Design and Analysis of Hybrid Segway Vehicle

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Abstract : This paper presents the design and analysis of Segway vehicle for human transportation a two-wheeled, self-balancing vehicle that works on the principle of an inverted pendulum. And the whole model is dynamically stabilized and also Multi-directional shock absorber. They have a digital accelerometer with head and tail lamp fixed to it. We aim at producing a full y-operational model of a Segway vehicle with a compact design which caters for shock absorption on rough terrains and includes the different type of analysis done on Segway vehicle. The vehicle has a top speed of 25 km/h, without any load acting on it and on an applied load speed may vary from 19 km/h - 21 km/h from our calculation a load capacity of over 2000N and a balancing time of fewer than 2 seconds and an additional feature added on to the Segway vehicle is the powerful solar panels to charge the battery.

Keywords - Segway; gyroscope; accelerometer; inverted pendulum; dynamic stabilization.

I. INTRODUCTION

A Segway is an electrically powered standup scooter with a higher degree of freedom than normal vehicles and mostly used for personal transportation in an urban environment. This was invented by Dean L. Kamen, an American entrepreneur and first produced by Segway Inc. of New Hampshire. Segway have had success in niche markets such as transportation for police departments, military bases, warehouses, corporate campuses, and industrial sites. The legal roadworthiness of the Segway varies with different jurisdictions classification of the device as a motor vehicle. There are many variants available in Segway. However, the most popular and commonly used ones are the two-wheeled Segway, known as Segway Personal transport. 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.

The factors are taken into consideration during the mechanical design were dimensions, weight, materials used for the vehicle fabrication and solving differential equations for inverted pendulum in order to find the state equations for the system. Modeling the system mathematically resulted in providing the equations that were used international standards to find the optimum compensator constant values for the system. Extending these results, the state equations were also used to calculate the required torque and power to drive the vehicle. These values were used then for motor selection. The state equations that were found from the mathematical modeling of the system

II. LITERATURE SURVEY

[1] Survey on Self Balancing Two Wheel Electric Prototype

Prashant Govardhan, Akhilesh Thakre, Nehal Shende, Nachiket Phadnis

Studying the project survey and report prepared by the above mentioned students we can say that the. maximum weight their model could hold was up to 90kg. So to overcome this problem we are making use of hard plastic and fiber for the base of the vehicle which can support a load up to 130kg without compromising on the speed and performance of the vehicle.

[2] Designing the Self –Balancing Platform (Segway)

Prof.Yogesh Risodkar, Mr.Ganesh Shirsath, Ms.Monali Holkar, Mr.Mayur Amle

As stated by the above mentioned professors in their project report that the vehicle designed by them can achieve a speed of 15 km/h. We are planning to achieve a minimum speed of 20 km/h by using aluminum for our main skeletal fabrication as it is lighter compared to other materials and thus helps us in reaching our target speed.

[3] Design And Development Of Segway

Velaji Hadiya, Aakash Rai , Sushant Sharma, Ashwini More

They have studied a two-wheeled self-balancing electric transporter which can operate in manned and unmanned mode. It was constructed as a term project in Mechatronics in Automotive Engineering course in 2009. As part of this thesis, physical system is improved. A load carrier mechanism is mounted in front of the system. This is the first step to transform into an Segway RMP. Also, electrical construction is rearranged and components are placed more appropriately. Sensor set is improved by integrating an encoder on the shaft of the motor. They have Programed the arduino board as per the logical flow so that at the last we can see that Segway can be manufactured at a very low cost.

III. PROBLEM FORMULATION

In the current design of vehicles, kinematic and compact modeling is most important to maintain. Clearance in between the Road and the tiers, for local transportation the vehicles which run on fuel are hard to transport when compared with the Segway vehicle. Used especially for schools, colleges, patrolling, concerts, police security, etc.

The main problem faced in the current world is pollution Segway vehicle gives a smart solution for the pollution and So, in the current study, we are going to investigate the static structural analysis and explicit dynamics distribution for Segway vehicle in different cases and also to optimize the model by providing aerodynamic structure. The CAD model first meshed and then put through a series of ANSYS modeling analysis. The ANSYS analysis was carried out in two parts: one for static structure analysis for safe loads as well as failure loads and second crash analysis and giving a suitable report to it.

