International Journal of Research in Engineering, Science and Management
Volume 7, Issue 4, April 2024
www.ijresm.com | E-ISSN: 2581-5792

Design and Simulation of Mechanical Components in EV Using CATIA

K. Narayana Rao[1], S. Sujatha Devi[1*], Ch. Supreeth[2], G. Varshni[2], P. Kedareswari[2]

[1]*Assistant Professor, Department of Electrical and Electronics Engineering, Avanthi Institute of Engineering & Technology, Makavarapalem, India*
[2]*UG Student, Department of Electrical and Electronics Engineering, Avanthi Institute of Engineering & Technology, Makavarapalem, India*

***Abstract*: The transition toward electric vehicles (EVs) has created a need for efficient, lightweight, and structurally robust mechanical components tailored to the unique demands of electric propulsion. This paper presents a comprehensive study on the design and simulation of the principal mechanical components of a two-wheeler EV - the chassis and the handlebar using CATIA V5, a computer-aided design (CAD) and computer-aided engineering (CAE) software suite. The work begins with a review of two-wheeler EV architecture, chassis types, and suspension systems, followed by a systematic CATIA-based design methodology covering sketching, part modelling, assembly, and simulation. A scooter chassis was modelled in AISI 1018 mild steel and a handlebar in aluminium alloy, with wheelbase, ground clearance, and geometric specifications derived from SAE-style frame guidelines. Finite Element Analysis (FEA) was carried out on the handlebar using the Generative Structural Analysis workbench in CATIA, with restraints and loads applied to obtain the Von-Mises stress distribution. The resulting peak stress of 135.93 N/mm² was found to lie safely below the 90–140 MPa allowable stress range for aluminium, confirming that the design meets structural safety requirements. The study demonstrates that CATIA-based virtual prototyping allows engineers to validate the strength, stiffness, and durability of EV mechanical components prior to physical fabrication, reducing development cost and time while improving design reliability.**

***Keywords*: Electric Vehicle, CATIA V5, Chassis Design, Handlebar, Finite Element Analysis, Von-Mises Stress, Two-Wheeler EV.**

1. Introduction

An electric vehicle (EV) is a vehicle propelled by an electric motor that draws power from a rechargeable battery, either alone (all-electric) or in combination with an internal combustion engine (plug-in hybrid). Electric motorcycles and scooters are two- or three-wheeled plug-in electric vehicles powered by a rechargeable battery driving one or more electric motors; electric scooters are distinguished from motorcycles by a step-through frame rather than a straddled one. The transition to two-wheeler EVs represents a major shift in urban mobility, driven by concerns over air pollution, greenhouse-gas emissions, and fossil-fuel dependency. Their compact size and agility make them well suited to congested urban streets, while continuing improvements in battery energy density, fast-charging infrastructure, and smart connectivity features are steadily improving range, convenience, and user experience.

The earliest recorded electric bicycle patents date to 1895, when Ogden Bolton Jr. and Hosea W. Libbey independently filed applications for an "electrical bicycle." Subsequent decades saw incremental progress from the Socovel electric motorcycles of 1936 to the first mass-produced electric scooter, the Peugeot Scoot'Elec, in 1996 before the field accelerated rapidly in the 2000s and 2010s with successive land-speed and drag-racing records set by vehicles such as Killacycle and the Lightning Motorcycle, and the emergence of commercial manufacturers including Vectrix, Mission Motors, and Zero Motorcycles. In India, companies such as Ola Electric and Odysse Electric have since begun large-scale manufacturing, supported by government programmes such as the National Electric Mobility Mission Plan (NEMMP), which targets 30% EV adoption by 2030.

