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Design Analysis and Fabrication of All-Terrain Vehicle (Quad-Bike)

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ABSTRACT: This Design report aims to generate conceptually sound and optimized design analysis of quad bike. In order to accomplish this task, there is a different designing and analysis can be carried out to enhance the safety of different sub-components of the quad bike like chassis, suspension, steering system, braking etc. It also describes in detail, there is a variety of methodology consideration in the entire design process. These effort have been validate the design by theoretical calculations, simulations are also carried out.

KEYWORDS: Quad bike, All Terrain Vehicle, Analysis, Chassis

I.INTRODUCTION

The objective of this report is to highlight the design report of the Quad-Bike vehicle. We approached our design with a rough 2D sketch of the chassis in AutoCAD and we created the virtual assembly of our quad-bike using solid works and the analysis was done using ANSYS simulation software. Based on the analysis the model was retested with boundary conditions under the practical parameters. So the design focuses on safety, serviceability, strength, ruggedness, standardization, cost, ergonomics and aesthetics. The design objectives set out to be achieved were three simple goals applied to every component of the bike: durable, light-weight, and high performance, to optimizing the design by avoiding over designing, which would also help in reducing the cost. With this we had a view of our quad bike. Our college will be providing us a well-equipped laboratory and guided in all aspects. This started our goal and we set up some parameters for our work, distributed ourselves in groups.

II. RELATED WORK

In the design of today's vehicles there is a strong emphasis on reducing the vehicle weight and to lower the aerodynamic drag in order to leave a smaller ecological and economical footprint. This has shown to affect the crosswind sensitivity for ground vehicles, which is of importance for handling and safety [1].Most engines have a single spark plug per cylinder, a notable exception being in aircraft where the complete ignition system is duplicated to improve reliability. The spark usually is provided by a battery and coil, although until the 1920s, a magneto often was used.For a continuously variable transmission (CVT) to produce an improvement in fuel economy, it must be efficient and have a wide span (range of ratios). There are two significant types of CVT-the Van Doorne belt system, and the Torotrak system-both of which have been the subject of much development work [2]. The steering system is a mechanism on a vehicle that serves to regulate the direction of the vehicle by means of deflecting the front wheels [3, 4].It takes an astonishing amount of energy to decelerate a moving vehicle-in fact it takes the same amount of energy to decelerate from one speed to another as it would to accelerate between the two speeds-except that we can decelerate faster because most of the inertial forces are working for us rather than against us [5].



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Description	Specification	Description	Specification
Wheel Base	55 inches	Tire Size	19*7(front)18*7.5(rear)
Overall Length	65 inches	Engine & Transmission	9.5kw @ /7000 rpm
OverallHeight	60 inches	Engine Max Torque	16 N-m
OverallWidth	45 inches	Max Speed	60 km/h
OverallWeight	280 kg	Gear Ratio	9.0:1
GroundClearance	10 inches	Steering	Ackermann

 Table I: Technical Specification

III. DRIVE TRAIN

A. ENGINE & TRANSMISSION

The engine used here isLifan 167FMM Series runs cooler and cleaner, delivering more power, smoother operation, longer engine life and improved fuel economy. Excellent performer for mid-duty applications. This high quality Lifan 250cc engine comes from and peak power through its high comp-free flowing head Lifan power in Chongqing. It delivers plenty of torque.Dura bore cast iron cylinder sleeve withstands wear and abuse to provide improved oil control and extended life. Gear driven Dura Lube splash lubrication system continuously supply oil to all internal parts magneto electronic ignition system delivers quick and dependable start with no maintenance required. Float feed one start carburetor delivers constant one pull start-ups.



Fig 1: Lifan 167FMM



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The following table lists the engine specifications of the selected engine

Description	Specification	
Max torque & Rotating speed	16 N-m (or) 15.6 N-m	
Gross Net power	11.5 kw/7000rpm	
Bore*Stroke	67.0mm*65.0mm	
Compression ratio	9.0:1	

Table II:Engine Specifications

B. CHAIN DRIVE TRANSMISSION SYSTEM

We know that basic transmission ratio is,

N1/N2 = Z2 / Z1 = 1.5 (Assumed for the required output of 70 km/h) N1 = 3300rpm Therefore N2 = 2200rpm and by assuming Z1 =23 Therefore we get Z2 =32

Where Z2 is the sprocket in the rear axle, The center distance between the pinion and the sprocket is a=700 mm

a = (30 to 50) p mm p = a/30 - max = 700/30 - 32 = 8.6 p = a/50 - min = 700/50 - 23 = 9

Considering the maximum value and by selecting the standard pitch from design data book we conclude the pitch value as **9.525mm**.