IV. METHODOLOGY

The vehicle was physically modeled based on inverted pendulum principle and the mathematical model was generated

1. Principle on which the Segway vehicle works
2. 2D drafting of the prototype in SOLIDEDGE ST8
3. 3D modeling of the prototype in CATIA V5
4. Rendering of the 3D modeled prototype in AUTODESK FUSION 360
5. Calculation of torque and power output from standard values
6. Meshing the 3D model for analysis in ANSYS 15.0 WORKBENCH
7. Conducting static structural, modal and explicit dynamics analysis in ANSYS for different trials
8. Manufacturing of the scaled prototype model
9. Final buffing and assembly of all the components

PRINCIPLE ON WHICH SEGWAY VECHICLE WORKS

The deployment of electric vehicles in vast quantity can viewed as a carbon free transportation sector. As because of pollution the environment is also getting weaker and hence the quality of life also affect dramatically. The majority of the carbon emission is due to the fossil fuel vehicles.

The two-wheeled balancing vehicle is a project that has become very popular technology in the field of Mechatronics and Robotics. This project draws on the theoretical principles of the equally popular experiment of the inverted pendulum. The inverted pendulum system, unlike many other control systems is naturally unstable. The system therefore has to be controlled to reach stability in this unstable state. The theory behind controlling this vehicle is moving the base of the chassis handle towards the direction that the vehicle is falling and hence keeping the center of gravity of the vehicle vertically above the axis of the wheels at all times. This way the vehicle remains upright and does not topple over.

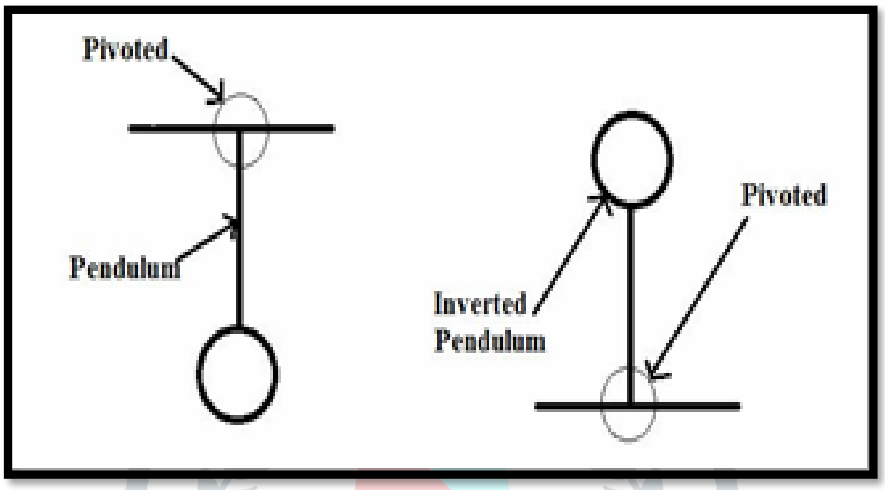

Fig 4.1 Normal and inverted pendulum

2D DRAFTING OF THE PROTOTYPE IN SOLIDEDGE ST8

A draft file consists of the 3D model projected to one or more 2D views of a part or assembly file.

Solid Edge integrates with Sharepoint and Teamcenter to provide product lifecycle management. Solid Edge also integrates with PLM products from third parties. Solid Edge ST9 brought a new data management capability that leverages the Windows file indexing service to add basic data management functionality without the need for an additional server or set-up.

