An Overview on Design and Development of Multi Purpose Buggy(All Terrain Vehicle-ATV)

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Abstract-*The All-terrain vehicle name itself implies that the vehicle cover all types of roads including from muddy to Rocky Mountains. The all-terrain vehicle is used to handle any type of terrain it faces. This paper covers the information about the design of roll cage and manufacturing processes used for ATV. There are many facets to an off-road vehicle i.e. chassis, suspension, steering, drive-train, and braking. The main part of an ATV is the roll cage, which is to be designed for endurance over rough terrain. The roll cage is a 3-D shell which protects the occupants in case of collision and toppling incident. Another vital part of terrain vehicle is suspension which is responsible to maintain contact between the tire and the driving surface, & provides shock absorption. The paper aims to give an introduction to the material selection procedure (physical and chemical properties), tubular sections (pipe) size selection and various tests that need to be done before finalizing the design, using ANSYS ® WORKBENCH 16.2. The various factors such as impact load, loading point, brake over angle, approach angle, Factor of Safety (FOS) and cost efficient are given in present work and it can be used as medium of transport in remote areas like desert areas, hilly areas easily, in farm fields too are studied.*

Keywords-ATV, terrain, design, rollcage, suspension, braking

I. INTRODUCTION

To run on the uneven surface roads or on those roads on which other vehicles cannot work and run properly.These vehicles travel on low pressure tires, having a seat for operator along with the steering system to control the vehicle. Three wheeled ATV's are also present but are not used at higher extent. These vehicles are also present with six wheeled model which are used for specialized operation and have special application. These vehicles have roll cage which act as the skeleton and also forming the safety features for the driver. This roll cage is made up of the hollow pipes of material mild steel or stainless steel. These vehicles are designed in such a way that they can run on the places like desert, mountains, snow covered path and the places where normal vehicle can run. These vehicles can be single or double sitter. In some countries it is legal to drive these vehicles on the road while in some countries it is still banned to drive these vehicles on the road. It can be used in farms also for various farm works.

II. HISTORY

In 19th century Royal Enfield built and sold the first powered quadracycle in 1893. The term "ATV" was originally coined to refer to non-straddle ridden six-wheeled amphibious ATVs such as the "Jiger" produced by the Jiger Corporation, the Amphicat produced by Mobility Unlimited Inc, and the Terra Tiger produced by the Allis-Chalmers Manufacturing Company in the mid 1960s and early 1970s. The first three-wheeled ATV was the Sperry Rand Tricart. It was designed in 1967 as a graduate project of John Plessinger at the Cranbrook Academy of Arts near Detroit. The Tricart was straddle-ridden with a sit-in rather than sit-on style (similar to the contemporaneous Big Wheel toy). In 1968 Plessinger sold the Tricart patents and design rights to Sperry-Rand New Holland who manufactured them commercially. Numerous small American manufacturers of 3-wheelers followed. These small manufacturers were unable to compete when larger motorcycle companies like Honda Entered the market in 1969. Suzuki was a leader in the development of four-wheeled ATVs. It sold the first model, the 1982 Quad Runner LT125, which was a recreational machine for beginners. Suzuki sold the first four-wheeled mini ATV, the LT50, from 1984 to 1987. After the LT50, Suzuki sold the first ATV with a CVT transmission, the LT80, from 1987 to 2006.In 1985 Suzuki introduced to the industry the first high-performance four-wheel ATV, the Suzuki LT250R Quad Racer. This machine was in production for the 1985–1992 model years. During its production run it underwent three major engineering makeovers. However, the core features were retained. These were: a sophisticated long-travel suspension, a liquid-cooled two-stroke motor and a fully manual five-speed transmission for 1985–1986 models and a six-speed transmission for the 87–92 models. It was a machine exclusively designed for racing by highly skilled riders.

III. LITERATURE REVIEW

Khelan Chaudhari, Amogh Joshi, Ranjit Kunte, Kushal Nair[1], "Design And Development Of Roll Cage For An All-Terrain Vehicle", International Journal on Theoretical and Applied Research in mechanical engineering. The study aims to design, develop and fabricate a roll cage for an All-Terrain Vehicle (ATV) in accordance with the rulebook of

BAJA 2013 given by SAE. A roll cage is a skeleton of an ATV. The roll cage not only forms the structural base but also a 3-D shell surrounding the occupant which protects the occupant in case of impact and roll over incidents. The roll cage also adds to the aesthetics of a vehicle. The design and development comprises of material selection, chassis and frame design, cross section determination, determining strength requirements of roll cage, stress analysis and simulations to test the ATV against failure. Finally the roll cage is fabricated as per the tools and techniques available in the workshop, the study of roll cage was carried out successfully by knowing various parameters and the dimensions required. The roll cage is used to build an ATV by integrating all the other automotive systems like transmission, suspension, steering, brakes and other miscellaneous elements.