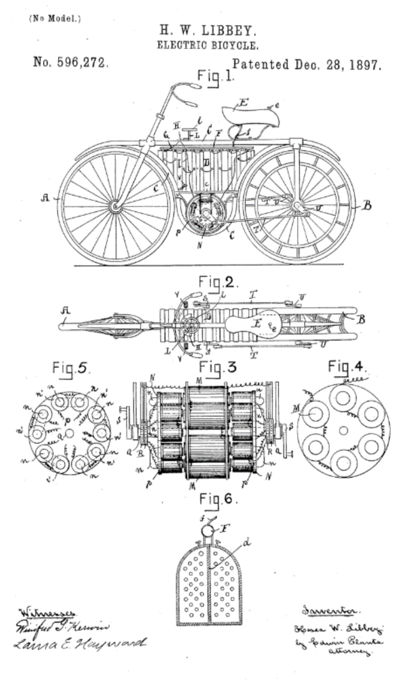

Fig. 1. Patent drawing for an "Electric Bicycle" (1895)

A two-wheeler electric scooter integrates a frame, electric

*Corresponding author: seelamsujatha2006@gmail.com

motor, battery, wheels, brakes, throttle and controls, deck, and suspension into a single subsystem, as summarized in the block diagram of Fig. 2. In operation, the battery's positive terminal connects to the motor stator while the negative terminal grounds to the vehicle body; current through the stator field coil magnetizes it and drives rotation of the rotor shaft, which is coupled through a clutch assembly to the driven wheel. An alternator mounted on the opposite end of the rotor shaft converts a portion of rotational energy back into electrical energy to recharge the battery while the vehicle is in motion, typically through a V-belt/pulley arrangement, as illustrated in Fig. 3.

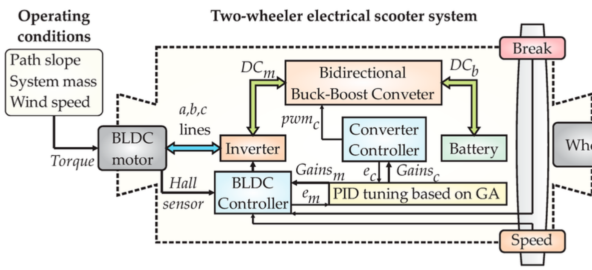

Fig. 2. General block diagram of a two-wheeler electric scooter, subsystems, and operating conditions

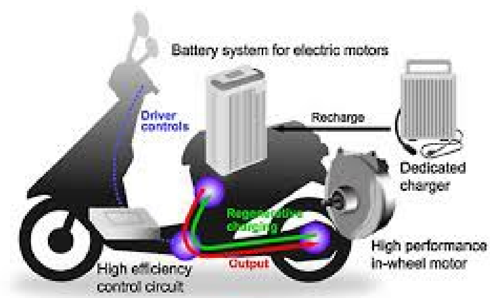

Fig. 3. Working principle of an electric two-wheeler

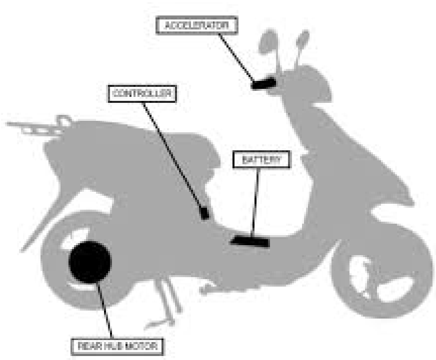

Fig. 4. Representative alternator and associated charging-system components

Two principal electrical sources exist on the vehicle: the battery, which stores charge and sustains the electrical system when the motor is off, and the alternator, which generates electricity while the motor runs and recharges the battery on the go. A standard 12 V two-wheeler battery is a six-cell lead-acid unit, each cell nominally 2.1 V, giving roughly 12.6 V when fully charged (Fig. 4 shows relative market demand for lead-acid versus lithium-ion batteries). Battery packs are steadily being upgraded from lead-acid to lithium-ion chemistries (Fig. 6) for their higher energy density, despite a higher unit cost and historically greater thermal-runaway risk, which newer cell chemistries are addressing. The alternator (Fig. 5) generates AC current that is rectified to DC and voltage-regulated before being distributed to the vehicle's electronics, while a wiring harness routes power to each subsystem and a motor controller brushed or brushless governs motor operation.

