Design and Manufacturing of Electrically Driven ATV for Enhanced Vehicle Performance

Gayathri Natarajan, L.Ashok kumar

Abstract: This paper aims to produce an Electrical all-terrain vehicle with Smart Driver Kit design which is more durable and comfortable to meet the robust conditions of Defense and Forest Sector, not just recreational user market. The Smart Driver Kit design will take this vehicle experience to a new dimension with valuable information about Energy Consumption, Stealth Mode, Real-time Elevation and Terrain Data. The paper implies the prominence of bringing up innovation in terrain vehicles to cover wide range of market preferably terrain based commercial activities. Clear understanding of Vehicle Dynamics and Automotive Design leads us to the development of a product which would fulfill the consumer expectations sought at every level around the globe. The structural integrity and durability of the vehicle of this vehicle would be an advancement for innovation in All-Terrain Vehicle.

Keywords: All-terrain vehicle, Stealth mode, Smart driver kit, Vehicle dynamics.

I. INTRODUCTION

The main objective of the paper is to inspire the future generation researchers and designers to innovate more of electric mobility, create a demand for electric vehicles by encouraging the consumers to opt for electric vehicles irrespective of the nature of work. In a growing lethal environment with dominance of various kind of pollutants than fresh air and several other environmental experts warn that the entire world is at the verge of global warming which could never be revoked to normal habitable environmental conditions after three years if the same environmental policies fail to achieve significant reductions in greenhouse gas emissions.

Lowering emissions globally is a monumental task, but this opportunity to develop an E-ATV further after deep research suggests that it is vital, necessary, desirable and achievable by shifting to electric drive technology of any type of vehicle. [Sayed.B.M, Mohamed Fanni, 2016].It is designed to handle a wider variety of terrain than most other vehicles [Malmedahl.G, Dembski 2006]. Electrical All-Terrain Vehicle (E-ATV) is slightly different but more versatile than all other existing ATV's.

This E-ATV concept would be a seed for a new revolution in Automobile Industry. In comparison to traditional fuel based ATVs and any other E-ATVs, concept is to be more fuel efficient with great structural integrity to withstand any robust conditions.

Incorporation of Electrical Drive Technology would reduce the adverse environmental risks caused due to vehicle based pollutants.

II. STRUCTURAL DESIGN AND ANALYSIS OF CHASSIS FRAME

Chassis is the cage on which an automobile is built. The chassis is the rigid structure that supports all other components such as driver cabin, engine, gearbox, front and rear axles, suspension system, steering, drive train, etc. It acts as the main structure for holding all the components against gravitational force of the earth during movement by taking up all the stresses created by different components. It is the three-dimensional arrangement of members of different lengths to obtain a virtually indestructible structure. The main motive of any structure which is to house a living being is the minimizing of the effects caused by the external forces which act on the structure such as impact forces (by external agents), thereby ensuring the maximum safety of the living being. In the case of an automobile, this virtually indestructible structure is to be moved at constant or varying phase with a human housed in it. So, a human being inside such a structure is prone to a lot of forces due to its movement which include impact force, collision, bumps, twisting effects, etc.

The design of a chassis is the most important part of any vehicle fabrication. Any design engineer must have rampant skills to decide on what type of design to create, the feasibility of fabrication of the design, the economic value of certain aspect of design, etc. The design is the part of vehicle development where a design engineer has full freedom of selecting his own touch, also satisfying the functional requirement of the design. It explains about the structural design in the point of view of a consumer who is the final experimenter of our design. In the point of view of an engineer, the main motive is to increase the bending strength, torsional strength of a structure which is necessary to maintain the rigidity, reduce the chance of failure of the design. A rigid structure of high strength can be obtained by using a material having high magnitude of tensile strength. Steel is one type of material which has high tensile strength but is heavier on the downside. Aluminium on the other hand is light in weight but has a very low value of tensile strength. So, a design engineer must have the capability to balance between strength and weight of a material.

