Fabrication and Simulation of an E-Vehicle

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Abstract. An electric vehicle is one that is powered by on-board electric sources and is driven by electric motors. Electric vehicles have emerged only because of the rise in cost of fuels and pollution. As they are ecologically sound, they are referred to as green transportation. The electric motor based was selected based on its rating of energy efficient. The rated values of the vehicle dynamics include on various parameters e.g motor output, power, traction-torque and speed. The motor rating is adjusted according to the carrying load, so as to achieve the characteristics of traction. The IC engine of the traditional vehicles is replaced by the electric motor which would act as the leading prime mover component used to drive the E-vehicle. Thus, the selected electric motor provides an adequate power for traction purpose. The structural optimization of the vehicle in-terms of deflection, proof-resilience and Von-misses stress analysis has been carried out using FEA software. EVs are gaining popularity due to their low emissions, reduced operating costs and advances in battery technology, which have increased their range and performance.

Keywords: Electric Vehicle; Battery Powered Vehicle; Hybrid Vehicle

1 Introduction

Electric vehicles differ from those fueled by conventional energy sources in producing variety of energy inputs like nuclear power and renewable energy sources including solar, wind, and tidal power, or any of these in combination. The energy is sent to the car either directly by an electrical cable, wirelessly through inductive charging, or over overhead power lines. Suspension and regenerative braking or the capacity to retrieve energy lost in braking and convert it into electric power to be added back to the battery, is a fundamental benefit of electric or motorized electric cars.

Mechanically, electric motors are fairly straight forward. Electric motors frequently achieve 90% energy conversion efficiency and may be accurately controlled. Regenerative braking systems have the capacity to transform energy of motion into electricity that is stored, is also used in conjunction with them. This can be utilized to lower the overall energy needed for a trip and lower the brake systems' wear.

