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A Process to Make a Hybrid Flywheel-Buoyancy Energy Storage System

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Abstract: This paper presents a conceptual hybrid energy storage and recovery process that combines flywheel energy storage, liquid redistribution under centrifugal effects, and buoyancy-assisted energy extraction within a single cyclic system. The proposed

arrangement consists of a liquid-filled multi-arm flywheel, a buoyant member positioned along the axis of rotation, and controllable valve–turbine mechanisms located between interconnected chambers. During operation, external energy is supplied to rotate the

flywheel, causing the liquid to redistribute radially outward under centrifugal action. This redistribution creates a liquid-deficient region near the axis while simultaneously increasing the gravitational potential energy of the displaced liquid. A buoy is then positioned and locked within the central region. After extraction of the flywheel's rotational kinetic energy, the stored liquid is allowed to flow back through turbine mechanisms, enabling recovery of energy associated with the elevated liquid configuration. Subsequently, the buoy is released, and its upward motion under buoyancy is utilized for additional energy extraction. The process concludes with a secondary liquid redistribution stage that restores the system to its initial configuration, thereby completing a repeatable operating cycle. The concept seeks to integrate rotational, hydraulic, and buoyancy-based mechanisms into a unified energy storage architecture. The presented figures illustrate the sequential operational stages of the proposed system and provide a framework for further theoretical and experimental investigation.

Keywords: Flywheel Energy Storage, Buoyancy Energy, Centrifugal Liquid Redistribution, Hybrid Energy Storage System, Hydraulic Energy Recovery, Mechanical Energy Storage, Energy Conversion

I. INTRODUCTION

The increasing demand for efficient and reliable energy storage technologies has led to significant research into mechanical, gravitational, hydraulic, and buoyancy-based energy storage systems. Conventional energy storage methods such as batteries, pumped hydroelectric storage, compressed air energy storage, and flywheel energy storage possess various limitations.

Buoyancy-based systems have attracted attention due to their potential to store and recover energy through controlled movement of bodies within a liquid medium. Similarly, rotational systems can influence liquid distribution and pressure characteristics within a container, thereby creating conditions that may be utilized for energy storage and energy transfer.

However, existing systems generally fail to effectively integrate buoyancy effects, liquid displacement phenomena, and rotationally induced liquid redistribution within a single cyclic energy storage arrangement. There remains a need for a system capable of utilizing these physical effects in a coordinated manner to facilitate controlled movement of a buoyant member and the storage and recovery of energy.

The present process seeks to address these limitations by providing a system comprising a liquid-containing structure, chambers, and a buoyant member arranged to undergo a sequence of operational stages involving liquid redistribution and buoyancy-assisted movement. The inventive process aims to provide an alternative energy storage and recovery mechanism that may be scalable and adaptable for various applications. The present inventive process relates to energy storage systems and more particularly to systems utilizing liquid media, buoyancy forces, and rotational effects for storage and recovery of energy.

II. DESCRIPTION

This is a novel process to combine and make a hybrid process to store and harness energy using flywheel energy storage system and the buoyancy. A flywheel is filled with a suitable liquid and a buoy is inside the flywheel. The flywheel is given input energy and is made to rotate. The liquid inside the flywheel redistributes itself sideways under the influence of the centrifugal force and rise in the outer sideways region of the flywheel and a space void of liquid is created in the vicinity of the axis of rotation. A buoy is lowered down in the flywheel along the axis rotation in the region void of liquid.

The geometric center and the center of mass of the buoy always remain on the axis of rotation. The buoy is lowered along the axis of rotation at the optimum bottom position in the flywheel and is locked in this position. The liquid inside the flywheel redistributes itself away from the axis of rotation and when the flywheel reaches rotational equilibrium the liquids are also locked in the outer sideways position internally. The input energy of the flywheel is divided into two parts: i) the rotational kinetic energy of the flywheel, & ii) the raised potential energy of the liquid due to the sideways rising of the liquid in the flywheel due to the centrifugal force.

