Gravity Light

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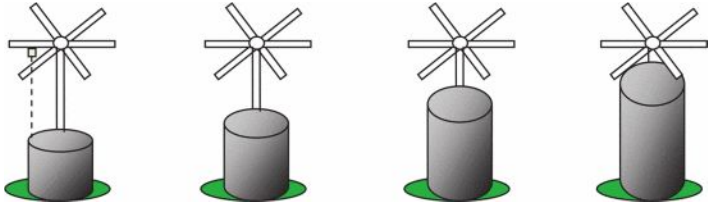
Basic Principle

- Gravity light works on the principle of converting Gravitational potential energy into Electrical Energy
- In this mechanism we hang a weight to a gear/pulley/sprocket. This element is in-turn connected to a gear train or a pulley mechanism.
- The elements are connected such that when the weight falls slowly it rotates the gear/pulley/sprocket it is connected to. This in-turn rotates the gear train.
- At the end of the gear train we connect a motor-generator which produces power when rotated
- The gear train is designed such that the velocity of the gears increases down the train such that the gear connected to motor/generator rotates the fastest

Applications

- This mechanism of converting Gravitational P.E --> K.E --> Electrical power can be used widely as it is a sustainable source of power.
- In construction sites, these mechanisms can be mounted on to cranes, such that whenever a crane lowers weight, it can produce power that can be used in the construction sites or stored in battery for further use.
- In power grids whenever there is excess power, instead of letting it go to waste we can lift few weights using that power and drop these weights to produce power when there is a shortage
- It is independent of the location or climate.



Limitations

- These devices are around 30% efficient and have scope for improvement
- The operating time is less when compared to other sources of power and has to be reset every few hours/minutes depending on the design.
- Max. Power output of a small gravity light is relatively small and can power only small devices like LED's, motors etc.
- If used in cranes in construction sites power generated could be high.

Concept Matrix

- The process of converting Gravitational potential energy into electrical power can be done in several ways.
- In our process it is being converted through Kinetic energy of falling weight.
- To obtain this mechanism there are mainly two concepts:
  - Gear Train based mechanism (or)
  - Pulley mechanism
- The below concept matrix compares these two concepts in various scenarios:

Concept Matrix:

SNo.	Aspect/Scenario	Concept 1 (GearTrain)	Concept 2 (Pulley-mechanism)
1	Cost	0	+1
2	Efficiency	+1	0
3	Inertia of system	+1	0
4	Power Produced	+1	0
5	Availability of Parts	0	+1
6	Transport	+1	0
7	Repairs	0	+1
8	Energy Calculations	0	+1
9	Durability	+1	0
10	Scope	+1	0

Concept Matrix

Conclusion:

- Gear Train gets a score of '6' while pulley rope mechanism gets score of '4'.
- Gear Trains are better when you consider all the aspects.
- But when you give weightage to certain aspects the pulley mechanism is also better. (like cost and availability of parts)
- For now we will proceed with the Gear Train mechanism and make the necessary calculations.

Calculations

- Components:
  - Weight and counterweight
  - Chain and sprocket
  - bearings
  - gear train
  - shaft
  - belt
  - motor/ generator
  - output

Mass and Energy calculations

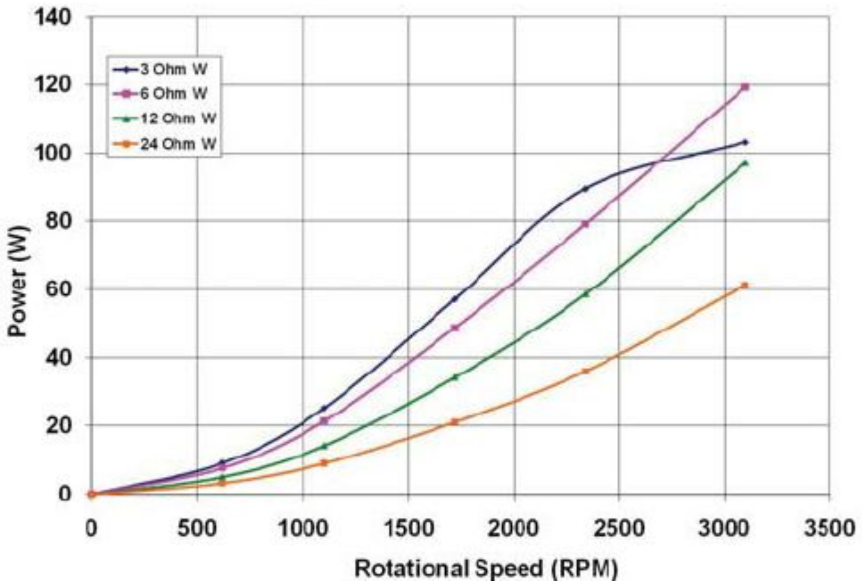
- The maximum energy that can be produced should be **mg(h2- h1)**
- Assuming a 30% efficiency, for a 10 kg weight, raised to a height of 1.5 meters, energy generated is

