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Gravity Based Energy Storage System

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Abstract: *We are directly reliant on electrical energy as humans. The consumption of electrical energy is increasing every day. We have been generating electrical energy from fossil fuels, but the resources are depleting due to the increasing demand of the industrial revolution and commercial needs, and will be gone one day. As a result, we must transition to more feasible and sustainable energy sources. This problem cannot be completely solved with present battery technology. Our research is based on the concept of storing electrical energy as potential energy by harnessing gravitational energy. The research will focus on a newly created alternative power source that uses gravitational force. A natural force that is reasonably steady and abundant across the planet's surface. The project will demonstrate the potential of gravity as a renewable energy source, as well as its limitations in terms of quantity and quality of power. The goal of this project is to design and build a small gravity-powered generator that can supply power for a set period of time. A suspended mass will be used in the design, which will descend at a slow steady pace while generating electricity.*

Keywords: Electrical Energy

I. INTRODUCTION

In our daily lives, we all require energy. Since our arrival on the planet a few million years ago, humans have used energy at an increasing rate for their survival. As a result, our energy requirements grew over time. With the industrial revolution and the growth of industries, fossil fuels were utilized to generate power to fulfil the demands of manufacturers, and non-renewable sources were also exploited to generate energy. We will employ an efficient type of energy source to store electricity in this project. Gravity will be the energy source, and it will be used to store electricity. As a result, in order to solve this problem, we must apply the most efficient use of conventional energy sources. During peak demand hours, there is a disconnect between demand and supply. Our goal is to store energy using environmentally friendly methods such as gravity and dropping the weight when demand is high, and to store the power and thus meet demand requirements as efficiently as possible. This method has various advantages, including the possibility to integrate compressed air energy storage with little surface land use. The technology is supposed to be the most appealing, but the maximum energy storage capacity is restricted by the shaft's diameters and the maximum weight that can be employed practically. The technical potential of gravity energy storage with hung weights is examined in our project. The size of the suspended weight is discussed in order to enhance the energy storage capacity. The project prototype's efficiency is low due to its low height and weight , however this can be improved by raising the system's height and weight.

II. LITERATURE REVIEW

In [1], the goal of this research is to employ a good storage system that works with gravitational, potential energy on a small scale. The system in question has a 12m shaft, a 5m piston height, and a 4m diameter. It saves up to 11KWh of electricity. It has a 90 percent efficiency and a 50-year life duration. In comparison to other systems, it also has a larger storage density.

In [2], this storage method is pollution-free, cost-effective, has a long life duration (over 40 years), and has a greater round-trip efficiency of 75 to 80%, making it an ideal alternative for high-capacity energy storage. It has a design life of 50 years, no cycle limit, and no degradation.

In [3], this project makes use of the most abundant source of energy available in our daily lives. It is a non-convectional method of energy production. Convectional sources such as coal, oil, and other fossil fuels may not be sufficient and may be depleted by the end of the century. It aids in the investigation of the potential for harvesting energy from a variety of non-convectional energy sources. The demand for new types of resources is growing. Gravitational energy is an infinite form of energy that exists everywhere on the planet and can be transformed into electric energy.

In [4], for abandoned mine shafts, Thomas Morshyn designed gravity energy storage using suspended weights. Solar energy is a renewable energy source with a capacity of over 23,000 TW per year, which could completely meet global energy need (around 16TW per year).

III. WORKING PRINCIPLE

We employed two motors, one of which is a pure dynamo and the other which lifts the load. Potential energy is a form of energy that can be stored. To lift the load, we used a 200 RPM motor, while the other was used to transform potential energy into electrical energy. The motor comes to a halt when it reaches the maximum height. With the use of a gear system, we were able to increase the torque required to lift the load. With the same motor specification, a gear train allows you to raise a heavy load.

After raising the load, we must convert mechanical energy into electrical energy using a pure dynamo motor. When the load is at its highest point, the second motor kicks in. We'll disconnect the gear train from the second motor and use a connector to attach it to a shaft. With the help of a dynamo, the load is reduced and mechanical energy is turned into electrical energy.