Eshaan Ayyar,Isaac de Souza,Aditya Pravin,Sanket Tambe, Aqleem Siddiqui & Nitin Gurav[2], "Selection, Modification and Analysis of Suspension System for an All-Terrain Vehicle", International Journal on Theoretical and Applied Research in Mechanical Engineering, The real pleasure of driving for an off-road enthusiast can be described as the thrill of the terrain coupled with a capable machine to handle the terrain. However, this pleasure can be derived only when the comfort level of the driver is maintained. Thus, it is concluded that the suspension system (which is responsible for providing a comfortable ride quality to the driver) is one of the most important sub-systems to be designed. This paper aims at selecting, modifying, analyzing and fabricating a suspension system capable of handling rough terrains while maintaining the ride quality, the paper contain the detail information about the fabrication of the suspensions parts like wish bones, knuckles etc. The paper also dealt with the analysis of the various suspensions parts. The analysis results are also provided. The modification data of the suspension is also useful for the construction of the ATV.

Deep Shrivastava,"Designing of All Terrain Vehicle (ATV)"[3], International Journal of Scientific and Research Publications.Designing purpose of this Quad bike is to manufacture an off road vehicle that could help in transportation in hilly areas, farming field and as a reliable experience for a weekend enthusiast. Vehicle was analyzed, and certain elements of the bike were chosen for specific focus. There are many facets to an off-road vehicle, such as the chassis, suspension, steering, drive-train, and braking, all of which require thorough design concentration. The points of the car I decided to specifically focus on were the chassis, drive-train, and suspension. The most time and effort went into designing and implementing these components of the vehicle because it was felt that they most dramatically affect the off-road driving experience. During the entire design process, consumer interest through innovative, inexpensive, and effective methods was always the primary goal, the design was first conceptualized based on personal experiences and intuition. Engineering principles and design processes were then used to verify and create a vehicle with optimal performance, safety, manufacturability, and ergonomics.

Dipalkumar Koladia,"Mathematical Model to Design Rack And Pinion Ackerman Steering Geomtery"[4],International Journal of Scientific & Engineering Research. In order to turn the vehicle, steering mechanism is required. Nowadays most of the fourwheelers are having steering mechanism based on ackerman principle. In order to design steering mechanism based on ackerman principle, one method is to use rack and pinion with tie rods. In the present work, new mathematical model is developed in order to design steering geometry mentioned above considering different geometry parameters. This mathematical model includes three equations. By solving this three equations we can get different steering geometry parameters by fixing some variables according to restriction and considering optimum steering geometry with respect to steering effort and %ackerman. This model can be used for ackerman as well as reverse ackerman steering geometry and further it can be used for two wheel steering as well as four wheel steering by applying this model on front and rear steering design, by applying and solving three equations of mathematical model for any vehicle, rack and pinion ackerman steering geometry for any vehicle can be designed. Steering geometry can be optimized by using mathematical model for ackerman condition for different inner wheel angles and select geometry for which percentage Ackerman as well steering effort is optimum. This mathematical model can be applied to rear wheel steering also. To design four wheel steering in which rack and pinion geometry is at front as well as rear side, this mathematical model should be applied on front and rear side separately.

Swapnil R. Abhang,D.P.Bhaskar[5],"Design and Analysis of Disc Brake",International Journal of Engineering Trends and Technology. Each single system has been studied and developed in order to meet safety requirement. Instead of having air bag, good suspension systems, good handling and safe cornering, there is one most critical system in the vehicle which is brake systems. Without brake system in the vehicle will put a passenger in unsafe position. Therefore, it is must for all vehicles to have proper brake system. In this paper carbon ceramic matrix disc brake material use for calculating normal force, shear force and piston force. And also calculating the brake distance of disc brake. The standard disc brake two wheelers model using in Ansys and done the Thermal analysis and Modal analysis also calculate the

deflection and Heat flux, Temperature of disc brake model. This is important to understand action force and friction force on the disc brake new material, how disc brake works more efficiently, which can help to reduce the accident that may happen in each day, the ceramic discs are more efficient for the disc brake. The various parameters were derived which proves the phenomenon. The importance of action force and the friction force were determined which is important for effective working of the brakes.

