DESIGN ANALYSIS AND FABRICATION OF THREE WHEEL SEGWAY

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Abstract

In the present days, we are dealing with a problem of increase in number of vehicles with ever-lasting demand of fuel to run them. If this situation remains with time, it would be difficult for us to save our future from increasing pollution and fuel demand. With time the population on earth increases obviously; which cannot be controlled so to fulfill the demands of fuel or energy in future world, effective steps should be taken as soon as possible. Our dependence on fuel can be reduced with an alternative such as, use of battery-operated vehicles. The aim of this project work is to build up an Tri-wheel electric segway at a very low cost, highly efficient rate and easy to handle and operating also. Three wheels Segway is an electric scooter of future technology; it is often used to transport a user across mid-range distances in urban environment. It has more stability than car or bike and is faster than pedestrian. They are more efficient than fuel powered vehicles for shorter distance and time of travelling.

Keywords: Mechanical segway motors, wood plate, two wheels and one small supporting wheel (self-balancing)

1. Introduction

A segway is a three wheeled vehicle which was introduced by Dean L. Kamen in 2001. It can self-balance itself as well as the weight of the rider. It is provided with a control handle bar, vertical to the platform, which is pushed front or pulled back and accordingly the motion of the segway is noticed. The device is primarily driven by the dynamics of the rider either forward or backward. This is an eco- friendly mode of transport for short distances since no fuel is consumed and rechargeable batteries are used instead. A segway consumes very less space and helps reduce the extreme traffic to quite some extent. In our project, the prototype demonstrates the mechanism of the segway by balancing itself. For the rider's convenience, we have also introduced remote sensing, which is attached to handle itself. Thus a rider can access his/her vehicle from a certain distance. There are many variants available in Segways. However, the most popular and commonly used ones are the three wheeled segways, known as the Segway PT. It is an electric, self-balancing human transporter with a computer-controlled gyroscopic stabilization and control system. The device is balanced on two parallel wheels and is controlled by moving body weight.

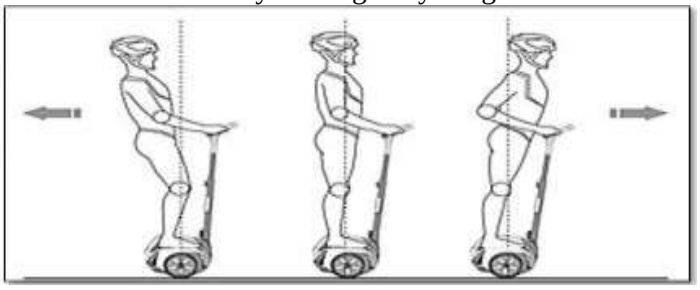

Fig.1.1 Acceleration Mechanism of Segway

2. Literature Review

Ganesh Shirsath et.al. There is increase transportation of goods and public transportation. The adverse effects are known and well documented. Discussions about various views of the best solutions for these problems are taking place around the world. One of these visions involves the use of advanced technology based on the public transit as the basis for all sustainable solutions. In this search for different methods, MPTDs could help promote a modal transfer away from the automobile for short-distance trips. Electric scooters and Segways are two, user friendly, "in" modes of transportation that facilitate effortless travel and could provide suitable transportation in metro cities. Our aim is to make a design and fabrication of Segway personal transporter. The Segway is based on the principle of inverted pendulum that will keep an angle of Zero degrees with vertical at all times.

Mayank Sharma et.al. The Segway Human Transporter is one of several low-speed transportation devices (e.g., bikes, scooters, wheelchairs) that, under certain circumstances, travel on sidewalks, roadways, and other shared-use paths. The objective of this research was to examine the primary operating characteristics of the Segway. In this thesis, we designed and constructed mechanically based system for a two wheel balancing Segway robot. In this paper we present a Segway based on gyro sensor, accelerometer along with a microcontroller and use of mechanical and electrical hardware's. The dynamics of the vehicle is similar to the classical control problem of an inverted pendulum, which means that it is unstable and prone to tip over. This is prevented by electronics sensing the pitch angle and its time derivative, controlling the motors to keep the vehicle balancing. This kind of vehicle is interesting since it contains a lot of technology relevant to an eco-friendly and energy efficient transportation industry. This thesis describes the development of a similar vehicle from scratch, incorporating every phase from literature study to planning, design, vehicle construction and verification. The main objective was to build a vehicle capable of transporting a person weighing up to 70-80 kg and capable of travelling to some km distance with varying speed.