Fig. 5. Relative market demand for lead-acid versus lithium-ion batteries

	Lead-Acid	Lithium-Ion
Construction	Lead Dioxide (PbO_2)	Lithium Metal Ions
Performance/Maintenance	Undesirable	Desirable
Energy/Weight Ratio	Low	High
Applications	Non-weight, space critical applications (Car Starters)	Low weight, low space consumption

Fig. 6. Battery technology upgradation from lead-acid to lithium-ion

India's EV market was valued at approximately USD 1,434.04 million in 2021 and is projected to reach USD 15,397.19 million by 2027, driven principally by growth in the two- and three-wheeler segments. Key drivers include reduced CO2 emissions (an estimated one-gigaton cumulative reduction by 2030), increasingly competitive purchase and running costs relative to comparable fossil-fuel vehicles, expanding fast-charging and battery-swapping infrastructure, and a smoother, quieter driving experience. Government policy, including tax incentives and the National Electric Mobility Mission Plan, targets 30% EV adoption by 2030 and is projected to create around 50 million direct and indirect jobs in the sector.

2. Mechanical Components and Chassis Types

Compared with internal-combustion vehicles, EVs replace the engine and fuel-related hardware with an electric motor, battery pack, and power electronics, while retaining a broadly similar set of structural mechanical components. Key components include: (1) the electric motor, which converts electrical to mechanical energy to drive the wheels; (2) the battery pack, typically composed of lithium-ion cells connected in series/parallel to reach the desired voltage and capacity; (3) power electronics (inverters, converters, controllers) that manage energy flow, motor speed/torque, and regenerative braking; and (4) the charging system that replenishes the battery. This paper focuses on two structural mechanical components central to vehicle safety and handling the chassis and the handlebar.

The chassis is the basic structural framework of the vehicle, onto which the engine/motor, transmission, suspension, and other subsystems are mounted; it must be lightweight for efficiency yet strong and durable enough to protect the rider in an accident. Two-wheeler chassis designs are generally classified into four types:

- Backbone chassis: A single large-diameter tube running along the vehicle centerline serves as the main structural element to which other components attach.
- Single cradle chassis: A single large-diameter tube runs from the steering head to the swingarm pivot, supporting the engine/motor and transmission.
- Double cradle chassis: Two parallel large-diameter tubes run from the steering head to the swingarm pivot, forming the main structural elements.
- Perimeter (twin-spar) chassis: A perimeter-like structure wraps around the motor, balancing strength and weight; commonly used in sports bikes.

Fig. 7. Backbone chassis (left)

Fig. 8. Single cradle chassis

Fig. 9. Double cradle chassis

Fig. 10. Perimeter chassis

The handlebar is the primary rider-vehicle interface, providing mounting points for the brake, throttle, clutch, horn, light switches, and mirrors, and supporting part of the rider's weight and steering effort. Handlebars are typically fabricated from hollow aluminium alloy, mild steel, chrome-plated steel, stainless steel, carbon fiber, or titanium tubing, with holes drilled for internal cable routing and bar-end weights added to shift the resonant frequency away from motor-induced vibration.

Fig. 11. Motorcycle/scooter handlebar assembly

The suspension system ensures a smooth, comfortable ride while maintaining stability and control over varying road conditions. Three common suspension types are used in two-wheelers:

- Hydraulic suspension: A piston/cylinder filled with hydraulic fluid dampens vibration by forcing fluid through restrictive channels as the wheel encounters bumps.
- Spring (coil) suspension: Thick steel wire coil springs, sometimes combined with an internal shock absorber (forming a suspension strut), provide the primary springing element.
- Telescopic suspension (front forks): An inner fork slider moves within an outer fork tube, with internal springs and damping mechanisms absorbing road irregularities.