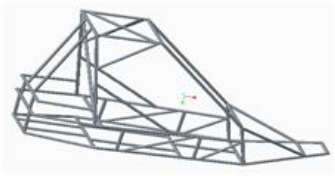
K. Suganeswaran, Dr.R.Parameshwaran, S. Amirthamani, D.Palanimohan[6],"Design and Optimization of Muffler for Manufacturing". The main purpose of a muffler in an automobile is to reduce the engine noise. An automotive muffler is designed and modified to achieve attenuation and back pressure targets. Attenuation and back pressure characteristic of base muffler is altered by changing its internal configuration. The target value was set at the time of conceptual stage and to obtain these targets, the muffler internal construction is modified. The targeted value is a compromise between the transmission loss and the backpressure. CAE tools are used for simulating the environment to achieve targeted TL (Transmission Loss) and back pressure. Experimental test have been conducted to check and correlate with CAE results in order to evaluate the effect of muffler internal construction on both TL and backpressure, the model variant 2 was tested and was selected as the test material for optimisation. And the simulation results were verified with optimisation results. It was also proved that the tail pipe noise and the back pressure can be reduce by increasing the perforation without increasing the density of absorption material.

IV. COMPONENTS OF ALL TERRAIN VEHICLES

4.1. Rollcage

It is the skeleton of the vehicle on which other parts are mounted. Rollcage should sustain the load occurred by the other parts and the weight of the driver. Rollcage is built such that in any accidental condition it should not cause any harm to the driver.Materials with high modulus of elasticity increase the bending stiffness of the frame which is desirable. High yield strength is necessary so the steel does not yield if impacted which is vital in securing driver safety. The materials used for this purpose are AISI 1010 which has following properties as follows

Material	Young's modulus (GPa)	Yield strength (MPa)	Tensile strength (MPa)	Density (g/cc)
AISI 1010	206	305	365	7.87



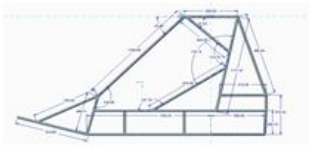


Fig.1:-Roll cage

4.2. Impact loading

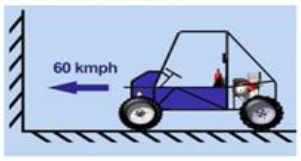


Fig.2:- Front impact

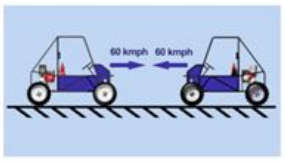


Fig.3:- Head on collision

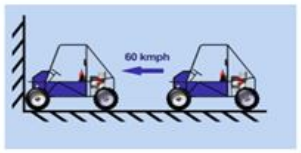


Fig.3:- Rear impact

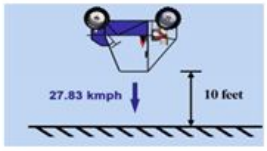


Fig.4:- Roll over impact

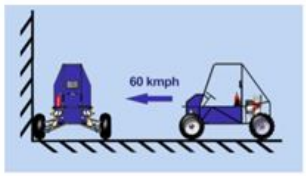


Fig.6:- Side impact

Considering the vehicle is running with average testing speed of 60kmph. The vehicle carries a momentum; the impact forces are generated during impact of vehicle. Various impact conditions tend to generation of impact force loadings on the members of spaceframe chassis.

The various conditions and generation of impact forces are classified as given below:

i. Front impact ii.Rear impact iii.Side impact iv.Roll over impact

Front roll over(longitudinal)
Side roll over (transverse)

The vehicle is assumed to run with average speed of 60kmph.

The work done is calculated by work energy principle i.e. change in kinetic energy.The final velocity is

zero and initial velocity is 60kmph. The calculations are as follows. The impact time is respectively considered for inelastic (rigid bodies) and elastic (deformable).

Forces:-Forces for each impact loading conditions are required for calculation of stress and strain, FEA, bending moment, twisting moment etc.