IV. COMPONENTS

1.	Spur Gears (3D printed)	10 Teeth (30 mm Dia.) 30 Teeth (80 mm Dia.) Width = 10 mm
2.	Bearings	8mm ID × 22mm OD × 7mm Thick
3.	Shaft (Stainless Steel)	8mm OD, Length = 400 mm
4.	DC Motors (12 V)	200 RPM, Torque = 6 kg.cm
5.	Coupling (Aluminium)	Inner top Dia. = 5mm Inner below Dia. = 8mm Height = 25 mm
6.	Belt pulley (Aluminium)	60 Teeth, 8mm Bore for 6mm width
7.	DC Power Adapter	12 V, 1A
8.	Plywood	600 mm × 40 mm × 12mm
9.	PCB Board, LEDs, Resistor	

V. CALCULATIONS

Design of Shaft :-

It is based on two types- (1) Based on Strength (tmax)
(2) Based on Rigidity (θmax)

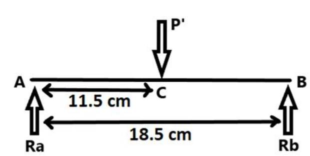
- Between the two dimensions, maximum will be the safer choice and between the loads, minimum will be the safer choice.
- As material of shaft is usually ductile we will use maximum shear stress theory.

tmax = syt/2FOS (yield strength in Tension)

OR

τmax = sys/FOS (shear strength)

Motor speed = 200 rpm
Motor torque = 12 kg.cm
Gear Ratio = 9
Type of Shaft = Solid Shaft
Material of Shaft = (En32) Alloy Steel
Speed (N) = 22.22 rpm
Supported length of the Shaft = 18.5 cm = 185 mm



Maximum tensile strength (yield strength) = 551 MPa = 551 N/mm2
Factor of safety = 4
Safe Stress (Permissible Stress) = yt/2×FOS
= 551/2×4 = 68.875 N/mm2

Diameter of Shaft, D = ?
Considered Load (pl) = 2.5 kg = 2.5×9.81 = 24.525 N
Torque on Shaft = 6×9 = 54 kg.cm = 54×0.0980 = 5.292 Nm = 5.292×103 Nmm
The shaft will be subjected to both twisting and bending, so, here the shaft will be designed based on twisting moment and bending moment.
Power = 2πNT/60 = 2×3.14×22.22×5.292/60 = 24.41 Watt
P = 24.41 Watt
Torque on Shaft = 2.646 Nm = 2.646×103 Nmm
Forces in Y-axis,
PI = RA + RB
24.525 N = RA + RB
2RA = 24.525 N ----- (RA = RB)
RA = 12.26 N = RB
Bending moment at the point C,
MC = RA × AC
= 12.26 × 115 = 1409.9 Nmm = 1409.9 Nmm
Equivalent twisting moment is given by,
TEQ = $\sqrt{T2 + M2}$
TEQ = $\sqrt{(5.292 \times 103)2 + (1409.9)2}$
TEQ = 5476.59 Nmm
TEQ = π/16 × D3 × t (By strength criteria for shaft design)
5476.59 = π/16 × D3 × (68.875)
D3 = 405.1715
D = $\sqrt[3]{405.1715}$ = 7.39 mm = 7.39 mm

Energy Storage Capacity:-
Given data :- η = 75 % ------- (Assumed)
Height of Cylinder = h = 0.2m
Outer Dia. Of Cylinder = d1 = 0.185m
Inner Dia. Of Cylinder = d2 = 0.03m
Density of sand = ρ = 1602 kg/m3
Total depth = D = 0.75 m
DI = D – h = 0.75 – 0.2 = 0.55 m
Energy storage capacity of the system is given by,
E = ηmgDI = 75×2.5×9.81×o.55
E = 1011.650 J
Total Energy Storage Capacity is given by,
E = η [mgD – 4m2g/ π(d12 – d22)ρ]
= 75 [2.5×9.81×0.75 - 4×2.52×9.81/ π(0.1852 – 0.032)×1602
= 75 [18.39 – 1.464] = 1269.45 J
E = 1269.45 J
E = 1269.45×2.78×10-4
E = 0.3529 Whr

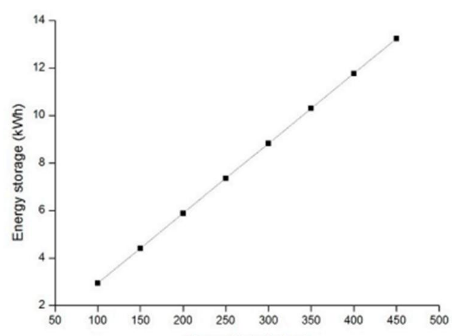


Fig. The effect on energy storage potential as a function of the amount of mass of the block.

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Ball Bearing :-

Method- Step (i) Selection of Bearing.

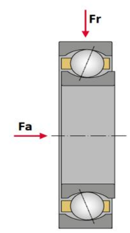
Step (ii) Calculation of Equivalent Load.

Step (iii) Checking Bearing Capacity (Static / Dynamic).