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2 Literature Review

Ahmed Abd El Baset et.al [1] showcased the types of EVs, their different configurations, batteries, equalizers, charging and control system. Reis, J. [2] emphasized on the scope, implementation and the use of alternate fuels of electric vehicles. Swapnil Namekar et.al [3] focused on the types, technologies and the different models of the battery. Muhammad Yousaf Iqbal et.al [4] dealt with various hybrid powertrain configurations based on different topology combinations. Karan Mahal et.al [5] focused on data analysis of an E-vehicle and the concept of retrofitting along with the EV Market in India. Carlo Villante et.al [6] emphasized on different concepts of vehicles and characterization of Electrical Behaviors using Matlab Simulation. Clean Energy Ministerial [7] The more ambitious Sustainable Development Scenario, which the author researched, aims to achieve a light-duty EV sales share of 30% by 2030. Fifteen member nations support it, and it was presented at the 8th Clean Energy Ministerial (CEM) in June 2017 along with numerous international companies and organizations. Ravi et.al [8] Through the use of Vehicle-to-Grid (V2G) devices, the prospect of intelligently and bi-directionally integrating vehicles' own Electric Storage Systems with the electric grid emerges. This would enable at least some localized adaptation to the always rising demand for power and energy, as well as the fluctuations in that demand. Providing ancillary services, such as frequency stabilization, which provides active power, and reactive power from the vehicle to stabilize the grid voltage in response to variations in demand, is in fact one among the primary benefits of vehicle-to-grid (V2G) technologies. M. S. Hossain et.al [9] looked into the global aspects and demand of electric cars along with the various technologies used in an E-Vehicle. W. Su et.al [10] In modestly charged ports, the high fees for electric vehicles are private. In the future, however, charging stations will be built at businesses to transform them from gas stations for electric vehicles into full-service charging stations. A. Rakesh Kumar et.al [11] The world is becoming more polluted; thus, every effort is being made to lower emissions of CO2 and preserve the environment. The launch of EVs is an endeavour. Reducing CO2 emissions is necessary because the transportation sector is one of the largest emitters of the gas. The government has devised ambitious plans to introduce electric vehicles (EVs) into the Indian market and maintain pace with the worldwide EV rollout. One component of the National Electric Mobility Mission Plan 2020 is an extensive report on electric vehicles. India's move away from internal combustion engines is beset by serious challenges to electric vehicle (EV) technology. R&D and extensive planning are required for this. To address range anxiety, charging infrastructure needs to be constructed appropriately. By making all government buses electric and providing tax breaks for private EV owners, it is imperative to create demand. Janardan Prasad Kesari, 2019 et.al [12] India's Prospects and Opportunities for Electric Vehicles: by Janardan Prasad Kesari, Yash Sharma, and Chahat Goel It will be difficult but necessary for the government to design a vigorous plan for EV adoption in India and see to it that its implementation is carried out properly. India's diversity and topography will provide challenges that call for careful thinking. With the purchase of buses for public transportation, three-wheeled vehicles for government offices, and four-wheeled vehicles for government offices, public procurement is anticipated to play a significant role in the growth of electric vehicles. Investments from food delivery services and fleet operators like Ola and Uber are anticipated to stimulate the initial growth of two and four-wheeled electric vehicles. But it might take five or six years for private EVs to become widely accepted. Sonali Goel et.al [13] looked into the fabrication and the optimization techniques used to meet the demands of Indian market. Menonjyoti Kalita et.al [14] The energy storage system found in electric vehicles was covered by the author. using premium materials to guarantee peak performance and seamless operation free from corrosion and explosion. Ibrahim Shanono et.al [15] mostly emphasized on the classification of EV’s, how they differ from ICE, mainly the energy consumption of electric vehicles. K. Sharma et.al [16] The motor of an electric vehicle (EV) is powered by the battery through a regulated power circuit. There is a fair amount of auxiliary control for auto electronics in addition to the circuit for the motor. D.R. Wright et.al [17] Li-ion batteries are becoming the standard battery technology for the automotive industry due to their growing popularity. J. Smith et.al [18] Every energy storage system requires protection and upkeep to function properly. Due to thermal effects in the batteries, there are safety and cost issues with electric vehicles using Li-ion batteries. A. Mahmoudzadeh Andwari et.al [19] Li-ion batteries in electric cars must be shielded from excessive charging and discharging. This is due to the fact that it has been demonstrated that excessive discharging of Li-ion batteries results in high rates of heat generation and electrochemical reaction, making the batteries vulnerable to temperature increases. Ogura et.al [20] Heat built-up inside Li-ion batteries is the primary cause of safety problems like thermal runaway, swelling, electrolyte fires, and explosions. Muhammad Yousaf Iqbal et.al [21] EVs require recharging because their power comes from energy storage devices like batteries rather than fuel. As a result, additional energy must be supplied by the current power plants and grid. As a result, it is necessary to use renewable energy sources like solar and wind power.

Form the literature it is observed that the researchers have not covered, to the best of the author's knowledge is as follows. Audit of energy provided by batteries with the aim of assuring their safety and reliability, lifespan of a battery in terms of cycles of charging, efficacy (percentage of power) that the battery provides compared to the energy that is charged and usage of a BLDC motor to offer high efficiency, controllability and starting torque and to minimize harmful emissions and fuel costs while maintaining a conventional vehicle's power, range, cost, and safety.

3 Working Principle – Layout of an EV:

Electric motor is powered by a lead-acid battery and is situated close to the posterior part of the vehicle. The back wheel is propelled by an electric motor that is installed inside the wheel. High voltage supplies are transformed into low voltage supplies using an AC to DC converter. Here, electrical energy is transformed into rotational energy, which propels the car forward. A throttle that accelerates the car with the aid of a speed controller is located on the steering handle.

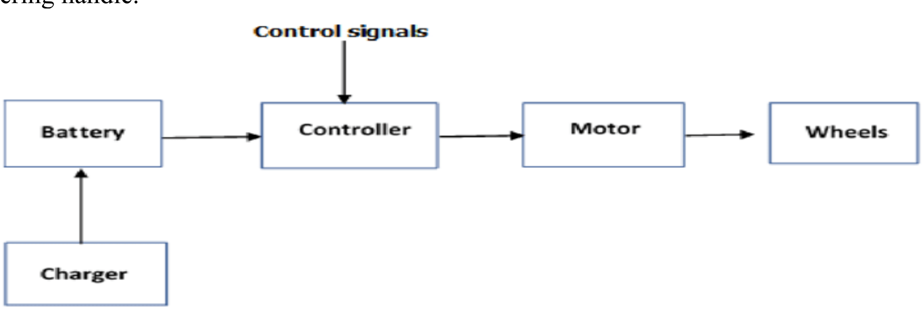


Fig. 1. Block diagram of an Electrical Visitor's vehicle

Both forward and reverse are options. The following things happened when the car is in gear and the accelerator pedal is depressed:

- For the electric motor, power is transferred from the DC battery to AC. The controller, which is activated by the accelerator pedal, changes the frequency of the AC current from the inverter to the motor, which links to and rotates the wheels through a gear.