  0.3*10*9.8*1.5 = 44.1 J

- Using a 10v dc generator motor, a maximum current of 4.41 ampere can be generated.
- Considering a crane that lowers 100kg weight from a height of 20 meters, power generated will be **5.9kJ**

Motor/Generator calculations

- The minimum RPM for any generator to produce power is 1000 RPM. Let's say we want 1200 RPM for our case.
- Depending upon the generator/motor used the maximum power produced might vary.



Chain and sprocket calculations - 1

- Suppose the mass is elevated to 2m above ground. And let's say the run time we need is around 10 minutes.
- Therefore the chain speed coming out of sprocket is
  - 2 m / 10 min = 0.2m/min.
- We are using a sprocket of pitch = 6.35mm, teeth = 80T, pitch diameter = 161mm, weight = 305g
- The chain velocity V is defined as the length of the chain coming out per unit time. Thus the chain velocity in mm per minute is

  V= (Npn)/1000 where

  N = number of sprocket teeth = 80 T

  n = sprocket speed(rev / min)

  p = chain pitch(mm)

- V = 0.2m/min . Hence the sprocket speed we get is n= 0.4 rev/min

Design of gear train

- The gear train plays a vital role in the working of such a mechanism. As discussed earlier the gear connected to the motor/generator has to rotate with the highest speed.
- We can exactly calculate the speed ratio using the **Train value** of the Gear train:
    - **e = (product of driving tooth numbers/ product of driven tooth numbers)**
    - **nL= e*(nF)**
- The exact ratio depends on the weight we are using and the power output required.

Gear Train calculations-1

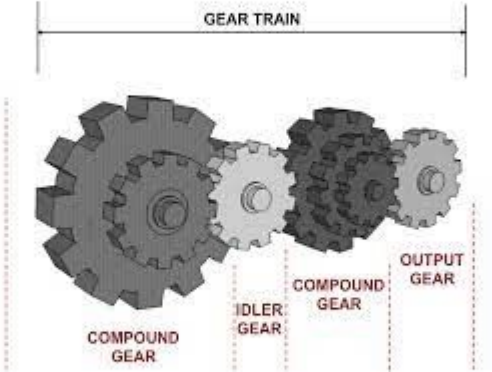
- Since the first gear and the sprocket are connected by a shaft they have same angular velocity .i.e, NF = 0.4 rev/min
- The last gear and the generator are connected by "flat belt". Assuming no slip, the generator and the gear have the same angular velocity .i.e NL = 1200RPM.
- Therefore, the **train value**, **e** = nL/nF = 1200/4.72 = 3000
- The **train value** is very high. We will need a train value of around **100** for practical purposes.
- Therefore we need a higher sprocket speed.

Calculations-2

- In previous calculation we concluded that the train value obtained is not suitable for practical reasons
- In this calculation we changed runtime to 4 minutes and also assumed the motor generator requires a minimum rpm of 300 revolutions per minute.
- Therefore the chain speed coming out of sprocket is
  - 2 m / 4 min = 0.5m/min.
- We are using a sprocket of pitch = 13.56mm, teeth = 22T, pitch diameter = 88mm, weight = 258g.

Calculations-2 contd....

- Hence the sprocket speed n=1.67 revolutions per minute
- For gear train,
  - nL = 300rpm;   nF= 1.67rpm;
- Hence the train value becomes **nL/nF = 179.65**
- Assuming a four component gear train, the train value of each component becomes **3.66**.
- This value is more practical and feasible.



Belt Calculations

- We decided to go with a flat belt as it has the highest efficiency among the other belts.
- Flat belts are quiet, they are efficient at high speeds and absorb more torsional vibration from the system than either V-belt or gear drives.
- We also decided to go with Open belt geometry.Therefore the length of the belt is given by
  - $L = (4C^2 - (D-d)^2)^{0.5} + 0.5\,(D\mathrm{Thetha}_D + d\mathrm{Thetha}_d)$
- This calculation can be done when we are finally assembling the parts, then we will know the centre to centre distance C.

