Quad Bike Design and Simulation: A Pre - Manufacturing Methodology

Srijan Manish, Jitendra Kumar Rajak, Vishnu Kant Tiwari, Rakesh

***Abstract*— This paper aims at developing a technically sound and conceptually engineered ATV called quad bike. This paper describes in detail the procedure followed, methodology used and the considerations made in the entire design process. First the design approach is discussed and then the resulting design procedure and design analysis has been explained. Due efforts have been put to validate the design by theoretical calculations, simulations and known facts. Through this paper, an effort has been made to introduce a reliable yet cheaper methodology for industrial quad bike designing and simulation that may be used as a reference for many upcoming industries as well as many research and development projects.**

***Index Terms*— Quad Bike Design Methodology, Design, Simulation, Centre of Gravity, Braking System Design, Suspension System Design, Automotive Engineering, Automotive Innovations, All Terrain Vehicles**

I. INTRODUCTION

For simplicity and keeping into consideration the requirement and design constrains, we have assumed that the design process of this quad bike will incorporate a general engine of about 1000cc which is usually used in small ATVs and concept vehicles like quad bike.

The selection of engine has been influenced by the parameters like the functionality and performance with respect to torque, acceleration, traction, maneuverability and endurance of the vehicle.

1. Reliability. 3. Safety and Ergonomics.
2. Aesthetics. 4. Market availability and components.

Also, the design methodology is so chosen to reflect a few constrains like, the engine should first of all be comfortably fitting in the space provided. Also, the heat emitted by the engine should not affect the accessories, mountings and the driver and the vibration frequency exhibited by the engine should have minimum affect the vehicle frame so that frequency rupture can be avoided.

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II. DESIGN APPROACH

The task of designing began by conducting extensive analysis on the available species of ATVs and quad bike and knowing its various technical whereabouts. Then keeping the voluminous data from our research in mind, the design on a CAD platform has been implemented to achieve the best standardized as well as optimized design. CATIA V5R20 is the CAD software used for designing while the simulation engine used for analysis is ANSYS12.0.

III. FRAME DESIGN

The primary objective of the frame is to ensure driver's safety, provide reliable mounting locations for the engine and other vehicle components sidelined with attributes like aesthetic appeal, low in cost and light in weight. Various factors are taken into consideration to reflect the same. The generated design through the CAD software is as follows.

Fig1: Frame(side view)

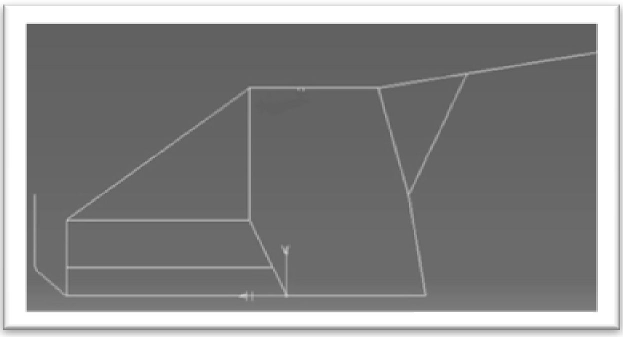
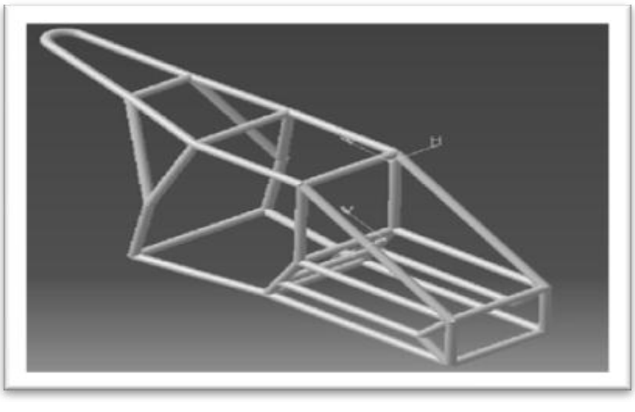


Fig 2: Frame (Isometric)



Now to provide the required strength to the frame we choose the frame material with utmost care, after a vivid comparison among the materials available. We first considered AISI 4130, A 1020 DOM, ST 52 and 4130 chromoly. Table 1 is a side by side comparison of these materials.