Consider,
Weight of vehicle = 540kg
Initial velocity before impact = 60kmph
Final velocity = 0kmph
Impact leading impact time = 0.13 sec. (for rigid member)
Impact leading impact time = 0.30 sec.(for deformable member)
Work done = change in K.E.
W = 0.5(mv2 **final** –mv2 **initial)**
W = 0.5(0-0.5*540*(16.67)2
W = 75030.003 Nm
Now,S = impact time*velocity
S = 0.13*16.67* **= 2.16 m**
Now,Work done = F*S
F = 75030.003/2.10
F = 34736.11 N
F = 35000 N (approx.) [front impact]

4.3. Suspension system

The suspension system of a vehicle maintains contact between the tire and the driving surface and provides shock absorption. Without a suspension system, the slightest bump in the road would provide an upward force that lifts the tires off the ground since it would provide an upward force that lifts the tire off the ground since it would be attached to the frame. This would make handling difficult. A suspension system allows the tire to move up with the surface of the road while maintaining the frame height. Generally, different types of suspensions are used at the front and the back. Double-wishbone and a-arm suspensions system are often used in the front, while trailing-arm and semi-trailing arm are often used in rear.

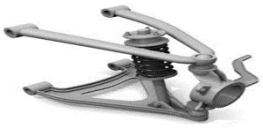


Fig.7:-Wishbone suspension

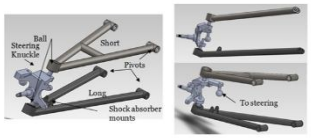


Fig.8:-A-Arm suspension

4.4. Steering system

This system gives directional control to the vehicle. In the proposed vehicle rack and pinion steering system is used. It consists of two gears, the pinion, a circular gear, the rack, a linear gear bar. The pinion is rotated when the driver turns the steering wheel of the vehicle, which is connected to the pinion by the steering column. As the pinion rotates it moves the rack in the direction of rotation. The rack is connected to the wheel by the tie rods, which attach onto the knuckle. As the rack moves, so do the tie rods, which push or pull on the wheels to turn the vehicle.

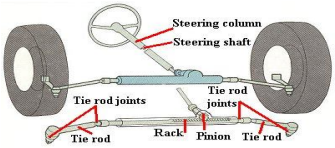


Fig.9:- Rack And Pinion Steering System

Formulae's used in calculation

a. R = d/2+Lcosec (A/2+B/2) = 5.9m
b. % Ackerman=(A-B)/(tan^{-1} (1/(tan (B)-1))-B)
c.Outer angle- tanA = L/(R-d/2) = 23.78^0
d.Inside angle- tanB = L/(R+d/2) = 18.95^0

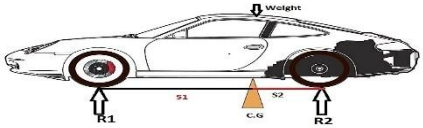


Fig.10:- C.G. of the proposed vehicle

The arrow in the above figure shows the point of centre of gravity.Following is the procedure for calculating point of canter of gravity:
Mass of vehicle = 540kg
Total weight = 5297.4N
Considering weight distribution of 40% on front wheels and 60% on rear wheels
> R1 = 40% of 5297.4N = 2118.96N
> R2 = 60% of 5297.4N = 3178.44N
Now taking moment we get
> R1S1 = R2S2
> 2118.96*S1 = 3178.44*S2
S1 = 2.5*S2
Now we also have the equation
> S1 + S2 = S
Where, S wheel base of our proposed vehicle
And S = 90 inch
> 1.5*S2 + S2 = 90
Therefore we get
S2 = 36 inch
And S1 = 54 inch
Therefore point of centre of gravity lies 36inch in front of centre of the rear shaft as shown in figure.

4.5. Braking system

It is a most important system in a vehicle, without braking system the driver will be in unsafe position. The design criterion for the brake system is that it must lock all four wheels and comply with all the rules. The brake system consists of four wheel solid disc brakes actuated by a dual master cylinder. The disc used is a petal disc having 4 to 5mm thickness. The calliper is having single or double cylinder. The brake pedal uses a 6.2:1 pedal ratio to multiply the input force applied by the driver. A side by side dual master cylinder of 1 inch bore each was used to meet the requirement of having two independent front and rear brake circuits. We chose this setup over tandem master cylinder and proportioning valve because it was easier to install and adjustable.

Fig.11:- Brake of ATV

4.6. Drive train

The drive train is the system that turns transfer the torque output from a vehicle's engine to a vehicle's drive wheels. The drive train in an ATV consist of the transmission, the gear box, and the axel shafts. The transmission is connected to the engine by the drive shaft. It changes the gear ratios which transforms the input RPM and torque from the engine into the desired RPM and torque. When going uphill, higher torque and lower RPM is desired; this is achievable by adjusting gear ratios. To travel quickly on the highway, torque can be lower but higher RPM is mandatory. The transmission allows for the ideal gear ratio to be achieved for different conditions. The gearbox is the set of gears where different gear ratios are achieved. Most automobiles have four forward gears and one reverse gear. The engine of mauti 800 has four speed gear box. This gearbox is connected to the wheels by the axels, which drives the vehicle.