Calculation of Bearing life.

If needed, Step (iv) Bearing Reliability.

Selected a single deep grove ball bearing.



Radial load, Fr = 9.81×5kg = 49.05 N

Axial load, Fa = 0 N   (considered)

At speed N = 500 rpm & average life of 5 years at 10 hours per day,

Data :- Fr = 49.05 N

Fa = 0 N

N = 500 rpm

Lh = 5 years, 10 hrs/day

Lh = 10×365×5 = 18250 hrs

Assumed, Diameter of Bearing = 10 mm

From Design data book , by K.Mahadevan , Table 16.9(a) , Series 62 , For medium duty.

ISI No. :- 10BC02

For, d = 10 mm

D = 30 mm

B = 9 mm

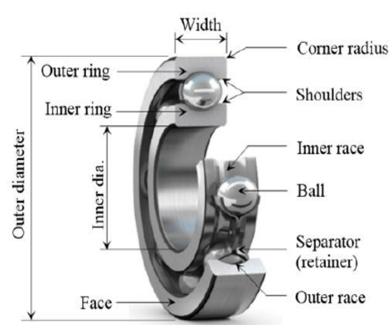
r = 1 mm

Static capacity,

Co = 2160 N

Dynamic capacity,

C = 3925 N



Calculation of Equivalent load :-

P = (XFr + yFa)S   , S = Service Factor (From Page No. 42)

1.1-1.5 ≈ 1.5

For X & Y , Page No. 336 (Table No. 16.5)

X = 0.6 and Y = 0.5 (For Radial Contact Groove Ball Bearings)

P = (0.6×49.5+0.5×0) ×1.5

P = 44.55 N

Checking Bearing Capacity from graph of L and N :

For N = 500 rpm , L = 18250 hrs

C/P = 10.80

C = 10.80×44.55 = 481.14 N < [Co , C]

[2160 , 3925]

Therefore, Bearing is selected.

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VI. CAD DESIGN AND MODEL

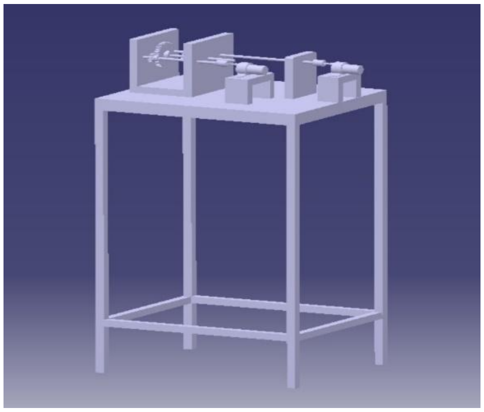

Fig. Isometric view of CAD model

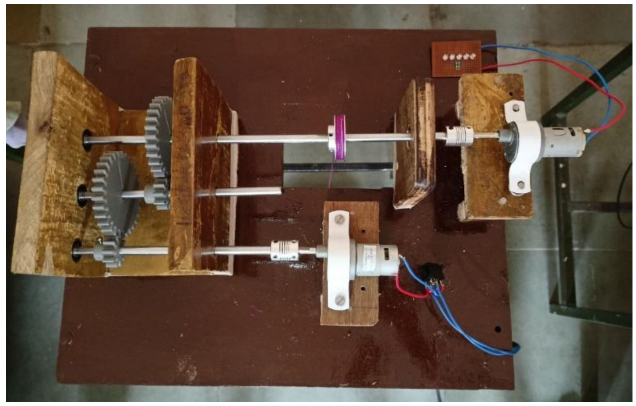

Fig. Top view of the prototype

VII. METHODOLOGY

1. Firstly, we have gone through the literature review on the gravity based energy storage system.
2. We have calculated the required parameters for the designing purpose.
3. We have designed the prototype as per our calculation parameters.
4. The prototype was fabricated to exhibit the idea.
5. The prototype was validated with the analysis results.

VIII. CONCLUSION

The key conclusion drawn from this project proposal is that gravity-based energy storage systems have several advantages, including a simpler structure that is more environmentally friendly, long-term energy conversion, and consistent energy output. We are seeking for a suitable substitute for battery technology for large capacity storage as a result of this project proposal. This concept has a lot of promise in the future.

IX. FUTURE SCOPE

1. Increase the overall efficiency of the model.
2. Automation in the engaging and disengaging mechanisms.
3. Using sensors and IOT, calculating and monitoring the charging percentage in the system.
4. Design and development of the large-scale model and analysis for the large-scale load in the shaft and the respective members.

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