Constant RPM Water Wheel Clock

S. R. Narvekar ME (Mech)

Lecturer in Automobile Engineering
Email: sm33@rediffmail.com

Abstract:

This paper is an attempt to use the proposed constant rpm water wheel to drive and operate a clock instead of a pendulum. This paper includes the analyses, fabrication and testing of a clock which operates on this constant rpm water wheel. Time period of rotation of this water wheel remains constant and it can be set as desired.

Mathematical expressions that have been derived in this paper have helped to achieve better control on time setting.

1. Introduction

The Pendulum was used in the wall clocks in the olden days Later on, the torsional spring-loaded wheel oscillator largely replaced the pendulum. Recent years have seen the development of the ' Quartz Crystal' as the oscillator for watches and clocks.

Some of the machines and their working principles have been described in fair detail in some of the ancient Indian literature. These mechanisms have largely remained unnoticed on account of language constraints. One of such mechanism deals with a water wheel rotating at constant rpm. This mechanism was called as Jala Chakra Yantra which works with water and mercufy. In this paper above mechanism is modified and is used to drive a clock. The original idea of this unit is from ancient Indian literature.

In the section 2 wheel rotating at the constant cycle time is discussed. this section also discusses the modifications, description, operation and working of water wheel. Section 3 discusses on the requirement and the function it has to perform. Section 4 calculates the limiting water mass, torque developed by the proposed oscillator and the time period of rotation. Graphical test results are also included in this section. Section 5 concludes and discusses the scope for improvement.

2. Water Wheel

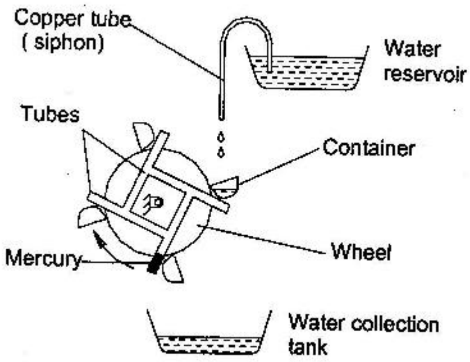
It consists of (ref fig 1) a wheel attached with 4 containers, along the periphery of the wheel, spaced equidistant from each other. Wheel is attached with the hollow tubes as shown in the figure. Tubes are filled with some mercury. Tubes are interconnected such that, as the wheel rotates the mercury enters from one tube to the other. Water from an overhead tank is made to fall drop by drop through a copper tube into one of the container attached on the wheel.

2.1. Constant RPM water wheel.

The Constant rpm water wheel being proposed is similar to the Jala Chakra Yantra with few modifications which can be enumerated below:

The wheel is mounted on the central shaft with bearings at both ends. The wheel is made light in weight. Four containers are attached along the periphery, equi-spaced and are made triangular in shape. Glass tubes are attached as shown in the fig 2.

Four containers, four interconnected glass tubes, wheel and the central shaft forms one complete assembled unit. All glass tubes are sealed. This forms the water wheel.



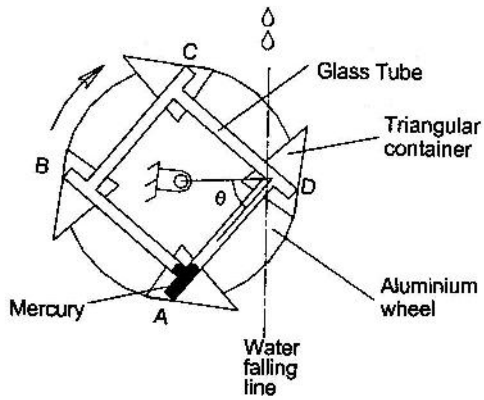


Fig 1 Water wheel as described in Shrisuryasidhant[Ref2] Fig 2 Modified water wheel.

2.1.1 Description

Wheel is attached with a shaft at the center with bearings at both ends. Four containers are attached at equidistant along the periphery of the wheel. Containers are made triangular in shape. Glass tubes are attached as shown in fig 2 and are filled with some quantity of mercury. Tubes are inclined at an angle θ^0 as shown. Water falls in the container as shown. Mercury within the tube can slide from one tube to the other.

