Design and Analysis of a Hybrid Tricycle for Different Frame Materials

Kumar Mangalam Singh Rathore[1], Dr. Sudhir Tiwari[2]

[1]*M.Tech Scholar, Dept. of Mechanical Engineering, SGSITS Indore, Madhya Pradesh, India*
[2]*Professor, Dept. of Mechanical Engineering, SGSITS Indore, Madhya Pradesh, India*

---***---

Abstract - *Concerns about traffic and pollution related to using motor cars for personal mobility are growing. The goal of this project is to develop a vehicle that might serve as a practical short-distance transportation substitute for cars. Efficient-Cycle encourages domestic transportation applications to be less reliant on fossil fuels. This project work consists of a vehicle design (tadpole design) for a tricycle that can be driven by both electrical and human energy and can seat two passengers side by side. The focus of this research is to examine four different materials AISI 1080, AISI 304, AISI 4130, and ASTM A36 (Carbon steel, Stainless steel, Alloy Steel, and Mild steel respectively) for the vehicle's frame, and to choose the best material for the frame based on its strength, weight, and cost-effectiveness. SolidWorks Version 2020 had been used to model the vehicle frame design. For the impact analysis, ANSYS Workbench Version R1 was implemented to ensure the safety and optimum material for the design analyzed using FEM. overall deformation, the highest stress, the highest strain, and the safety factor are all used to derive the result. After analyzing all the materials on the vehicle frame AISI 4130 steel performed the best for the vehicle. The material should have better results in terms of overall deformation, the highest stress, the highest strain, and the safety factor for the drivers, according to the results. It is also a lightweight, medium-cost material*.

Key Words: Efficycle, Green Technology, Hybrid Tricycle, Finite Element Analysis

1. INTRODUCTION

It is imperative to create alternative, more eco-friendly forms of transportation to ensure a sustainable future, as the use of conventional fossil fuels in transportation places a risk to the continuation of life on Earth. The study's goal is to create a vehicle that could effectively replace cars for short rides. This vehicle's hybrid human-electric driving mechanism powers it. The tricycle that is propelled including human muscular strength and electric energy is known as a mixed passenger and a battery electric vehicle. The underlying idea is to combine the technology of bicycles with electric vehicles. A maximum of two people can drive this three-wheeled vehicle, which has two passenger seats side to side arrangement. The tricycle has four batteries with lead-acid sealed, each rated at twelve volts, a BLDC 1.5 HP electric drive mounted on the back, and a chain drive for transferring electric power. The ability to switch between manual and electric driving modes as needed. This vehicle has a tadpole-type configuration, having one wheel attached at the back and two wheels connected up front. The tricycle has a single-driver steering system in the style of Ackermann (Right-hand side). For proper and efficient braking, the disc brakes on all three wheels are connected via sliding calipers. The roll cage material selection process aimed to balance cost, weight, and strength. Safety, convenience, reduced weight, and the cost of producing the chassis were the main factors taken into account.

Gunjal et al, showed a study about the design of an ultra-lightweight vehicle which was designed made like a three-wheel cycle (1 wheel in the front and 2 wheels in the rear). the design adopted an off-the-shelf type and the vehicle roll cage design weight is only 16 kg because of their design. this vehicle is a hybrid human vehicle that is powered by both human and electrical power. For electric power, the PMDC motor was selected, and aluminum alloy 6061 T6 was selected for the frame material. the primary focus was on creating vehicle ergonomics for a typical adult. Modeling software PRO-E WILDFIRE 4 was used to create the design, and FEM analysis ANSYS 12.0 software was used to analyze it [1].

Sarvadnya et al, performed the fabrication and evaluation of a three-wheel hybrid vehicle's modified front double wishbone suspension (Tadpole design). The primary goal of this research is to identify the ideal suspension system for a three-wheel hybrid vehicle. there are mainly two types of suspension systems are dependent system and the independent system. An independent system has a mac-Pherson suspension system and a double-wishbone suspension system. So, the double-wishbone suspension system was selected for their vehicle. that system decreases the unsprung mass while also improving the vehicle's traction, stability, and ride comfort. Furthermore, the suspension geometry may be designed with a great deal of versatility using the double-wishbone suspension system and is lightweight and easy to pack. the suspension design was made on CATIA software and analyzed on the FEM software ANSYS [2].

