Ram Pump Application for Agricultural Irrigation in Çankırı

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Abstract

It is of great importance that water, which is the key to life, is transported from its source to another place and/or transferred to higher levels than it is. Many studies have been done and are still in progress to solve this problem. Conventional thinking is that these transfers will be made by various types of water pumps driven by electricity or an internal combustion engine. These pump systems operate at high efficiency but they get their energy from electricity or fossil fuels. Although the ability to transfer water with the help of the power of running water or the vacuum effect dates back to the VI centuries BC, it is still used especially in agricultural irrigation. In this study, necessary theoretical calculations and designs are presented for the transportation of water passing through the city centre and flowing from Tatlıçay to the related lands with a ram pump in order to irrigate approximately 40000 m^2 of agricultural land in the central Karaköprü locality of Çankırı province. Two electric motor centrifugal pumps with 1000 l/s flow rate are used in the current irrigation system. The aim is to minimize the electricity consumption used in irrigation. The water will flow into a canal 9 meters high and 30 meters away from the source, and the agricultural lands associated with this channel will be irrigated. The amount of water required for irrigation is 2000 litters per hour. As a result of the theoretical calculations, it has been seen that carrying all the water needed with a ram pump will bring additional costs due to insufficient slope, but a ram pump can be used instead of an electric motor. In addition, alternative methods that can be used other than water pumps are also presented in the study.

Keywords: *Irrigation, Pumps, Ram pump, Çankırı*

1. Introduction

The main element of life and the most basic need is water. Clean waters that can meet the needs of living things are very limited, especially when compared to salty waters. The total amount of water on earth is about 1.4 million km^3 and 97.5% of this water is salt water in the seas and oceans. Only 0.5% of the remaining amount is usable, while more than 90% of the freshwater is at the poles and underground [1].

Fresh water can be found on the earth; collected in a reservoir or flowing in the streams. Transporting the water from these sources to living spaces is one of the problems that need to be solved today, as it was in the past. Today, these problems are overcome with advanced technological equipment. It has become quite easy to transport water with many different pump systems to be selected depending on the type of water, its distance to the source, and the required amount of water [2].

There are many different pump systems that allow water to be transported from or to higher levels from the source (such as centrifugal, reciprocating, immersion, peristaltic, gear pumps). In order for these pump systems to operate, they must be driven from the outside by an external motor. These motors can be electric or internal combustion and run on electricity or energy from fossil fuels [3].

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It is of great importance that water, which is the key to life, is transported from its source to another place and/or moved to higher levels than it is. The source of the first studies on the transport of water goes back to ancient times. It is known that the "shaduf" system, which works with human power, was used in Mesopotamia and Egypt around 3000 BC. This system is still used especially in the primitive tribes of Africa. When it comes to the VI centuries BC, it is seen that the mechanical systems (water wheel) consisting of a series of shafts and wheels moved by animal power began to be used. Archimedes, who lived between 287-212 BC, developed the "Archimedes Screw", which is named after him [4, 5].

Apart from the aforementioned systems that get their power from humans, animals, or engines, there are systems that get their power from the flow of water and the height difference of the waterbed. The first studies on this subject were made by er-Rezzâz el-Cezerî (Cezerî). The Muslim scholar, inventor, and engineer Cezerî, who lived in the Turkish-Islamic geography between 1136-1206, included his work that works with the piston principle (lift and force) by making use of the flow of water in his book [6]. By the middle of the 18th century, French Montgolfier, known as one of the inventors of hot air, invented the water ram pump in a paper mill to raise the water to a higher position. This pump system was developed and commercialized in the following years. Although the demand for water ram pumps decreased in parallel with the development of electric motors and power line systems, towards the end of the 20th century, the interest in water ram and similar pump systems was revived due to the need for sustainable technology in developing countries and energy saving in developed countries [7, 8].

