Optimisation of Flywheel Materials by using Solidworks and Ansys Workbench Software

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Abstract: ***Energy can be stored in various forms, such as in chemical energy (batteries), gravitational potential energy (pumped hydro), and kinetic energy (flywheels). Flywheels store energy through the inertia of a rotating mass. This project aims to compare the rotational speed of flywheels made from different materials to identify the most efficient option. The comparison involves assessing the material densities using simulation software and validating the findings through practical experimentation. The study also considers the cost and availability of the materials used, detailing the experimental procedures.***

Keywords: energy storage systems (ESS), flywheel energy storage systems (FESS), flywheel red; in chemical bonds (Fuel)

1. Introduction

1.1 Background

The flywheel, one of the earliest mechanical energy storage systems, has been used for thousands of years. The potter's wheel is an early example, utilizing the flywheel effect to maintain energy through inertia. Similar rotary objects like water wheels, lathes, and hand mills were also employed, powered by humans and animals. The evolution of flywheels saw metals replacing wood in machine construction during the 18th century, especially in steam engines. This period also marked the advent of one - piece flywheels made from cast iron, enhancing their moment of inertia within a given space. The term "flywheel" emerged during the Industrial Revolution, with applications in steam engines, factory machinery, and transport. Notable developments include large flywheels with curved spokes and the first three - wheeled vehicle by Benz in 1885. Significant advancements in flywheel design and analysis occurred in the early 20th century, positioning flywheels as viable energy storage systems. An example is the Gyrobus, powered by a 1500 kg flywheel, produced in Switzerland during the 1950s. The 1960s and 1970s saw proposals for flywheel energy storage systems (FESS) for electric vehicles and stationary power applications.

1.2 Problem Statement

Traditional energy resources continuously consume large amount of fossil fuels that is depleted, emitted in atmosphere and destroy the environment. Therefore, the development of new energy sources which is clean and non - polluted to the environment is getting more demand in our world today. The energy storage considered next is regenerative in the way that taking up and returning of energy are possible in a reversible way. By this characteristic energy storage systems can reduce the fossil energy demand and the related environmental pollution. The known energy storage systems can be distinguished depending on the kind of energy that is stored of which kinetic energy storage. Kinetic energy can be stored as rotational energy in a flywheel. The flywheel storage capacity, with respect to volume and weight, was relatively small. However, with the development of strong and light materials (composites), the storage capacity has been increased.

1.3 Objectives

The primary objective of this project is to evaluate and compare different flywheel materials to enhance their energy storage capacity using ANSYS Workbench. The study aims to design a new flywheel motor by utilizing CAD software, specifically Solidworks, for simulation purposes. Additionally, a physical model of the flywheel generator will be constructed to validate and refine the simulation results. This approach seeks to optimize the performance and efficiency of flywheel energy storage systems.

2. Literature Review

2.1 Common Uses of Flywheels

Flywheels are constructed from various materials, with the choice depending on the specific application requirements. For instance, lead flywheels are commonly used in children's toys, while cast iron flywheels are utilized in vintage steam engines. In automotive applications, flywheels may be made from cast or nodular iron, steel, or aluminum, depending on the performance demands. High - strength steel or composite flywheels are considered for vehicle power storage and braking systems due to their superior energy storage capacity per unit weight.

The efficiency of a flywheel is primarily influenced by the amount of energy it can store relative to its weight. As the rotational speed or angular velocity of the flywheel increases, so does the stored energy. However, this also leads to an increase in centrifugal stresses. If these stresses exceed the tensile strength of the material, the flywheel may disintegrate.

Consequently, the tensile strength of the material limits the maximum energy storage capacity of a flywheel. For example, a lead flywheel in a child's toy is not highly efficient, but the toy's design ensures that the flywheel's velocity remains well below its burst threshold due to the limited force exerted by the child.

In contrast, automotive flywheels operate at specific angular velocities and are confined by the space available in the vehicle. Thus, the focus in these applications is on maximizing energy storage per unit volume, making material selection crucial.

2.2 Key Studies

In 2008, Ivo Černý, George Jeronimidis, and Rayner M. Mayer conducted a study titled "Static and Fatigue Resistance of GRP Materials and Flywheel Disc of a Storage Unit for Environmentally Friendly Urban Vehicles. " This research was part of the EUREKA E! 2462 TRUS project, which aimed to demonstrate a novel hybrid electric drive system for zero - emission public transport without overhead lines. The study involved experimental evaluations of the static mechanical and fatigue properties of long glass - fiber reinforced polyester composite materials with biaxial or multiaxial structures. The results contributed to the development of an onboard energy storage unit (flywheel) designed to capture and store energy otherwise lost during braking.