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Strength to Weight ratio is one important factor a design engineer must consider before selecting any material for structure design. All-Terrain Vehicles (ATV) are automobiles designed to travel on any terrain conditions without compromising on the performance of the vehicles. In general, these terrains are not suitable for commercial passenger vehicles. The ATVs that traverse on these roads face a number of instances where the structure is subjected to instantaneous peak values of impact forces.

The ATVs must be designed to cope up with these situations without facing breakdown.

III. DESIGN METHODOLOGY

Any design process must follow certain standards to convince ourselves that the design is carried out in the right order. [Cherif.M, Ch. Laugier]
The order of design process for ATV:

- Study of ATV frame design guidelines
- Performing pencil sketches of rough design
- Drafting life size sketches of the ATV to be designed by seating the driver as in the vehicle on the floor
- Collecting the dimensions of the life size sketches drawn
- Modelling a 3D sketch of the vehicle in solid modelling software like SOLIDWORKS, CREO, etc.
- Applying the required cross section of different sizes as specified in the guidelines on the sketches
- Analysing the sketches by applying different real-life impacts like front, rear, and side impacts. This is done in ANSYS Workbench software
- Optimizing of the design by using the results of analysis
- Analysis of the structure

Any frame built using three-dimensional arrangement of pipe members of different cross section must be analysed to identify the weak parts, stress concentration regions. [Nicolas Bouton, Roland Lenain2009] [Xu Chen, Yu Wang 2011] After the deduction of the above parameters the design is optimised by different methods:

1.By changing the position of the intersection of different tube members
2.By addition and removal of different tube members
3.By changing the lengths of the tube members
4.By changing the cross-section of the tube members

In general, stress and deformation values are computed for the frame,the stresses at different regions are analysed.The design is modified and analysis is computed again. Hence, the design is optimised
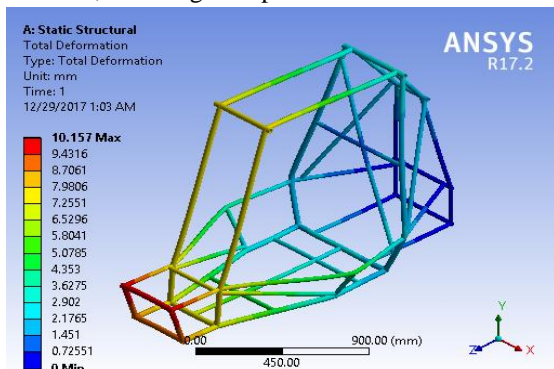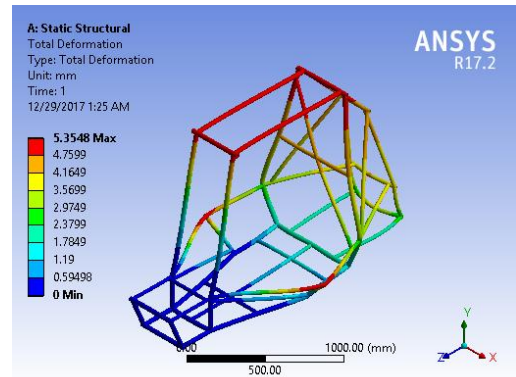