Fig. 12. Hydraulic suspension

Fig. 13. Spring suspension

Fig. 14. Telescopic suspension

3. Design Software and Methodology

CATIA (Computer Aided Three-dimensional Interactive Application), developed by Dassault Systèmes, is a multi-platform CAD/CAM/CAE suite supporting 3D modelling and product lifecycle management (PLM) across surfacing, mechanical, electrical, and systems engineering disciplines. Originally used in aircraft design (notably the Mirage fighter), CATIA was subsequently adopted widely across the automotive sector. In this work, CATIA V5 was used for all sketching, part modelling, assembly, and structural-simulation tasks, using its Generative Structural Analysis (GPS) workbench for Finite Element Analysis (FEA) of parts and assemblies.

Fig. 15. CATIA V5 software

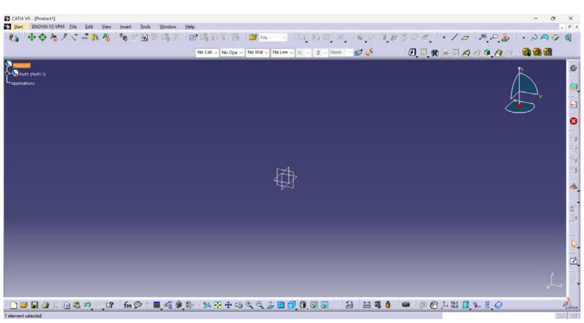

Fig. 16. CATIA V5 simulation workbench layout

Mechanical components were designed in CATIA following a systematic five-stage methodology:

- Conceptualization: Establishing design requirements, functional specifications, and constraints, and sketching conceptual ideas.
- Sketching and drafting: Creating constrained, dimensioned 2D profiles representing component outlines and features.
- Part modelling: Extruding or revolving 2D sketches into 3D solids, with fillets, chamfers, holes, and ribs added as required.
- Assembly design: Positioning and constraining individual parts (mates, coincidences, offsets) into a complete assembly, checked for interference.
- Analysis and simulation: Applying boundary conditions, loads, and material properties to evaluate stress, displacement, and deformation, and iterating the design accordingly.

Three principal simulation techniques were relevant to this study: Finite Element Analysis (FEA), which evaluates structural behaviour under applied loads to compute stress, strain, and deformation and assess safety margins and failure modes; kinematic simulation, which studies motion, clearance, and interference in mechanisms such as suspension and steering linkages; and dynamic analysis, which evaluates the time-varying response of components to vibration, shock, and oscillatory loading (e.g., modal or transient analysis). Design and simulation of EV mechanical components in CATIA yields performance optimization, energy-efficiency gains through lightweighting, safety assurance via structural validation, compatibility with electrical subsystem mounting, and support for regulatory-compliance assessment while offering design validation, performance prediction, risk reduction, and faster, better-informed design iteration ahead of physical prototyping.

4. Chassis Design and Simulation

The chassis is the principal load-bearing structure of the scooter, supporting the battery, motor, seat, and bodywork while resisting shocks and impacts and providing the stiffness needed to protect the rider. Chassis modelling in CATIA V5 R20 made primary use of six features: Pad (adds material normal to a cross-section), Mirror (reflects geometry about a reference plane), Rectangular Pattern (creates linear duplicate features), Multi-section Solid (blends material between multiple cross-sections), Shaft (revolves a profile about an axis), and Rib (sweeps a profile along a center curve).

AISI 1018 mild steel was selected for the chassis on account of its low density, favourable strength, and ready market availability, using 1.25-inch-diameter, 2 mm-thick seamless pipe for the complete frame. Its chemical composition and mechanical properties are summarized in Tables 1 and 2.