In this study, necessary theoretical calculations and designs are presented for the irrigation of approximately 40000 m2 of agricultural land in the central Karaköprü locality of Çankırı province, for the transportation of the water flowing through the city centre and flowing from Tatlıçay to the related lands with the water ram pump. Two electric motor centrifugal pumps with 1000 l/s flow rate are used in the existing irrigation system. The aim is to minimize the electricity consumption used in irrigation. The water will flow into a canal at a height of 9 meters and 30 meters from the source, and the agricultural lands connected to this canal will be irrigated. The amount of water required for irrigation is 2000 litters per hour.

2. Materials and Methods

2.1. Water Ram Pump

The fluid flowing in a pipe with constant flow loses its continuous flow regime and gains variable flow characteristics when its flow is stopped or slowed. This causes the kinetic energy of the fluid to change. For example, in pipes with a valve at the outlet, if the valve is suddenly closed, a dynamic load will occur in addition to the normal static load inside the pipe, and this dynamic load is called water hammer. When the valve is closed, the kinetic energy of the fluid trapped in the pipe turns into potential energy. Since the flow will stop when the valve is closed, its kinetic energy becomes zero, but this energy is not lost in accordance with the principle of conservation of energy, and it turns into turbulent energy in the form of extreme pressure waves, causing the water in the pipe to become compressed and the pipe wall to expand, which is called "water shock" [9, 10].

With the closure of the valve, we stop the movement of the water flowing continuously (constant flow) in the pipe in a short time, that is, we apply a braking acceleration (b) (Equation 2) to the mass of the water (m) (Equation 1). In this case, the inertia resistance (P_{dA}) that will occur due to the speed change is expressed by Equation 3.

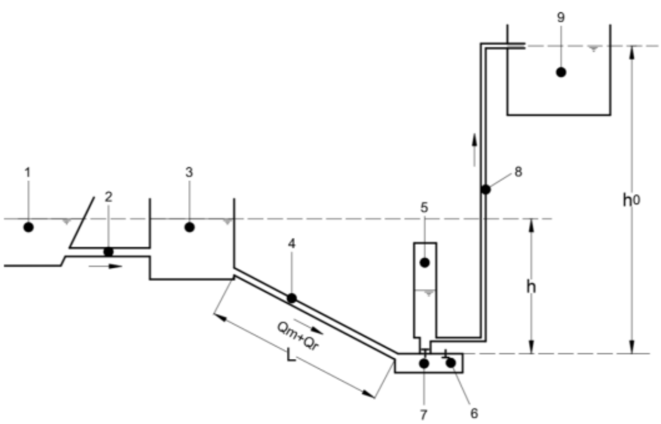
$$m = Q/g \tag{1}$$

$$b = \frac{dv}{dt} \tag{2}$$

$$P_{dA} = m \times b = m \times \frac{dv}{dt} \tag{3}$$

If the valve is closed abruptly ($dt = 0$), the value of P_{dA} becomes infinity (Equation 3). However, in practice, it is not possible to close the valve suddenly; a certain time is required for closing. The shorter the closing time (dt), the greater will be the magnitude of the force generated. This increase in force (water hammer) can be exploited by a device that will be placed at the end of the pipe close to the valve. The water ram pump is a hydro-mechanical mechanism based on the evaluation of this energy. The working principle of the water ram pump is shown in Figure 1.

The water flowing from the water source (1) flows into the forebay (3) via the supply pipe (2). The D_0 diameter loading pipe (4) coming out of the forebay conveys the water in the pool to the entrance part of the water ram body (5) below with a height difference of h and a flow rate of Q_0 ($Q_m + Q_r$). The water reaches the valve (6), which is open under the influence of its own weight in the normal position, and some water (Q_m) comes out of this valve at the first moment and flows out of the body. Under the influence of the speed and pressure of the water coming from the loading pipe (4) to the water ram body (5), valve number 6 closes rapidly. The shock wave, which occurs as a result of the water impact caused by the sudden pause of the water flow, quickly moves backward. The excessive pressure caused by this shock wave opens valve 7; water quickly enters the reservoir (*V*) of the water ram from here, compressing the air there, and at the same time rises a little in the outlet (rise) pipe (8) of diameter D_i. The air trapped in the reservoir of the water hammer reacts in the opposite direction to the water with the increase in its pressure, allowing valve number 7 to close and the water to rise in the riser pipe (8) and reach the water tank (9) above. Initially, the pressure waves that occur with the sudden closing of valve number 6 move towards the loading pipe, and at the same time, with the opening of valve number 7, the water enters the *V* reservoir. As soon as valve 7 is closed, the water pressure in valve 6 drops below the normal pressure and this valve opens from its own weight and some water flows out of the water ram body again. As long as the process continues, some of the water in the forebay (Q_m) continues to flow out of valve 6 intermittently, and some (Q_r) continues to flow into the reservoir (such as the channel, tank) above. This is a cycle and when the cycle is completed, the process continues unless there is any external intervention to the system. The time between the two openings of valve 6 is 1 cycle. It is repeated 40-200 times per minute, depending on the size, capacity, construction, and establishment characteristics of the water ram pump.