Now, the rotational kinetic energy of the flywheel is extracted externally. When the entire rotational kinetic energy is extracted, the flywheel comes to rest. However, due to the locking of the buoy and the locking of the liquid in the redistributed sideways position, the internal rest positions of the buoy and the liquid is not same as its initial positions. The central region of the flywheel has void of liquid and has buoy at the bottom, & the radially side regions of the flywheel is filled with the liquid with raised level. The liquid is now allowed to flow from the side regions of the flywheel to the central regions by removing the locking mechanism for the liquids. The liquid flows to fill the void region in the central part of the flywheel and the energy is extracted from the flow of the liquid. The liquid releases its potential energy and is harnessed. The buoy is kept locked and is now completely submerged in the liquid in the central region. The liquid flows till the level of the liquid is same throughout the flywheel and the energy is harnessed from the flow of the liquid. When the liquid reaches the same level inside the flywheel and stops flowing, the lock from the buoy is released, and the buoy moves towards the surface of the liquid due to buoyancy. The energy from the movement of the buoy under the influence of buoyancy is harnessed. The buoy is now at the top of the surface of the liquid and is moved to its initial position. As the buoy surfaces on the top of the surface of the liquid, again some liquid flows from the sides to the central region of the flywheel to fill the vacant volume of the buoy, and again energy is harnessed from the motion of the liquid. Now, the levels of the liquid inside the flywheel again return to its initial level (after the removal of the locking and energy extracting mechanisms). The flywheel completely returns to its initial state. All the frictional and viscous losses are ignored, the mass of the buoy is considered negligible and the volume of the valve cum turbine mechanisms are considered negligible.

III.FIGURES

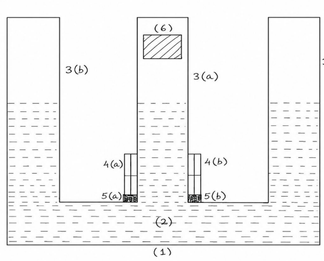

FIG (1)

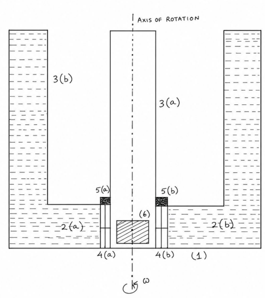

FIG (2)

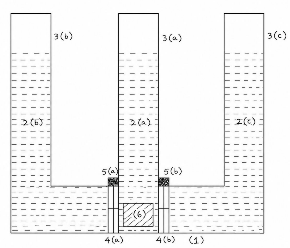

FIG (3)

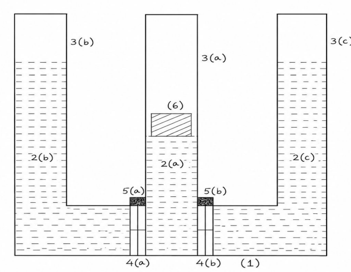

FIG (4)

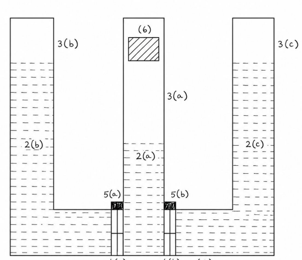

FIG (5)

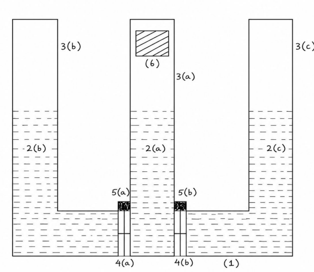

FIG (6)

BRIEF DESCRIPTION OF THE DRAWINGS

1) Figure (1)

Figure (1) illustrates the schematic diagram of the three-arm flywheel initially at rest. Following are the components of the figure:

1. represents the body of the three-arm flywheel.
2. represents the liquid inside the flywheel

3(a) represents the central arm of the flywheel
3(b) represents the left arm of the flywheel
3(c) represents the right arm of the flywheel
4(a) and 4(b) represent the valve cum turbine mechanism
5(a) and 5(b) represent the inlet mechanism for the valve cum turbine
6 represents the Buoy

2) Figure (2)