Table 1
AISI 1018 chemical composition

Element	Content
Carbon, C	0.14 – 0.20 %
Iron, Fe	98.81 – 99.26 %
Manganese, Mn	0.60 – 0.90 %
Phosphorus, P	≤ 0.040 %
Sulphur, S	≤ 0.050 %

Table 2
AISI 1018 mechanical properties

Property	Value
Density	7.87 g/cc
Ultimate Tensile Strength	440 MPa
Yield Strength	370 MPa
Modulus of Elasticity	205 GPa

The chassis design balances two objectives - driver comfort/safety and subsystem mounting following SAE-style frame design rules. The scooter's geometric layout (Fig. 17) specifies a wheelbase of 1310 mm, ground clearance of 150 mm, and wheel-center distance of 1800 mm.

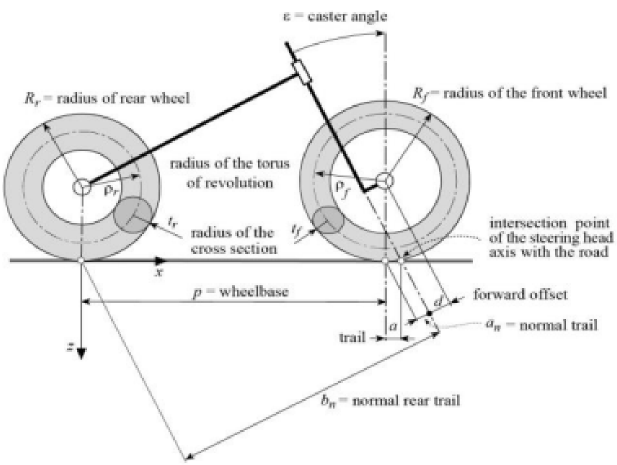

Fig. 17. Scooter chassis geometric layout

Design in CATIA proceeded by sketching the 2D chassis profile on the appropriate reference plane, extruding it into a 3D solid via the Pad tool, refining edges with fillets and chamfers, and assembling sub-parts using the Assembly Design workbench, before validating the design using Generative Structural Analysis. Impact-load calculations were performed assuming a 2g deceleration event, with impact load computed from the combined rider-and-vehicle weight and impact time derived from mass, velocity, and impact load; separate factor-of-safety (FOS = yield stress / working stress) checks were carried out for front-impact, side-impact, rear-impact, and torsional loading cases (Table III). Resistance to forward motion was evaluated by summing gradient resistance ($Fh = Mg \sin\Phi$, for incline angle $\Phi = 2.5°$), rolling resistance ($Fr = CrW \cos\Phi$, with $Cr = 0.004$ for asphalt), and aerodynamic drag ($Fd = 0.5\rho CdAV^2$, with $Cd = 0.5$ and frontal area $A = 0.7$ m²), from which the propulsion power requirement $P = F \cdot V$ was obtained.

Table 3
Chassis Factor of Safety (FOS = Yield Stress/Working Stress)

Load Case	Factor of Safety
Front impact	FOS = yield stress / working stress
Side impact	FOS = yield stress / working stress
Rear impact	FOS = yield stress / working stress
Torsion test	FOS = yield stress / working stress

The completed chassis was modelled in isometric, top, front, back, and side views, shown in Figs. 18–22, with final design specifications summarized in Table 4.