Ashish Srivastava et.al. The present paper aims at expanding the use of two wheel system by creating a small, compact high performance control and instrumentation system that can be integrated into future transport systems. This system is based on the principle of inverted pendulum and is an electrically activated balancing machine with only two wheels with a feature to spin on the spot. This system manages to bring itself to the equilibrium point by creating an opposing force in the direction opposite to that of the user. The project explores the use of Kalman filter for sensor fusion and State feedback control algorithm for regulatory and tracking performance. This system may also be used as a test bed to investigate the performance of other control algorithms.

Ankit S. Khanzode et.al. In this project work, two wheeled and one small supporting wheel self-balancing as well as manually balancing Mechanical Segway vehicle is prepared which is also known as a personal transporter Segway. The system is able to operate in transporter mode and robotic mode. The first goal is to maintain stabilization in pitch dynamic. This project focuses on to manufactured Segway without using any type programming & Sensors a state feedback to stabilize system on transporter mode. The system consist of forward and backward movement when the driver operating DPDT switch in transporter mode in order to stabilize body. Small wheel is used so that there is no need of gyroscope for balancing purpose. The aim of this project work is to build up at a very low cost, highly efficient rate and easy to handle and operating also. The tests are performed on mechanical Segway to confirm that Mechanical Segway operating very well and high efficient rate.

Sandesh Pitambare et.al. In the present days, we are dealing with a problem of increase in number of vehicles with ever-lasting demand of fuel to run them. If this situation remains with time, it would be difficult for us to save our future from increasing pollution and fuel

demand. With time the population on earth increases obviously; which cannot be controlled so to fulfill the demands of fuel or energy in future world, effective steps should be taken as soon as possible. Our dependence on fuel can be reduced with an alternative such as, use of battery-operated vehicles. The aim of this project work is to build up an Tri-wheel electric segway at a very low cost, highly efficient rate and easy to handle and operating also. . Three wheels Segway is an electric scooter of future technology; it is often used to transport a user across mid-range distances in urban environment. It has more degrees of freedom than car or bike and is faster than pedestrian. They are more efficient than fuel powered vehicles for shorter distance and time of travelling.

3. Development of prototype:

After studying different papers on Design & Fabrication of segway ,we have made our project motto as application of Design, Analysis & Fabrication of three wheel segway, by using low cost equipment under normal feasible conditions.

In this project, we are using the equipment with low cost and the equipment can also sustain particular loads only. Because this project is for keeping the model with exact parts of segway, in this we are using Two plastic wheels, one supporting wheel, batteries and motors. So, the aim of this project centers around the concept of making a Segway type standup scooter that is Economical, Reliable, Stable and Fail-safe.

Parts used for fabricating the model.

Table 1.euipment used

Description	**Type**	**Quantity required**
DCMOTORS	24 V , 50KG , 200RPM	2
TWOWHEELS	Dia 12cm, width 3cm	2
SWVELWHEEL	Dia 6cm	1
BATTERY	24V – 18AH	1
SWITCHES	POLARITY VARIES	2
CONNECTINGWIRES	ELECTRICAL WIRING EQUIP	5
PIPE'S	1.5M	3
NUT BOLTS	6MM DIA	12
WOOD BOARD	25*30*3	1

4. Design and Analysis of three wheel segway.

Fig. 4.1.1 Isometric view of the segway model.