2.1. 2 Operation and Working

In the initial stage all containers are empty. At this stage wheel will remain as shown in the fig 2. Let A, B, C. and D be the points on the wheel as shown in the fig. Mercury is in the lowermost position in the tube at 'A' and water gets accumulated in the container at 'D'.

As the water gets accumulated in the container at 'D' it becomes heavier and heavier. Slowly wheel starts rotating and it covers an angle equal to θ. Thus tube A -D attains horizontal position. This is considered as limiting state. After this state mercury gets shifted form point 'A' to point 'D'. This shifting of mercury causes an imbalance force at the point 'D'. This force is due to the weight of the mercury and weight of water both present at point D.

This force rotates the wheel further through an angle equal to θ . Now the point 'D' attains the position of point A and container which was at point C attains the position of point D. Angle moved by the wheel is equal to $2\theta^0$.

As this new position is occupied by the wheel, water gets accumulated in the container at 'C'. The process of rotation continues to rotate the wheel further in the similar manner as before. Each container rotates the wheel by 90^0 . To make one complete revolution all four containers have to pass by.

3. Adaptation of Constant rpm water wheel to a Clock

In order to adapt the constant rpm water wheel to operate a clock, it is essential that it should fulfill the following requirements :

1. Time period of rotation should be constant.
2. It should create sufficient torque to drive the gear train of the clock.
3. There should be proper provision to set the time period as desired.
4. It should not swing as it rotates.
5. Entire unit should be well aligned and balanced

3.1 Other requirements

Container should retain sufficient quantity of water. Shape of the container should be such that the container should empty completely when it attains the lowermost position. Flow of water into one container should not be obstructed by the next approaching container.

If the shape of the container is made triangular as shown in fig 2 then some of above requirements can be achieved. Containers should be mounted on wheel at proper location.

3.2 Other Attachments.

This wheel is mounted with a central shaft. This central shaft is mounted on bearings at both ends. This central shaft is attached with ratchet and pawl mechanism. Pulley is also attached to the central shaft. This pulley drives the clock gear train. With this attachments this unit appears as shown in the fig 3.

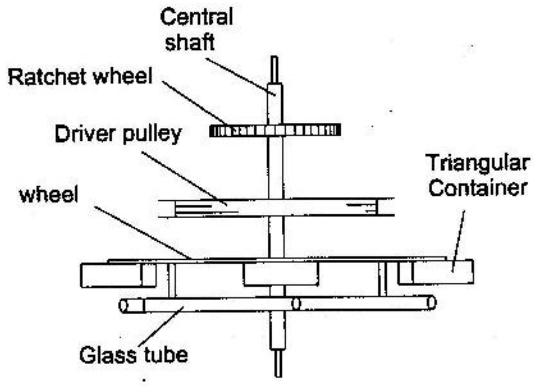


Fig 3 Water wheel assembly.

3.2.1 Clock Gear -Train Driving Mechanism.

This wheel has to drive clock gear train. Belt drive or gear drive can be used, timing belt is more suitable. Author has used friction belt drive in the fabricated model. However friction belt may create an error due to the slip of belt, specially when it operates for a very long time. Pulley diameter ratio of 4 :1 is used in the fabricated model. As the rotor rotates by 90^0 the minute arm rotates by 6^0. Ratchet wheel and driving pulley is shown in the fig 3.

3.3 Constant Rate of Water flow

Water gets filled in the container drop by drop and as the container gets filled completely with the water, the wheel rotates. It is essential to maintain the rate of flow of water constant. An intermittent tank is provided with float valve. This intermittent performs two functions like:

1. It maintains the constant rate of flow of water.
2. It has a provision to adjust the height of water column. This tank can be used to regulate the rate of flow.