Figure 1(a). Front Impact

Fig 1(b). Rear Impact

Fig.1(a) explains the frontal deformation of the ATV which depicts the load which was made to act on the front part of the ATV and analysed. The Roll Cage was analysed in three dimension for better view of the deformed part. Figure 1. (b) explains the force acting on the rear side of the ATV which was analysed to calculate the amount of deformation produced.
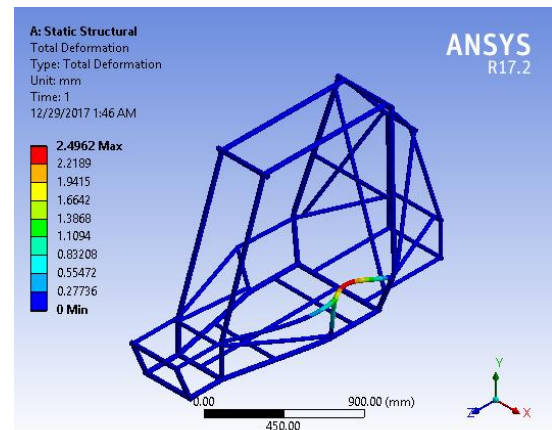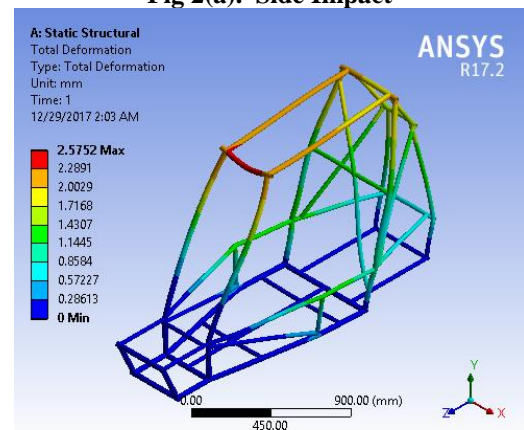

Fig 2(a). Side Impact

Fig 2(b). Rollover Impact

Fig.2 (a) explains the lateral or side impact shown when a force was made to act on it and was later analysed to calculate the deformation produced. Figure.2 (b) explains the force experienced when the ATV is made to rollover and was later analysed to calculate the impact caused.

IV. BRAKING SYSTEM FOR ENHANCED PERFORMANCE CHARACTERISTICS

Function of brakes in general is to decelerate a moving vehicle to our need. Over the days, we have seen tremendous increase in the rise of technological growth in the automotive sector. In a way more simpler term, we can define the braking action as the conversion of Kinetic Energy of the moving vehicle into heat energy with the help of frictional or resistive forces. For ATV's in general, hydraulic brakes is more commonly applied and used.
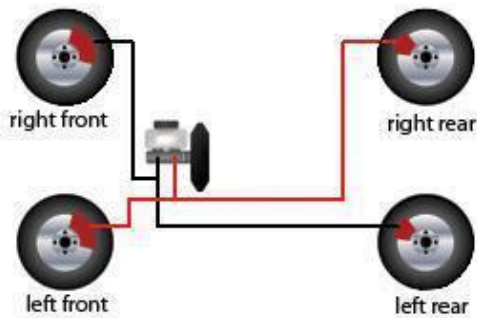
Fig 3: Schematic figure of X-Split Braking

Hydraulically actuated disc braking system is more preferred, because of its simple configuration. Both inboard and outboard braking can be used only in hydraulic system. X-Split braking configuration is more preferred in ATVs to avoid bumps and accidents thereby providing safety and comfort to the driver which is the primary goal. Hence proper vehicle ergonomics depends upon the braking system of the buggy. Disc brakes are more favourable for the ATV because of its light weight feature. This is the main reason why disc brakes are preferred more than drum brake assembly [Lin.Y and Anwar.S 2007].

Table: 1 Brake Calculations

Particulars	Values
Weight transfer (40kmph to 0kmph)	775.3
Static Rolling Radius	269mm
Coefficient of friction	0.7
Brake Force	2362N
Brake Torque	633Nm

Table 2: Force Calculations

Particulars	Values
Stopping distance	2.44m
Pedal Ratio	4:1
Pedal Force	490N
Locking	Front left and Rear right

Particularly the stopping distance of the ATV plays a pivotal role in the Brake test performance. This is the main factor which tests the efficiency of the braking system of the vehicle. The stopping distance is highly dependent upon the coefficient friction of the road and velocity at which the vehicle travels.

