Tropical Agricultural Research Vol. 4 1992

Development and Testing of the Chinese Tube Chain Water Wheel

C.L. Rajapakse and B.F.A. Basnayake[1]

Postgraduate Institute of Agriculture
University of Peradeniya
Peradeniya

ABSTRACT: *A study was conducted on selecting a suitable manually operated water lifting device for small scale cash crop growers in the dry zone. After the study, the Chinese Tube Chain Waterwheel was decided upon as one suited for the above mentioned group of farmers. This water lifting device has now been developed and tested at the Farm Mechanization Research Center (FMRC) of the Department of Agriculture. During the tests carried out at FMRC and several other locations this machine proved to be a promising device.*

Two operators using this machine could achieve a delivery of about 10 m^3/h over a head of about 6 m while only about 1.2 m^3/h could be achieved by using the same man power with rope and bucket. On the basis of the above output, it has a potential of irrigating 0.2 ha to 0.4 ha (0.5 ac to 1 ac) of land depending on the crop and field conditions.

This eqiupment together with a suitable irrigation system would, therefore, be a good solution to the irrigation problems of many dry zone farmers. This implement could be fabricated in an ordinary village level workshop at a reasonable price.

INTRODUCTION

The origins of the Chain and Washer pump go back over 2000 years. They work on a simple principal where a series of linked discs or plugs are pulled through a pipe. They lend themselves to human, animal or mechanical prime-movers, and are most commonly powered by either a team of two to four people or a traditional windmill. (Shoufan *et al.*, 1992, Rushan *et al.*, 1979).

1 Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya.

A major advantage of this kind of pump is that it requires a steady rotary power input. Therefore it is suitable to use a crank drive with a flywheel, which is mechanically efficient as well as being a comfortable way of applying muscle power. It also matches readily with engines and other mechanical prime-movers (Rothbast, 1964).

The main advantage of the Chain and Washer Pump is that it can be used over a wide range of pumping heads (1 to 20m). For low lifts, loose fitting washers are good enough to lift water efficiently through the pipe, since the back-flow will remain a small and acceptable fraction of the total flow. At higher lifts however, tighter fitting plugs rather than washers are necessary to minimize back-leakage (rubber or leather washers supported by metal discs of a smaller diameter are commonly used). Most Chain and Washer pumps have a bell mouth at the base of the riser pipe to guide the washers smoothly into the pipe. The capacity of the Chain and Washer pump is a function of the diameter of the riser pipe, and of the upward speed of the chain.

Chain and Washer pumps have been, and still are in very widespread use, especially in China, where industrially manufactured pumps of this kind are commonly used and are often known as "Liberation Pumps". They represented a major improvement over more traditional and primitive water lifting techniques used in China, and have been an interim step to modernization in powered centrifugal pumps.

Table 1. Characteristics related to typical Chain and Washer pumps used in China (Fraenkel, 1986)

Motive power	Maximum pumping head	Discharge rate	Efficiency
2 men	6 m	5-8 m^3/h	76%
Donkey	12 m	7 m^3/h	68%
3kW electric motor	15 m	40 m^3/h	65%

This indicates that the Chain and Washer pump is not only versatile. but also rather more efficient than most pumps. It also has an important characteristic for a positive displacement pump, of generally needing less torque to start it than to run it, which makes it relatively easy to match to prime-movers having limited starting torque (Watt, 1977; Heber, 1978).

There are a number of designs of the Chain and Washer pump, and the Chinese Tube Chain Water Wheel is an improved version. If this pump is operated under the conditions described earlier, the labour requirement would be two persons the total irrigation requirement would be 10 mm/day (the depth of water is 6m and the time spent to pump water as 4 hours and the pumping efficiency is 50%), and it can be calculated that the area that could be irrigated is about 0.2 ha. If the time spent to operate the device is varied the amount that could be irrigated can change.

Improvements made on the Tube Chain Water Wheel

After doing a thorough study on the Chinese Tube Chain Water Wheel, it was further modified and developed (Figure 1 shows a diagram of FMRC developed Tube Chain Water Wheel) by including the following features:

a. The smallest possible link chain was used instead of the original larger one. However, even the present smaller chain also undergoes much lower stresses than its ultimate breaking load.

b. The chain pulley, the main frame, two handles and the bearing housings were fabricated instead of casting, using mostly flat irons.

c. The pulley spindle was made simple using shafting bars.

d. Two ball bearings and the ratchet were replaced with two push-bicycle free-wheels.

