ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

Modeling of Human Transportation Segway Vehicle and analysis using ANSYS

Sireesha Koneru*[a],

[a] Assistant Professor, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Green fields, Vaddeswaram, Guntur.

P.Saritha[b],

[b]Assistant Professor, Department of Mechanical Engineering, Anurag University, Telangana

*Corresponding author: sireekonerus@gmail.com

Muni Tanuja Anantha[b],

[b]Assistant Professor, Department of Mechanical Engineering, Anurag University, Telangana

*Corresponding author: sireekonerus@gmail.com

Sravan kumar chilukuri[a]

[a] Assistant Professor, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Green fields, Vaddeswaram, Guntur.

[b] Assistant Professor, Department of Mechanical Engineering, Anurag University, Telangana

*Corresponding author: sireekonerus@gmail.com

Abstract.

The Segway is a popular personal transportation device, is frequently utilized for efficient mobility across moderate distances in urban settings. It offers users a greater degree of freedom in movement compared to conventional vehicles and bicycles. In the present work the 3D model is developed for the Segway and imported into ANSYS using para-solid design, and Finite Element Analysis has been conducted to assess the structural integrity. The study includes a static analysis focusing on the applied load on the stationary seat of the Segway, as well as a dynamic analysis of the overall Segway structure to identify stresses and propose preventive measures. Emphasis has been placed on optimizing the design for the mentioned conditions. This research involves the design and enhancement of a Segway vehicle assembly, specifically addressing structural integrity and vibrations. The results reveal a maximum average von-Mises stress of 92.2 MPa on the Segway assembly under static loading conditions.

Keywords: ANSYS, Finite Element Analysis, von-Mises stress.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

1. Introduction

Segway is used in urban areas to move a client. The Segway proposal originated from the IBot, a wheelchair equipped with six wheels to allow people with inabilities to climb up without the wheelchair losing stability. Jeremy Searock et al [1] discussed on a Segway Human Transporter (HT) by a single person dynamically and self-balancing vehicle. Dr. Rongfang (Rachel) Liu, AICP, PE.et al [2] discussed on the constantly-increasing demand for capacity across civic streets of America, which has created a need for quicker, easier, and eco-friendly means of transportation. To satisfy the above needs, Segway Human Transporter (HT) has been developed and has attracted the transportation professionals, political leaders and normal citizens also. Karl T. Ulrich.et al [3] have discussed regarding a private electric vehicle (PEV) that aroused as a substitute to a transportation device in 1990s. PEVs moves one passenger for trip distances of 1 to 10 km with the usage of electricity as they need motive energy source. Christopher Dunkers, BrianHetherman.et al [4] discussed about a Segway RMP, using it in an assistive technology mode. A research was performed to develop a model of the robot and configuration of the given RMP was updated and a robotic arm was also designed to improve the platform's capabilities. This robot base imparts typical robustness and capabilities with a distinctive feature of dynamic balancing. It has been addressed in the present work about the challenge of using Segway RMPs to discover robots that are ready to play soccer independently. Sheryl Miller et al [5] discussed regarding the Segway Human Transporter, as shown in figure 1, is one of the low-speed transportation automobiles (e.g., bikes, wheelchairs, scooters) that were under some circumstances, travels on pedways, roadways, and also shared-use paths. The Segway is a motorized device which will achieve a speed as high as 12.5 mi/hr (20.1km/hr). The traveller can operate the vehicle during a standing point, which will allow the Segway HT to possess a comparatively tiny footprint.

Ming Li et al. [6] explored the limited use of Segways for transporting users over short distances in urban settings. Unlike bicycles or cars, Segways offer greater freedom of movement and are faster than walking. However, the navigation system discussed in this study has not been thoroughly investigated. Existing navigation systems are designed for car

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

drivers and pedestrians, and adapting them for Segway use could enhance user experience, reduce workload, and improve safety. This paper introduces a Segway Augmented Reality (AR) Tangible navigation system, presenting a mobile interface that displays the route through augmented reality. In a related work by Hiroaki NISHIUCHI, Yasuhiro SHIOMI, Tomoyuki TODOROKI, et al [7], elemental characteristics of Segway behaviour were analysed through experimentation. The study considered participants' varying levels of experience in driving Segways, examining trajectory data under different conditions such as acceleration, deceleration, overtaking pedestrians, and emergency braking. The research aimed to provide insights into the Segway's running behaviour based on participants' driving times. Brett Browning and collaborators [8] introduced a new domain named Segway Soccer in their paper. This domain explores the coordination of dynamically formed human-robot teams in real-time decision-making and response tasks. The study focuses on team tasks, requiring coordination and cooperation among human and robot players in the unique context of Segway Soccer.