3D model of the segway is created using **Solid Works 2013,** a solid modeling computer-aided design (CAD) and computer-aided engineering(CAE) computer program developed by **Dassault Systems Solid Works Corp**

Table 2. List of machining operations carries out on the foot plate:

S.no	Operation carried out	Machine used
1.	Cutting the plate to required dimensions	Horizontal hack saw machine
2.	Rounding the corners and chamfering the edges	Hand angle grinder
3.	Drilling the holes on the wood plate at required positions	Horizontal drilling machine

After carrying out the required machining operations, the motors, bearings, drive wheels, swivel wheel and springs are mounted onto the footplate. After mounting the components under the foot plate, a handle made of GI pipes is fixed on to top of footplate by using a threaded flange coupling. After making the circuit wiring and connecting the electronics, the assembly of segway is shown in the. Two rechargeable lead acid batteries of 12V each and of capacity 10AH each are connected in series are used to power the segway.

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4.1 .MODEL CALUCULATIONS:

Taking,

Total mass**, m** = 100 kg

Angle of inclination, **Θ** = 20˚

Total efficiency, **e** = 85%

Radius of the wheel, **R** = 0.1016 m

Supply voltage, **V** = 24V

Desired acceleration, a **= 0.2 m/s²**

Let, the Segway speed on incline **v** = 2m/s = 120m/min.

So, 2ΠRN = 120

$2\times\pi\times0.1016\times N = 120$

This equation gives,

N = 188 rpm.

w = 19.6850 rad/sec.

mgx = $100 \times 9.81 \times \sin(20^{\circ}) = 89.59$

mgy **=100 × 9.81 × cos(20°) = 400.32**

Starting torque is given by**,**

T = $(100/85) \times ((0.2 + (9.81\times\sin(20^{\circ}))\times100\times0.1016))$ **/** 2 = 21.24 **Nm**

Maximum current induced is given by,

I = (21.24 × 19.6850)/24 = 17.428

Battery capacity is given by
C= 17.428 × (30/60) = 8.714 AH

This is the battery capacity needed for each motor. To calculate battery capacity needed for entire segway, this should be multiplied by no. of motors.

C**= 8.714 × 2 = 17.428 AH.**

4.2 Analysis of segway:

The project began with exploring ideas for the design and inspired by similar devices in the market. Ultimately, a rectangular platform with two motor-powered wheels and one caster wheel was chosen. Parts were purchased and connected, and then model was built and tested. During testing, it was found that the model did not perform as well as expected. Because the motor did not able to grab the load of the specified battery what we have kept. And also we have designed some pictures in solid modeling software. Not only designing the model we have tested in stress strain analysis also for better result.

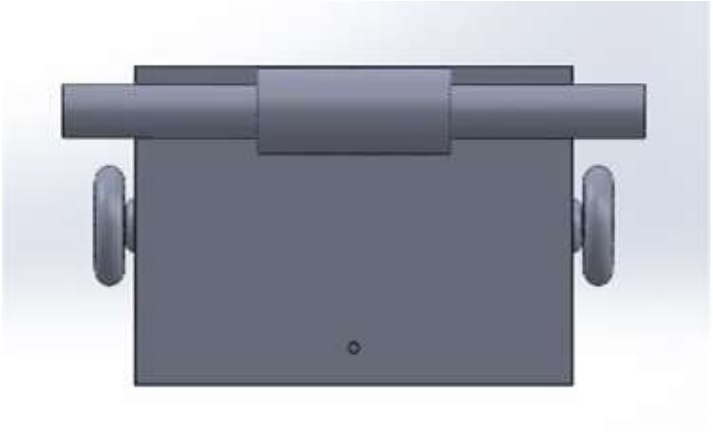

Fig. 4.2.1Top view of the model

The aim of this analysis is to check the deformation, stresses and strains induced due to loading on the footplate of the segway. Here loading included the weight of the person, weight of the batteries, motors and other components. However, the weight of

Before analysis a model of the foot plate is created using **solid works.** This model shows how the foot plate looks after machining, with rounded corners and drilled holes for mounting motors, bearings, handle and the swivel wheel. The areas with maximum stress would be the gaps between the holes. The distance between these holes is maintained as maximum as possible (without affecting the design), to minimize the stresses induced. The below picture shows the model of the machined footplate created in **Solid Works** software that should be analyzed for stresses, strains and deformation.