Table1: Material Comparison

Property	Chromoly 4130	1020 DOM	ST 52	AISI 4130
Yield strength	517 Mpa	496 Mpa	355 Mpa	435 Mpa
Ultimate strength	655 Mpa	600 Mpa	520-680 Mpa	670 Mpa
C %	0.28-0.33	0.17-0.23	0.20	0.28
Young's Modulus	205 Gpa	200 Gpa	210 Gpa	205 Gpa
Poisson's Ratio	0.30	0.30	0.30	0.29
Density	7.80 g/cc	7.87 g/cc	7.80g/cc	7.85g/cc
Cost	Rs.200/ft.	Rs.185/ft.	Rs.220/ft.	Rs.215/ft.

Table 2: Material Selection Decision Matrix

Parameters	Chromoly 4130	1020 DOM	ST 52	AISI 4130
Availability	3	3	1	2
Cost	2	3	3	2
Weldebility	2	3	1	1
Total	7	9	5	5

The decision matrix in Table 2 led us to choose 1020 DOM as our frame material.

III.A FINITE ELEMENT ANALYSIS OF A FRAME

After completing the design of the Frame, Finite Element Analysis (FEA) was performed on it using ANSYS 12.0 to ensure that expected loadings do not exceed material specifications.

Fig 3. Frontal Impact

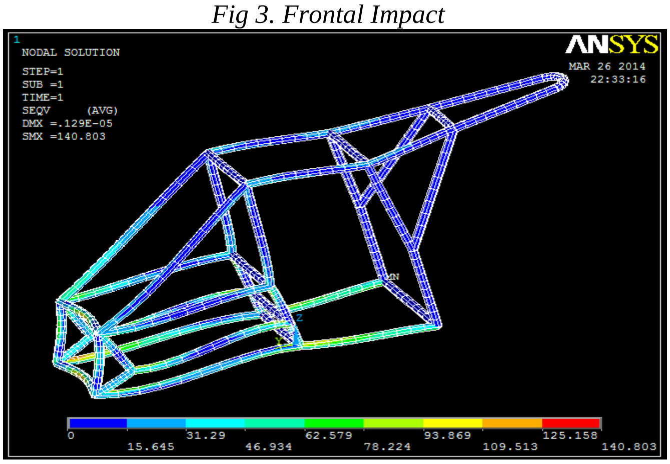


Fig 4. Rear Impact

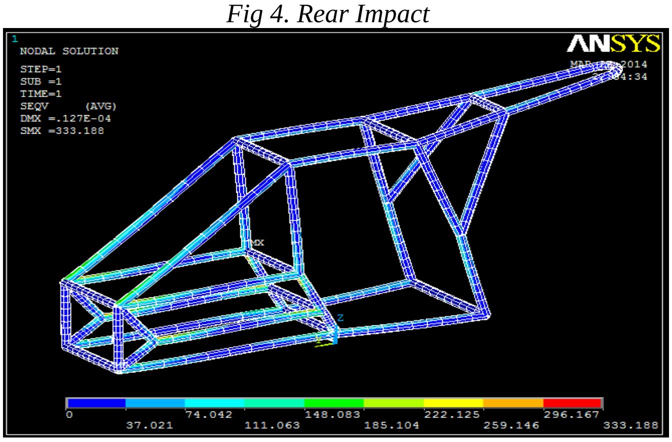


Fig 5. Side Impact

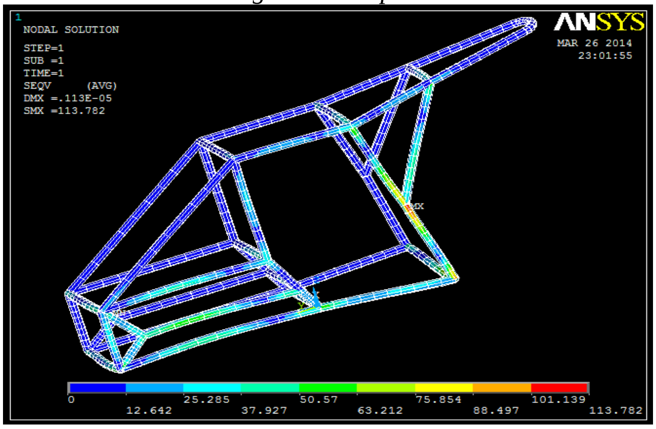


Fig 6. Rollover Impact

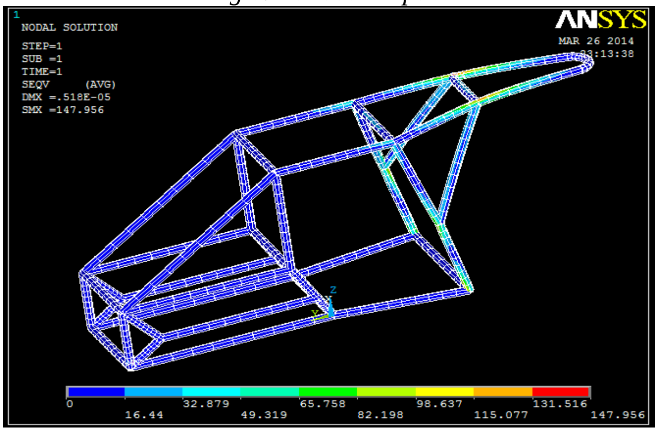


Fig 7. Torsional Analysis