2. Design Calculations

2.1 Modulus Calculations for a hollow cylindrical shaft:

Shear load (σc) = 25 kg(f)/mm^2 ; Load(wc) =300 kgs

Load on each wheel (Wc) = wc*1000/2

=150 kgs Distance between Rails (Lr) =1200 mm Distance between Shaft Loading Brackets (Lb)= 400 mm

Maximum Bending Moment (Bmax3) = Wc*(Lr-Lb)/2 = 60000 kg-mm

Max Bending Moment (Bmc) = Bmax3/1000

= 60.0kg(f)-m Required Sectional Modulus (Z7) = Bmax3/σc

= 2400mm^3

2.2 Design calculations for the model

Circular shaft

$$S = \frac{\pi\left(r_2^4 - r_1^4\right)}{4r_2} = \frac{\pi\left(d_2^4 - d_1^4\right)}{32d_2}$$

Where

ISSN PRINT 2319 1775 Online 2320 7876

Research paper **UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019**

d1 =Outer diameter of circular shaft = 20,

d2 =Inner diameter of circular shaft = 40

S = 3.14(40^4 - 20^4) / 32(40)

S = 7536000 /1280 S = 5887.5 mm

3. Modelling of Modified Segway Vehicle Structure

The alterations are made dependent on the mode shapes acquired at various frequencies from the modular investigation. The adjustments made on the Segway vehicle are as follows: The outer and inside distances across the shaft are 40mm and 20mm separately by diminishing the pole thickness to 10 mm the measurements are 30mm and 20mm individually. The rotor shaft thickness has been diminished to 10mm and the heaviness of the Segway vehicle is decreased from 74kgs to 71kgs

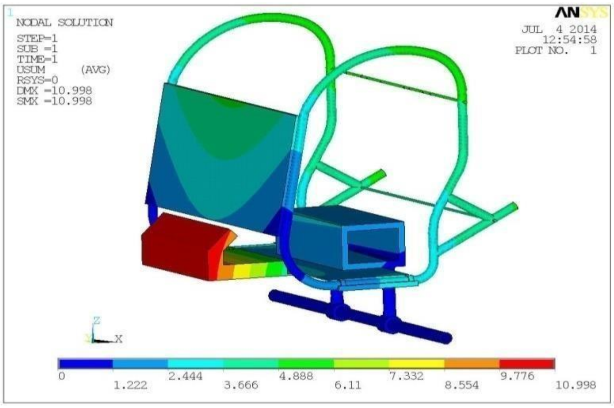
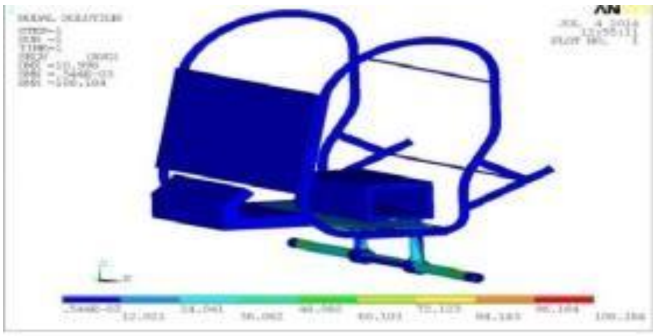


Figure- 1: The uniform deflection of varied segway assembly max deflection is 10.9mm.

3.1 Von-Mises Stress:



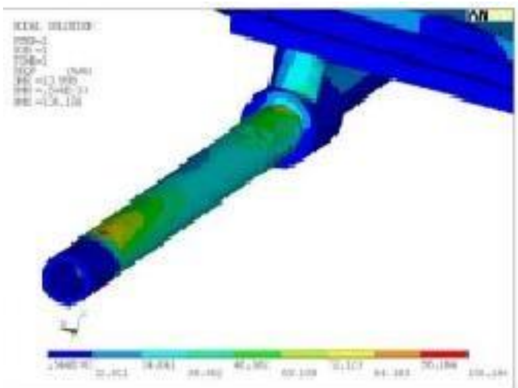


Figure- 2. The max von mises Stress in Modified Segway assembly

Figure- 3.The max von mises stress in modified segway assembly

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

S.no.	Deflection (mm)	von-mises Stress (Mpa)
1	10.9	108

Table 1: Max. Deflection and Max. Von-misses Stress

The Max Deflection 10.9mm was observed on the Modified Segway for static stacking conditions. The Max Avg. Von-Misses Stress watched 108Mpa on the Modified Segway get together for static stacking conditions.Furthermore, the Yield quality of the material chosen, aluminum and steel are 190 Mpa and 250 Mpa. respectivly. Hence as indicated by the Max. Yield Stress Theory, the von-mises Stress is not exactly the yield quality of the work piece.