3. Results and Discussion

3.1 Results

The analysis of the flywheel speed across 10 different shapes shows that the total deformation is consistent across all models. In ANSYS simulations, the frequency corresponds to the torque angle, which in turn relates to the rotational speed. The material used for these simulations was Aluminum Alloy, and the results were evaluated to determine the optimal performance characteristics for each shape based on the frequency and deformation metrics.

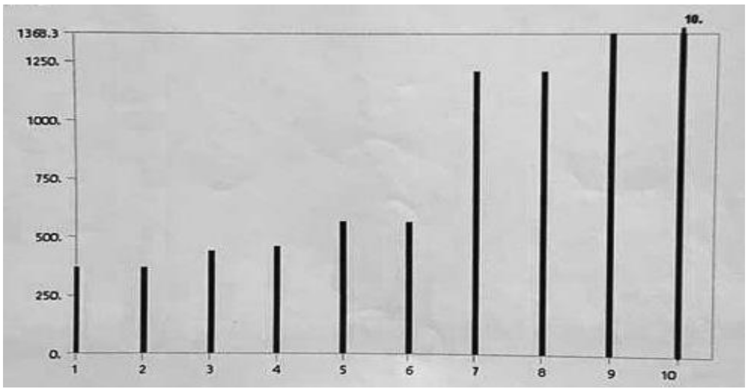

Figure 4.1: The bar chart illustrates the frequency corresponding to each calculated mode for ten different shapes of the flywheel, all made from aluminum alloy

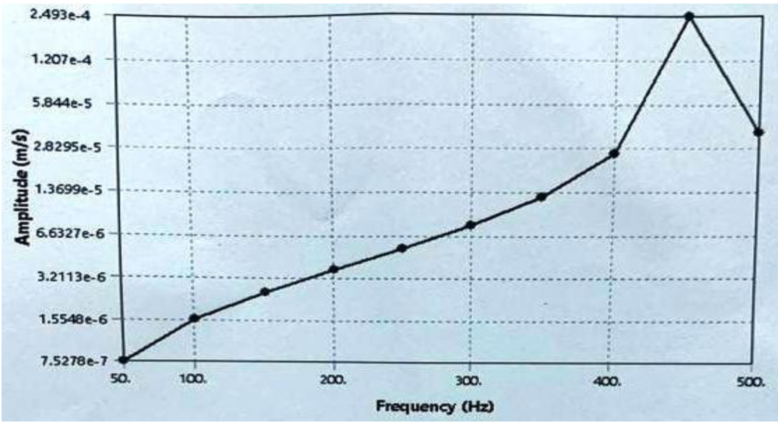

Figure 4.2: Frequency response of the flywheel made from aluminum alloy.

3.2 Discussion

The measured speeds for various materials are as follows: Aluminum Alloy (1368.3 m/s), Concrete (1016.3 m/s), Copper Alloy (981.55 m/s), Epoxy Carbon Woven (230 GPa) Wet (1616.3 m/s), Epoxy Carbon Woven (395 GPa) Prepreg (1744.7 m/s), Epoxy E - Glass UD (804.98 m/s), Gray Cast Iron (1069.5 m/s), Honeycomb (16.574 m/s), Magnesium Alloy (1345 m/s), PVC Foam (60 kg/m³) (293.91 m/s), Resin Epoxy (485.53 m/s), Resin Polyester (428.66 m/s), Stainless Steel (1355.2 m/s), Structural Steel (1374.2 m/s), and Titanium Alloy (1223.5 m/s).

The highest speed among these materials is observed in Epoxy Carbon Woven (395 GPa) Prepreg, followed by Epoxy Carbon Woven (230 GPa) Wet. Due to the unavailability of these high - speed materials for the experiment, Aluminum Alloy was selected for the fabrication of our flywheel. Aluminum Alloy also exhibits a commendable frequency response.

