Development of a mechanical Archimedean screw

By

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Abstract

The aim of this research is increasing discharge rate, For irrigation all crop such as sugar beet, sugarcane, grain and forage crops, decreasing power consumption and consequently decreasing irrigation cost for mechanical Archimedean screw model or Egyptian traditional pump (Tambour Elwady). Some design factors affecting on the performance of mechanical Archimedean screw were studied as follow:-

A. The relation between top and bottom diameters, three rates, (1:1, 1.5:1 and 2:1).
B. Impeller fixed positions (1- At the bottom end, 2-at distance equal bottom diameter inside the screw 3-at distance equal bottom radius inside the screw).
C. Clearance between impeller and casing (three different clearances: 2, 4, and 6mm).
D. Different impeller speeds (450 – 650 r.p.m).

The highest discharge rate, lowest power consumption and best economical condition noticed at:-

- Screw top diameter equal 1.5-bottom diameter.
- Impeller fixed on distance equal bottom radius inside the screw.
- 2.0 mm impeller clearance.
- Impeller speed about 500 to 600 r.p.m.

Key word: Mechanical Archimedean Serew, Egyptian Tambour, Model, Impeller and Discharge

Introduction

Egypt is mainly an agricultural country in which agricultural and irrigation technologies play an important role in supporting national economy. Surface irrigation is the prevailing system in Egyptian fields (**Fouad and Abd Ellatif 1991**), the Egyptian traditional Tambour pump (Mechanical Archimedean screw) was the common pump used in Egyptian fields for lifting water from the irrigation canals by the reaction of lift forces that produced by rotating its impeller. This action pushes the water towards the upper end of screw and to the land surface.

The centrifugal pumps have been using instead of Egyptian Tambour. The centrifugal pumps or some parts are exported from foreign countries with higher price. Main while, farmer and end-user are retuning back to use Egyptian mechanical Tambour (mechanical Archimedean screw) to avoid exported spares parts and higher price for centrifugal pump. The PULLEY of the tractor is used to rotating impeller of the Tambour. Therefore the main goal of this research is to increase the discharge rate and consequently decrease lifting water costs for irrigation all crop such as sugar beet, sugar cane, grain and forage crops **Ibrahim et al (2001)** found that the best and economical operating conditions (for the Egyptian traditional axial flow pump) were achieved using conical casing shape, double stages with 25 cm spacing between the two impellers, blade angle 25º and impeller speed of 540 r.p.m. fouad and **Fouad** and **Abd Ellatif. (1991)** reported that the commonly used low lift irrigation pumps in Egypt are the centrifugal pumps.

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The used types of them are: A) Axial – flow pumps (fixed). B) Radial – flow pumps (fixed or movable). C) Mixed – flow pumps (fixed or movable). **Schwab et al (1991)** classified the flow through impeller (dynamic) pumps as radial, axial, or mixed. In radial-flow pumps, the fluid moves through the pump impeller perpendicular to the axis of rotation of the impeller. In axial flow pumps, the fluid moves through the pump parallel to the axis of rotation of the impeller. Pumps that discharge flows from their impeller on vectors that lie between radial and axial are mixed – flow pumps, **FAO (1986).** Reported that the Archimedean screw can only operate through low heads, since it is mounted with its axis inclined so its lower end picks up water from the water soured and the upper end discharges the water in to a channel. Each design has an optimum angle of inclination. Inclination of 30º to 40º could be used, depending on the pitch and the diameter of the internal helix. **Morcos (1996*)*** recorded that the discharge of the screw depends mainly on the inner volume between each two adjacent blades, which is occupied with water. This volume is affected by the operating angle of the screw B, the number of blades n, and the screw pitch P. it is clear from the maximum discharge occurs at B= zero, **El-Awady (1998)** reported that in Egypt, the number of diesel operated pumps was about 33000 (according to 1995 enumeration) most of them are imported in spite of the achievement of old local industry. This variation is related to the difference between the local and the imported kinds in operating power (the local production is between 5-15 hp) and the imported ones are distinguished by the better efficiency and the cheap price especially the Indian types. **Abdel-Maksoud et al (1994).** Found that the highest installation and pumping energy was recorded with permanent sprinkler. Moreover, they indicated that the energy requirements for irrigation could be minimized through the pumping energy.
Objective of this research to obtain higher discharge rates at minimum costs of mechanical Archimedean screw through evaluate some design parameters.

