International Journal of Mechanical and Production Engineering, ISSN(p): 2320-2092, ISSN(e): 2321-2071
Volume- 7, Issue-3, Mar.-2019, http://iraj.in

OPTIMUM PARAMETRIC ANALYSIS OF MECHANICAL OSCILLATOR FOR PUMPING APPLICATION

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Abstract - 2 stage mechanical oscillator is a mechanism with new mechanical effects. This was invented by a Serbian scientist, Veljko Milkovic. It is a source of clean energy. In this mechanism, we use a higher efficient energy transformation from the input to the output side of the mechanism. A pendulum oscillates on one side of a lever, which is pivoted. The oscillation of the pendulum is converted to output via the lever. The output contains a bellow, which uses the reciprocating motion to pump air and water. Various analyses like length ratio, weight ratio and efficiency test were conducted with the fabricated oscillator. Oscillator is constructed with a telescopic pendulum which facilitates the adjustment of length. The pivot position as well as the weight ratio of the lever is varied throughout the experiment and the optimum location and weight ratio corresponding to maximum discharge is found out. Maximum efficiency of oscillator utilized for pumping the water corresponds to 92.07%. With the improvement of the mechanical oscillator can be effectively used for pressurizing the working medium - air.

Keywords - Pendulum, Clean Energy, Energy Harvesting, Pendulum Pump.

I. INTRODUCTION

Energy is not still available in many parts of the world. In places where there is the absence of conventional sources of energy or those places which are economically backward cannot meet their energy demands. In such places, the applications of a 2-Stage Mechanical Oscillator can be made into action. Here, we use a mechanical oscillator to deliver energy with the aid of gravity. Making such a device mobile will further increase the scope of the project. The energy given to the input side will be transferred efficiently to the output side. The input energy is in the form of a varying potential of force. This can be achieved by attaching a pendulum. As the pendulum oscillates, the forces acting at the pivot point of the pendulum varies. When the pendulum is in the bottom position, the force acting in the pivot will be maximum and when the pendulum in the minimum position, the force acting in the pendulum will be minimum.

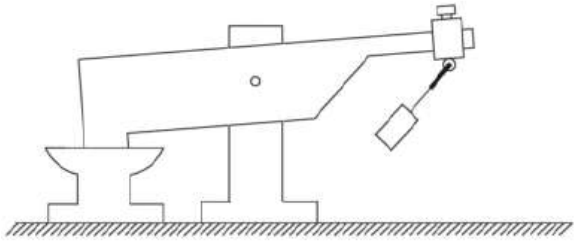

Fig. 1: Schematic of 2-stage mechanical oscillator. [1]

Fig. 1 depicts a simple mechanism with new mechanical effects represents the source of clean energy. This gravity machine has only two main parts: a massive lever and a pendulum. The interaction of the two-stage lever multiplies input energy into output energy convenient for useful work with the aid of gravity. This energy can be used for various applications like in a hand pump, an electric power generator, mechanical hammer, air pump, mechanical blower, etc. Hand water pump with a pendulum is a very simple solution for pumping water. It provides alleviation of work because it is enough to move the pendulum occasionally with a little finger to pump the water, instead of large swings. Work is alleviated because easier, long-lasting and effortless use of the hand water pump has been enabled. Also, a single push on the pendulum can pump water for a considerable amount of time depending on the constructional features.

Reguera F et al. [2] and Krishnan Nandakumar et al [3] studied the harvesting of pendulum energy from its rotational motion. The difference is that the former one provides the pendulum aid to maintain its rotation and accelerate the motion by varying the position of mass whereas the latter one inferred that non harmonic excitation show better result than harmonic excitation. G Gatti et al [4] and Michal et al [5] studied harvesting energy from time limited harmonic vibrations. They gave a brief idea about utilization of reciprocating energy. Nelson et al [6] studied the oscillation of simple pendulum in air, after various studies he concluded that the factors affecting the damping of a pendulum are negligible. Shankar et al [7] studied the damping of a pendulum due to drag on its string. He concluded that the drag on the string is negligible as compared to that of bob. Franco et al [8] conducted experiment on harvesting energy from damping of a pendulum using energy harvesting devices. He showed that the experiment and simulations are in good agreement, especially for long time. Alevas et al [9] harvested energy from parametrically excited pendulum using novel wave