- The motor is transformed into an alternator when the brakes are applied or the vehicle is slowed down and generates electricity that is returned to the battery.
  The stator's coils, which are constructed from conducting wire and positioned on either side of the stator core, essentially serve as magnets. Therefore, the coils produced revolving, magnetic forces that pulled the rotor's outside conducting rods running behind it when the motor received electrical energy from the vehicle battery.

3.1 Components of an EV

3.1.1 BLDC Motor Controller

The brushless motor controller for electric vehicles produce strong take-off current and strictly regulates the battery current. Although it had a relatively tiny battery, the motor speed controller gave strong acceleration and hill climbing. High power MOSFET and PWM are used by BLDC motor speed controllers to attain 99% efficiency.

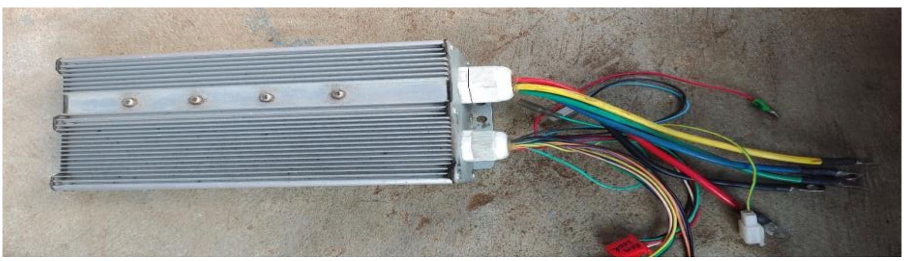


Fig. 2: BLDC Motor Controller

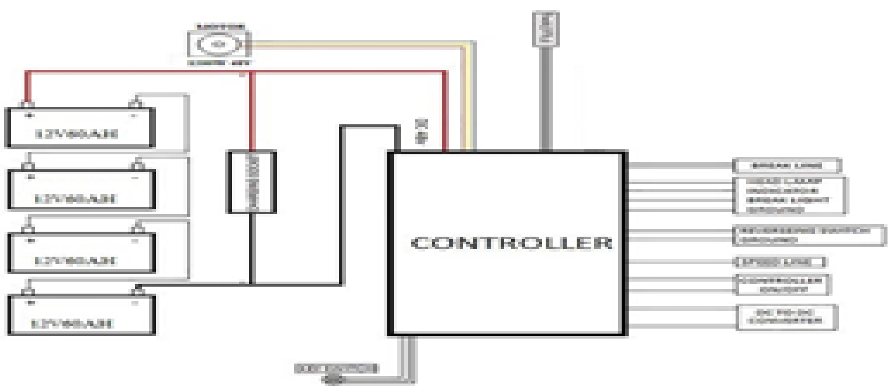


Fig. 3. Electrical Circuit Diagram

This controller's task was to draw electricity from the battery and deliver it to the electric drive motor. The electric controller delivered different powers at varying speeds and controller's technical requirements included heat resistance, nearly universal motor compatibility, speed locking, speed switching, reverse switching, overload protection, high torque delivery, and control of other electrical systems.

3.1.2 Battery

Battery electric vehicles (BEVs) are propelled by rechargeable batteries known as electric vehicle batteries (EVBs) or traction batteries. The cheapest and most used traction battery type is a flooded lead-acid battery, which is typically depleted to 80%. For quick charges, they tolerate high charge rates. Batteries that have been flooded need to have the electrolyte level checked and the water replaced.