Materials and Methods

The mechanical Archimedean screw was a constructing model similar to the traditional design in the Egyptian market Fig (1). It is consists of Casing shape, drive shaft (1), Impeller , two bearings , power source (An electrical motor 0.4 hp), and cone pulley was fixed on the top of drive shaft to obtain different speeds. The screw was fixed on a well. The well is a barrel (0.6 m diameter and 1.0 m height), the water flow from screw top in a water tank (1.0 m width and 0.5 m height). Measuring scale was fixed inside the water tank for measuring the height of the water and subsequently calculating the discharge rate of the screw. After calculating the discharge rate the water flow in a barrel similar to the previous in the dimensions. Through a cylindrical tube 0.3 m diameter) in bottom the water reached to the screw well.
Some design factors of mechanical Archimedean screw were considered such as:-

1- Top and bottom diameters (three ratio 1:1, 1.5:1 and 2:1), Fig 1
2- Clearance between impeller and casing (three clearances 2, 4, 6 mm).
3- Impeller positions at the bottom, at distance equal radius of the bottom and at distance equal to the diameter of the bottom inside the screw, fig (2) These design factors studied on discharge rate, power requirement and water lifting cost under different impeller speeds (450, 500, 550, 600 and 650 r.p.m). The experiments were conducted in the laboratory of El-Serw Agric. Res. Station, Demitted Governorate.

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Measurements

- **Consumed energy was measured by watt –hour meter.**

$$SpecificEnergy = \frac{consumedenergy(kw/h)}{Discharerate(m^3/h)} = kw/m^3$$

- Discharge rate was measured by using water –meter.
- Speedometer for measuring screw speed r.p.m.
- Stop watch for measuring the time.

