DEVELOPMENT AND ANALYSIS OF A SELF-BALANCING TWO-WHEELER TRANSPORTER

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***Abstract*— The "Self-Balancing Transporter" is a term given to vehicles that can balance itself on two wheels without the intervention of an external support. Self-balancing in these vehicles is usually achieved with the help of built-in high-performance computers, control algorithms and by using the principle of classical Inverted Pendulum problem with the help of sensors like gyroscope and accelerometers. Our aim is to make a model, fabricate and analyses this transporter at low cost. Self-balancing in our model is achieved with the help of Arduino Uno, which takes input data's in the form of angles from the gyroscopic sensor MPU6050 and gives output to the motor controller, which in turn gives input to the motors connected to the wheels and thus balancing itself with the help of wheel movement. The gyroscope takes data as a result of the person leaning towards the direction, he /she wants to move. As a result, 3D model of the transporter was prepared on SOLIDWORKS referring from already existing single occupancy vehicle models. Later on, analysis of different stresses acting on the model was done using ANSYS WORKBENCH. The resulting model is highly unstable non-linear system that should always maintain degree with the surface. The final model was able to self-balance itself with the help of low-cost sensors and components with zero pollution.**

Keywords*— *Self-balancing, Inverted Pendulum, gyroscope, Ansys, SOLIDWORKS.

I. Introduction

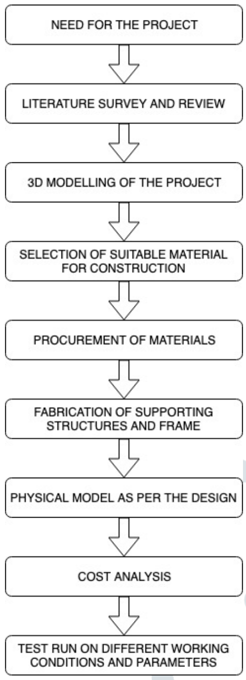
Everything that we use around us these days require some form of energy for its working. From our electric trimmer to washing machines to cars to airplanes, everything requires some form energy for its working. And the required energy for these things come in the form of electricity and fuel, which come from natural resources. Natural resource is something that can be obtained from the natural environment for people to use. These things don't necessarily require mankind for its generation and hence the name natural resource. Everything that we see around us are made up of natural resources, they are either used naturally or transformed into some other form. The basic survival of humans and other living organisms on this earth depends upon the natural resources [1]. Hence it is important that we take good care of the natural resources around us. Examples of some common natural resources around us are land, rocks, forest, fossil fuels, water, mineral, sunlight etc. With the increasing population there has been an increase in level of consumption per person, leading to the depletion of Natural Resources. The problem arises when the natural resources are consumed at a faster rate than they can be renewed [2]

Keeping this in mind, a mode of transportation has to be found that does not use much of the natural resources available, produces zero pollution, is cheap and is compact so as to be used at congested places. One better way we found was to use a transporter vehicle that uses battery for its working. Electric vehicles do not consume oil and produces zero pollution [3]. However, to make the transporter cheap, we would have to reduce the cost on gyroscopic sensors, which would give problems like drift, but this problem can be solved if these lost cost sensors are used with filters like Kalman filter and complimentary filters [4].
The self-balancing part of the transporter works on the principle of overcoming the classical inverted pendulum problem which forms one of the basis of control education [5]. There are a lot of self-balancing transporter existing in the market that use high-performance computers for its control. But since we wanted to make a transporter that was cost effective, we decided to go with Arduino Uno, which is cheap as well as easy to use and learn about [6]. A 3D model of the transporter was prepared on SOLIDWORKS referring from already existing models of self-balancing transporters available [7].

With increasing population, there has been an increase in consumption per person and thus leading to increased usage of natural resources such as oil and petroleum. In coming years amount of natural resources available in the form of oil is going to reduce so a mode of transportation has to be found that does not use fuels like petroleum or diesel for its running. Also, with the increase in infrastructure, the amount of time and distance to be travelled to reach from one point to another inside the same organization has increased. SBT deals with all of these problem by using battery, being compact, eco-friendly. SBT can easily be parked anywhere, considering its size, it produces zero pollution, it uses motors instead of engines, and also uses electronic components like Arduino and gyroscopic sensors.

II. EXPERIMENTATION

This chapter discusses various steps that were involved as shown below in the flow chart. The process are discussed in



detail.

- **Need for the project** -The need for this project was to develop a transporter vehicle that would increase mobility inside big institutions, just like ours. Increasing mobility would not only make it easier to travel but also save a lot of time that is usually spent while walking. The model that we have designed and fabricated is compact, eco-friendly, self-balancing, cost-effective and easy to use.