This tank has been discussed in the later section 4.3.1

4 Calculations of the operating parameters

The water wheel should develop sufficient torque to rotate the gear train of the clock. Water mass known as limiting water mass, which is essential to rotate the wheel. This limiting mass has to be calculated. Similarly time period of rotation has to be calculated. Following assumptions are made for these calculations:

1. Weight of the wheel, glass tubes, containers is negligible.
2. Center of gravity of the mercury is located as shown in fig 4.
3. Frictional losses are to be neglected.
4. The impact of the falling water is negligible.
5. Container gets emptied instantaneously, when the mercury is in the down position.
6. C.g. of the mercury and c.g of the water are on the same radial line.

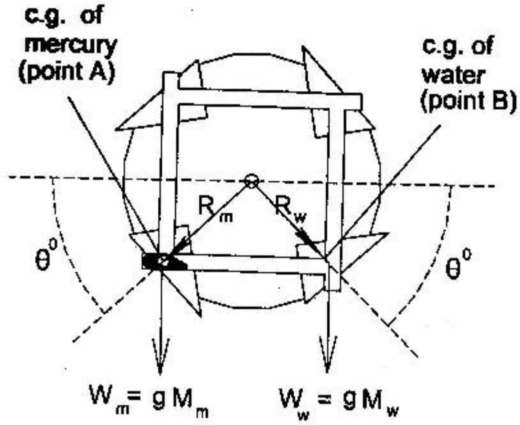


Fig 4 Water wheel during limiting state.

4.1 Limiting water mass

During limiting stage mercury is in extreme left position (that is point 'A') and water is in extreme right position (that is point 'B') as shown in the Fig 4. Mercury in the tube which is at the left hand side balances the water in the container in the right hand side. During this stage mercury is about to slide from left to right hand side (That is from point A to point B) .

Let : R_w be the distance of cg of the container to the center.

R_m be the distance of mercury from the tube to the center.

M_w be the mass of water in the container at limiting state,

M_m be the mass of mercury.

θ be the angle of spoke as shown, and is 45^0 for disk having four containers.

W_m be the weight of the mercury.

W_w be the weight of the water in the container at limiting state.

Taking moment about point 'O' we get :

$$\Sigma M_0 = - W_w [R_w \cos(\theta)] + W_w [R_m \cos(\theta)]$$

$$\Sigma M_0 = - g\, m_w [R_w \cos(\theta)] + g\, m_m [R_m \cos(\theta)] \quad \text{------(1)}$$

At limiting stage mercury is in the extreme left position and water is in extreme right position and moment caused is Zero. $\Sigma M_0 = 0$. Substituting this in the equation (1) we get :

$$M_w = \frac{M_m R_m}{R_w} \quad \text{------(2)}$$

This is the quantity of mass of water required to be filled in the container for the wheel to rotate by 90^0

4.2 Torque developed

During the limiting state, mercury is about to slide from left to right. With little further rotation of the wheel mercury gets shifted from left to right. Since mercury has changed its position, sign of the moment caused by the mercury in equation(1) changes and we get the torque developed as:

$$\text{Torque} = + g\, M_w [R_w \cos(\theta)] + g\, M_m [R_m \cos(\theta)] \quad \text{------(3)}$$

This is the torque which rotates the wheel further at an angle equal to θ^o. Torque required to rotate the clock gear-train is developed by eq (3). This torque should be kept at its minimum to reduce the water consumption.

4.3 Time Period

Time period of rotation depends on rate of flow of water. It is essential to find out all the factors on which time period depends. As the limiting water mass gets filled in one of the container, container gets rotated by 90^0. Rate of flow of water into the container will decide the time period.

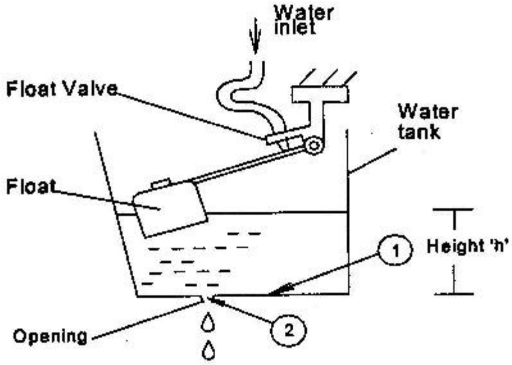


Fig 5 Intermittent tank with float valve.