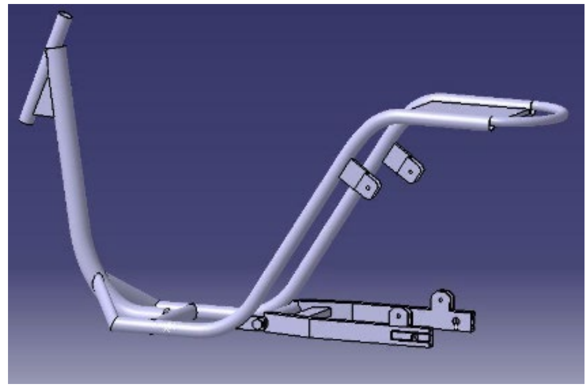
Fig. 18. Chassis isometric view

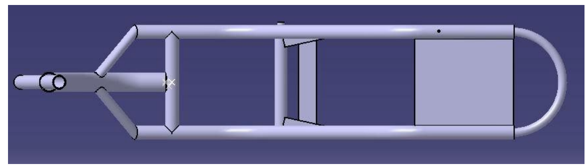
Fig. 19. Chassis top view

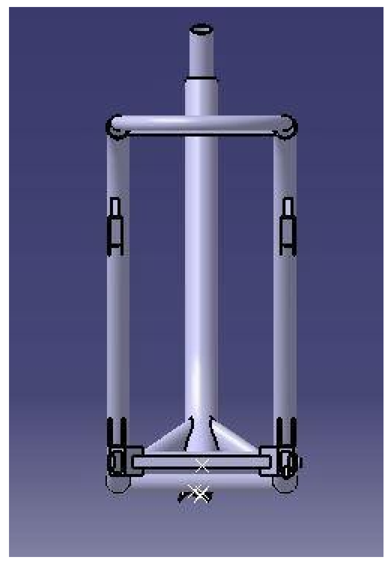
Fig. 20. Chassis front view


Fig. 21. Chassis back view

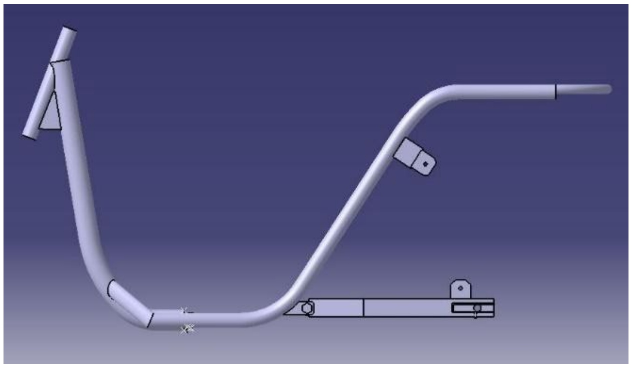

Fig. 22. Chassis side view

Table 4
Chassis design specifications

Parameter	Value
Length	1140 mm
Width	220 mm
Handle height	1000 mm
Head tube angle	27°
Seat height	665 mm

5. Design and Simulation of Handlebar

Simulation of the handlebar prior to fabrication is important for several reasons: safety verification of structural integrity under operating loads; performance optimization of ergonomics and steering response; cost reduction by catching design flaws before physical prototyping; rapid iterative design improvement across candidate materials and geometries; regulatory-compliance assessment; support for rider customization; and early mitigation of risks such as stress concentration or vibration-induced fatigue.

Common handlebar materials include aluminium (lightweight, durable, cost-effective - the most popular general choice), carbon fiber (very light with excellent vibration damping, but costlier and less durable), steel (heavier but highly impact-resistant, suited to heavy-duty use), titanium (light and durable but expensive), and composite combinations. Aluminium alloy was selected for this design; its mechanical properties are given in Table 5.

Table 5
Material properties - Aluminium handlebar

Property	Value
Young's Modulus, E	68.9 GPa
Poisson's Ratio, ν	0.33
Density, ρ	2700 kg/m³
Yield Stress	214 MPa
Ultimate Tensile Stress	250 MPa

Following the same CATIA Part Design workflow used for the chassis - sketch, extrude, fillet/chamfer, validate the handlebar and steering column were modelled in 3D, shown in Figs. 23 and 24 respectively.