Fig.12:- Drive Train Assembly

4.7. Engine

It is the power source of the vehicle. The engine used is the engine of maruti 800 which has an engine displacement of 796cc with a maximum speed of 144km/hr. The maximum power of this engine is 37 bhp at 5000 rpm. This engine is high powered so that it can work in any kind of condition.

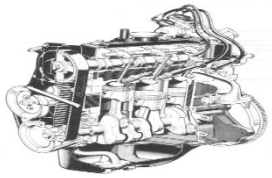


Fig.13:-Engine

4.8. Tyres and rims

The tyres and the rims of the ATV are specially designed so that they can work on any kind of road. These tyres are low pressure tyres which helps them to work on the rough terrain. The design of the rims is in such a way that the suspensions can be fitted properly and easily. According to SAE standards big horn with medium hard component tyres are used in all terrain vehicles and the rim is made up of alloy. We are using tyres of radius 12inches in our terrain vehicle.

Fig.14:- Tires Used In ATV

4.9. Exhaust system

The exhaust system of a vehicle consist of manifold, catalytic converter, muffler, tail pipe.The emission through the exhaust should be low and the noise should also be low so that it is not injurious to human being. The exhaust system should be able to lower the emission of hazardous gases in atmosphere. Muffler of an exhaust system is used to attenuate the sound. The muffler converts the sound energy into heat energy. And the main purpose of catalytic converter in an exhaust system is to reduce the pollutants coming out from the combustion chamber. Due to destructive interference taking place in the muffler noise is to be reduced. The muffler should be so effective that it should not make of more than 80db because if it exceeds it is injurious to human health.

Fig.15:- Absorptive type muffler

4.10. Seat

The seat of the vehicle should be comfortable for the driver with seatbelts for safety.

Fig.16:-Seat of Terrain Vehicle

V.FIXTURE

A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation) and support the work.Fixtures use in UTV is as follows:

a. Double wishbone A-arm suspension fixture.

b. Roll cage fixture.

Advantages of Jigs and fixtures

a.Reduction in operation time.

b.Increasesaccuracy.

c.Uniform quality.

d.Interchangeability.

e.Reduction in scrap**.**

Fig.17:- Fixture A-arm

VI.MANUFACTURING PROCESS

- Procurement of row material.
- Chassis layout according to jigs and fixtures.
- Selection or member cutting.
- Bending if required.
- Notching or hole saw cutting.
- Fixture trough welding.
- Fastening etc. grinding , finishing.
- Assembling (suspension arms, seats, accessories etc)
- Painting.

VII. CALCULATION OF GROUND CLEARANCE AND WHEEL BASE

The distance from the point of contact of tire and ground to component of vehicle which is not meant to be touching the ground is known as ground clearance. The ground clearance of the proposed design of all terrain vehicles is 14inches.The longitudinal distance between the centres of front wheel to the centre of rear wheel is known as wheelbase which is 90inches.

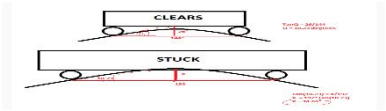
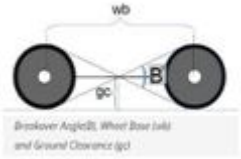


Fig.18:-Calculation of ground clearance and wheelbase

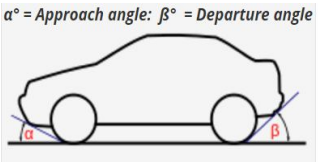
VIII.CALCULATION OF BREAKOVER ANGLE AND APPROACH ANGLE



$$\beta = 2 \cdot \tan^{-1}\left(\frac{2 \cdot gc}{wb}\right)$$

Fig.19:- Breakover angle

The maximum angle that a vehicle can drive over without the ground touching the vehicle's undercarriage is known as breakover angle. The breakover angle calculated is 8.840.



$$\alpha = \sin^{-1}\left(\frac{h}{l}\right)$$

Fig.20:- Approach angle

The maximum angle of a ramp onto which vehicle can climb from a horizontal plane without interference (scraping) the ramp or incline is known as the approach angle. The approach angle calculated is 34.560.

XI. CONCLUSIONS

The study and analysis of various literatures and all terrain vehicles were done to decide various factors for designing our proposed vehicle. Various factors for designing ATV were decided. According to Indian road conditions, design approach was considered. As per Static analysis, Impact loading forces were calculated to consider safety. Optimisation is done in terms of design consideration and cost efficient.

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