Consider a tank (Intermittent tank) as shown in fig 5 with the opening at the bottom. Let the point 1 be at the bottom of the container and point 2 at the opening,

Let : A be the area of the opening at the bottom of tank

h be the height of the water column, Q be the Rate of flow, r be the density of water.

V_1 and V_2 be the velocity of the water at point 1 and 2.

Q be the rate of flow. m be the Mass rate of flow of water.

g be the acceleration due to gravity.

ω be the specific gravity of water. P_1 and P_2 be the pressure at point 1 and 2 resp.

Applying Bernoulli's equation at point 1 and 2 we get :

$$Z_1 + \frac{V_1^2}{2g} + \frac{P_1}{\omega} = Z_2 + \frac{V_2^2}{2g} + \frac{P_2}{\omega}$$

$$V_2 = (2gh)^{1/2}$$

But $Q = V_2 A$ = Rate of flow in terms of meter^3 /sec

$$Q = A(2gh)^{1/2} \text{ meter}^3/\text{sec}$$

Multiplying both the sides of equation by density of water we have:

$$Q\rho = A\rho(2gh)^{1/2}$$

But $Q\rho = m$ = Rate of mass flow of water in terms of Kg /sec

$$m = A\rho(2gh)^{1/2} \text{ Kg/sec} \quad \text{------(4)}$$

m is the mass of the water falling per second. M_w is the quantity of the mass of water required to complete ¼ th of the cycle.

Therefore time required to fill one container $= \dfrac{M_w}{m}$

Time period required to complete one full revolution is $T = 4 \times \dfrac{M_w}{m}$

Substituting M_w from per equation (2) and m from equation (4) we get :

$$\text{Time Period} = T = 4 \times \frac{\dfrac{M_m R_m}{R_w}}{A\rho(2gh)^{1/2}} \quad \text{------(5)}$$

4.3.1 Time setting arrangement

As per the equation (5) time period depends on M_m, R_m, R_w, A, ρ and h. Time period can be adjusted with this factors. However Rm and Rw can be varied during the design stage only. But M_m, A, and h can be varied later as desired. Time period also depends on ρ, but for given liquid it is constant. Other liquid can also be used having different density instead of water. Equation (5) indicates that M_m and A can be used for rough adjustments of time period and 'h' can be used for fine adjustment of time period as it is inversely proportional to the square root of height. These adjustments are shown in the Fig 5. In the fabricated model 'A' is kept constant. After full assembly, mechanism appears as shown in the figure 5. Fig 6 shows the theoretical and actual graphs. Actual graph is plotted with test results.

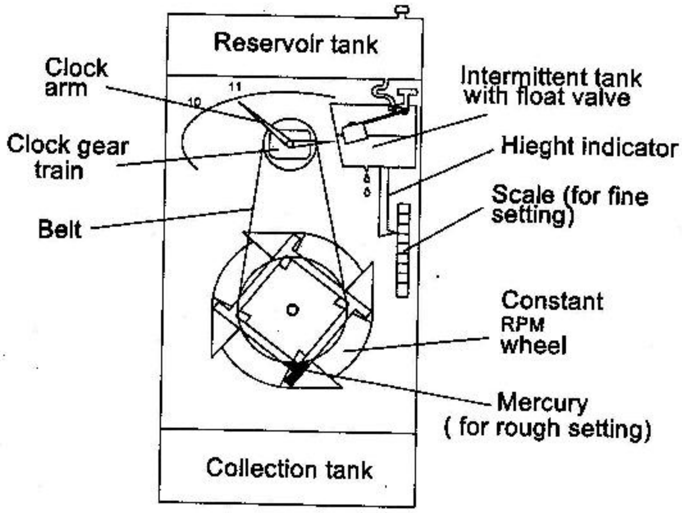


Fig 6 Block diagram of assembled clock.