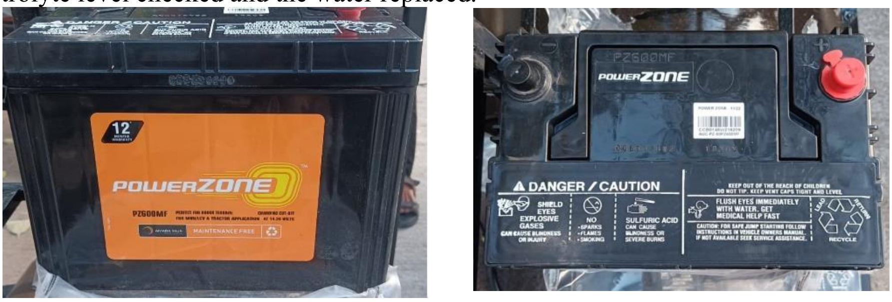


Fig. 4. Lead Acid Battery

In EV applications, lead-acid batteries make up to half share of the overall gross vehicle weight. They have an energy density of 30–40 Wh/kg, which is much lower than that of petroleum fuels, like other batteries.

3.1.3 DC-to-DC Converter

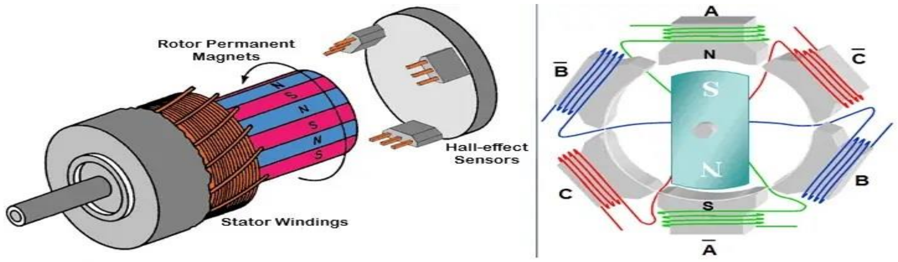
DC-to-DC converter is a circuit or electromechanical device that changed the direct current (DC) source's voltage. It's a particular kind of electric power converter. Low-voltage batteries have very low levels of power, while high-voltage power transmission has very high levels of power.

Fig. 5. DC/DC Converter

The receiver voltage is typically additionally governed by circuits for DC-to-DC converters. Another is the use of straight forward charge pumps, which increased the output voltage by two or three times.

3.1.4 Motor

Because of their better performance, long lifespan, smooth delivery of torque, and speedy operation, brushless DC (BLDC) motors have replaced induction motors and brushed DC motors in frequent applications. The Lorentz force law, states that a conductor carrying current experiences a force whenever it is placed in a magnetic field, is the same principle that underlies the operation of a BLDC motor. The reaction force will cause the magnet to



experience an equal and opposing force. In a BLDC motor, the current-carrying wire is stationary while the permanent magnet moves. When the stator coils are electrically switched by a supply source, they transform into electromagnets and start to create a consistent field in the air gap. The electromagnet stator and permanent magnet's interactional force causes the rotor to continue rotating.

Fig. 6. BLDC Motor Construction

The rotor magnet will rotate clockwise if we now apply current to coils B and C in that order, one after the other. We can create twofold attraction by winding the opposing coils around one coil to boost efficiency. We can simultaneously power two coils so that one coil draws the magnet while the other repels it, enhancing efficiency even more. The third will be idle during this time.

3.1.5 Hall Sensors

Three Hall sensors are typically integrated into the stator of BLDC motors. Every time the rotor poles come within close proximity to a sensor, signals that are high and low are generated. According to the combined reaction of these three sensors, it is possible to pinpoint the precise commutation sequence to the stator winding.

3.1.6 Leaf springs

The main benefit of parabolic springs, aside from weight reduction, is their increased flexibility, which translates into an improved ride experience that is comparable to coil springs; the drawback is a decreased load bearing capacity. There are fewer leaves in this pattern and their thickness changes along a parabolic curve from the centre to the ends. Another benefit of a leaf spring over a helical spring is that the leaf spring's end can be directed along a predetermined path.