energy converter. After numerical and experimental studies he concluded that increase in potential energy of pendulum lower the value of wave length. Ibrahim [10] conducted a study on Nigeria to find out the contribution of clean energy on economic growth whereas Oncel [14] gave new ideas to improve green energy. Both concluded that green energy contribute very much to the economy of the country. James et al [11] compared the pendulums with varying length and oscillating support. He concluded that pendulum with varying length have high damping coefficient and is hard to stabilize in upward position when compared with oscillating support. Musharrafa et al [12] studied the conversion of wind energy to electrical energy by using an oscillating coil pendulum. Ming He et al [13] studied the mechanical vibration on roads and utilizes this vibration for energy conversion using piezoelectric material. They concluded that the experiment is found to be effective and is applicable. Anton et al [15] studied the behavior of weightless rod pendulum with point mass sliding along the rod axis. He concluded that the numerical results are in good agreement with experiment. Arnaud et al [16] studied that electro mechanical system subjected to nonlinear springs he concluded that for a particular range of spring constant the power obtained will be of higher values as compared to case without spring. Khalid et al [17] studied the storage of energy for utilization in future. They concluded that gravity energy can be utilized effectively stored by using compressed air storage system. Malaji et al [18] studied the use of array of pendulums as potential energy harvesters. They conclude that the power extracted increases with increased in array of pendulum up to a point and further increase in pendulum does not contribute to power. Uwe [19] studied a low frequency pendulum mechanism. He concluded that the major factor which affects the pendulum is the decreasing effect of natural; frequency. Shang-Teha [20] used an active pendulum system for neutralization of vertical vibrations. He concluded that by adjusting the external force by inertia force without affecting the angular momentum, less power is required to sustain the system. Jerzy et al [21] studied the chaotic behavior of pendulum system. He concluded that the region of rotation of pendulum is located between the chaotic regions.

II. ORIGIN OF ENERGY BASED ON DIFFERENCE IN POTENTIAL

Consumers of energy use the difference in the potential between the plus and the minus (direct current) and zero and the phase (alternate current). All heat and thermal motors accomplish useful work due to the higher temperature and pressure. Dams also generate power due to the different levels of water stored, huge aircraft also work on the principle of changing the momentum of the incoming flow of gases into its engine. It also experiences a lift due to the difference in the force over and under their wings which are formed due to their aerofoil shape. Thus, energy can be extracted from places where there is a varying potential of force acting at a point.

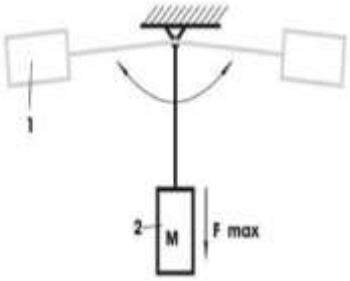

Fig. 2: Difference of the potential during oscillation of the physical pendulum. 1 - Weightless state in the upper position. 2 - Culmination of force during the fall in the lower position [1]

Since there is a difference in potential (Fig. 2) between the weightless state (1) and the culmination of force (2) during oscillation of the pendulum, the same is true for centrifugal force, which is zero in the upper position and culminates in the lower position at maximum speed. This is a simple Physical pendulum and is used as a single-stage oscillator. As the varying force potential changes, different amounts of work can be extracted from the pivot point. This can be done by altering the mass of the pendulum and changing the length of the pendulum. As in the figure, the pivot position is fixed and thus cannot move. But in the case of a 2-stage pendulum, the pivot position is also free to undergo an up and down motion. This motion is responsible for transferring energy from one side to the other. By altering the pendulum and constructional parameters such as the mass of the pendulum, length of the pendulum, and the pivot position of the main lever, we can alter the amount of work handled by the equipment.