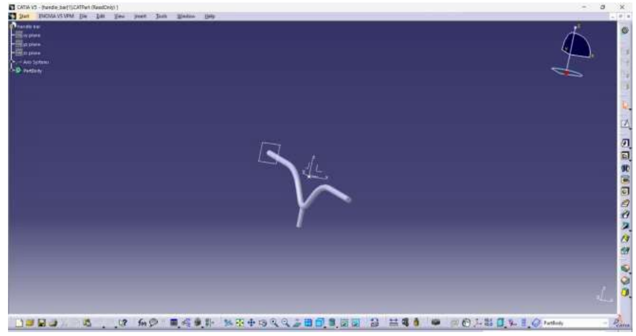

Fig. 23. 3D model of the handlebar

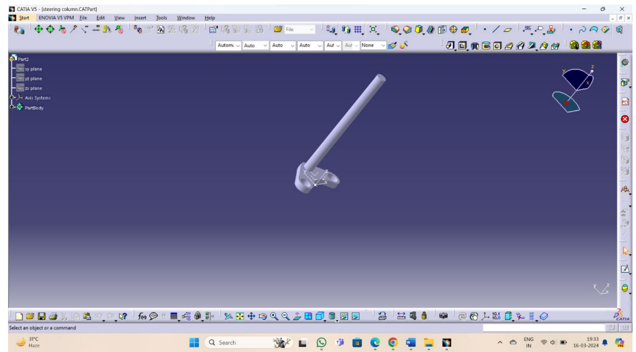

Fig. 24. 3D model of the steering column

6. Structural Analysis and Results

Finite Element Analysis of the handlebar was carried out in CATIA's Generative Structural Analysis workbench (Start > Analysis & Simulation > Generative Structural Analysis) in three steps: (1) opening the workbench and applying the aluminium material definition; (2) applying restraints (fixed boundary conditions at mounting points) and operating loads; and (3) computing the analysis and visualizing the resulting stress field.

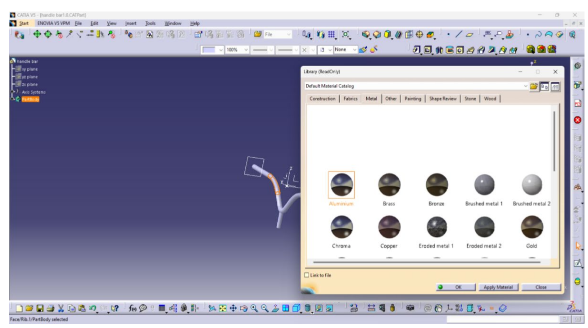

Fig. 25. Generative structural analysis workbench

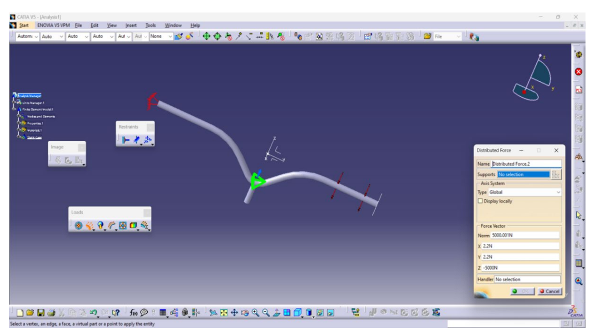

Fig. 26. Restraints and loads applied to the handlebar model

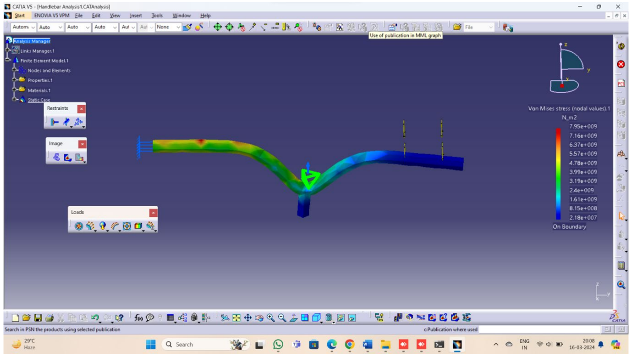

Fig. 27. Computed analysis and visualization of results

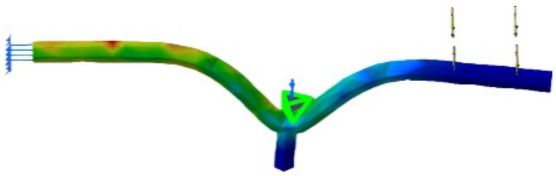

Fig. 28. Von-Mises stress distribution for the aluminium handlebar

The allowable stress range for pure aluminium is typically 90–140 MPa (N/mm²). The simulated peak Von-Mises stress on the handlebar was found to be 135.93 N/mm², which lies within and close to the upper bound of this allowable range, but below the material's 214 MPa yield stress. The design is therefore confirmed as structurally safe under the applied loading, though the margin relative to the allowable stress range suggests limited scope for further mass reduction without either upgrading the material or revising the cross-section.