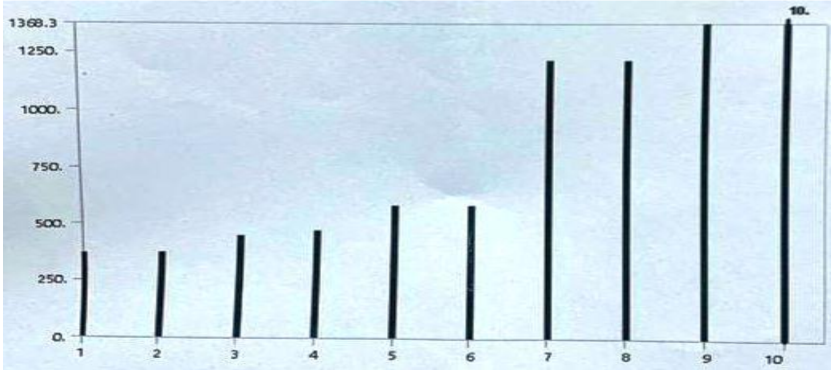

Figure 4.3: The bar chart illustrates the frequency response of Aluminum Alloy.

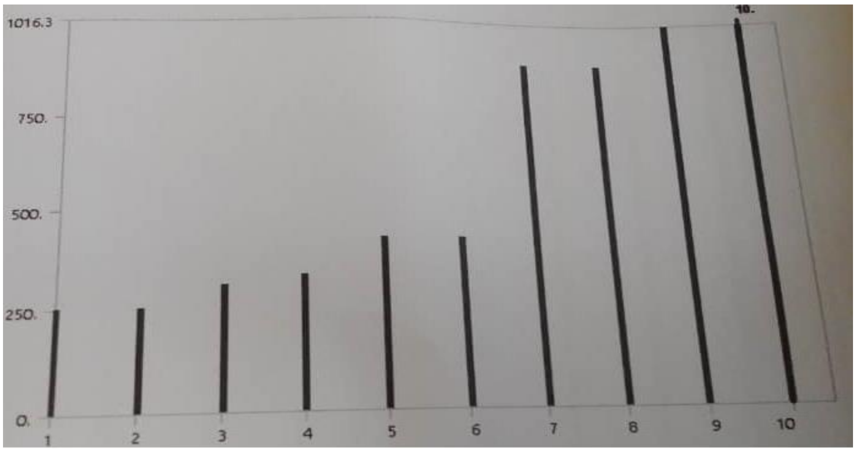

Figure 4.3: The bar chart indicates the frequency at each calculated mode (10 shapes) for the flywheel made of concrete

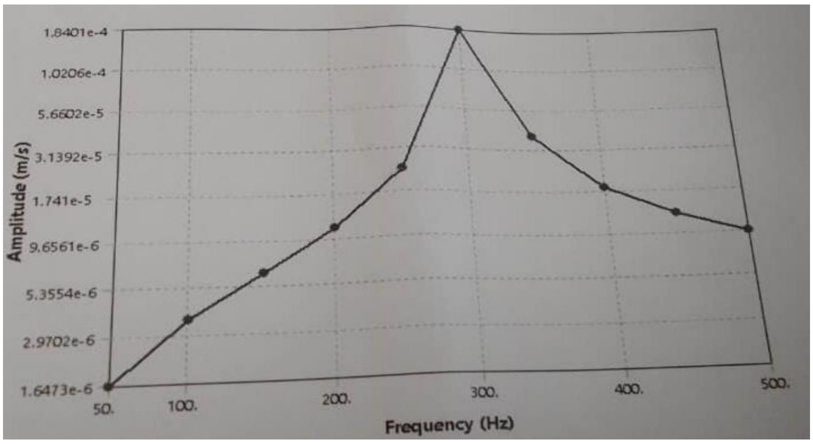

Figure 4.4: Frequency Response of Concrete

4. Conclusions and Recommendations

4.1 Conclusions

This study utilized two software tools: SolidWorks and ANSYS. Engine parts were designed and assembled to create an engine model. The flywheel was analyzed to determine the optimal material by comparing several properties, including the density of each material, which affects flywheel rotation speed, energy storage capacity, and cost. Based on these analyses, the results were tested using an aluminum alloy flywheel.

The study concludes that a lower material density results in higher rotational speed and greater energy storage capacity.

4.2 Recommendations

1) The simulations conducted in this study can be extended to other flywheel designs, including those that are hollowed out or contain spokes.
2) Future simulations should explore new materials, such as composites, due to their lightweight properties, which may offer improved performance in terms of speed and failure criteria.
3) It is recommended to complement this theoretical study with practical applications to validate the findings.

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