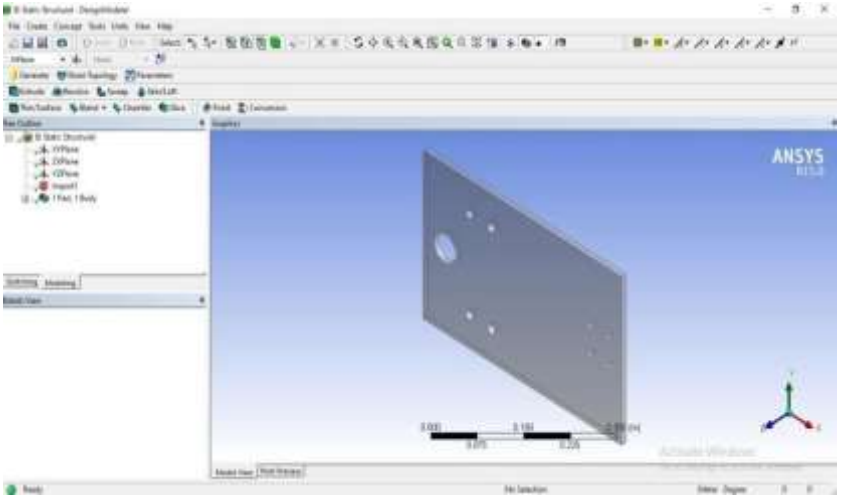

Fig.4.2.2 Foot plate modeled for analysis.

Since, the foot plate is supported by the bearings and the swivel wheel at three positions; simply supported boundary conditions are given at the positions of the two Plummer block bearings and the swivel wheel. Since, the weight acts at the standing positions of the person, two uniformly distributed loads of 50 kg each are applied on either side of the footplate at the standing positions areas. The same procedure is done using two point loads as well. Both results are nearly same.

- Total load = 100 kg
- No. of positions = 2
- Type of load = uniformly distributed
- Type of analysis = Static Structural

4.3 STRESS – STRAIN ANALYSIS:

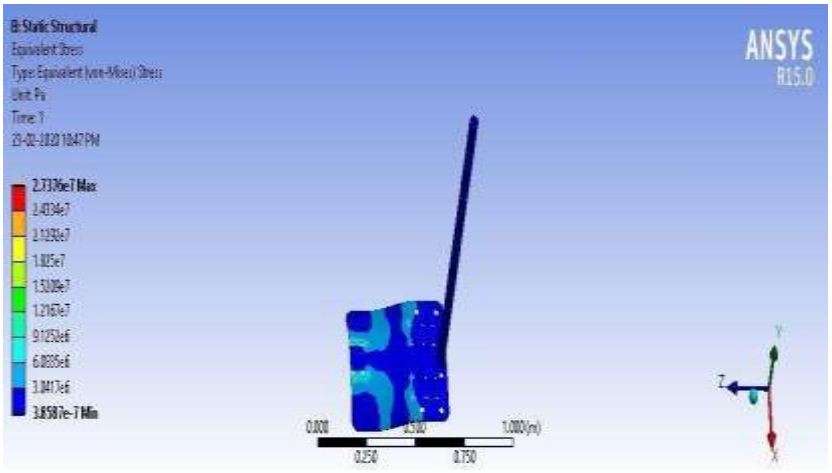

Fig. 4.3.1 Analysis results: Stress distribution on the foot plate.