- **Literature survey and review-** Literature survey helped us understand the working of the self-balancing vehicles, it also gave us a brief idea of the design. Studying different models from different papers helped us in coming with a design of our own. The paper helped us with algorithm that would go in building a self-balancing transporter. The paper also helped us studying the classical inverted pendulum problem and ways to overcome it. In general, studying these papers, gave us a brief idea about how the project would be like.

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- **3D modelling of the project** - A 3D model was prepared on SOLIDWORKS, based on different design parameters that were taken from different papers. Different individual parts were modelled and assembled on SOLIDWORKS based on the initial rough sketch that was prepared using pencil. The prepared model was given different material properties based upon different materials that were used. The model has base plate on which the actual person would stand. On the bottom of the plate is a shaft, to which the wheels are attached. At the top of the plate is attached a journal bearing to, which the steering handle is attached. The battery pack is kept at the top and all the electronic parts are attached at the bottom. This model was then experimentally tested in ABAQUS software.

- **Selection of suitable materials** - The transporter is designed in such a way that it should carry a weight of about 100kg and hence it was necessary to come up with a material that would stand this weight without failing. Also, the material used should be cheap and easily available. Based upon all these requirements, the material to be used for base metal was taken as mild steel. The shaft is also made of mild steel and the handle used is made of a hollow steel pipe. Two wooden blocks were attached through the shaft at the bottom based on additional strength. All these materials are decided upon considering the cost factor and strength.

- **Procurement of suitable materials** - All the materials required were procured locally from local stores. The metallic components were bought from a metal shop. Wheels were taken from the college scrapyard. The wooden blocks were bought from a local timber shop nearby. component like bearing, sprocket, chain assembly, nuts and bolts etc. were bought from local hardware shops. Electronic components were brought from different electronics shop in Bangalore.

- **Fabrication of supporting structure and frame** - Different process that were undertaken in building our model is as given below.

  - Cutting
  - Welding
  - Turning
  - Grinding
  - Shaping
  - Drilling
  - Boring

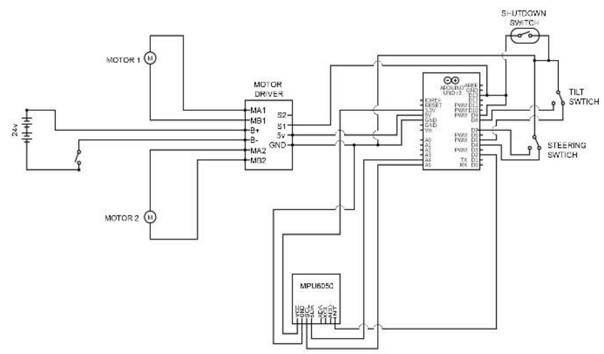
- **Physical model as per design** - Finally the physical model was obtained as per the design from SOLIDCAM. This physical model was able to complete the objectives as mentioned earlier. The physical model was able to balance itself as well as with a person on.

- **Cost estimation** - A proper cost analysis of the final physical model was done to check whether it was within the desired objective of the project. The cost analysis helped us in making the project as cost-effective as possible.

- **Pilot run and analysis** - Different test-runs were done on the final model based upon parameters like inclination of the road, terrain, load capacity, maximum speed without falling and running time. Experimental stress analysis on the 3D model was done using ABAQUS based on different loads. Different calculation such as torque and weight carrying capacity were done to come up with a proper motor.