Table 3: Brake Circuit

Particulars	Values
Braking Type	X- Split
Master Cylinder	Bore - 19.05mm
Disc Diameter	200mm
Brake Caliper	Bore- 28mm
Brake Fluid	DOT3
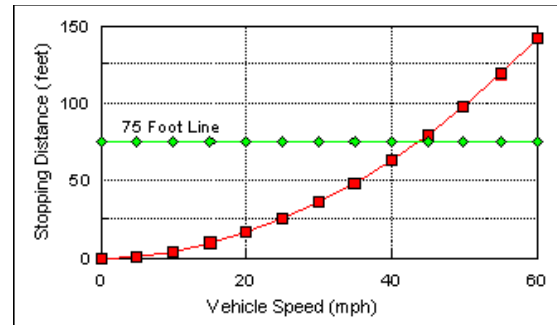
Fig 4: Speed Vs Stopping Distance

Figure 4.explains the stopping distance Vs Speed graph. Master Cylinder controls the pressure inside the braking system. Bosch Tandem Master Cylinder is more preferred for ATVs. DOT3 brake fluid is more preferred because of its hydrophobic capability and because of its ability to absorb less amount of heat, which prevents the damage of the system by brake failure. Custom made brake callipers and disc is used which works well in accordance with the knuckle assembly. Less wastage of material and light weight are important aspects which are taken into consideration for the manufacturing process. Maneuverability and safety are two most prime targets of the Braking System. It is designed keeping the above two factors into deep consideration. Brake technology remains to be evergreen and always innovation rises up leaving the current trend entirely obsolete. ATVs will face heavy load conditions with rugged pits for which advanced braking technology should be implanted in the vehicle to maintain proper vehicle ergonomics.

V. PNEUMATIC DAMPENING SYSTEM

The suspension is a system which brings out a relative motion between the wheel and the chassis of the vehicle. This system usually consists of linkages of various design, springs and dampers. The suspension system is used to isolate the vehicle body from uncomfortable road shocks. These shocks maybe in form of pitching, rolling, bouncing or swaying. Due to these shocks, the chassis are subjected to additional stress, which may cause rupture, loosing of fits, hazards to the occupants, etc. So the suspension system is used to prevent the shocks, prevent the occupant and devices from road shocks, to provide stability of the vehicle while travelling in a straight road and corners, and to increase the friction between wheels and road, while in motion. The suspension system is also an important aspect while acceleration and deceleration. The suspension system is inter-depended with the steering, the chassis and wheel assembly. So, the design and selection of a suspension depends upon these systems, and the load/masses rested on the chassis.

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According to the type of load carried by the vehicle, the suspension springs are classified as: Steel springs (Leaf springs, coil springs, torsion bars), Air springs/ Air shock absorbers and hydraulic springs. According to the type of linkages, which connects the wheel to the chassis, the suspension system are classified into independent and depended suspension system. In an independent suspension system is a type of suspension which allows each wheel, connected to same axle to move vertically independent of each other. Various examples of independent suspension system are Wishbone type, Mac Pherson strut type, Trailing arm type. In a dependent suspension system, the motion of the wheel is depended on the each wheel, i.e., motion in one wheel affects the other. Examples of these type of suspension are deDion axle system.