1	Water source (river, stream etc.)
2	Supply pipe
3	Forebay
4	Loading pipe
5	Ram pump
6	Valve 1
7	Valve 2
8	Water riser pipe
9	Reservoir (tank, raceway etc.)

Figure 1. Working principle of water ram pump

The efficiency in water ram pumps is found by the equations Aubusson (Equation 4) (the most widely known) and Rankine (Equation 5). In these equations; r_A: Aubusson water ram pump efficiency, r_R: Rankine water ram pump efficiency, $Q_0 = Q_m + Q_r$: Amount of water coming into the water hammer (l/sec), Q_m: Amount of water flowing from the body of the water hammer (l/sec), Q_r: Raised by the water hammer water amount (l/sec), *h*: incoming water drop height (m), h_0: water ram (raising) height (m).

$$r_A = \frac{Q_r}{(Q_m+Q_r)} \times \frac{h_0}{h} \qquad (4)$$

$$r_R = \frac{Q_r}{Q_m} \times \left(\frac{h_0}{h} - 1\right) \quad (5)$$

In these equations, the efficiency of the water ram pump essentially changes depending on the h_0/h ratio, along with the amount of water coming into the water ram pump ($Q_0 = Q_m + Q_r$) and the diameter of the loading pipe (D_0). It is possible to raise the water to a height of 20-25 times the drop height *(h)* with the water ram. However, its efficiency is as low as 20%. However, if the h_0/h ratio is around 5-10, its efficiency can increase up to 80%.

2.2. Application

Theoretical calculations for the water ram pumps and the necessary pipeline design were made in order to irrigate the agricultural land covering an area of approximately 4 hectares (40000 m2) in the Çankırı city center Karaköprü locality. Two electric motor centrifugal pumps with 1000 l/s flow rate are used in the existing irrigation system. The amount of water required for irrigation is 2000 litters per hour (≈ 33.34 l/min). Water ram pumps will be used in order to completely eliminate or partially reduce electricity consumption. The water source is Tatlıçay, which flows within the city centre and from the border of the related agricultural lands. The water will be pumped into an irrigation canal 9 meters high and 30 meters from the source. In the current system, water is pumped into this canal by centrifugal pumps, and agricultural lands are irrigated using the water in this canal.

The water flowing in the water source (1) will be collected in an open-top reservoir (2) of 1×2×3 m dimensions above the source. The reservoir will be made of concrete material, but the reservoir entrance and top will be made of perforated sheet metal. In this way, foreign objects that may hinder the operation of the water ram pump in the water will be prevented from entering the reservoir. The purpose of collecting water in a reservoir is to create a higher pressure effect (increase the water drop height) of the water entering the water ram pump and to partially purify the water from foreign materials. Water will be transmitted from the reservoir floor to the water hammer by a galvanized pipe (5), 3 m long and 1" (≈ 25.4 mm) nominal diameter. The water ram pump is positioned 0.5 m below the reservoir floor and outside the existing water bed in order to be able to intervene easily in case of any malfunction, to prevent damage to the pump in case of flood, and to benefit from the water pressure effectively. With the operation of the water ram pump, the water that will come out of the pump will be discharged to the water source through a PVC pipeline (7). The water coming to the water ram pump will be transported to the water channel (4) at a height of 9 meters and at a distance of 30 meters, by a galvanized pipeline (3) with a nominal diameter of 1/2".