Gupta et al, a tricycle operated by two people as well as by a 373 Watt Geared PMDC was designed utilizing a stepper motor and is efficycle powered with a built-in programmable position control gear shifter. The approach adopted in this paper's innovation is stepper motor-based programmable position control of the gear shifter. Programming regulates the speed of the motors, which in turn regulates the position of the gear changer. It enables more automatic control of the vehicle and lessens the effort required from the driver. The emphasis has been placed on the excellent performance, low maintenance, safety, and affordability of the design. Steel ST 52.3 Over AISI 1080 was chosen for the vehicle's material because it is too lightweight, extremely ductile, and strong. Solidworks was used to simulate the design, while Ansys software was used for analysis for tests such as front impact, side impact, rear impact, and rollover impact [3].

Chawla et al, displayed the suspension system design and hardpoint optimization of a three-wheel hybrid vehicle. The simulation modeling and analysis of suspension geometry are covered in this study. The suspension was created with superior handling and comfort for both drivers in mind. To replace the rickshaws that lack both front and rear suspension systems. So, they enhanced the suspension design by choosing hard point optimization (camber curve, bump steer curve, caster change rate, etc), Damper design, and Spring design. This paper's major objective is to improve the rolling and dive characteristics of suspension systems while maintaining good vehicle handling, a good balance between driver and drive stability, increased durability and reliability, and maximum wheel travel [4].

Abhay et al, demonstrated numerous lightweight techniques, including lightweight seats, wheels, and steering. This paper's innovation uses UV joints in the front axle to provide the vehicle with independent suspension and front-wheel drive, which are hardly ever seen on the front of a car, making it easier for the car to climb hills and resist stocks at the same time. The tadpole design was adopted with two wheels in front and one wheel in the back, and they chose various approaches for turning radius, stability, handling, and ease of maneuvering. They also reduced the weight of the vehicle by choosing lightweight equipment and materials that were still strong, and they optimized it for a lightweight vehicle so the material AISI 1080 was selected. The design was simulated and analyzed on SOLIDWORKS, and it underwent various tests including front, side, rear, and rollover analyses [5].

Aphale et al, performed the design and analysis of a roll cage for an electric hybrid tricycle demonstrating improving the roll cage's structural integrity and overall attractiveness, so the vehicle frame gives better safety for the drivers as well as ergonomic design and strength. Also, they selected the various type of materials for the frame after comparing their mechanical and chemical properties they selected HSLA 340 material for the frame of the vehicle due to its strong strength, low carbon content, and exceptional weldability. after that, they prepared the design in the CAD model namely PTC Creo 3.0, and FEA was undertaken in ANSYS Workbench 15 [6].

Prakash et al, developed a human-powered electric hybrid power tricycle to lessen reliance on fossil fuels for transportation to a short distances. This paper aims to visualize, design, and fabrication the tricycle known as efficycle. So first they focused on the chassis design of the vehicle and assumed considering the constraints and dimensions then a CAD was implemented to design the vehicles on software PTC Creo 3.0 then ensure the safety of roll cage/ frame design the vehicle chassis tested by using FEA software ANSYS V16.2. In this, they calculated the impact analysis for front, side, and rollover impacts in terms of total deformation, max. stress, max. strain, and factor of safety. The material AISI 1080 was used for the frame of the vehicle. After completing the design and simulation the vehicle was fabricated. The key parameter for this paper is cost-reducing, better strength for the vehicle, and a comfortable base for the riders [7].

Reddy et al, designed and fabricated an ultralight vehicle that is powered by both using electric power as well as human power. This study also concentrated on the affordability and simplicity of the vehicle design. The design was made using modeling software SOLIDWORKS keeping a view of drivers' ergonomics and placement of the aggregates and then the design was analyzed by Finite Element Method analysis software ANSYS 12.0 for Frontal, Side, and Rollover impacts analysis in form of total deformation, max. stress, and max. strain. For the frame, the type is a roll cage design, and the material was used Mild steel (ANSI 1026) with circular pipe dimensions: OD- 30mm, ID- 24mm, Thickness- 3, and Density- 7858 kg/cm3. The key parameters for this paper are ultra-lightweight, hybrid tricycles, and mechanical drive [8].

2. Modeling

2.1 Design of tricycle

The vehicle's measurements are presumptive, taking into account the limitations and proportions based on the compact design. Following the assumption of the proportions, consideration was made to making the vehicle ergonomic for a typical adult. The vehicle is then created using Solidworks V2020. ANSYS VR1, the software for finite element analysis, is used to assess the vehicle's structural integrity. The roll cage/frame design is adjusted for safety reasons before being finalized. Several factors, including serviceability, craftsmanship, and cost reduction, were taken into account when modeling the vehicle frame.

The following aspects are kept in mind for the drivers' ergonomics:

- Seat and steering angle placements.
- The driver's hand should be able to reach all levers and switches.
- Both drivers have more than enough headroom and legroom.

- The battery and BLDC motor are located behind the driver.
- To prevent injuries in the event of an accident, scratch protectors are fitted on both sides of the driver.