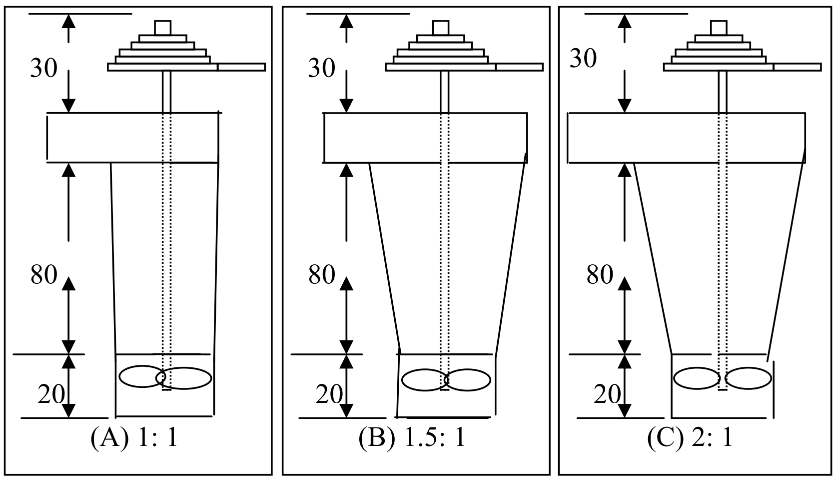

Fig (1) Relation between top and bottom diameters

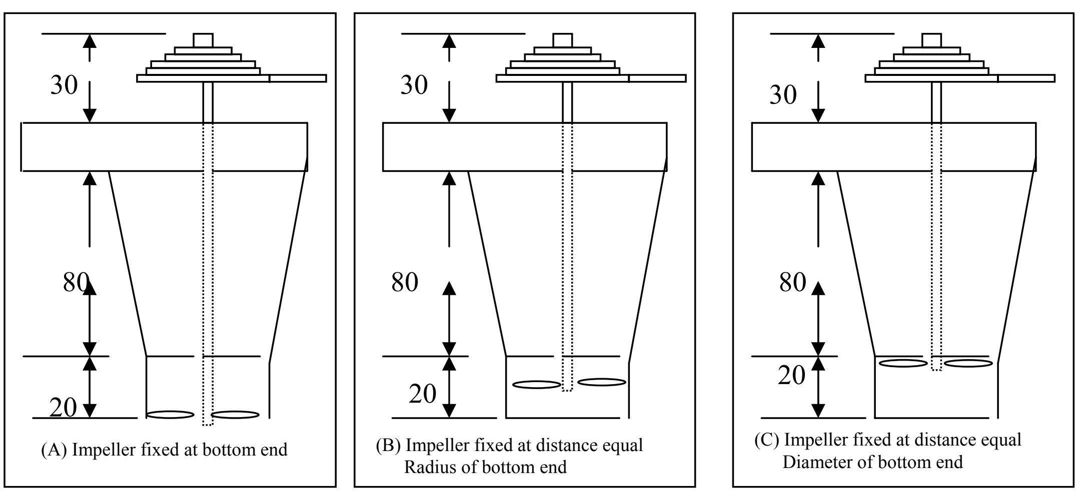

Fig (2) Impeller positions

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1- Mechanical Archimedean screw
2- Cone Pulley
3- Tank (1/2m3)
4- Water valve
5- Measurement scale
6- Electric Motor
7- V-Belt
8- Archimedean well
9- Irrigation canal

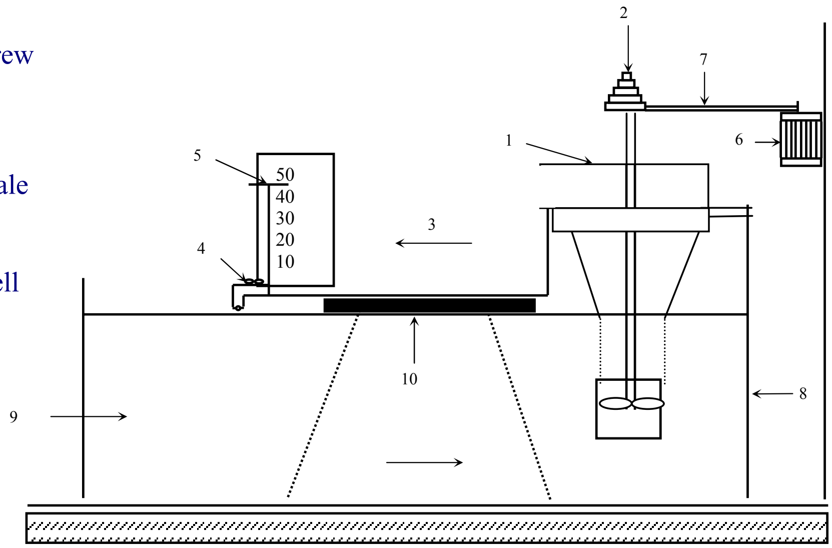

Fig (3) the experimental laboratory on mechanical Archimedean screw

Results and discussion

1) Effect of the relation between top and bottom diameters on discharge rate.

fig. (1) show that the effect of three ratio between top and bottom diameters screw (1:1), (1.5:1) and (2:1) on the discharge and power consumed under different impeller speed (rpm) with 6 mm impeller clearance and impeller fixed on distance equal bottom diameter inside the screw.

Table (1) Effect of top and bottom diameters on discharge rate and consumed energy. (At impeller, 2 mm impeller clearance)

Impeller Speed (r.p.m)	Top diameter : bottom diameter								
	1:1			1.5:1			2:1		
	Discharge Rate (m^3 /h)	Consumed Energy kW. h	Specific Energy kW /m^3	Discharge Rate m^3 /h	Consumed Energy kW /h	Specific Energy kW /m^3	Discharge Rate m^3/h	Consumed Energy kW /h	Specific Energy kw / m^3
450	15.17	0.51	0.0336	19.46	0.52	0.0267	16.10	0.48	0.0298
500	18.74	0.56	0.0299	22.57	0.56	0.0248	20.30	0.52	0.0256
550	21.56	0.62	0.0288	26.14	0.63	0.0241	23.44	0.58	0.0247
600	24.21	0.74	0.0306	28.11	0.69	0.0240	25.88	0.69	0.0267
650	25.78	0.81	0.0314	30.59	0.78	0.0255	27.55	0.77	0.0279

Data in (table 1) indicated that the highest values of discharge rates were 19.46, 22.57, 26.14, 28.11 and 30.59 m^3 / h noticed at rate of (1.5:1) between top and bottom diameter. While the lowest value of discharge rates were 15.17, 18.74, 21.51, 24.21 and 25.78 m^3/h when the rate of (1:1) between top and bottom diameter of screw. Also were remarked that the discharge rates increased with increasing impeller speed. While the specific power were decrease with increasing impeller speed,. this is due to increase discharge rate. And it is noticed that the lowest values of specific power when the impeller speeds at 500 to 600 rpm. On the other hand the consumed energy were increase with increasing impeller speeds.

