT

Mohamed El-Sayed Abdel-Rahman: Design of Self-Compensating Nozzle for Gated Irrigation Pipes. Unpublished Ph. D. Thesis, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, 2010.

Gated irrigation pipe is an important tool for improving surface irrigation, its development depends on replacing the gates by designed self-compensating nozzle (poppet nozzle).

The main objective of this study was to improve the distribution uniformity of water discharge along the gated pipe length, by developing a newly designed and locally manufactured self-compensating nozzles (poppet nozzles), to take the place of the gates.

Laboratory experiments were conducted at the Hydraulic Laboratory of Agricultural Engineering Department, Faculty of Agriculture, Ain Shams University, to test and evaluate the hydraulic characteristics of a self-compensating nozzle (poppet nozzle). Three disc diameters (25, 27 and 29mm) were selected for testing under pressure head ranged between 0.33- 3.4 m.

Field experiments were conducted in a maize field at a private farm in Ismailia Government. The poppet nozzle (25mm diameter) was evaluated under operating pressure head 50, 100 and 150cm.

The main results of this study showed the following:

Under operating pressure head ranged between 33cm to 340cm (3.3 to 34 kPa), the mean discharge of poppet nozzle with disc diameters of 25, 27 and 29 mm were 0.63, 0.46 and 0.28 l/s, and the mean corresponding discharge coefficients (Cd) were 0.75, 0.79 and 0.9 respectively. Mean water discharge for 25mm disc diameter was constant (0.81l/s) in spite of pressure increasing as a next 10, 30 and 34kPa (100, 300 and 340cm) with mean flow (0.81l/s). While mean discharge for

27mm disc diameters was constant (0.48l/s) in spite of pressure increasing from 6.8, 30 to 33kPa (68, 300 and 330cm). Water flow through poppet nozzle with 29mm diameter was shutting at operating pressure 12kPa (120cm).

The mean discharge of poppet nozzles along the pipes with initial pressure head (0.5m, 1.0m and 1.5m) were 0.5, 0.56 and 0.64l/s, with mean coefficient of discharge (Cd) 0.77, 0.75 and 0.72 respectively,

For initial pressure of 0.5, 1.0 and 1.5m the uniformity coefficient were 99, 91.7 and 90.2%, and the manufacture coefficient of variation is 0.094, 0.12 and 0.065 respectively.

Crop yield values were 10.4 and 11.9Mgm /ha for maize grain and one green cut of clover yield crops respectively. The field water use efficiency for maize grain was 1.5 kg/m³, while it was 6.6 kg/m³ for one cut of clover.

Key Words: surface irrigation, gated pipes, poppet nozzle, pressure, uniformity, maize, clover

CONTENTS

	Page
LIST OF TABLES	iii
LIST OF FIGURS	iv
LIST OF SYMBOL	vi
I-INTRODUCTION	1
II-REVIEW OF LITERATURE	3
2-1- Modified surface irrigation systems	3
2-2- Gated irrigation pipes	3
2-3- Hydraulics of irrigation pipes	12
2-4- Controlling of gated irrigation pipes flow	15
2-5- Compressing helical spring	18
2-6- Crop yield corresponds to irrigation system	21
2-7- Economical considerations	22
III-MATERIALS AND METHODS	28
3-1- Experimental site	28
3-1-1- Hydraulic laboratory	28
3-1-2- Field experimental site	29
3-1-3-Irrigation system	30
3-2-Modification of gated irrigation pipes	30
3-2-1– Self-compensating nozzle design	31
3-2-2- Helical compression spring design	34
3-3–Maize and clover crops under poppet nozzle irrigation pipes	37
3-3-1– Soil preparation	37
3-3-2– Irrigation requirements	37

3-3-3– Fertilization program	39
3-4-Measurements and calculations	39
3-4-1- Hydraulic measurements	39
3-4-2–Crop measurements	43
3-4-3-Pumping energy requirements	43
3-4-4-Cost analysis	44
IV-RESULTS AND DISCUSSION	47
4-1- Laboratory experiments	
4-1-1- Flow rate for poppet nozzle with various operating pressure	47
4-1-2- Spring deflection for three disc diameter under operating pressure.	54
4-2- Flow rate for poppet nozzle with various operating pressure (Field experiments) :	54
4-2-1–Flow rate for poppet nozzle irrigation pipes	55
4-2-2– Flow rate for poppet nozzle under various operation pressure	61
4-3–Flow rate versus pressure, spring deflection and flow area	63
4-4–Crops yield under poppet nozzle irrigation pipe	63
4-5–Energy analysis	64
4-6-Cost analysis	65
V-SUMMARY	67
VI-REFERENCES	71
VII-APPENDICES	80
ARABIC SUMMARY	

LIST OF TABLES

Table. No.		Page
Table. (1)	physical properties of soil.	29
Table. (2)	chemical properties of soil.	30