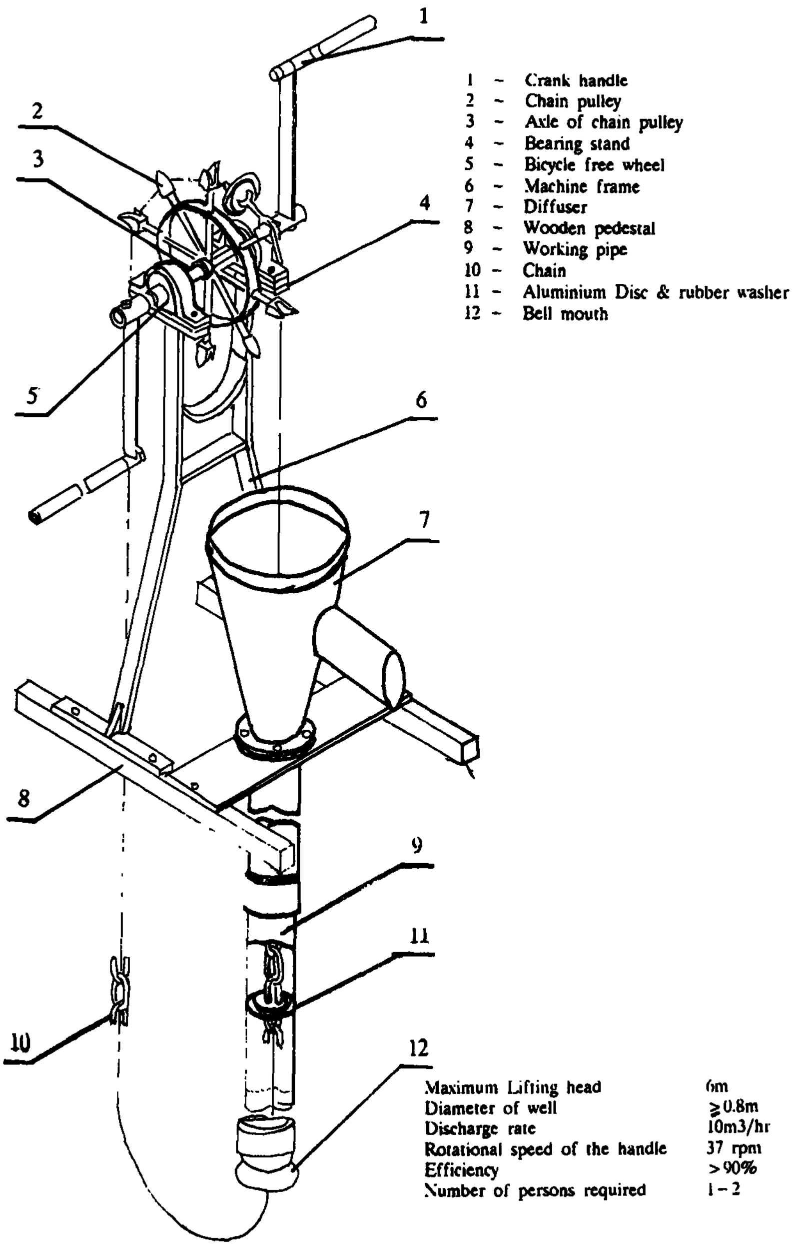


Figure 1. Isometric view of the developed tube Chain Water Wheel

e. The GI working tubes and the cast iron bell mouth were replaced with 400 gauge PVC tubes.

f. The diffuser which was below the base of the frame was taken above the base, made larger, and was integral with the water outlet using MS sheets so that water could be collected to a container.

The above changes were made in order to achieve the following objectives:

a. To simplify the production process vis – a – vis small batches in ordinary workshops.

b. To reduce the cost of materials and improvise with cheap and readily available spares, and to finally lower the cost of production.

c. To increase the efficiency of the machine and improve the handling comfort.

d. To improve durability by lessening corrosion.

OBJECTIVES

This study was undertaken to evaluate the chain and water pump in the field. A version of the pump was field tested. The machine was tested for its characteristics, performance and to get a feed back from the end user.