The suspension system, which is selected in ATV, for best results is Wishbone type suspension system, with shock absorbers. The Wishbone type suspension system is selected on basis of the parameters such as: Easy adjustment of steering parameters such as camber, castor, and toe in and out; can be easily manufactured; control of motion and wheel ratio; simpler knuckle design; cost efficient. The shock absorbers are chose because: They can be adjusted infinitely it can withstand high operating shocks, It has high life when compared to springs coils. The Wishbone and the knuckle is designed for the following wheel geometry.Table.4 explains the wheel geometry of the vehicle.
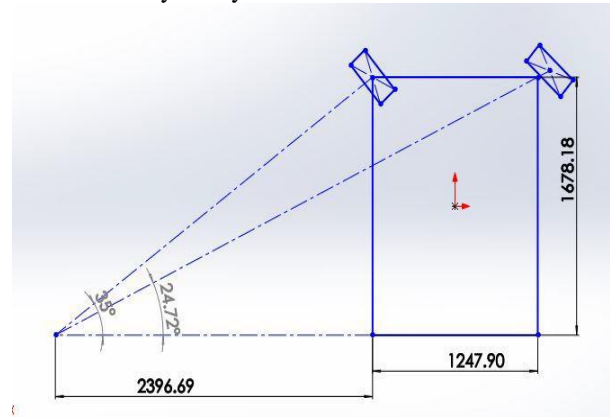
Table: 4 wheel geometry

Camber	-3°
Castor	0°
King Pin Inclination	8°
Toe in	3°
Ride Height	300mm

The camber, negative of 3deg is given because of better handling, road grip and responds better at corners. Negative of 3deg is found out by wheel alignment and steering capability. If a positive camber is given, the rolling radius differs for each point of tyre threads. The castor is zero degree because to balance the effect of toe-in and camber and easier steering design. The king-pin inclination of 8deg is given for better self –centering effect of the steering wheel. The front and rear assembly consists of double wishbone of unequal, non-parallel links, made of AISI 4130 of diameter 1" and a wall thickness of 1.5mm. The shock absorbers are of FOX FLOAT 3, which can withstand a pressure of 150psi. The motion ratio achieved is 0.5, according to the configuration of the mounting of the shock absorbers. These data are calculated on basis of sprung mass of 217kgs and un-sprung mass of 68kgs. The roll center height, which is found using Solidworks software is; for front wheel assembly it is 253mm and for rear wheel assembly it is 180mm.

VI. ERGONOMIC STEERING SYSTEM

All conventional four wheeled vehicles needs an efficient steering system to operate [Alex Cortner, James M 2012]. Likewise, in case of the electrically driven ATV, an efficient steering system is involved. The steering system used is the rack and pinion model which is to be operated by manual mode. Proper steering ratio (8:1) is applied for better steering and also the wheels turn easily in accordance to the movement of the steering column. The main mechanism used for steering is the "Ackerman Mechanism" [Mitchell,

W.Staniforth 2006]. The main significance for abiding by this mechanism is its capability in achieving "true rolling" for our four wheeled ATV. The steering system is properly mounted with proper ergonomics which is adjustable and comfortable for the driver. Efficient lock to lock, desired C-factor and eye to eye distance is chosen.
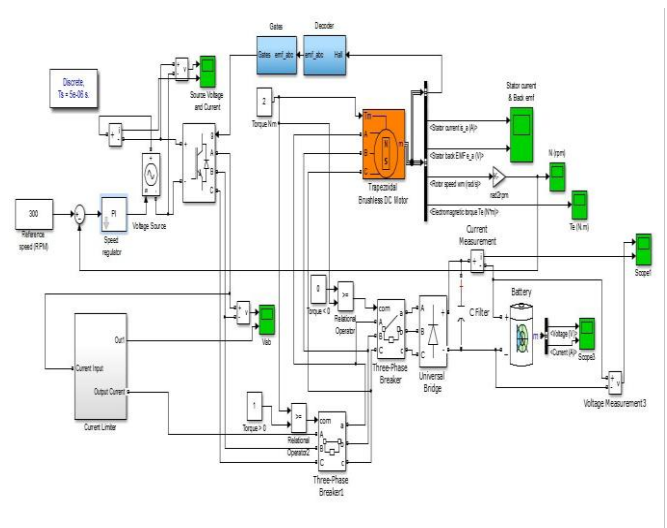

Fig 5: Ackerman geometry

Table 5 Steering and wheel geometry values

Description	Value & Type
Steering Ratio	8:1
Lock to lock	1.2
Eye to Eye	14"
C-Factor	7.2"
Steering Box	Rack and Pinion
Steering Mechanism	Ackerman Mechanism