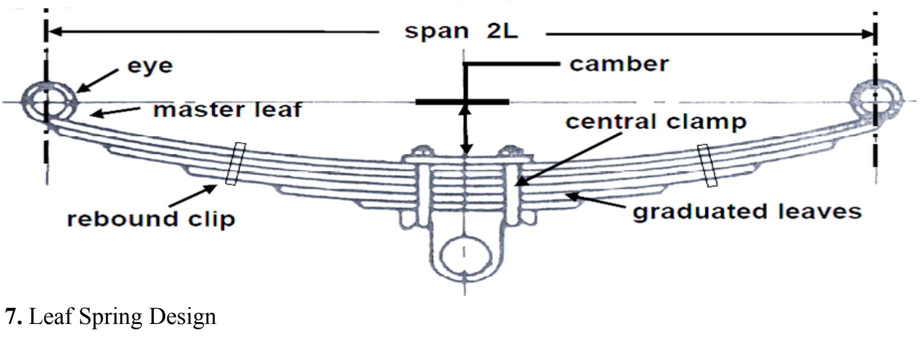


Fig. 7. Leaf Spring Design

3.1.7 Battery Charger

The charger measures the average resistance of the pack, which may result in certain batteries being overcharged. Batteries of different ages or depths of discharge cycles have different internal resistance. The following is required for an E vehicle by regulation:

- A maximum power of 2 KW
- 5 to 6 hours of charging time
- Charging voltage of at least 60 V
- Charging current of 10-15 amps

Fig. 8. Lead Acid Battery charger

3.1.8 Steering box

A steerage box is a tiny gearbox connected to the steering wheel of the driver and the steering system linkage. The gearing makes it possible for the front wheels to be moved easily from side to side and also stops road shocks from being immediately communicated back to the driver. which rotated a pinion gear that moved on a rack to turn the front wheels, is used by the majority of vehicles that are based on cars. Others employ "worm"-style steering gears with ball bearings placed on them, or recirculation ball systems.

Fig. 9. Rack and Pinion Steering Gear Box

In rack and pinion steering, the rack moves linearly as the pinion rotates, turning the wheels of the vehicle left or right. While a rack and pinion system may appear complex, Advance auto parts claim that it is gear fastened to a toothed bar. To produce linear movement, a motor or a hand crank is used to turn the pinion's shaft.

4 Modelling and simulation:

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CATIA designing is the initial stage of the production process. A 3D model of the complete, including the measurements, bodywork, and chassis, is created during this procedure. A CATIA program, which is used to create exact designs of the car, is employed for this. A prototype that can be utilized for testing and other purposes is made from the produced model. After completion of modelling the structure has been uploaded to the ANSYS R18 FEA analysis tool to analyse for deformation and Von-mises stresses under the action of load and defined boundary conditions. The load considered for the analysis is equals to three times of gradually applied load. The simulation has been carried to find the optimum load that the vehicle can carry.

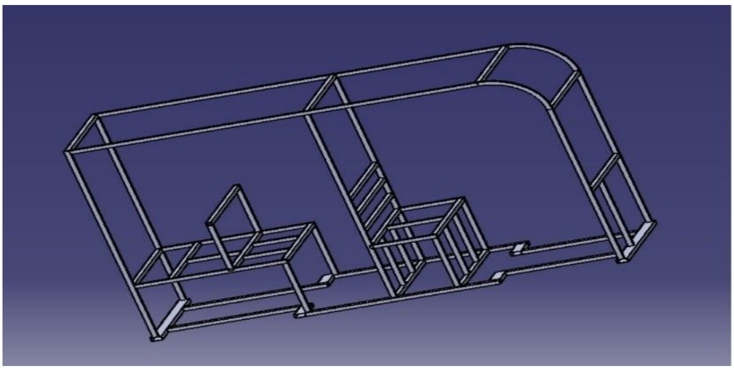

Fig. 10. CATIA design of Vehicle Frame

After modelling the structure has uploaded to FEA software for the simulation, under the given forces and applied boundary conditions. ANSYS R18 has used for the analysis. In the analysis the applied force considered, is equals to the three times of gravitational force.