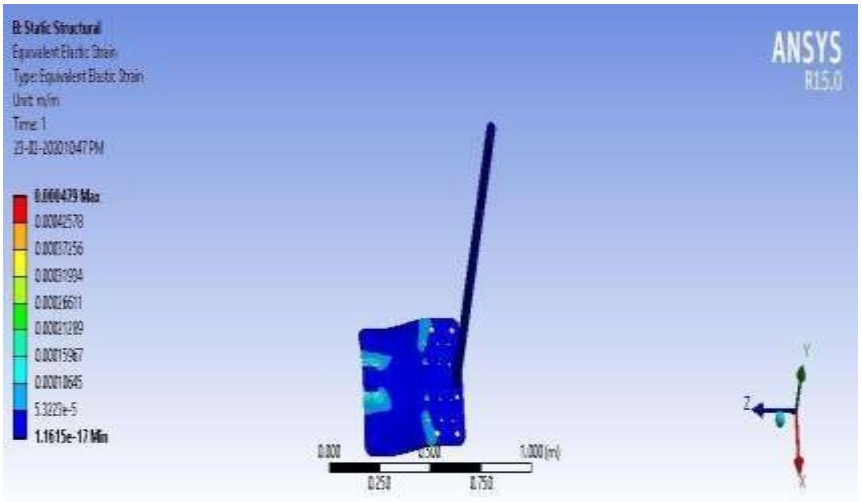

Fig. 4.3.2 Analysis results: Equivalent Elastic strain of the foot plate.

4.4 DEFORMATION:

The below picture shows the total deformation of the footplate in **m.** under the give conditions of loading and boundary conditions.

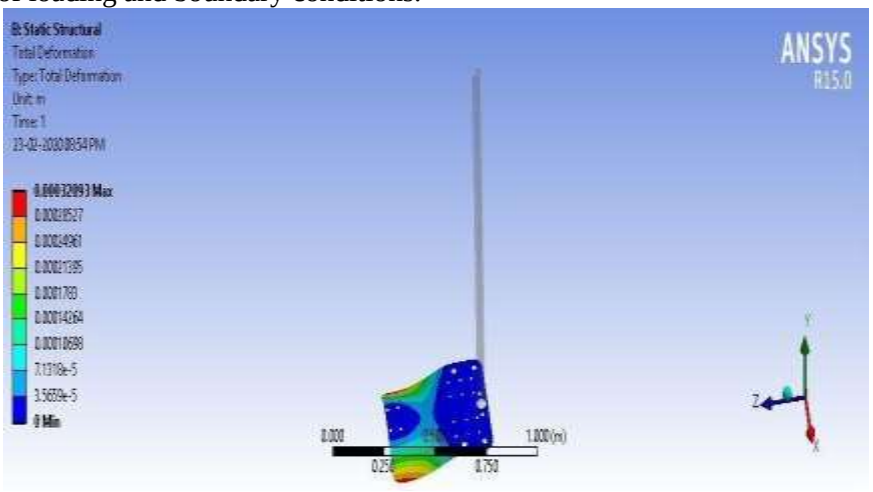

Fig. 4.4.1Analysis results: Total deformation of the footplate.

The resultant deformation style can be seen in above picture. The maximum deformation is found at the bottom corners of the plate. The value of this maximum deformation is around **0.3mm.**

- Maximum deformation areas = Bottom corners of plate
- Maximum deformation value = **0.3 mm**

Since, the **deformation is very small**, it will not have much effect on the structure of the plate under loading and there are no chances that this minute deformation affects the motion or stability of the segway.

5. CONCLUSIONS:

The three wheel segway is designed based on the **Fundamentals of machine design**, modeled in **Solid works** software and Analyzed in **Ansys15.0** and fabricated according to plan. Based on the factors like Stability and cost, three-wheel segway is found to be a good alternative for the two-wheeled version. Moreover, the fail-safe feature in this vehicle makes it more reliable than the two-wheel segway. The results from this project clearly shows that three-wheel segway when manufactured with efficient components, good control system and a good suspension system, can be the most **stable, reliable, economical and fail-safe** personal transporter.

Basically this investigation is successful achieved the objective with the acceptable outcome. The main goal of this project was a build in a prototype of two wheels and one supporting wheels transporter and this goal has been fulfilled. The overall functionality and performance of the vehicle has been evaluated thoroughly by a number of test drives. The vehicle has been tested by a number of different weights. This project is implementing with an idea to find an effective solution to transportation problem.

FUTURE SCOPE:

Less accurate bang-bang type control system can be replaced with Dual H-Bridge control, which can make the steering of the segway more precise. 3rd wheel can be provided with a better suspension system for more smooth movement of the vehicle Battery pack capacity can be increased by replacing the lead acid batteries with polymer batteries, which have much higher capacity for the same weight. This can improve the run time of the segway before complete battery discharge. Steering mechanism of Segway can be improved by using dual axis potentiometers. This makes the segway much easier to ride.

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