VII. OVERALL SCHEMATICS DESIGN OF ELECTRICAL POWER TRAIN

Fig 6: Overall schematic

BLDC motor drive is used, with regenerative braking capability. The motor is provided with 48V in each phase separately or in combinations of phases periodically, with periods with respects to the speed to which the motor is referred to the drive. [Chevrefils. S. Filizadeh, 2007]The references are provided by the accelerometer potentiometer and brake switch. Here 58V potential is provided with periodically varying input current between 0A and 2A.

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Thus, the speed of 300 rpm and 2 N-m torque is obtained by means of simulations. The reverse flow of current from motor terminals to the battery terminals will facilitate regenerative braking. Here, regenerative braking will generate the battery potential and current.
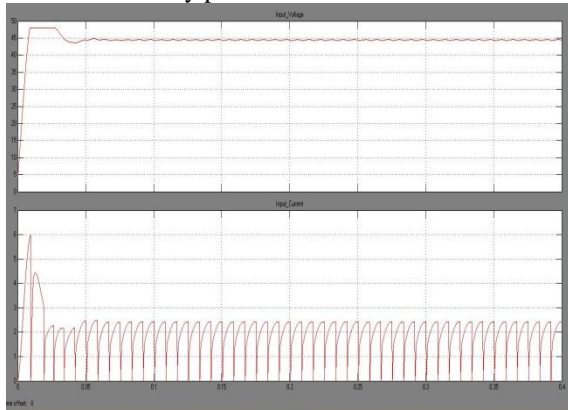

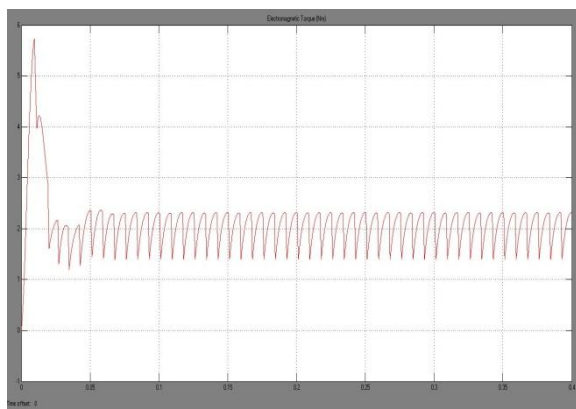**Fig 7: Input Voltage and Current (Forward)**

Fig 8: Torque curve Torque (Forward)

Fig.7 explains the input voltage and current variation of the drive with respect to time. Here the voltage is maintained at 45V.Fig.8 explains the variation of torque output of the motor with respect to time and hence inspite of the peak torque at momentary instance the torque oscillates across 2 N-m

VIII. IMPACT OF ELECTRICALLY DRIVEN VEHICLE IN ALL TERRAIN APPLICATION

Today transportation contributes to about 21% of CO_2 emission next to energy production. Plug in Electric vehicle is the most efficient one since the component which contribute to the power production also contributes to load is not integrated with the vehicle instead they are installed as mobile or immobile stations. Inspite of their efficiency they also suffer from serious problems like power production from fossil fuels (conventional energy production method) and driving range.

The problem of CO_2 emission due to conventional methods can be compensated by moving towards green energy production methods, and the range can be improved by various ways[Alaa Khamis, Mohammed Ashraf]One of such ways is to improve the efficiency of on-board components is motor, the BLDC motor which is comparatively efficient than 3-phase induction motor, which requires an inverter to convert DC to AC from batteries, and contribute to increased range and decreased load as its weight is comparatively lighter than 3-phase induction motor. Moreover the speed torque characteristics of the BLDC

motor clearly signifies the torque at lower speed is maximum which is more essential to make a vehicle maneuver in rough terrain, and makes the vehicle more suitable for all terrain application. The contribution of lithium ion batteries serves a major role in improving the efficiency of electric vehicle since they occupy lesser space with high charge density.