DISCUSSION

Field testing the machine

One prototype was installed in a farmer's field at a remote area in Anamaduwa in the Puttalam District. No instructions, except how to operate and maintain the machine was given, and the farmer was allowed to use it in his own way. Land preparation, laying out irrigation channels, selecting a crop, irrigation etc, were all decided and carried out by the farmer himself. This was monitored continuously for nearly six months, and the observations were recorded.

In this farmers' field the average water level of the well was found to be approximately 5 m below ground level. The selected crop was Chilies and the extent of cultivation was nearly 0.2 ha. Although the farmer did not use an efficient system of irrigation, he had divided the area cultivated into a number of plots and each plot was irrigated on a different day. About 3 - 4 hours each day was spent on irrigation. No inorganic manure was used, the only manure used being organic. The farmer was able to obtain a harvest of about 400 kg of Chilies, despite his poor irrigation system and other field management for example weeding, pest management etc. This gives a clear indication that with this water lifting device, any farmer could confidently irrigate about 0.2 ha under normal circumstances.

No failure was observed, even after six months. The rubber washers were found worn out slightly. The salt content in the ground water in this area is high and due to this the link chain was found slightly corroded. Except for these, the machine was in perfect working order, and it is very important to note that the farmer was highly impressed with this machine.

Testing the machine at the Research Center

A comprehensive test was carried out to ascertain the characteristics and the performance of the modified implement. This was done according to the test code published by the Regional Network for Agricultural Machinery - RNAM (Kibria, 1983).

The objectives of this test could be listed as follows:

a. To check its characteristics and performance.

b. To find out whether it is of sound engineering design.

c. To ascertain the economic viability and adaptability under the conditions obtained in Sri Lanka.

d. To explore the possibility of introducing further modifications with the following in view:
   i. Increased efficiency
   ii. Possibility of fabrication even at a local workshop
   iii. Reduced cost of production
   iv. Simplicity in operation

The pump was initially tested on a well at different water levels using only two men. The following measurements were taken:

a. Average speed of rotation
b. Delivery rate
c. Duration of continuous operation
d. Average time taken for one continuous operation
e. Durability and maintenance requirements
f. Difficulties encountered when operating

All the specifications such as the type of the machine, dimensions, weight, working principle, suitable water source, details about installation, operator requirements, maximum suction head, details of suction and delivery etc. were recorded before testing.

The following test conditions were recorded during testing:

a. Condition of the water source
b. Condition of the machine
c. Condition of workers
d. Ambient conditions

The following data was obtained:

a. Actual operating time
b. Time lost owing to rest
c. Speed of handle
d. The manner in which the worker operates the handle of the machine
e. Force required at the handle to operate the machine
f. Total static head
g. Discharge rate
h. Labour requirement

i. Simplicity of operation
j. Break down, repair, replacement of parts during test

All the above readings and observations were tabulated, and the following quantities at different suction heads were calculated, based mainly on the data obtained, and their behaviour was presented in a graph against the static suction head.

a. Torque required to operate the machine
b. Theoretical and actual discharge rates
c. Volumetric and system efficiencies

Torque (T) = $F_c gr$ (Nm) = $F_h gR$ (Nm)

where; F_c = Force at chain in kg.
F_h = Total force at handles in kg.
R = Length of the crank in m (0.3)
r = Radius of the chain pulley (0.16)
g = Acceleration due to gravity in m/sec^2 (9.81)

Theoretical Discharge (Q_t) = $\pi(D/2)^2 v60$ ($^1/m$)

where; D = Internal diameter of the working tube in m.
v = Linear velocity of the chain in m/sec.

Power input (P_i) = $(F_h gR) \times (N2\pi/60)$
= $F_c grN2\pi/60$ (Watts)