III. IMPLEMENTATION AND WORKING

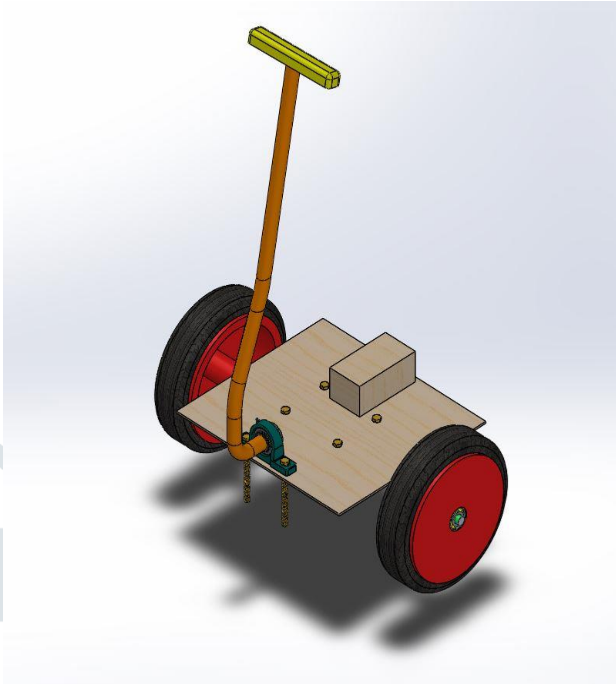
The single occupancy transporter works in such a way that, it follows the principle of the inverted pendulum problem and always tries to maintain zero-degree angle with respect to the ground. This is achieved with help of gyroscopic sensors, motor controllers like Arduino Board. The transporter balances itself with the help of its movement, which is achieved by the code which was generated and compiled in Arduino. The Arduino then takes this command and gives it to the motor controller, which in our case is a sabertooth 2x32. The sabertooth then decides how much the wheel should rotate and in the direction in which the wheels should rotate such that the transporter doesn't fall. The gyroscopic values for the code to run were taken from the Mpu6050 gyroscopic module. The orientation of the transporter changes as a result of the weight shift of the passenger. The passenger leaning to the front would cause the transporter to go front, the farther the passenger leans, the faster the transporter would go as a result of the code requiring it to maintain zero-degree angle with respect to the ground.



Mpu6050- the gyroscopic module used in this project is a 3-axis analog gyroscope and accelerometer module, used to find orientation. It's the values taken from this module helps Arduino give commands to motor controller owing to the changing angles as a result of weight shift of the passenger riding. It is mostly used in drones, robots etc.

A. Design

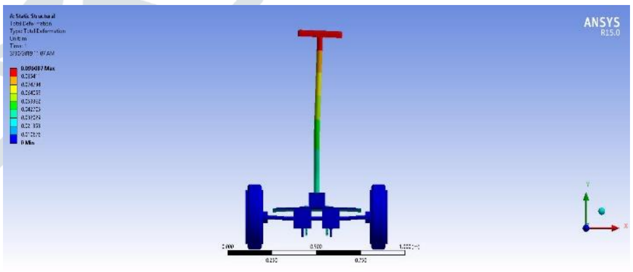
A 3d model was developed on SOLIDWORKS referring to the already existing single occupancy vehicle deign available commercially and in study. The below given model is the final model of our transporter developed on SOLIDWORKS.

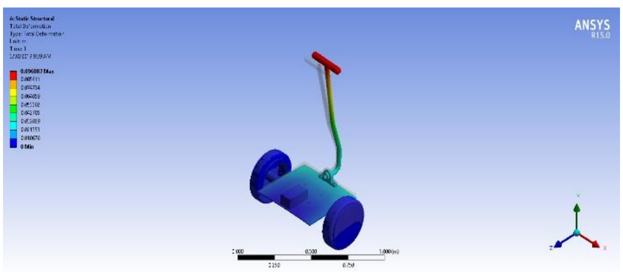


The above given model is the final model of our project, which has a base plate on to which the actual passenger is going to ride

B. Analysis

The above given CAD model was then subjected to analysis on ANSYS WORKBENCH to find the load carrying capacity of the model. It was also done to find the stresses acting on the model. The following results were obtained from the analysis.





The load applied was 400 Pa, maximum stress acting was found to be on the handle as shown in the above diagram. The handle also deformed as result of the applied load.

IV. RESULTS & CALCULATIONS

The Specifications is given below :

Torque Calculated: -
Maximum weight of rider = 80 kg
Chassis weight including batteries = 35 kg
Therefore, Total weight=115 kg (approx.)
Coefficient of friction between road and tire = 0.3
Torque required = Friction Force * Radius of Wheel
T = 115 x 0.3 x 17.78cm
T = 6.134 kg f m (Approx.)
As two motor are used.
Therefore, torque required by each motor
= 3.067 kg f m(Approx.)

Table 1.1

Weight (kg)	Distance Covered (meters)	Time Taken (sec)
90	50m	21s
100	50m	24s
115	50m	32s

The above table shows the result obtained for time taken with varying loads acting on the model for a constant distance of 50m.

CONCLUSION

A 3D-model of self-balancing two-wheeler was prepared using SOLIDWORKS. The analysis of the model was done using ANSYS Workbench. The transporter was programmed using Arduino and on the principle of inverted pendulum problem. Working conditions of the transporter was studied based on the application of different loads. The characterization and comparative study were taken into consideration and a graph of speed, cost and distance covered was formed. The model obtained was self-balancing that maintains zero degree with the ground and is also eco-friendly.

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