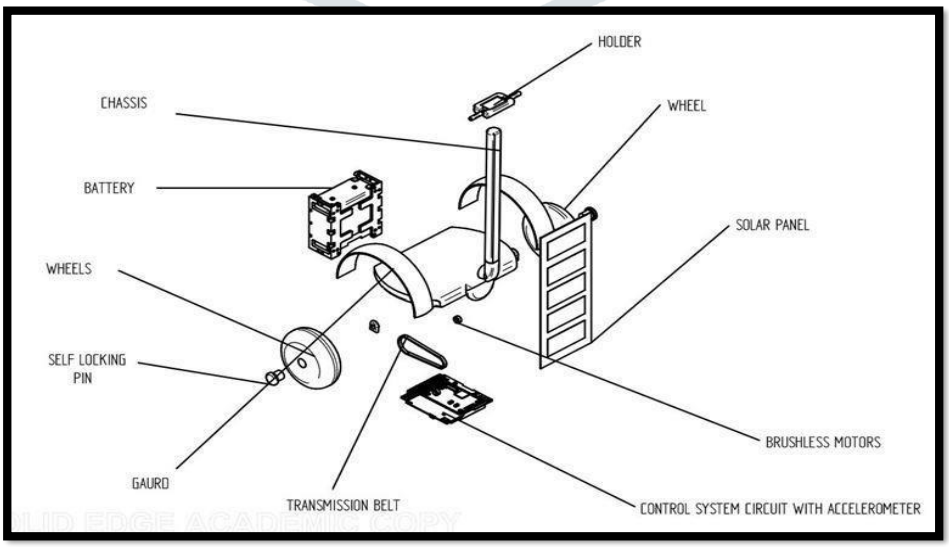

Fig 4.2 Line Diagram Of our Design Model

- **3D MODELLING OF THE PROTOTYPE IN CATIA V5**

Assembly modeling is a technology and method used by computer-aided design and product visualization computer software systems to handle multiple files that represent components within a product. The components within an assembly are represented as solid or surface models.

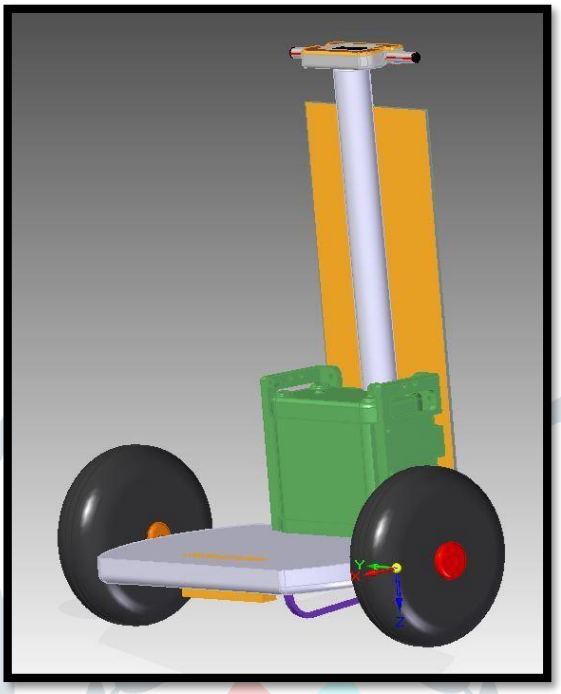

Fig 4.3 Assembled And Modeled (Iso-metric view)

- **CALCULATING SOLAR POWER REQUIREMENTS**

Battery capacity is measured in Amp Hours (e.g. 17AH). You need to convert this to Watt Hours by multiplying the AH by the battery voltage (e.g. 12V).

X= Battery size in AH
Y=Battery voltage
Z= power available in watt hours (WH)

Formula used:-

$X \times Y = Z$

Eg= X= 20AH & Y= 12v

hence

20 × 12 =240 WH

This means that the battery can supply 240 W for 1 hour and 120 W for 2 hours. This indicates that more the energy you take the faster the battery discharges.