The aim of the paper is to study the analysis and applications of a 2-stage mechanical oscillator and to create a working model of a 2-stage mechanical oscillator and to demonstrate efficient work transfer. The device is designed in such a way that the output energy can be varied by altering the pendulum parameters which makes it more useful in different environments. The system uses a bellow for pumping air and water at the output.

III. MEASUREMENT OF ENERGY

After the initial raising of a pendulum it is necessary to keep adding a same amount of energy to a pendulum to keep it swinging. Because the two-stage oscillator is supposed to be running for long period of the time, energy spent for the initial raising of the heavy pendulum bob can be disregarded. The pendulum with a fixed pivot point can keep swinging for several hours. The two-stage oscillator has a movable pivot point. It moves in the rhythm of the

lever whose frequency is double than the frequency of the pendulum. The movement of the pivot point, or better to say its acceleration, keeps spending energy of the pendulum which decelerates it. Friction in pendulum pivot point is very small in comparison with losses due to movement and acceleration of the pivot point and thus can be disregarded. Oscillators with the small and harmonic movement of the pivot point have better performances and that is the reason why special attention should be given to that problem. Also, the mechanism is highly sensitive to small changes in the dimensions or the masses in it.

IV. METHODOLOGY

The various components are designed using CATIA. Using moment equations, the mass required at various pivotal points are also calculated. The material for various parts is selected and purchased. The hinge points of the pendulum are determined.
At the hinge points, the main beam is connected to a shaft using lock nuts so that it can rotate freely in either direction. Also, it will be easy for disassembling. There will be springs provided in the shaft which will prevent it from toppling. Also, an elastic band can be attached with the same if required. The output of the system is clubbed with an air pump, which uses the output energy of the pendulum to pump air. This can be used to pump water as well. In this project, we also pump water using the same bellow and study the results.
The pendulum weight can be adjusted so that the output power can be varied. The materials are selected on the basis of weight reduction and strength. The hinge position can be changed by loosening the lock nut. There is also a provision for the adjustment of the length of the pendulum and mass of the pendulum. The length variation can be achieved by using a telescopic shaft arrangement and the mass can be altered by using a threaded shaft at the bottom of the pendulum rod and attaching a nut to it for proper fixing of the weights attached to it. The overall structure is in the shape of a truss. The structure of a truss was selected so that the forces acting upon the whole structure will be uniformly transferred to the ground which is required for the overall stability of the mechanism.

V. DESIGN

Figure 3: A mechanical oscillator

1. **MAIN LEVER**
2. **PENDULUM BOB**
3. **SUPPORT STRUCTURE**
4. **PENDULUM ROD**
5. **BELLOW**

VI. MAIN PARTS

1. MAIN LEVER

It is the main part of the mechanism. It's made up of a hollow Galvanized iron pipe. At one end of the shaft, the oscillating pendulum is fixed using a rod of mild steel. At the other end, an air pump is attached which pumps air.GI pipe is used because it is easily available in the market and it is the widely used part in the construction of trusses all over the world. It can also accept the load without deformation like ductile materials and without the formation of any cracks to some extent as we see in brittle materials. Cast iron is more brittle and cannot be used under bending loads.

2. PENDULUM BOB

It is made in the shape of a disc. It's made up of cast iron. It is attached to one end of the main lever using a rod. The main function of the pendulum bob is to create a varying potential of force at the pivot point of the pendulum in the main lever. The provision for introducing a varying mass of the pendulum bob is provided. Disc shape of the pendulum was selected because it had the least frontal cross section and hence drag is reduced. Cast iron was selected as the bob material because it has a higher density than other variants of steel. Cast iron discs are also easily available in the market. The weights are attached to the pendulum rod by means of threads in the bottom portion of the rod and a nut. A bearing is attached at the top of the pendulum rod which reduces friction during the oscillation and provides a free movement of the pendulum.