In the light of these data, a water ram pump that will operate under 2.5 m drop height (reservoir depth (2 m) + height difference between reservoir floor and water ram pump (0,5 m)) and which will be increased to 9m height, will be designed with a flow rate of 1 l/min the water it can pump per hour is about 200 liters. Considering the annual average flow of the water source and the pipe selections, the flow that feeds the water ram pump is 200 l/min. In this case, the amount of water that the water ram pump can remove from the water channel in 24 hours:

$200 \times 200 = 40000$ litter

is calculated as. This too,

$^{40000}/_{24 \times 60} \cong 27{,}78$ l/min

corresponds to.

Aubusson efficiency of the water ram pump in the light of calculations:

$r_A = {}^{27{,}78}/_{200} \times {}^{9}/_{2{,}5} \cong 0{,}50$ (%50)

is calculated as.

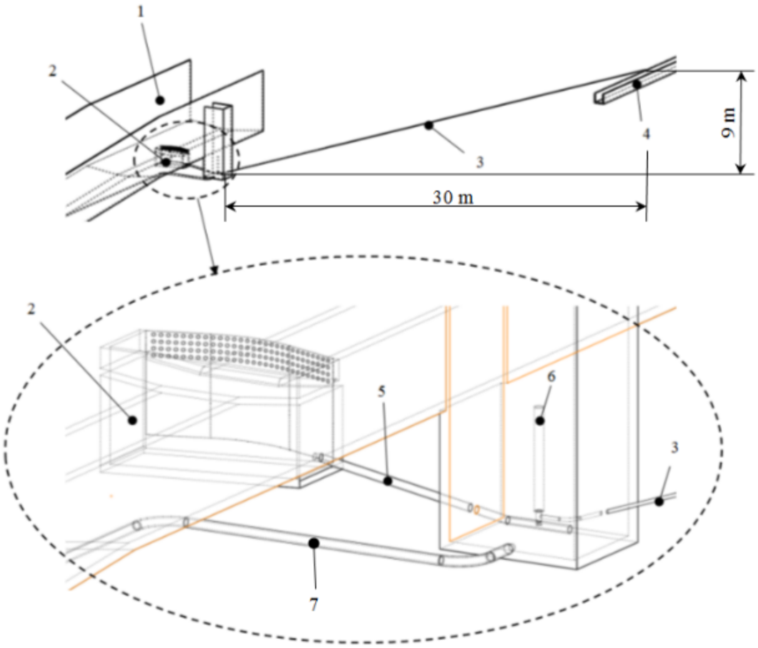


Figure 2. Aplication (1: Water source (river, stream etc.), 2: Forebay, 3: Water riser pipe, 4: Reservoir (tank, raceway etc.), 5: Loading pipe, 6: Ram pump, 7: Bleed pipe)

3. Results and Discussion

The amount of water required for irrigation of the agricultural lands subject to the application is 33.34 l/min. As a result of the theoretical calculations, it has been calculated that the water ram pump, which will operate for 24 hours, will pump water with a maximum flow of 27.78 l/min, and its efficiency will be 50%. According to these results, it is seen that it is not possible to pump all the needed water with a water ram pump. However, it is anticipated that the number and/or capacities of existing electric pumps can be reduced and thus energy consumption will decrease. In addition, it is predicted that the water ram pump, which is thought to work for 24 hours, will make a loud noise during the valve opening and closing process and will cause noise pollution. It is inevitable that the pump will be a negative choice since it is thought to work in the residential area.

The variable flow rate of the water source depending on the seasons and precipitation, as well as the possible noise problem, have negative effects on the use of the water ram pump. However, there are alternative pump systems that can be used other than the ram pump. Water can be transported by using a piston pump based on the lift and force (suction-discharge) principle developed by Cezeri by utilizing the flow of water. In addition, with various systems that provide water absorption by creating a pressure difference in a closed system, the electrical energy used in the existing system can be saved.

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