4. Model analysis

Modular investigation was completed on Modified Segway to decide the characteristic frequencies and hence mode states of a structure in the recurrence scope of 0 - 60 Hz. The mass of Modified Segway is 71kg. From the modular investigation, a sum of 15 common frequencies is seen in the recurrence scope of 0-60 Hz. The mode states of these frequencies were observed in the below figures. The mass support of every one of these 15 frequencies are recorded in the beneath table.

Mode	Frequency	Partic. Factor		
		X	Y	Z
1	4.42	0.11e+00	1.8e-04	0.118e+00
2	6.62	-1.8e-02	-3.3e-04	0.112e+00
3	8.53	5.2e-04	0.1 e+00	-4.3e-04
4	18.5	1.6e-02	7.3e-02	-5.1e-02
5	18.5	-1.4e-02	2.9e-02	0.12 e+00
6	23.2	0.193e+00	1.1e-02	1.5e-03
7	26.9	9.e-03	-0.14e+00	6.4e-03
8	29.9	9.0e-02	-1.4e-02	-4.6e-02
9	39.4	1.6e-03	3.3e-03	-2.2e-03

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

10	42.6	-1.1e-03	6.7e-02	-7.7e-04
11	47.5	3.6e-03	-2.7e-05	1.3e-04
12	47.6	1.8e-03	3.6e-04	-3.3e-03
13	48.1	1.2e-03	1.6e-04	-3.3e-03
14	49.9	1.3e-02	-1.6e-04	-2.0e-02
15	54.4	-7.7e-02	-1.5e-03	0.109e+00

Table 2: Frequencies and Mass Participation in Kgs for Modes in the range of 0- 60Hz.

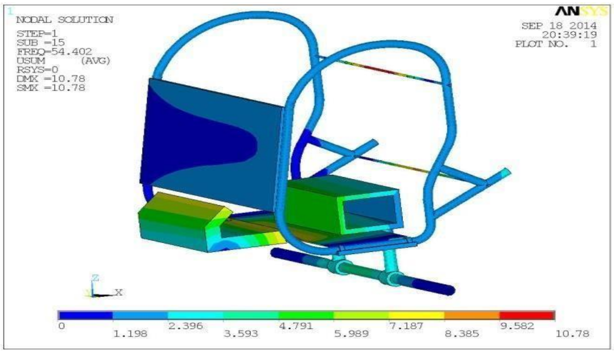
Mode	Frequency	Effective Mass		
		X	Y	Z
1	4.42	1.3e-02	3.2e-08	1.4e-02
2	6.62	3.5e-04	1.0e-07	1.2e-02
3	8.53	2.7e-07	1.0e-02	1.9e-07
4	18.5	2.6e-04	5.4e-03	2.7e-03
5	18.5	2.0e-04	8.4e-04	1.5e-02
6	23.2	3.7e-02	1.2e-04	2.2e-06
7	26.9	8.1e-05	1.9e-02	4.1e-05
8	29.9	8.1e-03	2.0e-04	2.1e-03
9	39.4	2.6e-06	1.1e-05	4.8e-06
10	42.6	1.2e-06	4.5e-03	6.0e-07
11	47.5	1.3e-07	7.4e-10	1.7e-07
12	47.6	3.5e-06	1.3e-07	1.2e-05
13	48.1	2.6e-06	2.8e-08	1.1e-05
14	49.9	1.7e-04	2.4e-08	4.3e-03
15	54.4	5.9e-03	2.2e-06	1.1e-02

Table 3: Frequencies and Mass Participation in Kgs for Modes in the range of 0- 60Hz.