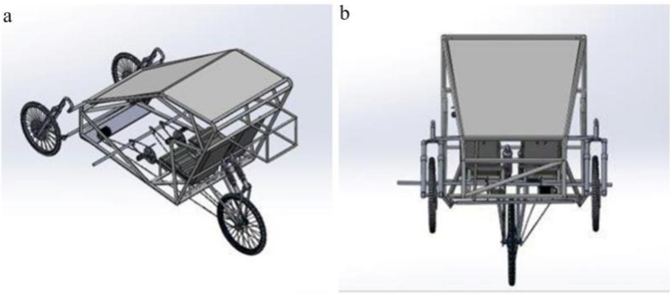

Fig -1: (a) Isometric image of the tricycle; (b) Front image of the tricycle.

2.2 Frame

The frame design was created with improved aviation and the riders' comfort in mind. For the protection of riders, additional battery placement, suspension, and sitting areas were created in addition to this roof covering configuration. The frame pipes are hollow with the dimension of outer diameter 25.4, an Inner diameter 21.4, and a thickness of 2 mm.

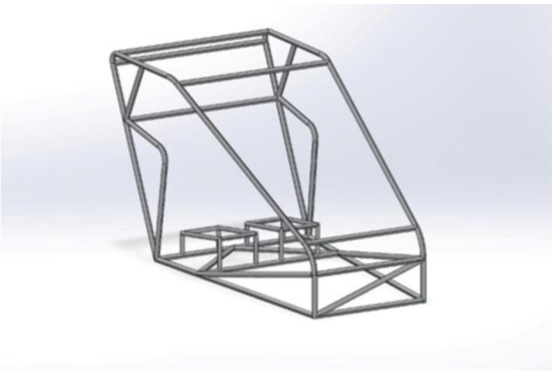

Fig -2: Frame of the vehicle.

2.3 Material selection

In this study there are four materials AISI 1080, AISI 304, AISI 4130, and ASTM A36 were selected for the vehicle frame. For the design of their vehicle frames, various study publications have chosen various materials based on their mechanical and chemical qualities. To determine which material is best suitable for a vehicle frame in terms of strength, lightweight, and affordability, we chose four common materials that were chosen in earlier research for this project and ran them through ANSYS using finite element analysis. Below table 1 & 2 show the Mechanical and Chemical material characteristics.

Table -1: Mechanical characteristics of four materials [6] - [8].

Mechanical properties	AISI 1080	AISI 304	AISI 4130	ASTM A36
Brinell Hardness	126	215	240	240
Ultimate T. S.	440 MPa	505 MPa	560 MPa	550 MPa
Yield T. S.	365 MPa	215 MPa	460 MPa	250 MPa
Modulus of elasticity	205 GPa	200 GPa	210 GPa	200 GPa
Bulk modulus	140 GPa	134 GPa	140 GPa	140 GPa
Poisson's ratio	0.29	0.27	0.30	0.26
Shear modulus	80 GPa	74 GPa	80 GPa	79.3 GPa
Density	7870 Kg/m^3	8000 Kg/m^3	7850 Kg/m^3	7850 Kg/m^3

Table -2: Chemical characteristics of four materials [6] – [8].

Chemical properties	AISI 1080 %	AISI 304 %	AISI 4130 %	ASTM A36 %
Iron	98 - 99	66.74 – 71.24	97.03 – 98.22	98
Carbon	0.75 – 0.88	0.07	0.280 – 0.330	0.25 – 0.29
Manganese	0.60 - 0.90	2	0.40 – 0.60	1.03
Sulphur	0.05 (max.)	0.03	0.040	0.05
Phosphorous	0.04 ((max.)	0.05	0.035	0.04
Chromium	-	17.5 – 19.5	0.80 – 1.10	-
Nickel	-	8 – 10.5	-	-
Silicon	-	1	0.15 – 0.30	0.280
Nitrogen	-	0.11	-	-
Molybdenum	-	-	0.15 – 0.30	-
Copper	-	-	-	0.20

3. Vehicle Frame Finite Element Simulation

After the CAD model of the vehicle, and the frame was finished, four materials were chosen and subjected to FEA study in the form of frontal impacts, side impacts, and rollover impact analysis to guarantee driver safety and improve the frame's strength. For analyzing all the results on the frame and the frame meshed on the ANSYS Workbench to get better and more precise results. When Frame was meshed on the software automatically selected the element size (20.33mm) and the default method coarse mesh but made manually selected a 5 mm element size and fine meshing because the more the number of elements on the frame produced precise results.