CALCULATION OF TORQUE AND POWER OUTPUT FROM STANDARD VALUES

Torque Calculation	Speed Of Motor Calculations
Formula used -: Torque (T) = Friction force*Radius of wheel* Total weight T = 0.3*20*140 T=8.4kgf Convert kgf (kilogram force) to Newton (N) Hence T=82.37 N So the torque from two different motors is 4.2kgf or 41.1N	Formula used -: $w = kv \times (Vinput - Rmotor \times I\ input)$ Kv= Speed constant.[Kv = 1/Kt]= 1.17 w= 1.17 ×(40 – 4.6 × 4) w= 1.17 × (21) w= 35 Convert into RPM by ×ly 9.55 So, w= 35 × 9.55 w= 334.25 RPM Diameter of wheel = 40cm Radius of wheel = 20cm

MESHING THE 3D MODEL FOR ANALYSIS IN ANSYS 15.0 WORKBENCH

Meshing is defined as the process of dividing the whole component into a number of elements so that whenever the load is applied on the component it distributes the load uniformly called as meshing. A component is analyzed in two ways. One is with Meshing and the other is without meshing.

ANSYS Meshing. ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient metaphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model.

Statistics	
Bodies	10
Active Bodies	10
Nodes	88320
Elements	55252
Mesh Metric	Orthogonal Quality
Min	7.19632415686877E-03
Max	0.996480279426868

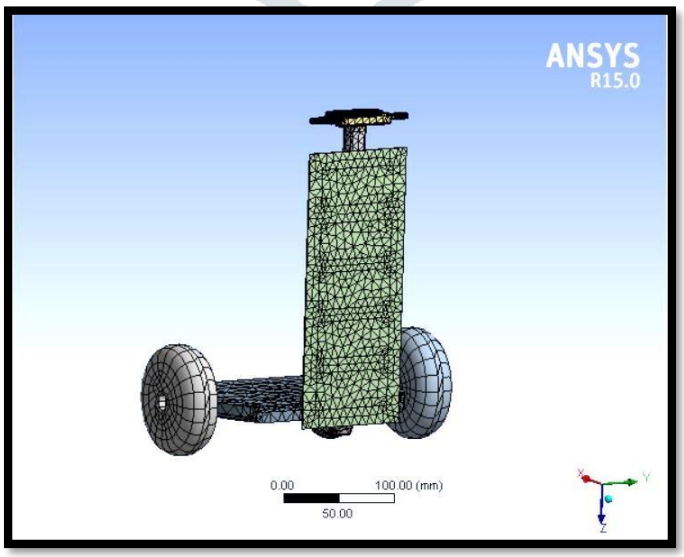

Fig 4.5 Meshed model in ANSYS

- **CONDUCTING STATIC STRUCTURAL AND EXPLICIT DYNAMICS (CRASH ANALYSIS) ANALYSIS IN ANSYS.**

- **STATIC STRUCTURAL ANALYSIS :**

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. A static structural load can be performed using the ANSYS, Samcef, or ABAQUS solver.

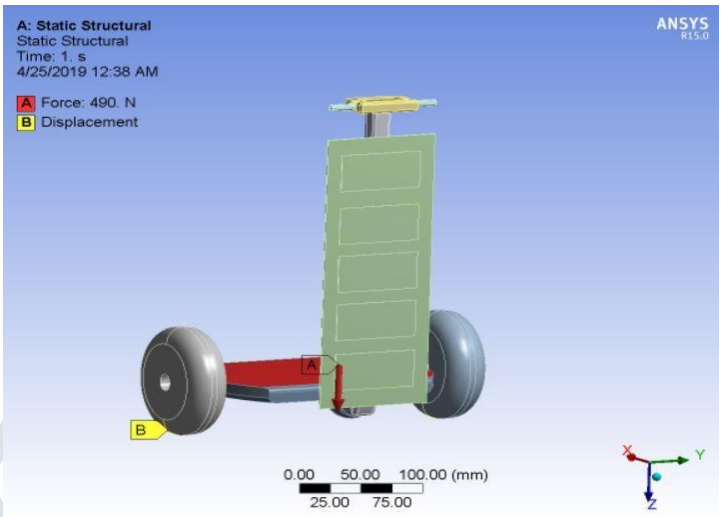

Fig 4.5 Applying boundary condition on the Segway vehicle

The two wheels are To be fixed, the load of 490N (50Kg) is applied on the flat plate surface of the Segway Considering the surrounding temperature to be 22°C