Since it occupies lesser space which contributes to increased passenger space and also high charge density contributes to improved driving range. Since there are no emission pipes (i.e.) physically no contact with the external atmosphere the power train can be perfectly sealed and isolated from external environment and hence makes the vehicle more suitable for all terrain application like sand or marsh. Since it is a plug in electric vehicle it requires charging stations, if these charging stations are fed from conventional power stations they contribute very less difference in co2 emission of 10g/kW. Hence an alternative green source of energy like solar or wind charging stations will exhibit a massive difference of 110g/kW and hence improve the environmental friendly nature of the vehicle and hence emits less carbon di-oxide. Thus the combined effect of less emission (emission from power source and production), efficiency and rugged nature, light weight and smaller size makes the power train more suitable for all terrain application.

IX. RESULTS AND CONCLUSION

The main aim in building the off-road electrically driven ATV is accomplished by designing and manufacturing it in low cost with high safety and proper vehicle ergonomics. The design was done with the help of tools such as Solidworks and later the design is analysed using analysis software such as Ansys. By this, the vehicle is completely simulated and tested to be made to use for varied applications. The entire design integrity and structure depends upon the material of the components and mixture, which makes it highly sustainable and effective.

Based on a completely iterative approach and multiple analysis of the existing ATV, the primary objective is to fabricate an ATV that both satisfies the requirements so as to be the best performing Vehicle and at the same time, meet the needs from a customer standpoint. The Fabrication is done keeping the following factors in mind: Safety, Cost, Standardization, Strength and robustness, Serviceability, Aesthetics and ergonomics. The existing designed ATV was focused on Driver Safety and Ergonomics which led to overdesign. Also, the overall weight of the Vehicle exceeded than what was expected. Thus, based on the continuous analysis, the following Design Parameters are proposed.

Table: 6 Design parameters obtained from the analysis

Wheel Base	57.09"
Front and rear track width	50" and 56"
Kerb weight	200 kgf
Time to reach maximum speed	6.4 s
Maximum speed	45km/hr

Weight transfer	404.46 N
Ground clearance	15"
Tyre spec	25x8-12 inches

The Electrically driven ATV serves as the beacon for initiatives such as "Go Green" and "Make in India". It also serves as an environmental tool which does not emits harmful gases. The ATV is a conventional model for a reliable, maintainable, ergonomic and economic production vehicle which serves not only in recreational user market but also in some important applications. Our future scope is to develop a hybrid model for this ATV which in turn reduces the fuel resource.

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AUTHORS PROFILE

N.Gayathri received the B.E. degree in electrical and electronics engineering from Saranathan College of Engineering, Tiruchirappalli, Anna University, Chennai, India. M.E. in Power Electronics and Drives in Sri Krishna college of Engineering and Technology, Coimbatore, India. Currently Pursuing PH.D in Anna university Chennai. Her research interest includes smart city, Transport management, embedded systems, robotics.

Dr L Ashok Kumar was a Postdoctoral Research Fellow from San Diego State University, California. He is a recipient of BHAVAN fellowship from Indo US Science and Technology Forum. His current research focuses on Integration of Renewable Energy Systems in the Smart Grid and Wearable Electronics. He has 3 years of industrial experience and 19 years of academic and research experiences. He has published 153 technical papers in International and National Journals and conferences. He has completed 26 Government of India funded projects and currently7 projects are under progress. His PhD work on Wearable Electronics bagged National Award from ISTE and he has received 12 Awards in the National level. Ashok Kumar has 12 patents to his credit. He completed his graduate programme in Electrical and Electronics Engineering from University of Madras and his post-graduation from PSG College of Technology, India and Masters in Business Administration from IGNOU, New Delhi. Presently he is working as Professor & Associate HoD in Department of EEE, PSG College of Technology.