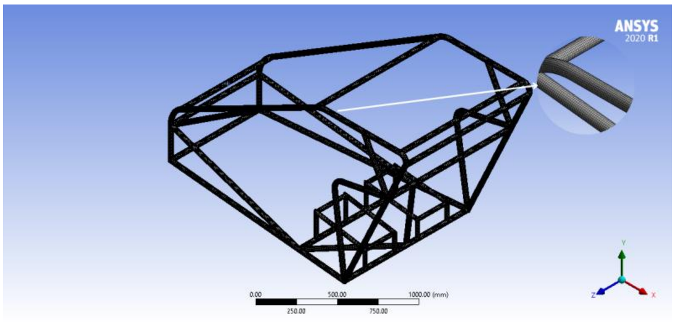

Fig -3: Meshing Frame of the tricycle

4. Frontal impact analysis

Considerations & Assumption to calculate frontal impact, it is estimated that the vehicle will reach final zero velocity in 0.6 seconds at a top speed of 35 kmph. The vehicle is estimated to weigh 150 kg, while the two drivers each weigh 90 kg. Any impact could be made to the vehicle, whether it is unintentional or deliberate. Finding impact forces and doing impact analysis are considered essential since the vehicle is anticipated to withstand the impact.

For the frontal impact force calculation: overall weight (m) is calculated as 150 + 90 + 90 kg, which is 330 kg, time (T) is 0.6 seconds, starting velocity (u) is 35 kilometers per hour or 9.722 m/s, and ending velocity (v) is 0 kilometer per hour. In addition, the front impact force is given by F = m dV/dT [7] = 330 * 9.723/0.6 or 5347.65 N. A maximum force of 5347.65 N must be taken into account for frontal impact.

4.1 Analysis of frame on AISI 1080

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 4(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.2748 mm	146.83 MPa	2.4859	0.0008873

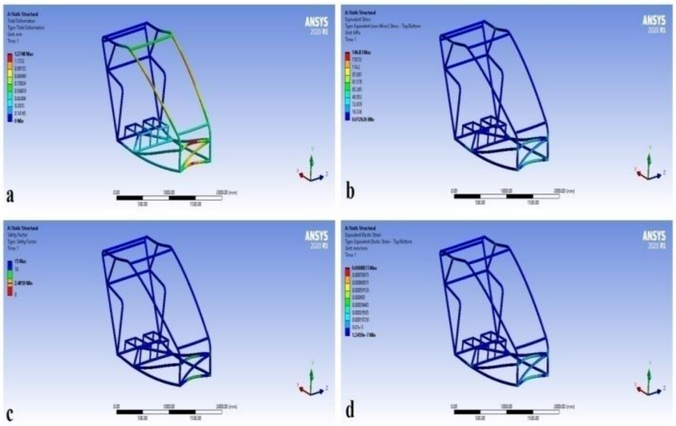

Fig -4: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

4.2 Analysis of frame on AISI 304

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 5(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.307 mm	147.66 MPa	1.45	0.00091178

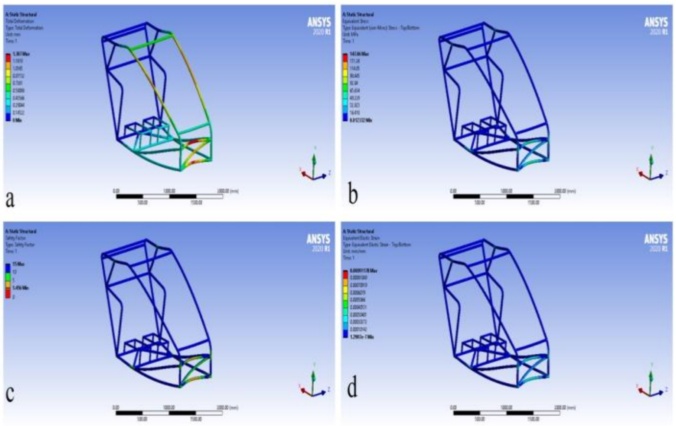

Fig -5: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

4.3 Analysis of frame on AISI 4130

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 6(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.2443 mm	146.27 MPa	3.14	0.00086485

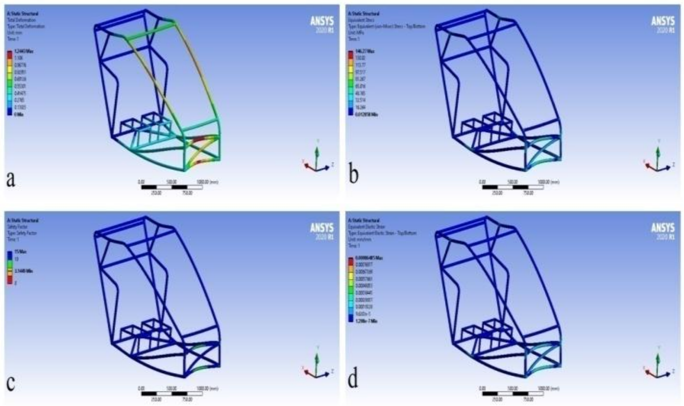

Fig -6: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

4.4 Analysis of frame on ASTM A36

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 7(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.3072 mm	148.48 MPa	1.68	0.00091432