Stainless Steel is the material used to conduct analysis

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
22	1.93e+011	0.31	1.693e+011	7.3664e+010

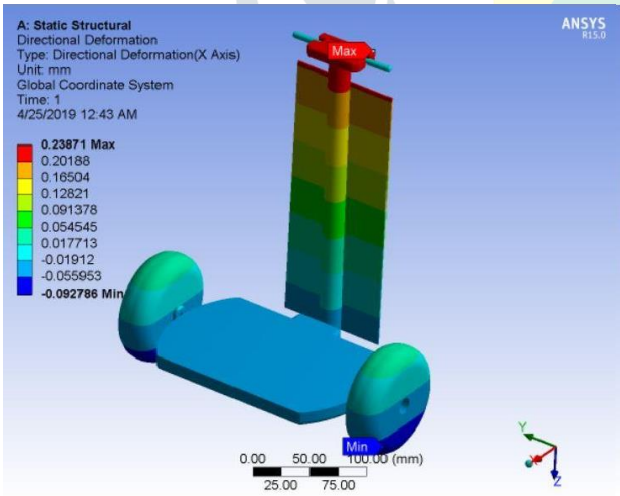

Fig 4.6 Directional Deformation on X-axis

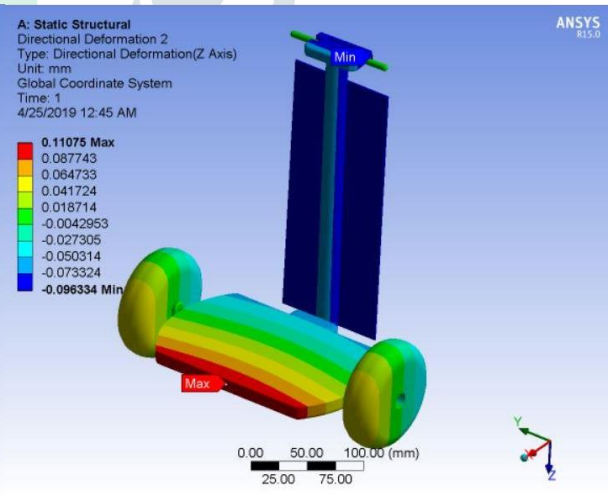

Fig 4.7 Directional Deformation on Z-axis

- From fig 4.6 The directional deformation along X-axis the max. deflection created is 2.3971e-005 m and minimum deflection X- axis is give as -1.136e-005 m that is the static structural directional deformation result on X-axis for 490N (50Kg) under time interval of 5 seconds.

- From fig 4.7 The directional deformation along Z-axis the max. deflection created is 1.3620e-005 m and minimum deflection Z- axis is give as -1.1796-005 m that is the static structural directional deformation result on X-axis for 490N (50Kg) under time interval of 5 seconds.

- **EXPLICIT DYNAMICS (CRASH ANALYSIS) ANALYSIS :**

You can perform a transient explicit dynamics analysis in the Mechanical application using an Explicit Dynamics system. An explicit dynamics analysis is used to determine the dynamic response of a structure due to stress wave propagation, impact or rapidly changing time-dependent loads