7. Conclusion

This work has demonstrated a complete CATIA V5-based workflow for designing and simulating two key mechanical components of a two-wheeler electric vehicle - the chassis and the handlebar. Systematic application of CATIA's sketching, part-modelling, assembly, and Generative Structural Analysis tools enabled a scooter chassis (AISI 1018 steel, 1140 mm length, 1310 mm wheelbase) and an aluminium handlebar to be modelled and validated entirely in the virtual domain before physical prototyping. Finite Element Analysis of the handlebar yielded a peak Von-Mises stress of 135.93 N/mm², comfortably below the material's yield strength and confirming the design's structural safety. More broadly, the study confirms that CAD/CAE-based virtual prototyping in CATIA allows engineers to optimize the performance, efficiency, and safety of EV mechanical components while reducing development cost, shortening iteration cycles, and supporting compliance with regulatory and safety standards making it a valuable tool for advancing innovation in electric-vehicle mechanical design.

References

[1] O. Bolton, Jr., "Electrical bicycle," U.S. Patent 552 271, Dec. 31, 1895.

[2] H. W. Libbey, "Electric bicycle," U.S. Patent 596 272, Dec. 28, 1897.

[3] M. Partridge, Motorcycle Pioneers: The Men, the Machines, the Events 1860–1930. London, U.K.: David & Charles, 1976.

[4] "Electric motorcycle," *Popular Mechanics*, vol. 16, no. 4, Oct. 1911.

[5] E. Tragatsch, *Alle Motorräder 1894–1981: Eine Typengeschichte*. Stuttgart, Germany: Motorbuch Verlag, 1997.

[6] Guinness World Records, "Fastest electric motorcycle (prototype)," 2013. [Online]. Available: https://www.guinnessworldrecords.com/

[7] "Peugeot's incredibly frugal electric E-Vivacity scooter," *Gizmag*, Jan. 25, 2010. [Online]. Available: https://www.gizmag.com/

[8] NDTV, "500-acre Bengaluru campus for world's largest e-scooter factory," 2021. [Online]. Available: https://www.ndtv.com/

[9] "Meet Odysse Electric: India's first on-sale sportsbike-inspired electric bike maker," *The Financial Express*, Nov. 19, 2020. [Online]. Available: https://www.financialexpress.com/

[10] Bajaj Auto Finance, "Types of motorcycle chassis." [Online]. Available: https://www.bajajautofinance.com/blog/types-of-motorcycle-chassis

[11] TechSci Research, "Manufacturing electric two-wheeler," Jun. 2021. [Online]. Available: https://www.techsciresearch.com/blog/manufacturing-electric-two-wheeler/92.html

[12] BENLG, "Electric scooter." [Online]. Available: https://www.benlg.com/electric-scooter/

[13] L. E. Moreno-Suarez, L. Morales-Velazquez, A. Y. Jaen-Cuellar, and R. A. Osornio-Rios, "Hardware-in-the-loop scheme of linear controllers tuned through genetic algorithms for BLDC motor used in electric scooter under variable operation conditions," *Machines*, vol. 11, no. 6, Art. no. 663, Jun. 2023.

[14] Dassault Systèmes, "CATIA V5 for analysis—Generative part structural analysis workbench," Product Documentation. [Online]. Available: https://www.3ds.com/products/catia

[15] Dassault Systèmes, "CATIA V5 documentation," Product Documentation. [Online]. Available: https://help.3ds.com/