Critical Modes are shown below:

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019



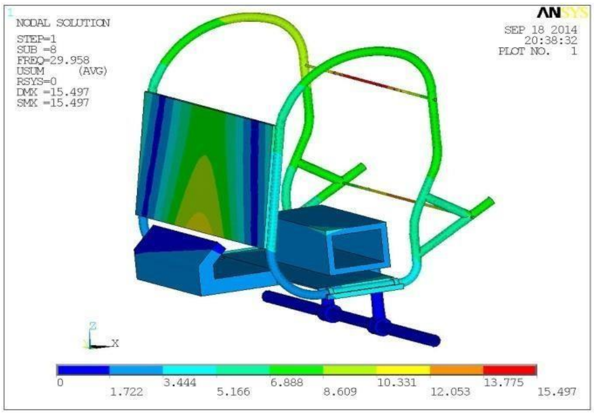


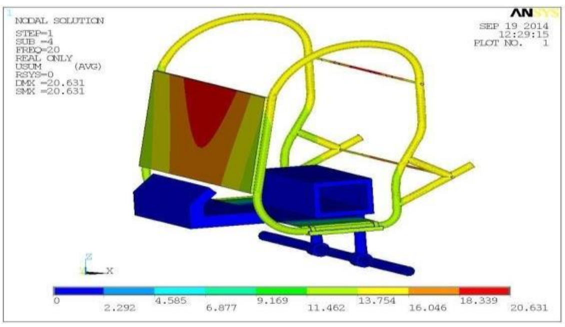
Figure-4: Modified Segway assembly Mode shape1@29.9Hz

Figure-5: Mode shape 2@54.4Hz for Modified Segway assembly

From the modular examination, it is seen that the greatest mass cooperation of 0.0138tone, 0.037tone and 0.014tone are seen in X-dir for the recurrence of 4.4Hz and 24.2Hz It is seen that the greatest mass cooperation of 0.01tone and 0.019 ton are seen in Y-dir for the recurrence of 8.5Hz and 26.9Hz.It is seen that the most extreme mass support of 0.014tone, 0.0125tone, 0.015tone, and 0.0151are saw in Z-dir for the recurrence of 4.4Hz, 6.6Hz, 18.7Hz, and 54.4Hz. To check the structure reaction at the referenced recurrence because of the working burdens, consonant examination is done on the Modified Segway get together.

4.1. DEFLECTIONS AND STRESS

Max. Deflection and Stress of frequency @ 20 Hz Deflection:



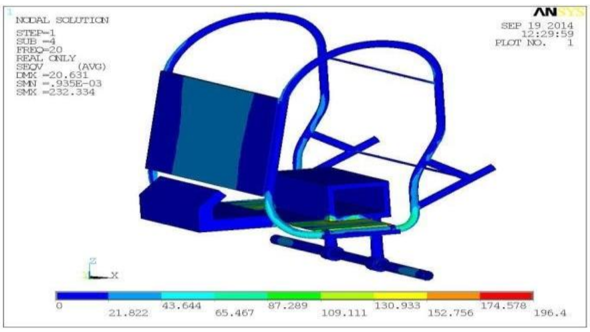


*Figure- 6**:** Max. Deflection of Modified Segway assembly*

Figure- 7: von-mises Stress of Modified Segway assembly

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

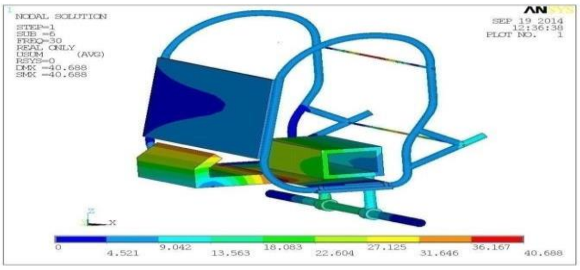


Figure- 8: Max. Deflection of Modified Segway assembly

4.2 Max. Deflection and Stress of frequency @ 30 Hz Deflection:

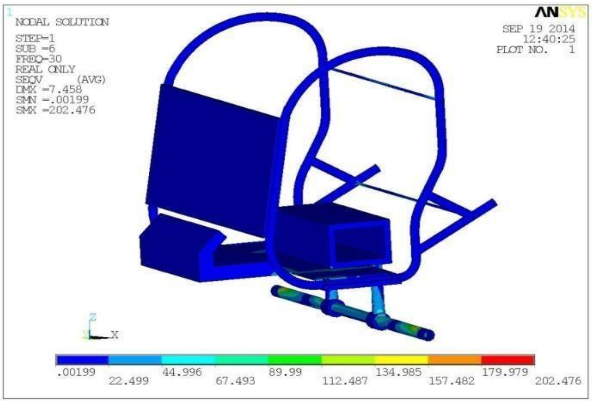


Figure-9: Von-Mises Stress of the modified Segway assembly

From the above results, it is clear that the basic frequencies 5Hz, 10Hz, 20Hz, 25Hz, 30Hz, and 55Hz are having stresses of 186MPa, 100MPa, 196MPa, 104MPa, 202MPa and 119 MPa respectively. The yield quality of the material utilized for Modified Segway is 250 MPa.