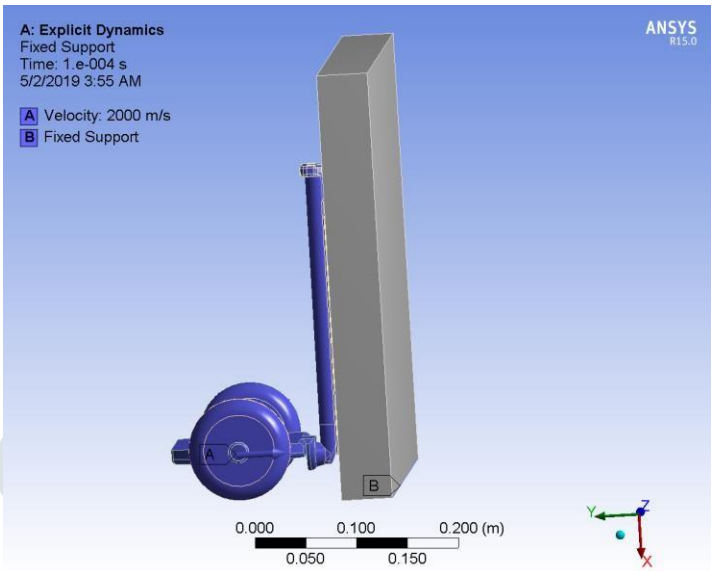

Fig 4.8 Applying boundary condition on the Segway vehicle

The two wheels are to be fixed, the load of 490N (50Kg) is applied on the flat plate surface of the Segway Considering the surrounding temperature to be 22°C

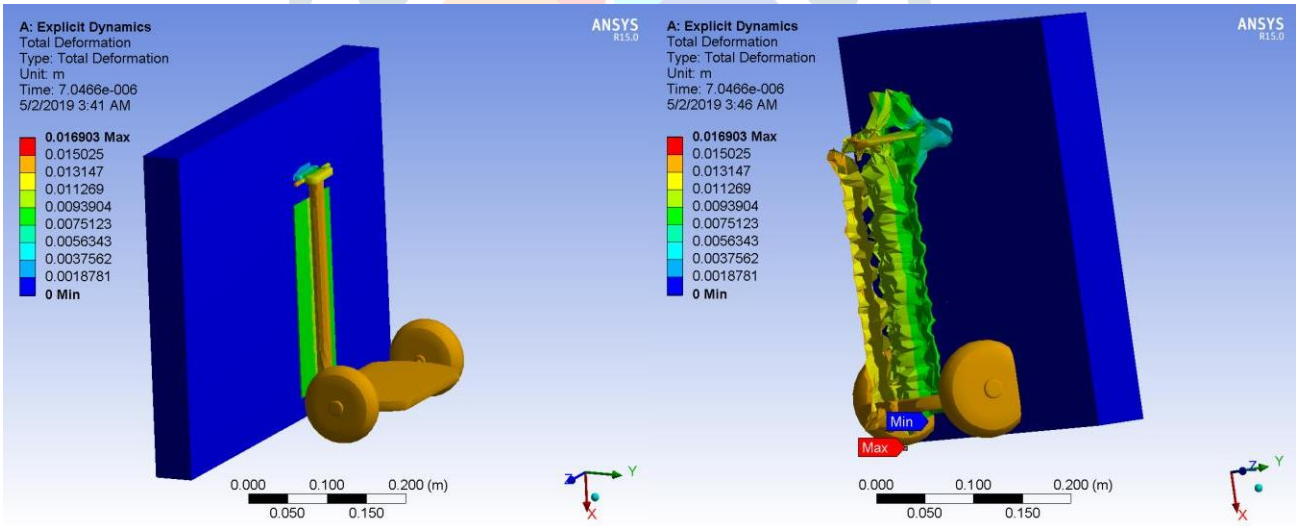

Fig 4.9 True scale deformation along X axis (20km/h) Fig 5.0 5X times deformation along X axis (20km/h)

- From figure 4.9 we can conclude that the model designed by us after crashing to the concrete wall at 20km/h the max deformation 1.69 e-005 m. Minimum deformation is 0.18e-005m.

FABRICATION AND ASSEMBLY OF THE MODEL

Fig 5.1 Finishing process (Buffing)

Fig 5.2 Assembled Chassis

Fig 5.3 Assembled view

CONCLUSION

In the course of this project we have designed the personal transporter with more efficient use of energy and providing alternatives to form an eco-friendly. This project was implemented with an idea to find an effective solution to transportation problem. The main objective is to achieve space utilization and minimize the fuel consumption especially for commuting over shortest distance.

The design of the Segway vehicle has been completed using various softwares like Catia, Solid Edge, Auto desk fusion 360. An analysis has been carried out using Ansys for two different loads 50 kg and 250 kg Embedded system development is also in progress. Upon conclusion the vehicle should be able to balance and move on two wheels without falling over.

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