<table>
<tr><th colspan="7">Definition</th></tr>
<tr><td>Suppressed</td><td colspan="6">No</td></tr>
<tr><td>Stiffness Behavior</td><td colspan="6">Flexible</td></tr>
<tr><td>Coordinate System</td><td colspan="6">Default Coordinate System</td></tr>
<tr><td>Reference Temperature</td><td colspan="6">By Environment</td></tr>
<tr><td>Behavior</td><td colspan="6">None</td></tr>
<tr><th colspan="7">Material</th></tr>
<tr><td>Assignment</td><td colspan="6">Structural Steel</td></tr>
<tr><td>Nonlinear Effects</td><td colspan="6">Yes</td></tr>
<tr><td>Thermal Strain Effects</td><td colspan="6">Yes</td></tr>
<tr><th colspan="7">Bounding Box</th></tr>
<tr><td>Length X</td><td colspan="2">0.6985 m</td><td colspan="3">2.54e-002 m</td><td>0.254 m</td></tr>
<tr><td>Length Y</td><td colspan="6">2.54e-002 m</td></tr>
<tr><td>Length Z</td><td colspan="2">2.54e-002 m</td><td colspan="3">1.0922 m</td><td>2.54e-002 m</td></tr>
<tr><th colspan="7">Properties</th></tr>
<tr><td>Volume</td><td colspan="2">1.0955e-004 m^3</td><td colspan="3">1.713e-004 m^3</td><td>3.9837e-005 m^3</td></tr>
<tr><td>Mass</td><td colspan="2">0.85998 kg</td><td colspan="3">1.3447 kg</td><td>0.31272 kg</td></tr>
<tr><td>Centroid X</td><td colspan="2">0.36195 m</td><td>-5.8461e-018 m</td><td>1.0922 m</td><td>2.1336 m</td><td>0.3175 m</td></tr>
<tr><td>Centroid Y</td><td colspan="2">0.381 m</td><td colspan="2">1.3716 m</td><td>0.508 m</td><td>0.381 m</td></tr>
<tr><td>Centroid Z</td><td>-1.27e-002 m</td><td>-1.1303 m</td><td colspan="4">-0.5715 m</td></tr>
<tr><td>Moment of Inertia Ip1</td><td colspan="2">1.6246e-004 $kg \cdot m^2$</td><td>0.1338 $kg \cdot m^2$</td><td>0.13381 $kg \cdot m^2$</td><td>0.1338 $kg \cdot m^2$</td><td>5.9078e-005 $kg \cdot m^2$</td></tr>
<tr><td>Moment of Inertia Ip2</td><td colspan="2">3.5047e-002 $kg \cdot m^2$</td><td>0.1338 $kg \cdot m^2$</td><td>0.13381 $kg \cdot m^2$</td><td>0.1338 $kg \cdot m^2$</td><td>1.7108e-003 $kg \cdot m^2$</td></tr>
<tr><td>Moment of Inertia Ip3</td><td colspan="2">3.5047e-002 $kg \cdot m^2$</td><td colspan="3">2.5404e-004 $kg \cdot m^2$</td><td>1.7108e-003 $kg \cdot m^2$</td></tr>
<tr><th colspan="7">Statistics</th></tr>
<tr><td>Nodes</td><td>575</td><td>691</td><td colspan="2">692</td><td>917</td><td>208</td></tr>
<tr><td>Elements</td><td colspan="2">126</td><td colspan="2">121</td><td>180</td><td>24</td></tr>
</table>