1 represents the flywheel body now rotating at the angular velocity ω
2(a) represents the liquid in the left arm of the flywheel under the influence of the centrifugal force
2(b) represents the liquid in the right arm of the flywheel under the influence of the centrifugal force.
3(a) represents the central arm of the flywheel, now empty as the liquid inside it has moved in the other arms due to centrifugal force.
3(b) represents the left arm of the flywheel, now completely filled with the liquid
3(c) represents the right arm of the flywheel, now completely filled with the liquid
4(a) and 4(b) represent the valve cum turbine mechanism now inside the flywheel at the junctions of the left and right arms of the flywheel with the central arm.
5(a) and 5(b) represent the inlet mechanism for the valve cum turbine
6 represents the Buoy, now at the lowered position in the central arm and in locked position

3) Figure (3)

1 represents the flywheel body, now at rest after the flywheel's entire rotational kinetic energy is extracted.
2(a) represents the liquid inside the central arm of the flywheel after it has moved in the central arm from the left and right arms of the flywheel passing through the valve cum turbine mechanism, generating some power.
2(b) and 2(c) represent the liquid in the left and right arm of the flywheel respectively, after some liquid has moved back into the central arm.
3(a) represents the central arm
3(b) and 3(c) represent the left and right arm of the flywheel respectively
4(a) and 4(b) represent the valve cum turbine mechanism now inside the flywheel at the junctions of the left and right arms of the flywheel with the central arm
5(a) and 5(b) represent the inlet mechanism for the valve cum turbine
6 represents the Buoy, now at the lowered position in the central arm and in locked position and also completely immersed in the liquid

4) Figure (4)

1 represents the flywheel body, now at rest
2(a) represents the liquid in the central arm of the flywheel at lower level than the levels of the liquid in the left and right arms of the flywheel, with the buoy now moved on the top surface of the liquid due to buoyancy and generating power.
2(b) and 2(c) represent the liquid in the left and right arm of the liquid, maintaining its level same as that of the level when the flywheel stopped rotating, as the valve cum turbine mechanism is not allowing the liquid from the left and right arm flow to the central arm.
3(a), 3(b) and 3(c) represent the central, the left and the right arm of the flywheel respectively
4(a) and 4(b) represent the valve cum turbine mechanism now inside the flywheel at the junctions of the left and right arms of the flywheel with the central arm
5(a) and 5(b) represent the inlet mechanism for the valve cum turbine

6 represents the buoy, now moved up to the top surface of the liquid in the central arm due to buoyancy, and generating power in the process.

5) Figure (5)
1 represents the flywheel body, now at rest
2(a) represents the liquid in the central arm of the flywheel at lower level than the levels of the liquid in the left and right arms of the flywheel
2(b) and 2(c) represent the liquid in the left and right arm of the liquid, maintaining its level same as that of the level when the flywheel stopped rotating, as the valve cum turbine mechanism is not allowing the liquid from the left and right arm flow to the central arm.
3(a), 3(b) and 3(c) represent the central, the left and the right arm of the flywheel respectively
4(a) and 4(b) represent the valve cum turbine mechanism now inside the flywheel at the junctions of the left and right arms of the flywheel with the central arm
5(a) and 5(b) represent the inlet mechanism for the valve cum turbine
6 represent the buoy moved up to the top initial position in the central arm

6) Figure (6)
1 represents the flywheel body, now at rest
2(a), 2(b) and 2(c) represent the liquid in the central, left and right arm of the flywheel respectively, now at the same level in each arm, as the liquid from the left and right arm is allowed to flow in the central arm through the valve cum turbine mechanism, generating power in the process
3(a), 3(b) and 3(c) represent the central, the left and the right arm of the flywheel respectively
4(a) and 4(b) represent the valve cum turbine mechanism now inside the flywheel at the junctions of the left and right arms of the flywheel with the central arm
5(a) and 5(b) represent the inlet mechanism for the valve cum turbine
6 represent the buoy moved up to the top initial position in the central arm

IV. DESCRIPTION OF THE PROCESS WITH REFERENCE TO THE FIGURES

The process can be obeyed by the flywheel energy storage systems with many geometric structure and configurations. However, to explain the concept of the process, an example of a three vertically armed flywheel is taken and the concept of the process is explained by the schematic/conceptual figures. Following is the point wise description of the process by taking example of a three-armed flywheel with respect to the figures:

1) In figure (1), a flywheel at rest is shown with three vertical hollow arms, 3(a) as the central vertical arm and 3(b) and 3(c) as the left and right vertical arms respectively. A suitable liquid (2) fills the flywheel and maintains same level (height) in the three arms of the flywheel. Mechanisms which can function as controlled valves and a power generating turbines, 4(a) and 4(b), are mounted near the bottom of the central arm externally. These mechanisms can enter inside the flywheel near the junctions of the left and right arms with the central arm through inlet mechanisms 5(a) and 5(b). The buoy (6) is kept in the central arm of the flywheel perpendicularly above the surface of the liquid in the central arm without making any contact with the liquid.

2) In figure (2), the flywheel is given an input burst of energy and is made to rotate. The flywheel starts rotating and reaches a rotational equilibrium having angular velocity ω. Due to the centrifugal force, the liquid from the central region move towards the left and right arm of the flywheel, and at rotational equilibrium, the left and right arm of the flywheel is completely filled with the liquid and the central arm has absence of liquid. The levels of the liquid in the left and right arm of the flywheel rises increasing the potential energy of the liquids in these arms. The buoy (6) is lowered in the region absent with the liquid in the central arm of the flywheel, maintaining its geometric center and the center of mass on the axis of rotation. The buoy is locked in this position. Also, the axis of rotation is the same line joining the mid points of the top and bottom mid points of the central arm. The valve cum turbine mechanisms are now inserted inside the flywheel in the region absent with liquid and at the junctions of left and right arms with the central arm of the flywheel. This mechanism can act as a valve or a turbine and is made to act as a valve now with not allowing any flow the liquid.

3) Now, the entire rotational kinetic energy of the flywheel is extracted by external means. When the entire rotational kinetic energy is extracted, the flywheel comes to rest. But now, the valve cum turbine mechanisms do not allow the liquids in the left and right arms of the flywheel to flow and the liquids the left and right arms of the flywheel remain at the raised levels with higher potential energy. The buoy is also kept locked at the bottom of the central arm. Now, valve cum turbine is made to act like power generating turbine. The liquids from the left and right arm of the flywheel flow towards the central arm and in the process run the turbines 4(a) and 4(b)in figure (3) and generate power and energy is harnessed. The liquids release its potential energy which is harnessed through turbines and the liquids flow till the levels of the reach the same level in all the three arms of the liquid. This moment is represented in the figure (3) and the buoy (6) can be seen completely submerged in the liquid at the bottom of the central arm.

4) Now, the valve cum turbine mechanism4(a), 4(b) is made to act like a valve and any motion of the liquid is not allowed. The buoy is now released from the lock. The buoy (6) moves towards the surface of the liquid in the central arm under the influence of the buoyancy acting on it. The energy from the motion of the buoy due to buoyancy, is harnessed. The buoy floats at the top of the surface of the liquid. The level of the liquid in the central arm drops and is now less than the level of liquid in the left and right arms of the flywheel. The valve cum turbine mechanism is preventing the liquid to flow towards the central arm from the left and right arm. The situation is represented in the figure (4)

5) In figure (5), the Buoy (6) is now moved away from the surface of the liquid to its initial position as that of in figure (1). The level of the liquid in the central arm remains lower than the level of liquids in the left and right arms of the flywheel.

6) In figure (6), the valve cum turbine mechanisms 4(a), 4(b) are again made to act like turbines and the liquid again flows from the left and right arms of the flywheel towards the central arm of the flywheel until the level of liquid reaches same in all the three arms of the flywheel. The power is generated and harnessed by this flow of the liquid through the valve cum turbine mechanisms.

Later, the valve cum turbine mechanisms, 4(a), 4(b) are returned to its initial external positions. The flywheel returns to its initial state.

V. CONCLUSIONS

The output harnessed energy from such a flywheel obeying the described process can be considered as the sum of the harnessed rotational kinetic energy of the flywheel, the harness of the raised potential energy of the liquid due to the redistributed position of the liquid by capturing the energy from the flow of the liquids when released from left and right arms towards the central arm of the flywheel, and the harness of the energy from the motion of the buoy under the influence of buoyancy.