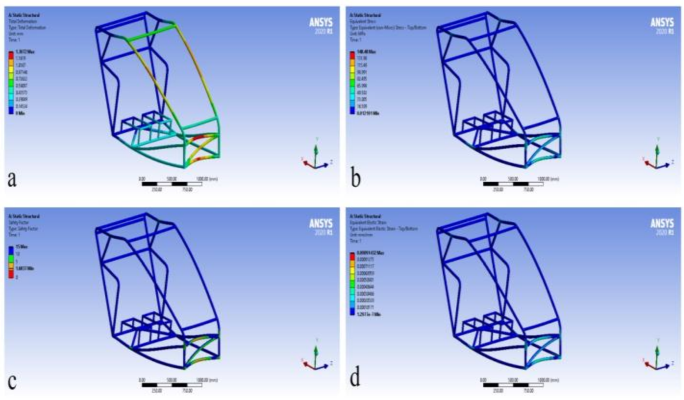

Fig -7: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

5. Side impact analysis

Considerations & Assumption to calculate side impact, it is estimated that the vehicle will reach final zero velocity in 1 second at 35 kilometers per hour is the maximum speed. The vehicle is estimated to weigh 150 kg, although each of the two drivers only weighs 90 kilograms. Any effect could be made to the vehicle, whether it is unintentional or deliberate.

For the side impact force calculation: overall weight (m) is calculated as 150 + 90 + 90 kg, which is 330 kg, impact time (T) is 1 second, starting velocity (u) is 35 kilometers per hour or 9.722 m/s, and ending velocity (v) is 0 kilometer per hour. In addition, the side impact force is given by F = m dV/dT [7] = 330 * 9.722/1 or 3208.26 N. A maximum force of 3208.26 N must be taken into account for side impact.

5.1 Analysis of frame on 1080

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 8(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
2.0298 mm	165.76 MPa	2.20	0.00081253

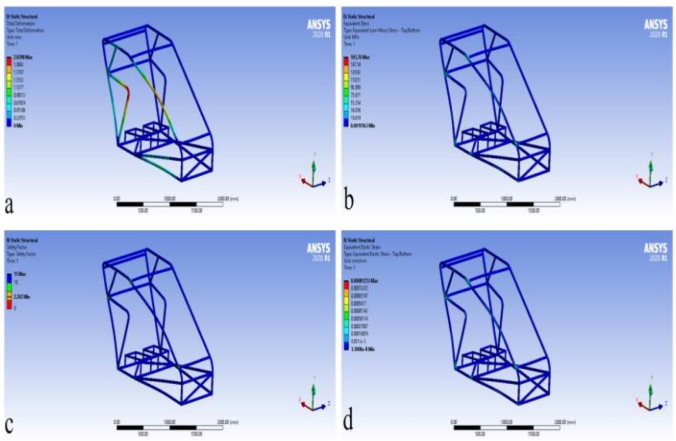

Fig -8: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

5.2 Analysis of frame on AISI 304

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 9(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
2.0767 mm	166.15 MPa	1.29	0.00083485

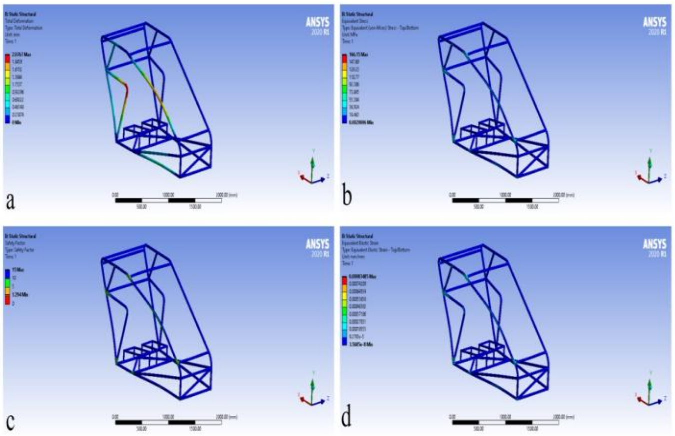

Fig -9: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

5.3 Analysis of frame on AISI 4130

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 10(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.9838 mm	165.48 MPa	2.77	0.00079184