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2) Effect of impeller clearance on discharge rate and consumed energy.

fig. (2) shows that the effect of three impeller clearance (2.0, 4.0 and 6.0 mm) on discharge rate and consumed energy at fixed impeller on a distance equal bottom diameter inside the screw and top diameter equal 1.5 time bottom diameter.

Table (2) Effect of impeller clearance on discharge rate and consumed energy at fixed impeller on a distance equal bottom diameter and top diameter equal 1.5 time bottom diameter.

Impeller Speed (r.p.m)	Impeller clearance (mm)								
	2 mm			4 mm			6 mm		
	Discharge Rate (m^3/h)	Consumed Energy kW. h	Specific Energy kW /m^3	Discharge Rate m^3/h	Consumed Energy kW /h	Specific Energy kW /m^3	Discharge Rate m^3/h	Consumed Energy kW /h	Specific Energy kw / m^3
450	22.46	0.38	0.0169	21.12	0.43	0.0204	19.46	0.52	0.0267
500	26.97	0.42	0.0156	24.75	0.49	0.0198	22.57	0.56	0.0248
550	29.78	0.49	0.0165	27.42	0.57	0.0208	26.14	0.63	0.0241
600	32.19	0.55	0.0171	30.12	0.64	0.0212	28.34	0.69	0.0240
650	34.42	0.62	0.0180	32.15	0.71	0.0221	30.59	0.78	0.0255

Data in (table 2) indicated that the lowest discharge rate and the highest consumed energy noticed at 6mm impeller clearance under different impeller speeds; while the maximum discharge rate and minimum consumed energy noticed at 2.00 mm impeller clearance.

Table (3) Effect of impeller fixed positions on discharge rate and consumed energy. (Impeller clearance =2.0 mm)

Impeller Speed (rpm)	Impeller positions								
	Fixed at the bottom end			Fixed on distance equal bottom radius			Fixed on distance equal bottom diameter		
	Discharge Rate (m ^{3}/h)	Consumed Energy kW. h	Specific Energy kW / m	Discharge Rate m^3 /h	Consumed Energy kW /h	Specific Energy kW /m^3	Discharge Rate m^3 /h	Consumed Energy kW /h	Specific Energy kw / m^3
450	15.46	0.34	0.0220	24.71	0.41	0.0166	22.46	0.38	0.0169
500	18.65	0.39	0.0209	28.86	0.44	0.0152	26.97	0.42	0.0156
550	22.29	0.46	0.0206	31.74	0.50	0.0158	29.78	0.49	0.0165
600	24.74	0.53	0.0214	33.92	0.57	0.0168	32.19	0.55	0.0171
650	25.31	0.58	0.0229	35.79	0.63	0.0176	34.42	0.62	0.0180

Table (3) show that the effect of three different impeller positions. First at the bottom end, second at distance equal bottom radius and the third at distance equal bottom diameter. On discharge rate and consumed energy under different impeller speeds when 2.0 mm impeller clearance. Data in Fig.(3) indicated that the maximum discharge rate was noticed with the second position more than with the first and third positions. Also the specific power with second position was little than it's with first and third positions.