It must be stated that the figures here are conceptual/schematic in nature and are only meant for the explanation of the concept of the process and the described process can be applied in many different structural configurations of the flywheel. The described process ignores all the frictional, turbulent and viscous losses, & considers mass of the buoy negligible and the volume of the valve cum turbine mechanisms negligible.

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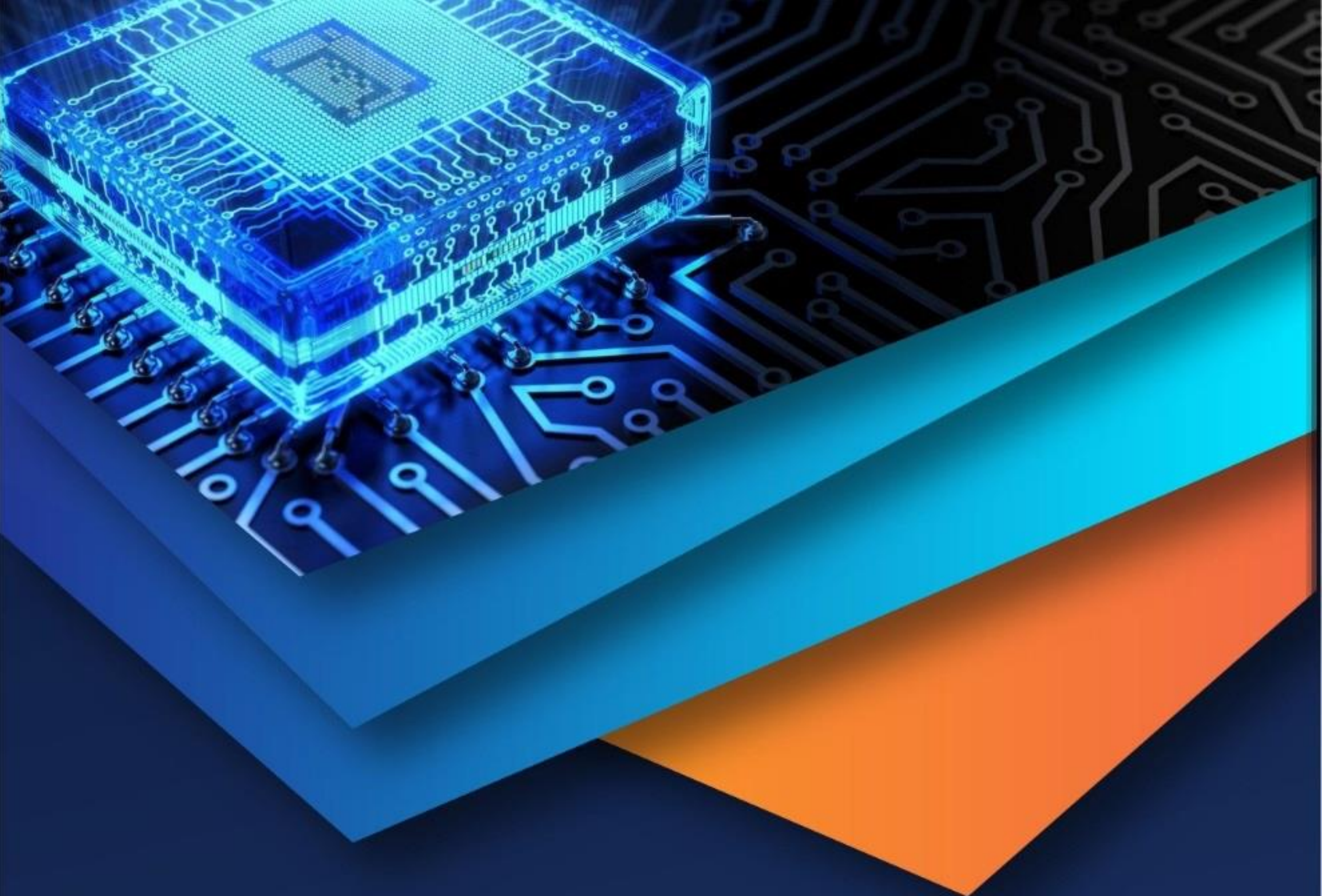

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