Fig. 11: Specifications For E-Vehicle Fabrication

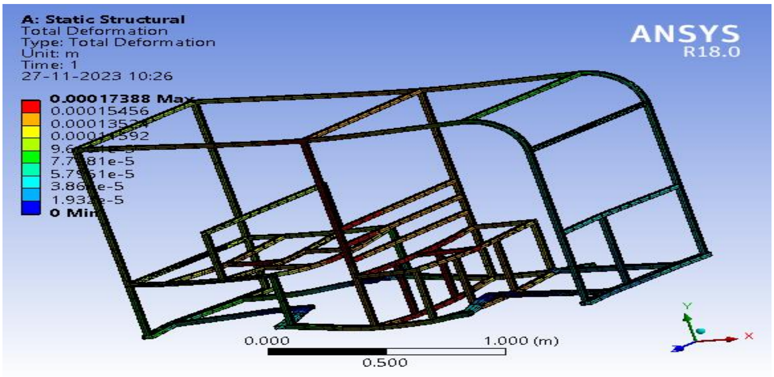

Fig. 12. Total Deformation on Application of Load

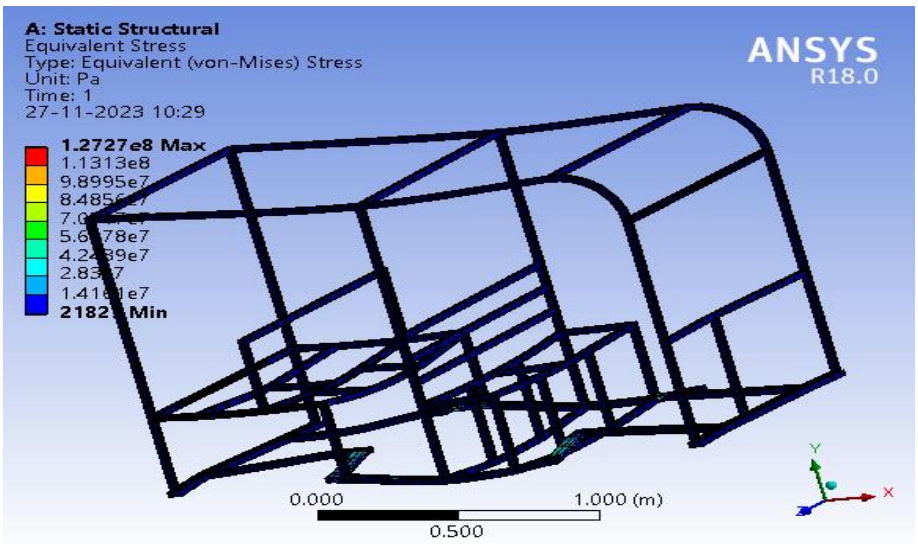

Fig. 13. Von-Mises Stresses

5 Fabrication of Vehicle

The fabrication process starts after the parts and supplies are stored. To produce the vehicle's structure and body, materials and components are cut and joined together throughout this procedure.

5.1 Metal Cutting

Metal cutting is a manufacturing process that involves removing material from a metal work piece to achieve the desired shape, size or finish. A multitude of steps are involved in the cutting of metal. The operating procedure depends on a variety of tools that include working gloves, saw blades, masks, goggles, measuring tapes, wrenches, workbenches, and clamps. Here a metal cutting saw is used to continue the procedure.

5.2 Welding

Arc welding is a welding process that uses an electric arc to join metals together. In arc welding, an electric arc is created between an electrode and the work piece. The electrode is connected to a power source and when the electrode comes in contact with the work piece, an electric circuit is completed and an intense heat source is generated at the tip of the electrode.

1. **Electric Arc Formation:** In arc welding, an electric arc is created between the electrode and the work piece. The electrode is connected to a power source and when the electrode comes into contact and an intense heat source is generated at the tip of the electrode.
2. **Melting and Fusion:** The heat generated by the electric arc is extremely hot often reaching temperature above 6000° F (3300°C). The intense heat melts both the electrode and the work piece at the point of contact, creating a molten pool of metal.
3. **Filler Material (if necessary):** In some types of arc welding, such as shielded metal arc welding (SMAW) and gas metal arc welding (GMAW or MIG welding), a separate filler material in the form of a consumable electrode is used. This filler material is fed into the molten pool to add material and reinforce the weld joint.
4. **Solidification:** As the molten metal cools, it solidifies, fusing the work pieces together and forming a strong bond. The electrode or filler material may also solidify adding material to the joint.
5. Processes for arc welding might be fully automated, semi-automated, or manual.

5.3 Grinding

A grinding wheel or grinder is used as the cutting tool in this abrasive machining technique. Given that grinding is a genuine metal-cutting operation, grinding is a subset of cutting. The cement industry and mineral processing facilities frequently use grinding. Work pieces that need to exhibit high surface quality and great accuracy of shape and dimension are finished with grinding. Grinding can be used in some roughing applications to quickly remove large amounts of metal.