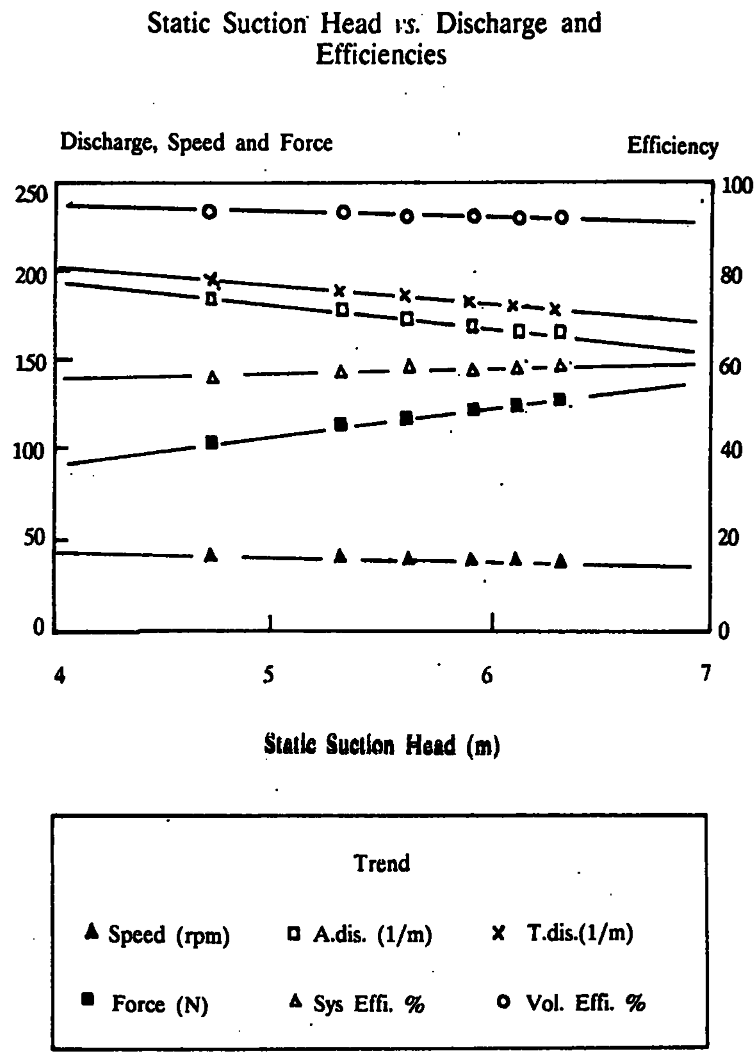
Power output (P_o) = $(Q_a \times g/60)H$

where; H = Static suction head in m
N = Speed of the handle in rpm
(Q_a) = Actual discharge rate in ($^1/m$)

Volumetric Efficiency ($_v$) = $(Q_a/Q_t) \times 100$
= $[(4xQ_a)/(\pi D^2 v] \times 100$

System Efficiency ($_s$) = $(P_o/P_i) \times 100$
= $\{[Q_a Hg/60)]/(F_h gR2\pi N/60)\} \times 100$

The Tube Chain Water Wheel



A plot of performance test data

Figure 2. Head *vs* Discharge and Efficiencies

Finally, these values were compared with the values of the original machine and it was observed that the developed machine performed better than the original Chinese Tube Chain Water Wheel. For example, while the discharge rate of the original pump was about 156.6l/m, that of the prototype was about 166.6l/m under the same operating conditions.

ACKNOWLEDGEMENT

I wish to record my appreciation and extend my sincere thanks to my Supervisors at the Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya respectively for their invaluable advice and guidance.

I gratefully acknowledge the generous financial assistance given me by the West German Government's Agency for Technical Co-operation (GTZ) and the unstinted support given by GTZ team.

My special thanks are also due to the Agricultural Development Authority for proposing this study, and all farmers and others who assisted me in carrying out the field survey.

I am also grateful to all members working in the Farm Mechanization Research Center for encouraging me continuously and rendering their services without reservation until the project was completed.

REFERENCES

Fraenkel, P.L. (1986). Water lifting devices. Irrigation and Drainage paper No.24, FAO. Rome, Italy.

Heber, G. (1978). Water pumping systems using renewable energies. German Appropriate Technology Exchange (GATE), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn, Germany.

Kibria, S.A.M.S. (1983). RNAM Test Codes & Procedures for Farm Machinery. Economic and Social Commission for Asia and the Pacific Regional Network for Agricultural Machinery, Technical Series No. 12, Bangkok, Thailand.

Rothbart, H.A. (1964). Mechanical Design and Systems Handbook. McGraw-Hill, Inc., United States of America.

Rushan, G. and Zhongde, Z. (1979). On the Development of Human, Animal, Wind and Water Power Lifting Devices for Irrigation and Drainage in China, Ministry of Water Conservancy, Beijing, China.

Shoufan, G., Jiangua, Y. and Zuxun, C. (1982). Tube-Chain Waterwheel, Proceedings UNDP/FAO China workshop of November, FAO, Rome, Italy.

Watt, S.B. (1977). Chinese Chain and Washer Pumps. Intermediate Technology Publications, London, England.