Length of chain, $L = \pi (R + r) + (R - r)^2 / a + 2a$ Chain velocity, v = (Z1*p*N1)/(60*1000), v = 11.385 m/s

IV. CHASSIS

A. MATERIAL SELECTION

A good strength material is important in a roll cage because the roll cage needs to absorb as much energy as possible to prevent the roll cage material from fracturing at the time of high impact. This **AISI 1020 STEEL** gains hardness and strength with heat treatment. This carbon steel is a commonly used plain carbon steel. It has a good combination of strength and ductility. The chassis is the component in charge of supporting all other vehicle's subsystems with the plus of taking care of the driver safety at all time. The chassis design need to be prepared for impacts created in any certain crash or rollover. It must be strong and durable taking always in account the weight distribution for a better performance. The chassis was mainly designed through solid works software.

Then it is also assured by analysis in solid works software. The various Physical properties of the material are follows



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S.No	PROPERTIES	VALUES	
1	Density	7.87 g/cm3	
2	Tensile strength	420 MPa	
3	Yield strength	350 MPa	
4	Modulus of elasticity	205 MPa	
5	Shear modulus	80 GPa	
6	Poisson's ratio	0.29	
7	Elongation at break	15%	

Table III: Material Properties

The material **AISI 1020** with 0.12 to 2% of carbon is used in the frame design because of its good weld ability relatively soft and strengthens as well as good manufacturability. The following table shows various chemical composition of the selected material. The below mentioned properties satisfy the technical requirement of material which is to be used in frame.

S. No.	ELEMENTS	VALUE
01	Carbon, C	0.18 - 0.23%
02	Manganese, Mn	0.30 - 0.60%
03	Silicon, Si	0.025%
04	Sulphur, S	0.05% (max)
05	Phosphorus, P	0.04% (max)
06	Iron, Fe	99.08-99.53%

 Table IV: Chemical Composition

The Frame was designed using 1.25 inch diameter tube with a thicker wall of 3 mm is used instead of 1.5 inch diameter tube with a thinner wall for manufacturability purposes. Although the thinner wall, 1.25 inch diameter tube would be slightly lighter than the thicker wall, 1 inch diameter tube, it would have been more material and more difficult to weld. Then it is also assured by analysis in solid works software.



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Fig 2: 3D-Model Isometric View

V. SIMULATION & RESULTS

A. FRONTAL IMPACT

Generally in the case of pure elastic collision in frontal impact the linear velocity remains at 60Kmph according to ENCAP (The European new car assessment program). Hence the value of force is calculated by mass moment equation that is- $\mathbf{F} = \mathbf{P} \times \Delta \mathbf{T}$



Fig 3: (a) Equivalent Stress (b) Total Deformation

B. REAR IMPACT

The rear impact force is also calculated in the same way as remaining two. In this case the velocity of collision was taken 72kmph or 20 m/s by the calculations and also as according to the ENCAP standards.



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Fig 4: (a) Equivalent Stress (b) Total Deformation

C. SIDE IMPACT

A side impact analysis is very necessary and the boundary conditions are taken relating to the real life situation that a go kart will experience. In the case of collision by side impact the value of the impact force generated is calculated in the same way as in front impact. For the side impact the velocity of vehicle is taken 72kmph or 20m/s according to ENCAP Standard and then the force is calculated



Fig 5: (a) Equivalent Stress (b) Total Deformation



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The following table shows simulation results of various impacts

	Front Impact	Side Impact	Rear Impact
Constraints	Rear Bumper Fixed	Opposite Bumper Fixed	Front Bumper fixed
Load Given	6G	4G	4G
Von-misses stress	3.36 Mpa	1.67 MPa	1.56 Mpa
Max. Deformation	8.31mm	4.55mm	0.0011mm
Factor of Safety	10.43	15	2.25

Table V: Load & Constraints

Note: Design is safe when FOS>2

The mass of the vehicle is 280 kg. Generally in the case of pure elastic collision in frontal impact the linear velocity remains at 60Kmph. The collision is assumed to be perfectly plastic.

VI. SUSPENSION

A. OBJECTIVE

Designing a suspension which will influence significantly on comfort, safety and manoeuvrability.Protect the vehicle from damage and wear from force of impact with obstacles (including landing after jumping) Maintaining correct wheel alignment. The overall purpose of a suspension system is to absorb impacts from course irregularities, such as bumps, and distribute that force with the least amount of discomfort to the driver. Proper camber and caster angles of the suspension were applied.