3. SUPPORT STRUCTURE

This is the major load carrying structure. It is also made up of hollow GI pipe. The main lever is attached to the main support structure by means of a key and bearings. The load acting on the support structure is not too high and to reduce the cost, we chose GI pipe. A locknut is provided in the support structure at the point where we fix the main lever which enables the main beam to be rotated in either direction freely. The whole support structure is in the shape of a truss.GI pipe is used because it is easily available in the market and it is the widely used part in the construction of trusses all over the world. It can also accept the load without deformation. The construction of trusses was selected because it helps in delivering the load uniformly to the ground and thus prevents toppling of the structure and helps in the overall stability of the mechanism

4. PENDULUM ROD

A variable length hollow mild steel rod is used as pendulum rod. It is pivoted on the main beam using a bearing and it carries the pendulum disc at the other end. It is made of a varying length rod which enables to alter the output power as the requirements.

As the length is varied, the centrifugal force produced by the pendulum bob varies and this, in turn, alters the output power. The varying length pendulum can be achieved by using a telescopic type of rod and locking it at suitable points via a bolt. As we see in an umbrella. The outer casing is a hollow MS rod and the inner rod is a solid MS rod.

5. AIR PUMP (BELLOW)

A bellow is fixed at the output side of the main lever and the energy from the bellow is absorbed by the bellow and this energy is converted to useful work. This amount of useful work can be calculated. The air pumped from the bellow can be used instantly or can be stored in a container for future use.

VII. RESULT AND ANALYSIS

1. PIVOT POINT ANALYSIS

The length of the pivot position is fixed at various points ranging from 1:3 to 1:2.25. At fixed pivot positions, the variation of discharge with the length of the pendulum is observed and tabulated. Thus, the point in the pivot position is located which gives the maximum discharge for the same weight of the pendulum as well as the counterweight. Length ratio can be defined as the ratio of the length of the longer side to that of the shorter one.

Discharge for air and water is calculated. For air, the output air is collected in a balloon and immersed in a bucket of water. By Archimedes' principle, the volume of water displaced is equal to the volume of air contained in the balloon. For water, volume of water stored per second is found out at a height of 1m.

1. For Air

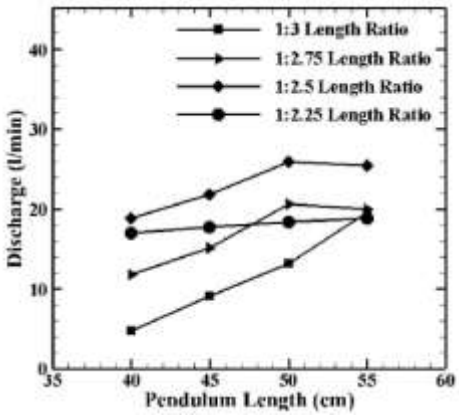

Fig. 4: pendulum length v/s Discharge plot

As observed from the graph, the pendulum length increases, the discharge measured also increases. Since the time period of the pendulum increases, the load acts on the bellow gradually increases and thus increases the discharge from the bellow. Different length ratios also give different discharges due to the change in length ratios changes the amount of energy transferred from the input to the output side.

2. For Water

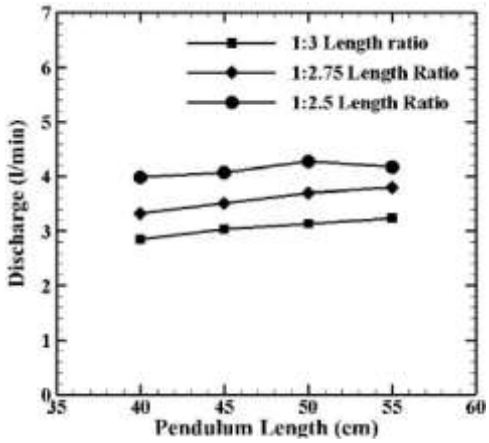

Fig. 5: Pendulum length v/s Discharge plot

As the pendulum length increases, the discharge measured also increases. For water, the discharge is low when compared with air due to the high density of water.