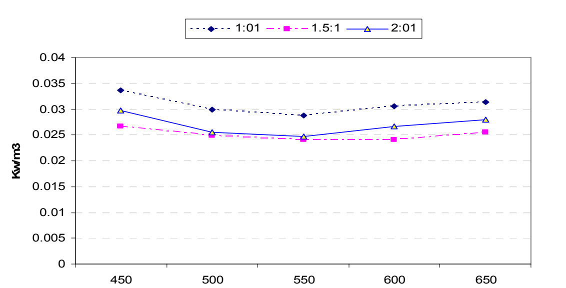

Fig (4) Relation between Specific Energy (KW/m3) and Top diameter : bottom diameter

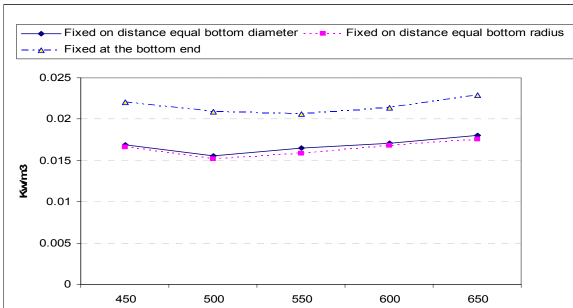

Fig (5) Relation between Specific Energy (KW/m3) and Impeller positions

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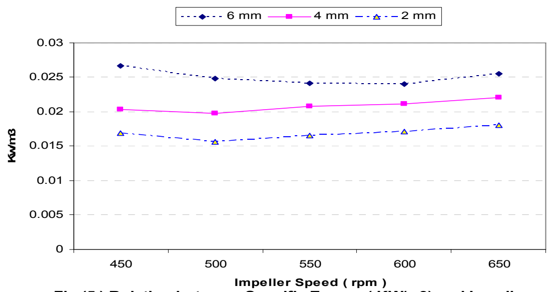

Fig (5) Relation between Specific Energy (KW/m3) and Impeller clearance (mm)

The statistical Analysis

Statistical analysis using statically package for social science (spss). Data indicated that discharge rate and economic operation energy consumption increased significantly when using 1.5:1 top to bottom diameter at 2mm impeller clearance compared with the other tested ratios (2:1& 1:1). Regarding the relationship between the discharge ratio and impeller speed the proper discharge was realized using impeller speeds of 500 to 600 rpm. On the other hand, when using the other tested ratios "2:1 & 1:1" top to bottom diameter the discharge increases were insignificant under 4mm and 6mm impeller clearances.

Table (4) the analyses of data in table (2).

Source	Type lll Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7571.193a	29	261.076	344.916	.000
Intercept	3301.763	1	3301.763	4362.068	.000
IMPSPED3	73.781	4	18.445	24.368	.000
ENERGY3	6262.538	2	3131.269	4136.823	.000
MECHANC3	6.137	1	6.137	8.108	.012
IMPSPED3*ENERGY3	140.198	8	17.525	23.153	.000
IMPSPED3* MECHANC3	.125	4	3.115E-02	.041	.996
ENERGY3* MECHANC3	18.924	2	9.462	12.500	.001
IMPSPED3*ENERGY3* MECHANC3	.252	8	3.144E-02	.042	1.000
Error	11.354	15	.757	-	-
Total	11404.560	45	-	-	-
Corrected Total	7582.547	44	-	-	-

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Table (5) the analyses of data in table (3).

Source	Type lll Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7580.732a	29	261.405	25.069	.000
Intercept	3642.066	1	3642.066	349.278	.000
IMPSPED3	71.256	4	17.814	1.708	.200
ENERGY3	6900.930	2	3450.465	330.903	.000
MECHANC3	37.484	1	37.484	3.595	.077
IMPSPED3*ENERGY3	133.938	8	16.742	1.606	.204
IMPSPED3* MECHANC3	4.631E-02	4	1.158E-02	.001	1.000
ENERGY3* MECHANC3	73.766	2	36.883	3.537	.055
IMPSPED3*ENERGY3* MECHANC3	9.129E-02	8	1.141E-02	.001	1.000
Error	156.411	15	10.427	-	-
Total	11562.040	45	-	-	-
Corrected Total	7737.143	44	-	-	-

Conclusions

The highest discharge rate, lowest consumed energy and economical operations noticed at:-

Out of the experimental design of the mechanical Archimedean screw considering top to bottom ratios, impeller clearances and impeller speeds it can be concluded that the proper design of the mechanical Archimedean screw which has 1.5: 1 top to bottom ratio impeller clearances of 2mm fixed on distance equal to bottom radius form inside, the maximum discharge obtained using impeller speed of 500 to 600 rpm.

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