Performancecriteria	Values	A-arm	length
Caster	6 deg +ve	Upper arm	14 inch
Camber	7 deg -ve	Lower arm	17 inch

 Table VI: Suspension Specifications

B. FRONT SUSPENSION

For our front suspension, we use double arm wishbone type suspension. The customized DUKE 200 springs are used in our quad.In a rolling situation, the tire need to gain a negative chamberFront Unequal Non Parallel double wishbone suspension



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C. WISHBONE ARM

A wishbone arm is an independent suspension design using two wishbone-shaped arms to locate the wheels. Wishbone system is fabricated by our own raw material allows to control the motion of the wheel throughout suspension travel, controlling such parameters like camber angle, caster angle, toe pattern, scrub radius and more. Design of the control arms also includes maximum adjustability in order to tune the suspension for a given task at hand.



Fig 6: (a)CAD model of Swing arm (b) CAD model of Monoshock

D. REAR SUSPENSION

In the rear part we are using the KTM DUKE 200 WP mono-shock suspension attached to the swing arm which is beingused in our Quad Bikes. Using this suspension, it is adjustable preload, compression, rebound, pro-lever, 140mm (5.6 inch) travel. It cover the dual shocks in the road is advantage due to ease of adjustment as there is only single damping unit and smaller unstrung mass. The shock absorber has necessary stiffness needed to swing arm to maintain ground contact as well as simpler in design and it will reduce overall weight of the vehicle

Factors	Spring index	Wire Dia (mm)	Spring OD (mm)	No. of turns	Free length of spring (mm)
FRONT	4.73	13	61.5	18	325
REAR	4.32	18.5	80	10	254.6

 Table VII: Spring Specifications



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Stiffness of the spring (K) = G x d⁴ / 8 D³ n Where, G = Modulus of rigidity = 84 Gpa

d = Wire diameter in mm Do = Spring outer Diameter in mm n = No. of Turns

Spring Force $(Fs) = K \times X$ Where,

 $\begin{array}{l} X = Spring \ Travel\\ Spring \ Index \ (C) = D/d\\ Motion \ Ratio \ (MR) = Spring \ Travel / Wheel \ Travel\\ Mean \ diameter, \ D = Do + d\\ Outer \ diameter, \ Do = D*d\\ Ka = 4C\text{-}1/4C\text{-}4 + 0.615/\ c \end{array}$

E. FRONT AND REAR CALCULATION

Front load = 100 kg = 950N (491N for each suspension) Shear stress $\tau = ka \ 8PD/ \pi d^3$ $\tau \ front = 39.84 \ N/mm^2$ and $\tau \ rear = 54.92 \ N/mm^2$ Deflection of the spring, $y = 8PD^3n/ \ Gd^4$ $y \ front = 3.3N/ \ mm^2$ and $y \ rear = 2.78 \ N/mm^2$ Stiffness, $q = Gd^4 / 8D^3n$ $q \ front = 146.04 \ N/mm$ and $q \ rear = 528.75 \ N/mm$ Maximum load, $y = 8 \ PD^3n/ \ Gd^4$ $P \ front = 461.1 \ kg \ and \ P \ rear = 1471.5 \ kg$

VII. STEERING&BRAKINGSYSTEMS

A. STEERING SYSTEMS

The steering system is the responsible for overall direction of motion of the vehicle. The steering system is designed to withstand the stress of safely maneuvering the vehicle through any type of possible condition at the time of driving. The purpose of the steering system is to provide directional control of the vehicle with minimum input. Simplicity and safety were the main design specifications for the vehicle's steering system. We are using YAMAHA FZ steering system and thumb throttle which is affordable to all adjustment in our quad bike. While designing the steering system the constraints that we possessed were centre alignment of steering system, track width, human effort at the steering wheel. After analysis all these we prefer YAMAHA FZ steering system.

% Ackerman geometry= Angle of inside wheel-angle of outside wheel/Angle of outside wheel for 200% ackerman



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B. BRAKING SYSTEMS

The purpose of the brakes is to stop the bike safely and effectively. In order to achieve maximum performance from the braking system, the brakes have been designed to lock up all four wheels at the same time. It is desired from a quad bike that it should have effective braking capability to negotiate rigid terrains.

	FRONT	REAR
No. of disc	2	1
No .of callipers	2	2
Dimension	230*50 (mm)	230*50 (mm)
Calliper type	floating	floating