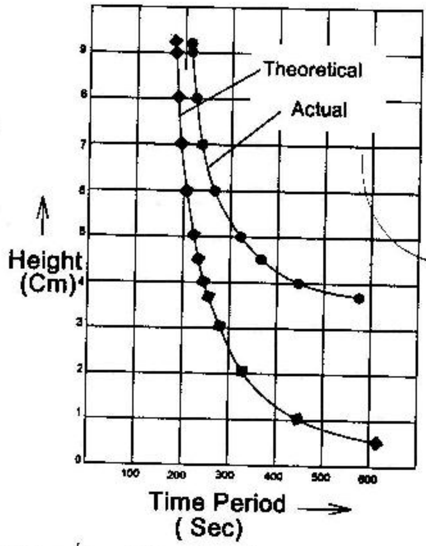


Fig 7 Graph of Height v/s Time period

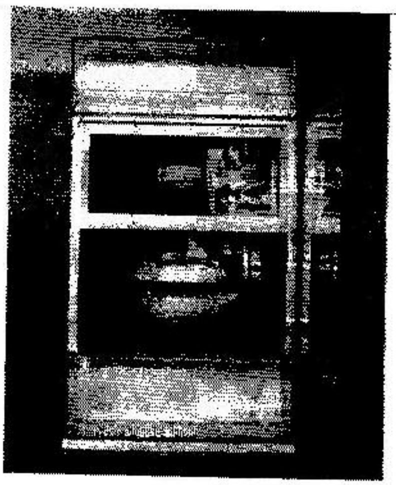


Photo 1. Mechanism of the clock

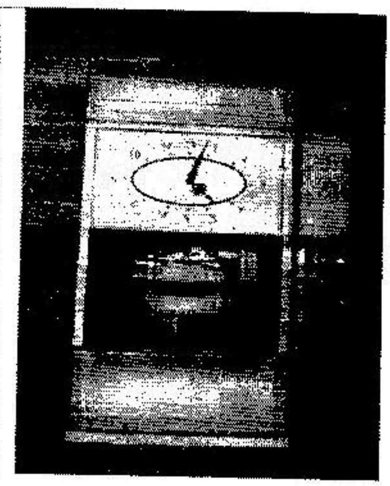


Photo 2 External appearance of the clock

5 Conclusion

This water wheel can be successfully used to drive and operate a clock. This water wheel can develop sufficient torque which can be varied as per clock gear train requirements. Graph indicate that the time period of rotation that is theoretically calculated, almost matches with the one that is actually measured. The derived equation have many parameters like M_m, R_w, R_m, A, h and ρ. All this parameters can be used to control the time period. Time period depend on fixed factors like R_m, R_w, ρ and variable factors like M_m, A, and h. As per the equation (5) it can be concluded that 'h' can be used for fine setting of time and M_m .and A can be used for rough setting of time. It uses only water potential as a sourse of energy to drive the clock

5.1 Scope for Improvement

Water wheel output shaft can be coupled directly to the input of the clock gear train. This will eliminate many transmission components and will reduce frictional losses. Then the unit will become compact. However it is essential to fabricate the special gear train for this purpose. Some of the errors may be created due to surface tension, surface adhesion of water, slip of the belt, suspended particles in the water, these errors which have to be considered.

Acknowledgement

Author is grateful to his sanscrit Guru Shri Vishwanath G. Joshi for helping him to interpret the description of Jala Chakra as described in ancient literature. Author is also thankful to Sanskrit Bharati.

References

1. Ballaney P. L., (1995) Theory of machines, Khanna Publications, (Pg 701)
2. Baladevprassadji Mishra (Ed), (1996) Shrisuryasidhant, Khamraj Shrikrishna Publication (Page 235)
3. McLEAN and NELSON, (1980) Engineering Mechanics, Schaum's series, (pg 33)
4. Muralidharacaturvedi, (1998) 'Sidhantsiromani of Bhaskaracharya" Sampurnanand Sanskrit University, Varanasi, (pg 476, pg 477).
5. V. Thanikachalam. (1993) Hydrulics and Hydraulic Machinery, Tata McGraw Hill, (Pg 71, Pg 109).