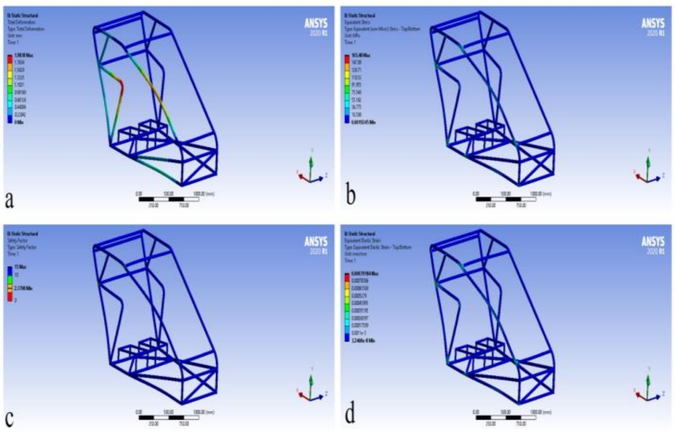

Fig -10: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

5.4 Analysis of frame on ASTM A36

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 11(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
2.0726 mm	166.52 MPa	1.50	0.00083674

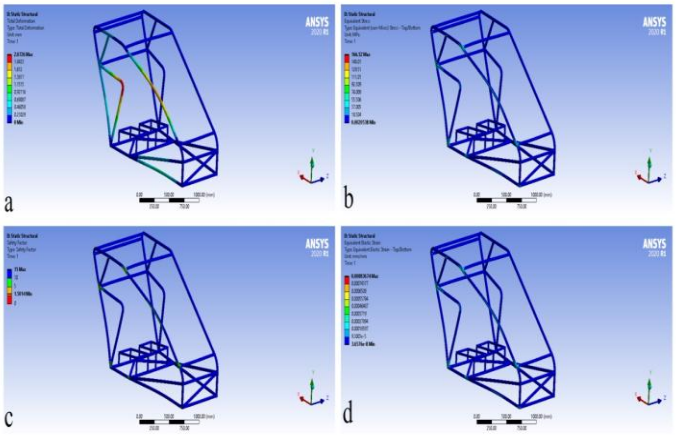

Fig -11: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

6. Rollover impact analysis

To calculate the roll-over impact, The vehicle is thought to have fallen from a height of 6 feet on its roll-over hoop members into the ground or the road. it is expected that the vehicle will reach its 35-kilometer-per-hour maximum speed in 6 seconds and that its ultimate velocity will be zero. The vehicle is estimated to weigh 150 kg, although each of the two drivers only weighs 90 kilograms.

For the rollover impact force calculation: the overall weight (m) is calculated as 150 + 90 + 90 kg, which is 330 kg, time. In addition, the Rollover impact force is given by F = {(N*W/2)*h} [7] =[330*9.81*1.83/2] or 2962.12 N. A maximum force of 2962.12 N must be taken into account for rollover impact.

6.1 Analysis of frame on AISI 1080

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 12(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.2132 mm	113.41 MPa	3.21	0.00057389

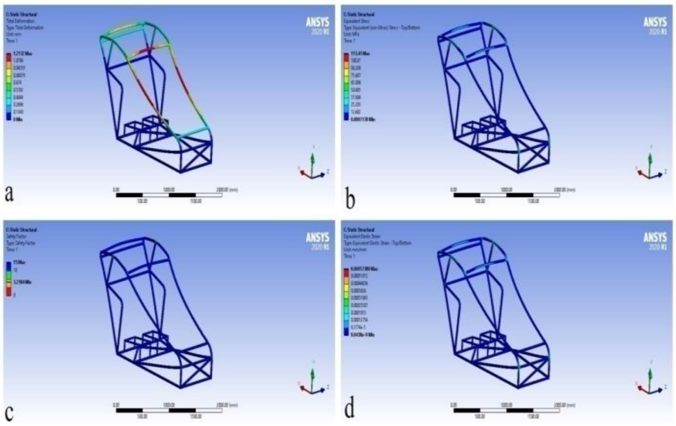

Fig -12: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

6.2 Analysis of frame on AISI 304

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 13(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.2444 mm	113.47 MPa	1.89	0.00058854