Table. (3)	chemical properties of irrigation water.	30
Table. (4)	Calculated consumptive use (mm/day) of clover .	38
Table. (5)	Calculated consumptive use (mm/day) of maize.	39
Table. (6)	Manufacture coeffiecient of variation (MCV) values of nozzles according to AENRI-LOFTI-MASE Standard (2002) .	41
Table. (7)	Poppet nozzle discharge versus gated pipe discharge	50
Table. (8)	Hydraulic parameters for poppet nozzle under laboratory experiments.	53
Table. (9)	Hydraulic parameters for poppet nozzle under field experiments.	55
Table. (10)	Hydraulic parameters for poppet nozzle under field experiments.	57
Table. (11)	Pumping power, energy requirements, and energy applied efficiency for poppet nozzle irrigation pipes.	64
Table. (12)	Cost analysis for poppet nozzle irrigation systems.	66
Table. (13)	Some data about of poppet nozzle irrigation system and gated irrigation pipes.	82
Table. (14)	Operation hours of irrigation time of maize.	83

LIST OF FIGURS

Fig. No.		Page
Fig. (1)	Laboratory apparatus constructed for poppet nozzle experiments.	28
Fig. (2)	Isometric view for self-compensating nozzle body (poppet nozzle).	32
Fig. (3)	Side view for self-compensating nozzle body (poppet nozzle).	33
Fig. (4)	Relationship between spring deflection and the change of the flow area reduction.	34
Fig. (5)	Basic inside components of self-compensating nozzle.	36
Fig. (6)	Flow rate for disc diameters (25, 27 and 29mm) under operating pressure head.	49
Fig. (7)	Gates flow rate under various operating pressure head.	51
Fig. (8)	Poppet nozzle flow rate under various operating pressure head.	51
Fig. (9)	Disproportionate relationship between flow area and disc diameter (elevation view).	52
Fig. (10)	Spring deflection for three disc diameter under operating pressure	54
Fig. (11)	Deviation of poppet nozzle discharge (l/s) from the mean discharge at 50cm initial pressure head.	58
Fig. (12)	Deviation of poppet nozzle discharge (l/s) from the mean discharge at 100cm initial pressure head.	58
Fig. (13)	Deviation of poppet nozzle discharge (l/s) from the mean discharge at 150cm initial pressure head.	59
Fig. (14)	Poppet nozzle irrigation pipes at field.	60

Fig. (15)	Poppet nozzle irrigation pipes during irrigation operation.	60
Fig. (16)	Furrow irrigation system using poppet nozzle irrigation pipes.	61
Fig. (17)	Flow rate distribution pattern for nozzle on irrigation pipes under three initial operating pressures.	62
Fig. (18)	Operating pressure head along PN pipes.	62
Fig. (19)	Flow rate versus pressure, spring deflection and flow area.	63
Fig. (20)	Geometry dimensions for designed helical compression spring.	80
Fig. (21)	Measuring of helical spring deflection during field operation.	81
Fig. (22)	Pressure gauge as connected with poppet nozzle.	81

LIST OF SYMBOLS

SYMBOL	Definition
a	= Cross section of flow area (m^2),
A	= Characteristic frontal area of the body(mm^2),
Bp	= Break horse power (Hp),
b	= Factor of the orifice dimensions,
C	= Hazen-william's coefficient, for PVC 150,
C_d	= Discharge coefficient,
C_i	= Spring index,
D.C	= price after depreciation (LE),
D_c	= Drag coefficient,
d_d	= Disc diameter,(mm),
D_i	= Inside diameter of spring coil (mm),
D_m	= Mean diameter of spring (mm),
d_n	= Inside diameter for nozzle body,(mm),
D_w	= Spring wire diameter (mm),
E	= The overall efficiency, 55% for pump driven by internal combustion engine,
E_a	= Application efficiency, %.where 60% in modified furrow irrigation,
E.C	= Energy cost of diesel (LE/Hp),
E_i	= Total system efficiency,
E.L	= Expected life (year),
$E t_o$	= Potential evapotranspiration, $mm \text{ day}^{-1}$
F.C	= Fuel price (LE),
F	= Force at disk and spring (N),
F_d	= Drag force (N),
g	= Gravitational acceleration (m/s^2),

- G** = Factor of Shearing ($80 \cdot 10^3 \text{ N/mm}^2$),
H = Annual operating hours (h),
h = Operating pressure head,
H_{sn} = Superimposed pressure head (m),
I = The interested (LE/year),
I.C = Initial cost (LE/ha),
IR = Irrigation water requirements, $\text{m}^3/\text{ha}/\text{day}$.
Kc = Crop Factor,
L = Space between PN and the first of the pipe line (m),
L_o = Free Length, The length of the unloaded spring (mm),
LR = Leaching requirements,
IS = Lateral installation cost (LE / year).
L_s = Solid length, the minimum length of the spring(mm).
MCV = Manufacture coefficient of variation for nozzles discharge (%),
N_a = Active coils,
PN = Poppet nozzle (self-compensating nozzle).
p = Pitch, the distance from center to center of the wire in adjacent active coils (mm),
q = Flow rate along the pipe(l/s),
Q = Water flow through flow area (m^3/sec .),
Q_{aver} = The mean of outlets discharge (l/s),
Q_d = Absolute deviation of each sample from the mean (l/s),
Q_n = Flow rate inside the poppet nozzle line just before any nozzle (l/s),
R_e = Pipe Reynolds number,
R & M = Repair and maintenance cost (LE / year). **R & M** cost taken as 3 % of initial cost,
Δr_o = Space from disc edge to inside body nozzle at first site (mm)
Δr_x = Space from disc edge to inside body nozzle at second site (mm)