Budget Estimation

- In order to prepare a prototype we have to order various parts. But we just can't go directly to any online shop and order stuff.
- In order to save money and order the proper components and ensure no wastage of parts we decided to do a Budget estimation.
- We have gone through various online shops and came up with a rough cost estimation for every component and listed it out and made an overall cost estimation.

Budget Estimation(Contd...)

SNo.	Part	Quantity	Price	Total Price	Link
1	Sprocket	x1	240	240	https://www.pantechsolutions.net/22t-freewheel-for-ebike
2	Gear Train/Gear Box	x(3-4)	4300	13000-17000	https://pincore.in/e-commerce/product/worm-gear-motor-speed-reducer-with-ratio-5-1-for-nema23-57mm/
3	Chain	x1	169	169	https://robu.in/product/25h-chain-for-ebike-motor-my1016-my6812/
4	Shafts	x(4-5)	-	-	-
5	Belts	x1	133	133	https://www.industrybuying.com/wedge-belts-fenner-MOT.WED.33300538/?utm_source=Google&utm_medium=PLA&utm_campaign=PLA_New_Motors_and_Power_Transmission&gclid=Cj0KCQjwgMqSBhDCARIsAIIVN1VUk949QAQrSGzoYJp8-KZsRabu3QWjzmujgI9rv9AtVH-mjbzZqHEaAoxYEALw_wcB
6	Motor/Generator	x1	2000	2000	https://shop2india.com/775-dc-12v-12000rpm-motor-ball-bearing-large-torque-high-power-low-noise/
7	LED/Bulb	x1	69	69	https://www.jiomart.com/p/groceries/eveready-b22d-cool-day-light-led-bulb-9-w/491361960

Problems and Soln

- From the budget estimation it's clear that gearboxes are very costly and making our own requires a lot of time and resources.
- Therefore for now we cannot get our hands on gears. So for alternative let's go back to Concept matrix in slide 6.
- If we cannot go ahead with Gear Train mechanism we will make a model with pulley mechanism.
- All the calculations we did above are correct but they cannot be applied for pulley mechanism. So we do the calculations for pulley mechanism in the following slides.

Calculations for Pulley mechanism

Components:

- Motor/Generator
- Large Pulley (Bicycle wheel rim)
- Small Pulley (Toy car wheel)
- Rope
- LED
- Sprocket and chain
- Weight

Sprocket:
This time we got an 18T sprocket from the market. The pitch is around 14.6mm.
The chain is the one that is supported by this sprocket. We bought them as a pair so that they are compatible with each other.

Motor/Generator:
We bought a High Torque motor that can also act as a generator when its shaft is rotated.
RS775 high rpm torque.
It is 12v brushed dc big strong motor
Voltage: 12 V

Calculations for Pulley mechanism(contd..)

Pulleys:
The diameter of the large pulley is : 55 CM
The diameter of the small pulley is: 6.5 CM

Weight:
The ratio of circumferences is (6.5/55) = 0.12
Weight Hanged = Approx.(2 KG)
Height = 90 cm
Time it ran = 5 seconds
Speed of the chain coming out of sprocket = 16 cm/sec
Rotational speed of small pulley = 135.4 cm/sec
Rotational speed of large pulley = 16 cm/sec

Ideal Power = (2*9.8)*0.9/5 = 3.5 W
Power Generated by our LED = approx. 0.5 W
Efficiency = (0.5/3.5)*100 = 14.3% ----> Close to our assumption of 20%.

Improvements to be made in future:

We had to make several changes to our original design of the prototype. One major mistake we committed was not taking into consideration the availability of parts and cost. SInce we were limited by the budget and availability of parts we went back to concept matrix and gave weights to certain aspects and decided upon pulley mechanism.
There can be improvements made to the present model:

- The efficiency of the system is very low. We can improve upon it by reducing the energy losses through proper lubrication etc..
- We can make the efficiency better by using a gear mechanism instead of pulley.
- With a proper gear Train design we can increase the run time and also the power output. We can build a circuit with capacitors, inductors and resistors to store the power and increase the power output and lifespan of LEDs.
- On a large scale we can fit this mechanism in a crane and use larger weights. With proper generators we can generate a large amount of electricity which can be used in the construction sites itself.

Sources

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