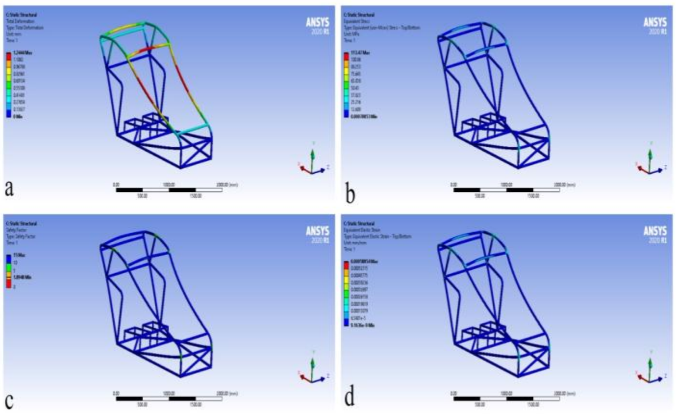

Fig -13: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

6.3 Analysis of frame on AISI 4130

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 14(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.1837 mm	113.38 MPa	4.0573	0.00056007

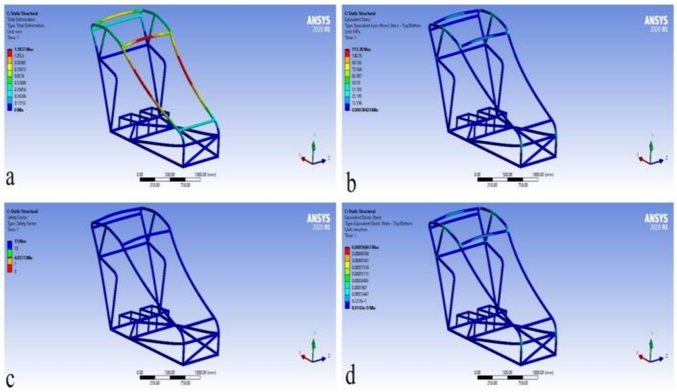

Fig -14: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

6.4 Analysis of frame on ASTM A36

The ANSYS Workbench platform is used to run the simulation. Results for overall deformation, max. stress, safety factor, and max. strain are illustrated in figures 15(a),(b),(c)&(d). Following are the measured values shown in below table:

overall Deformation	Max. stress	Safety factor	Max Strain
1.2452 mm	113.53 MPa	2.20	0.00058888

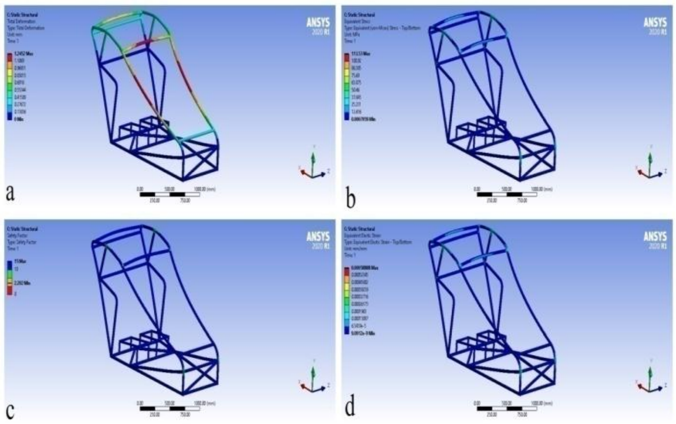

Fig -15: (a) overall deformation; (b) Max. stress distribution; (c) Safety factor (d) Max. strain.

7. Comparison with previous data

By contrasting the present findings with those from other research, the frontal impact, side impact, and rollover impact analysis are all validated in the form of overall deformation, max. stress, safety factor, and max. strain. Present study results are compared with Jay Prakash et al.[7] where they calculated applied forces on the vehicle frame for frontal impact, side impact, and rollover impact are 5348.16 N, 3208.59 N, and 1438.8 N respectively. Table no. 3, 4, and 5 showed results comparisons with previous studies, and its shows that present study results are more reliable and somewhere near to previous studies.

Table -3: Comparison of previous study frontal impact result in form of deformation, stress, safety factor, and strain with present study.

Materials	Authors	Overall deformation	Max. stress	Safety factor	Max. strain
AISI 1080	Jay Prakash et. al. [7]	4.341 mm	146.37 MPa	2.49	0.00088327
AISI 1080	Present study	1.2748 mm	146.83 MPa	2.48	0.0008873
AISI 304	Present study	1.307 mm	147.66 MPa	1.45	0.00091178
AISI 4130	**Present study**	**1.2443 mm**	**146.27 MPa**	**3.14**	**0.00086485**
ASTM A36	Present study	1.3072 mm	148.48 MPa	1.68	0.00091432

Table -4: Comparison of previous study side impact result in form of deformation, stress, safety factor, and strain with present study.