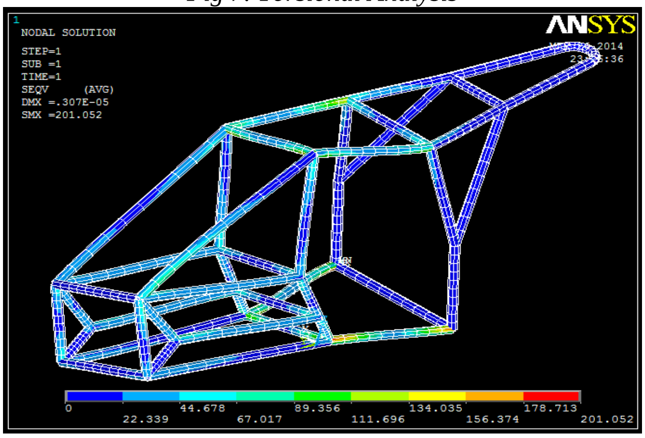
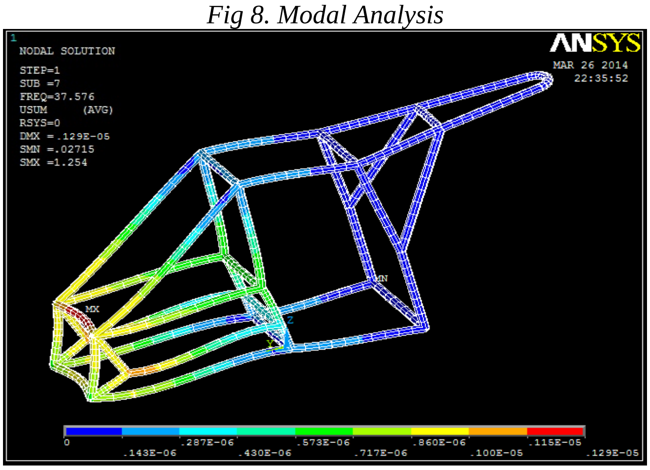


Fig 8. Modal Analysis



Beam 188 element was selected with the cross section as the dimensions of pipe. The meshing was done globally with a size of 3mm and smooth transition in mesh. Ex= 210 Gpa and PRXY= 0.3 was used as per 1020 DOM properties. Standard loads as per Europe National Car Assessment Program (EUNCAP) were applied on the key points and the results were obtained for Frontal, Rear, Side Impact, Torsion and Roll over Cases.

Table 3: Simulation Summary

3.1 (Impact Result)

Impact Case	Maximum Stress (MPa)	Maximum Displacement (m)	Factor of Safety	Margin of Safety
Front	140.803	0.129 e-05	3.522	2.522
Rear	333.188	0.127 e-04	1.488	0.488
Side	113.782	0.113 e-05	4.359	3.359
Rollover	147.956	0.518 e-05	3.352	2.352
Torsional	201.052	0.307 e-05	2.467	1.467

3.2 (Frequency Result)

Modes (#)	Frequency
1	0
2	0
3	0
4	3.01 e-4
5	10.4 e-3
6	41.4 e-3
7	37.6
8	71.4
9	73.7
10	80.8
11	99.3
12	112.3

IV. SUSPENTION DESIGN

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; while providing the best handling. Proper camber and caster angles were applied to the front wheels as well.