5. RESULTS & DISCUSSIONS:

According to Harmonic analysis:

In the operating range of 0 to 60 Hz natural frequencies, the deflections and stresses are tabulated as:

S.No	Frequency (Hz)	Defllection (mm)	Von-mises Stress (MPa)
1	5	36	186

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

2	10	9	100
3	20	20	196
4	25	9	104
5	30	40	202
6	55	7	119

Table-10: Deflections and von-mises Stresses for natural frequencies

From the above results, it is seen that the basic frequencies 5Hz, 10Hz, 20Hz, 25Hz, 30Hz, and 55Hz are having stresses of 186MPa, 100MPa, 196MPa, 104MPa, 204MPa, and 119 MPa respectively. The yield quality of the material utilized for the Modified Segway gathering is 250 MPa. Based on Von-Mises Stress Theory, the stresses along the Segway at the above frequencies did not match exactly with yield quality of material. Hence the plan of modified Segway is good for the above working conditions.

6. Conclusions

In this project work, a 3D model of the Segway structure has been finished. The created 3D model has been brought into Ansys utilizing the Parasolid design and Finite Element Analysis has been done on the Segway structure. Basic investigation has been performed on the static burden applied on the resting seat of Segway and dynamic examination is performed on the Segway structure, and stresses and its prevention are achieved. Endeavors are made to advance the getting ready for above-said conditions. In the current work, a Segway vehicle gathering has been planned and upgraded for auxiliary and vibrations. From the examination, the most extreme normal von-mises Stress observed is 92.2Mpa on the Segway get together for static stacking conditions. Hence, the yield quality of the material chosen, aluminum and steel are 190 Mpa and 250 Mpa that are most extreme normal von-mises Stress appeared as 108Mpa on the modified Segway get together for static conditions. Hence the yield quality of the material: aluminum and steel are 190Mpa and 250Mpa individually. The most extreme normal von-mises Stress watched 88Mpa on the Segway gathering and 62Mpa on the Segway wooden plate for static stacking conditions. Moreover the yield quality of the materials aluminum and wood are 190Mpa and 63Mpa respectively.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

References

1. Browning, B., Searock, J., & Veloso, M. (2005). Turning Segways into Robust Human-Scale Dynamically Balanced Soccer Robots. In D. Nardi, M. Riedmiller, C. Sammut, & J. Santos-Victor (Eds.), *Robocup 2004: robot soccer world cup VIII* (Vol. 3276, pp. 60–71). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-32256-6_5
2. Renne, J., Mitchell, B., & Wolshon. (2015) B Planning, modeling, and evaluating transportation system for emergency evacuations. *Journal of Emergency Management (Weston, Mass.), 13*(2), 85–86. https://doi.org/10.5055/jem.2015.0221
3. Ulrich, K. T. (2005). Estimating the technology frontier for personal electric vehicles. *Transportation Research Part C: Emerging Technologies*, *13*(5–6), 448–462. https://doi.org/10.1016/j.trc.2006.01.002
4. *Indoor Navigation and Manipulation using a Segway RMP*. (2014, April 30). https://digital.wpi.edu/concern/student_works/0k225c607?locale=en
5. Do, A., Emo, A. K., Kennedy, J. F., Miller, S., & Molino, J. A. (2008). Segway Rider Behavior. *Transportation Research Record: The Journal of the Transportation Research Board*, *2073*(1), 125–132. https://doi.org/10.3141/2073-14
6. , M., Mahnkopf, L., & Kobbelt, L. (2012). The Design of a Segway AR-Tactile Navigation System. In J. Kay, P. Lukowicz, H. Tokuda, P. Olivier, & A. Krüger (Eds.), *Pervasive Computing: 10th International Conference, Pervasive 2012, Newcastle, UK, June 18-22, 2012. Proceedings* (Vol. 7319, pp. 161–178). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-31205-2_11
7. Nishiuchi, H., Kishi, Y., & Todoroki, T., (2015). A fundamental study on evaluation of public transport transfer nodes by data envelop analysis approach using smart card data. *Transportation Research Procedia*, *6*, 391–401. https://doi.org/10.1016/j.trpro.2015.03.029
8. Browning, B., Rybski, P. E., Searock, J., & Veloso, M. M. (2004). Development of a soccer-playing dynamically-balancing mobile robot. *IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA '04. 2004*, 1752-1757 Vol.2. https://doi.org/10.1109/ROBOT.2004.1308077