Materials	Authors	Overall deformation	Max. stress	Safety factor	Max. strain
AISI 1080	Jay Prakash et. al. [7]	0.5236 mm	29.207 MPa	12.5	0.0001619
AISI 1080	Present study	2.0298 mm	165.76 MPa	2.20	0.00081253
AISI 304	Present study	2.0767 mm	166.15 MPa	1.29	0.00083485
AISI 4130	**Present study**	**1.9838 mm**	**165.48 MPa**	**2.77**	**0.00079184**
ASTM A36	Present study	2.0726 mm	166.52 MPa	1.50	0.00083674

Table -5: Comparison of previous study rollover impact result in form of deformation, stress, safety factor, and strain with present study.

Materials	Authors	Overall deformation	Max. stress	Safety factor	Max. strain
AISI 1080	Jay Prakash et. al. [7]	3.007 mm	70.205 MPa	5.19	0.000435
AISI 1080	Present study	1.2132 mm	113.41 MPa	3.21	0.00057389
AISI 304	Present study	1.2444 mm	113.47 MPa	1.89	0.00058854
AISI 4130	**Present study**	**1.1837 mm**	**113.38 MPa**	**4.05**	**0.00056007**
ASTM A36	Present study	1.2452 mm	113.53 MPa	2.20	0.00058888

8. CONCLUSIONS

The Effi-cycle is an Eco-green vehicle with an electric motor that was developed to reduce noise and air pollution. The focus has been laid to select the best-suited material for the vehicle frame to give better strength, lightweight, and economical material. In this project work, Four materials used from previous research AISI 1080, AISI 304, AISI 4130, and ASTM A36 (Carbon steel, Stainless steel, Alloy Steel, and Mild steel respectively) for the frame designing of Effi-cycle. After successfully analyzing these four materials on the vehicle frame Finite Element Analysis is calculated in the form of overall deformation, maximum stress, the safety of factor, and maximum strain for all impact loads. Concluded that the best-suited material is AISI 4130 for the Effi-cycle because of the strength aspect as well as the economic point of view. This AISI 4130 material produced the minimum impact loads as compared to other steel materials. So this research provided the vehicle with more strength and safety factors for both drivers.

REFERENCES

[1] S. U. Gunjal, G. D. Sonawane, S. P. Awate, and D. R. Satpute. (2014) "Design, Analysis & Fabrication of Efficycle: A Hybrid Tricycle." International Journal of Engineering Trends and Technology (IJETT) – Volume17 Number 8–Nov2014.

[2] Thakare, Sarvadnya Ajinkya, Prasad C. Antapurkar, Divyaj S. Shah, P. R. Dhamangaonkar, and S. N. Sapali. (2015) "Design and analysis of modified front double wishbone suspension for a three wheel hybrid vehicle." Proceedings of the World Congress on Engineering 2015 Voumel II system 3, 6.

[3] Gupta, Upendra S., Sumit Chandak, and Devashish Dixit. (2015) "Design of Efficycle-Human Powered Hybrid Tricycle with inbuilt Programmable Position Control Gear Shifter using Stepper Motor." International Journal of Engineering Trends and Technology (IJETT) – Volume 19 Number 3 – Jan 2015.

[4] Chawla, Gomish, and Shivam Setia. (2016) "Designing and hard point optimization of suspension system of a three-wheel hybrid vehicle." International Journal of Aerospace and Mechanical Engineering Volume 3 – No.1, February 2016.

[5] Tiwari, Abhay, I. Jaswal, Sulipt Das, and A. Singh. (2017) "Design of Efficycle-Human Powered Light Weight Hybrid Tricycle with Inbuilt Rear Wheel Steering and Use of Universal Joint in Front Axle." Advances in Automobile Engineering 6, no. 167: 2.

[6] Siddharth Aphale, and Pradnesh Lachake. (2017) "Design and Analysis of Roll Cage for an Electric Hybrid Tricycle." International Journal of Engineering Trends and Technology (IJETT) – Volume-44 Number-2 - February 2017 Carbon 2, no. 1: 3.

[7] Srivastava, Jay Prakash, Dheeraj Joshi, L. Vivek, G. Sai Manish, G. Sravan, K. Enosh, E. Naresh Naik, K. Vamshi Krishna, M. Prem, and K. Dayanand. (2019) "Design and Fabrication of Human-Electric Hybrid Power Tri-Cycle." In IOP Conference Series: Materials Science and Engineering, vol. 653, no. 1, p. 012004. IOP Publishing, 2019.

[8] Reddy, M. Varun, B. Rohith Kumar, P. Praveen Kumar, Y. Vijay Vardhan, and A. Ravindra. (2021) "Design, analysis and fabrication of effie-cycle: A hybrid tadpole vehicle." In AIP Conference Proceedings, vol. 2317, no. 1, p. 040015. AIP Publishing LLC, 2021.