The decision matrix table 5 is shown below:

Table 4:Decsicion Matrix For Suspension

Factors	*Double Wishbone*	*Mc-Pherson Strut*
AVAILABILITY	*3*	*3*
COST	*3*	*3*
MOUNTING	*4*	*3*
TOTAL	*10*	*9*

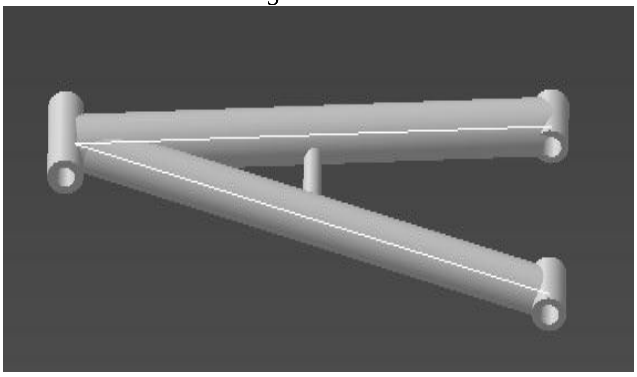
For the front suspension, we chose a double wishbone type suspension whereas in the rear part we are using the mono-suspension attached to the swing arm which is being used in Quad Bikes universally.

Table 5.The final specifications of front suspension

A-arm	*Length*
Upper	*16 Inch*
Lower	*18.5 Inch*
A-arm material: Chromoly 4130	

Performance Criteria	*Value*	
Caster	*3 deg +VE*	
Camber	*3 deg -VE*	
Roll Centre Height	*Front:9.6 Inch*	*Rear:11.22 Inch*

Fig 9: A-arm



V. BRAKING SYSTEM DESIGN

The braking system for the vehicle is responsible for stopping the vehicle at all times and is integral for the safety of the driver and vehicle. The vehicle must be equipped with a braking system that acts on all four wheels and must have two independent hydraulic circuits each having its own fluid reserve.

Table 6:Brake Decision Matrix

Factors	Disc	Drum
AVAILABILITY	3	3
COST	2	3
EASE OF MOUNTING	4	2
KEYPOINTS	*Better heat Dissipation *Performs better in case of repeated hard stop.	
TOTAL	9	8

Have used 3 discs in total, two at front with one calliper each and one on rear with dual callipers. Brake lines will be in diagonal split connection. Our hydraulic brake system is controlled by a single pedal in line with tandem master cylinders. Table 8.0 shows the brake parameters.

Table 7:Brake Specification

	Front	Rear
No. Of Disc	2	1
No. Of Callipers	2	2
Dimension	(in mm) 231*50	(in mm) 231*50
Calliper Type	Floating	Floating

Fig 10: Analysis of Rotor

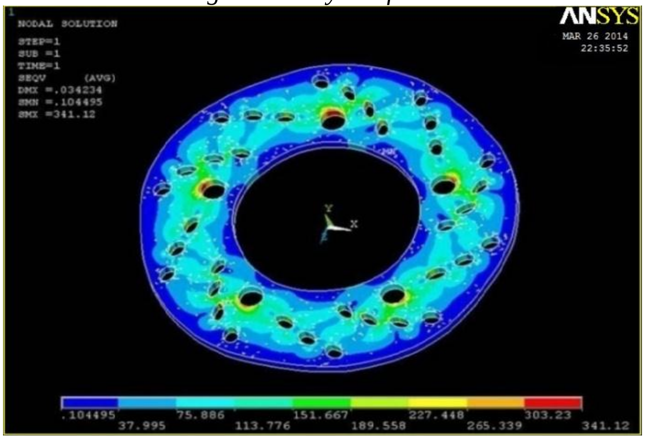
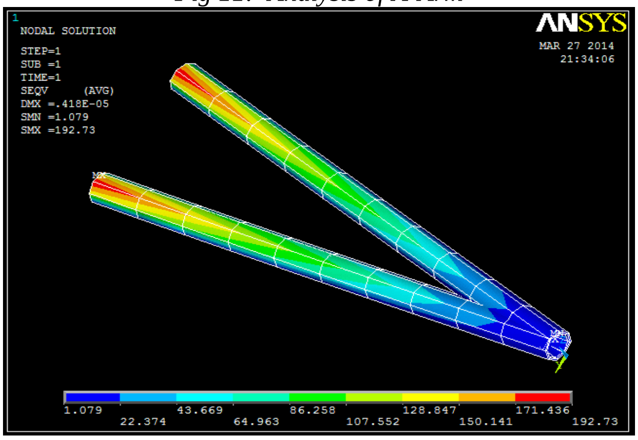