Table VIII: Brake system specification

C. CALCULATION OF TARGET PERFORMANCE OF THE BRAKING SYSTEM

Maximum deceleration = 0.82gMaximum Deceleration = 2271.7914 / (280*9.81)= 0.82g Total weight of the vehicle = 280 kgMaximum velocity of the vehicle = 22m/sTarget braking force = deceleration * total mass = 8.11 * 280 = 2270.8 N Target stopping distance = Max velocity $^{2}/(2 * \text{max.deceleration})$ = 29.83 m Maximum forceadrivercanapply is22 kgf. Force on the Master cylinder piston (FMC) =22*9.81*4=863.28N Area of the MC Piston (AMC) $=\pi^{*}0.01905^{2}/4$ $=2.85*10^{-4}m^{2}$ Pressure developed in the system (P) = force / area= $863.28/(2.85*10^{-4})$ = = 3031179.775 N/m² Since the pressure inthesystemis entirely thesame Therefore, the force on the brake caliper (FCAL) =P*ACAL =4199.524N Therefore the force on the rotor = 4199.524 * 2 = 8399.04N Total friction force = Clamp force * Coefficient of friction =8399.04 * 0.3 =2519.71N Therefore the torque on the rotor = Frictionforce *effective rotor radius =2519.71*0.09165=230.814Nm Therefore the force acting on one tire= Torque on rotor / radius of tire =230.814/0.2032 =1135.8957N Total brake force using selected brake force =1135.8957 * 2 =2271.7914N Deceleration= Force / mass $= 2271.7914/280 = 8.11 \text{ m/s}^2$ Stopping Distance = $(Max velocity)^2 / (2 * deceleration)$ $=22^{2}/(2*8.11)=29.83$ m

Since this system meets the target performance, we go ahead with the design



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D. BRAKE PEDAL, MASTER CYLINDER, CALIPER AND ROTOR SELECTION

Passenger cars generally use a pedal ratio of 4 to 6. We select a pedal ratio of 4, i.e., when the driver applies 1N force it gets multiplied by 4 times to produce a 4 N force. Analyzing the available ones, we chose the master cylinder ATV. The piston diameter of the MC is 19.05 mm. We compared the rotor caliper assemblies of two bikes namely TVS apache and pulsar 220. Finally we choose pulsar 220 which had the following dimensions

VIII. SUPPORT COMPONENTS AND PARAMETERS

A. BODY PANELS

The purpose of the body is to prevent debris from entering the vehicle, with the intent of protecting the driver and the vehicle's components. The design of the body works has been done in the cad software and the material mild steel with a reduced thickness supporting aerodynamic stability is selected for the body works. The body panels are made out of .080 inch thick mild steel plates. The mild steel material has desirable properties for a body panel. The panels are designed such that they tends to reduce the aerodynamic moments like pitching from front, yawing from side and also helps to create the downward force to which tends to make the good traction of vehicle with the road & also provide the properties necessary to protect the driver and vehicle components from rocks and other debris. When the panels were integrated into the bike, the panels were recessed into the chassis to provide visibility to the chassis members, making the bike aesthetically pleasing.

B. TIRES & RIMS

Traction is one of the most important aspects of both steering and getting the power to the ground. The ideal tire has low weight and low internal forces. In addition, it must have strong traction on various surfaces and be capable of providing power while in puddles. After going through the engine, transmission and some basic torque and angular velocity calculations we have finalized the diameter of front tires to 19 inches and the diameter of rear tires to 18 inches which would help us to transmit maximum power. The dimension of Front tires is finalized as $25 \times 10 \times 12$ inches and Rear tires $25 \times 10 \times 12$. We used ATV tires in our quad bike. The Rims which is made up of Aluminum to minimize the unsprang weight. We choose scooter rims with diameter of all four rims are 8 inches each.

C. ERGONOMICS

The seat in our quad bike is also designed to be very light it is very simple made of plastic material and is attached to the chassis by two points only and can be adjusted in angle of back rest according to the requirement of the drivers comfort the back side angle of the seat is at 180 degrees which is the good position of the drivers body rest according to the ergonomics point of view .the seat implemented in our quad bike provides a good combination of weight reduction and ergonomics. Ergonomically the quad-bike is building up with proper dimensions as given by the rule book. The driver seat is well cushioned. Alignment of the driver seat/driver sitting direction is parallel to vehicle's longitudinal axis. The driver is well sophisticated to drive a quad-bikewithout any disturbance.

D. KILL SWITCH

First, the electronics system supports the mandatory safety equipment, specifically the kill switch circuit. The bike's electrical system has been designed around main power buses, each with an independently fused circuit. These buses are for safety kill switch. Kill switch is provided in our vehicle as a safety to our driver in a case of emergency. If driver wants to kill the engine or stop the engine in case of emergency so he pushes the kill switch gently and our engine would stop. The electronics are designed so that when the kill switch is depressed, power is disabled on primary ignition coil of engine. Because the kill switch closes the circuit when activated, the kill switch function is achieved by using a pair of diodes to simultaneously ground out the engine's primary coil current



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IX. FINAL CAD MODEL

The following images display 3d modelled final assembly of the fabricated vehicle



(a)

Fig 7: (a) Orthogonal View (b) Rear View

X. ACTUAL IMAGE

The following images display actual image of the fabricated vehicle



(a)



(b)

Fig 8: (a) Front View (b) Orthogonal View

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