5.4 Sheet Metal Cutting

Cutting procedures involve exerting sufficient power to cause the material to fail in order to separate a piece of sheet metal. Shearing operations are sometimes used to describe the most frequent cutting techniques because they involve applying a shearing force. When a sufficient shearing force is applied and the material's shear stress exceeds its ultimate shear strength, the material will fail and separate at the cut spot. The tool above the sheet strikes the sheet metal that is resting above the lower tool with a swift downward impact, whether these tools are a punch and die or upper and lower blades. The material is easier to fracture since there is a slight space between the upper and lower tools' edges. Finally, the material cracks at an angle with a little burr forming at the edge because the shear stress is too high.

6 Results and Discussion:

A 1.5 HP motor has been analysed at various R.P.M for Torque values and tabulated as follows.

Table 1: Torque and Speed Variations at 1.5 HP Motor

S.NO	P(hp)	T(N.m)	N(rpm)	POWER(KW)
1	1.5	10.68153	1000	1.118
2	1.5	7.121019	1500	1.118
3	1.5	5.340764	2000	1.118
4	1.5	4.272611	2500	1.118
5	1.5	3.56051	3000	1.118

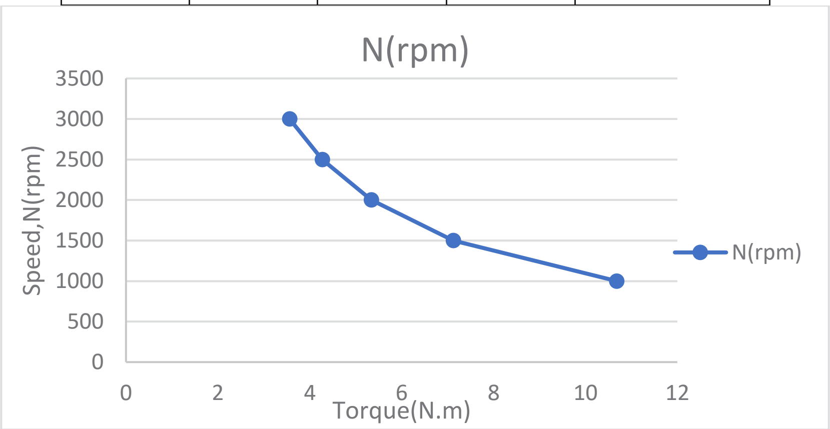

Fig. 14. Torque vs Speed

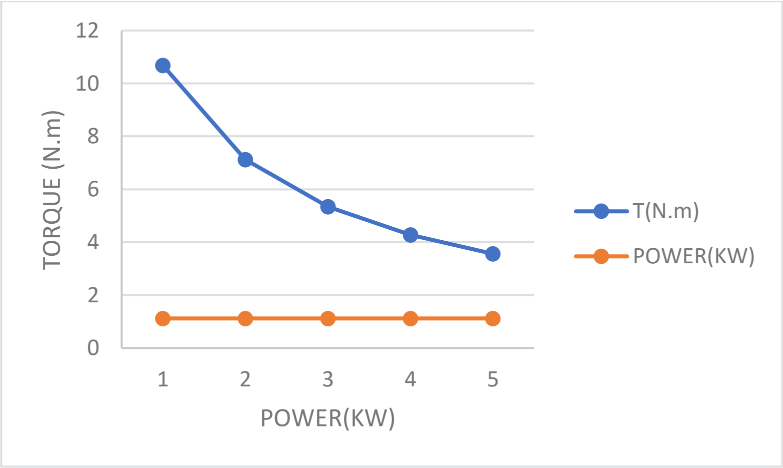

Fig. 15. Power vs Torque

In the figure 14, variation of torque with speed had been plotted and the stall torques values have been identified. It is observed that optimum torque had obtained at 2000 R. P.M with a value of 4.3 KN.M. it is also observed that the requirement of torque is reducing with increase in speed.

In the figure 15, variation of torque with power had been plotted to observe the nature of variation in between the two parameters. It has been noticed that the requirement of torque is reducing with increase in power produced.

From figure 12 The maximum deformation on the application of load is 0.000173 m in the transverse direction. The applied load has considered three time of the gradually applied load.

From figure 13 The maximum Von-Mises stress observed is 1.27×10^{8} Pa.

7 Conclusions:

- It is observed that the torque is directly proportional to the speed of the motor at constant power.
- The maximum deformation occurred is within the elastic limit.
- The Von-Mises stresses are satisfying the required Factor of Safety for the material considered.

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