2. OPTIMUM WEIGHT ANALYSIS

From the pivot point analysis, for the optimum pivot ratio of the lever, the variation of mass of the pendulum with discharge is studied. From these analysis, the configuration of the 2-stage mechanical oscillator for maximum power delivery at the output is found out.

Analysis are carried out in both air and water and the variations are studied. From the observation, the discharge for water is less as compared to that of air since water has got a higher density than air and thus more power will be required to pump water. Both air and water are pumped to a height of 1m.

Weight ratio can be defined as the ratio between the pendulum weight and the counterweight.

Weight ratio = Pendulum wt. / Counter wt.

Pendulum Wt. (Kg)	Counter Wt. (Kg)	Discharge (l/min)	Weight ratio
4.25	-	0	-
5.68	3.67	5.88	1.58
6.58	3.8	10.68	1.73
7.46	4.0	25.86	1.86
8.30	4.34	18.84	1.91

Table 1: variation of discharge with weight ratio for Air.

Pendulum Wt. (Kg)	Counter Wt. (Kg)	Discharge (l/min)	Weight ratio
4.25	-	0	-
5.68	-	0	-
6.58	3.8	4.10	1.73
7.46	4.0	4.27	1.86
8.30	4.34	4.47	1.91
9.20	4.72	4.39	1.94

Table 2: variation of discharge with weight ratio for Water.

From the table 1and 2, it is observed that the discharge increases with increase in weight ratio till a particular value and the decreases. Since the weight ratio increases, the momentum at output increases which aids the bellow to pump. After a particular value the moment at the output becomes too high, that the bellow doesn't work.

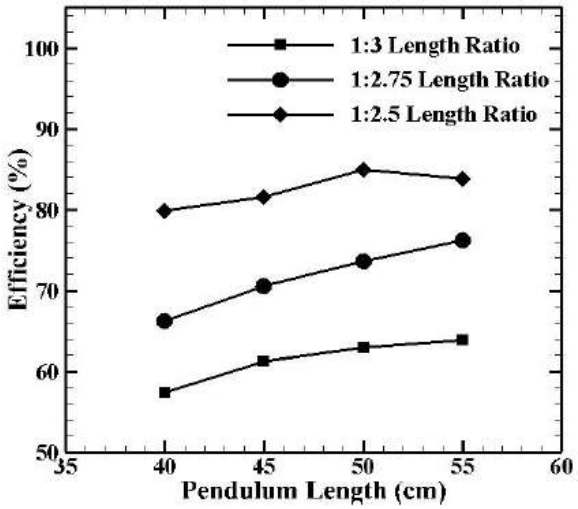

Fig. 6: Pendulum length v/s Efficiency

The maximum efficiency is observed to be at length ratio 1:2.5 because, further increase in length impart more weight on the output side. The efficiency curve initially increases, reaches a maximum point and then decreases. This is because that as the pendulum length increases, the effective degree of oscillation of the pendulum decreases.

CONCLUSION

The two-stage mechanical oscillator is a simple system consisting of a pendulum at the input. The oscillating energy of the pendulum can be transformed into useful work at the output.

An initial study was made to find the basic parameters taking into considerations the practical constraints. At the output of the pendulum, an air pump is fitted so that it can pump air and water. A provision for altering the length of the pendulum rod, and also altering the length of the main lever is done. From the experiment following conclusions are made,

- For air, the working range for length ratio is 1:3 – 1:2.25, and the optimum length ratio has been found to 1:2.5 with the length of pendulum 50cm. The maximum discharge is found to be 25.86 l/min.
- For water, the working range for length ratio is 1:3 – 1:2.5, and the optimum length ratio has been found to 1:2.5 with the length of pendulum 50cm. The maximum discharge is found to be 4.47 l/min.

This enables us to use the equipment at various places by altering the output power.

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