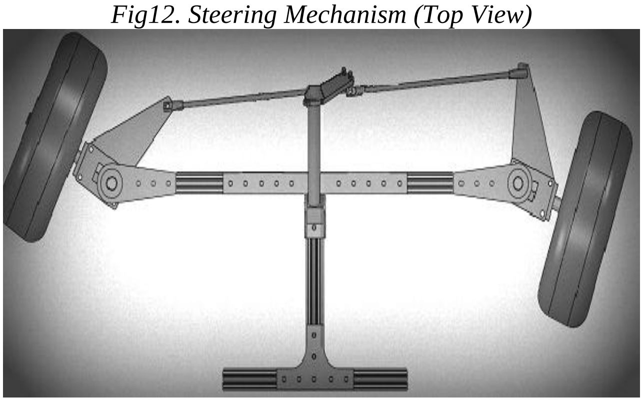
Fig 11: Analysis of A-Arm



VI. STEERING

The steering system is responsible for the overall direction of motion of the vehicle. In accordance with basic automobile rules governing the drive of a two wheeler or a vehicle being driven with a steering, it must be of mechanical links and must not be round or H-type.

Fig12. Steering Mechanism (Top View)



The steering is of handle type with a bell crank mechanism at the end of the steering column. The steering column or stem will be made out of the same material as the rest of the chassis. The tie rods for the steering will have knuckle joints to compensate for the suspension jounce.

VII. BODY PANEL DESIGN

The body panels are designed to protect the driver from objects entering the vehicle and to provide an appealing shell for our frame. It was understood that the body panels had to be light, moldable, and have a high impact resistance.

After a detailed analysis on carbon fibre, fibreglass, and aluminium sheet & G.I sheet, carbon fibre was found to cost more. That narrowed down our decision to fibreglass, aluminium sheet & G.I. sheet. Disadvantages of fibre glass are the time and the complex process involved in fabrication. The decision matrix (Table 9) explains the reason for choosing G.I. sheet as the body panel.

Table 8: Decision Matrix for Body Panel

Factors	*G.I. SHEET*	*ALUMINIUM*
AVAILABILITY	*4*	*3*
COST	*4*	*3*
WORKABILITY	*4*	*3*
TOTAL	*12*	*9*

Thus, G.I sheets are found suitable for bodywork.

VIII. CENTRE OF GRAVITY

Location of centre of gravity plays an important role in vehicle play and action when it is on road. If the centre of gravity doesn't coincide with the centre of mass of the vehicle, chances of vehicle toppling of vehicle and undue imbalance increase exponentially.

Fig.13.1 C.G Co-ordinates

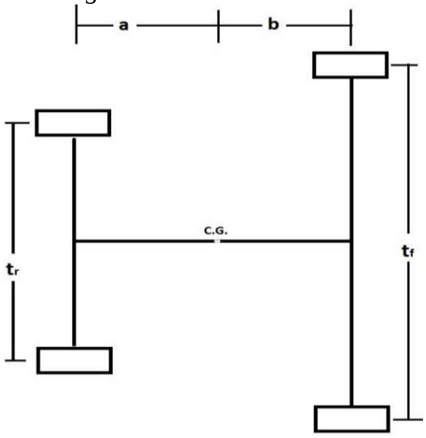
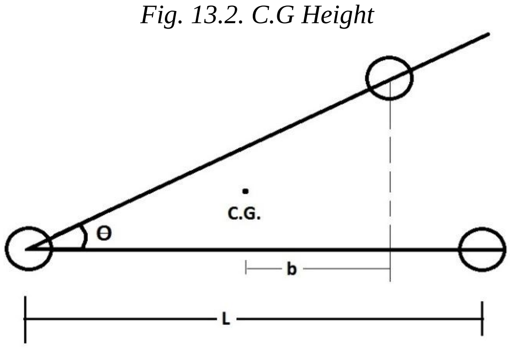


Fig. 13.2. C.G Height



Hence, it is a good practice to take into account the consideration where the centre of gravity closely coincide the centre of mass and lies in almost middle of the whole vehicle design.

IX. INDEX

Decision Matrix Rating:

1=Poor
2=Okay
3=Good
4=Best

Fig 14. View of Vehicle

X. CONCLUSION

We have introduced a distinct yet cost effective design methodology for a quad bike to be designed at industrial level. Considerations starting from vehicle concept, the way it is designed, keeping into account the requirements and target specifications and performance are described. The analysis of the design via the Finite Element Analysis method and its validation are defined in this paper in detail. Also, a detailed description of the segment suspension system design and the method of choosing and designing the desired suspension assembly, the braking system and the selection of desired rotor and drive safety, steering system and the control over the vehicle and other building factors are taken into account in detail. The concept of centre of gravity and its importance in a vehicle design is also described in detail. So in the conclusion, we have generated a successful and yet reliable method for generating a quad bike incorporating various automotive and mechanical concepts and tools.

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