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DESIGN AND STRUCTURAL ANALYSIS OF A FRAME OF A QUAD BIKE (ATV)

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Abstract- *The main objective of this paper is to design and analyze the frame for a Quad Bike. A Quad bike is a four wheeled all-terrain vehicle. As stated by ANSI, a quad bike is a vehicle that travels on low-pressure tires, with a seat that is straddled by the operator, along with handle bar for steering control. As it is an ATV, it must be designed to handle a wide variety of terrain than most other vehicles. Thus the frame of the quad bike is designed so that it is rigid, safe and comfortable for the driver.*

Key words: **Chassis, ANSYS, A-arm, Wireframe, TIG**

1. INTRODUCTION

Fully functional and movable unit except the body consisting of all the systems mounted on it is called as a chassis. And the most important component of the chassis is the frame. The frame is the structure which is rigid in bending and torsion. The main purpose of the frame is to make all the other subsystems constraint and fixed to work properly. It must be capable of supporting all the components and occupants and should absorb all kinds of loads fed into it without deflecting unduly. Also it should absorb the aerodynamic wind forces and road shocks through suspensions.

2. OBJECTIVE AND DESIGN PROCEDURE

The main objective of the final frame design is to provide the desired strength and increase the performance, safety and reliability of the vehicle. The idea of the frame design is taken by understanding popular and commercial quad bikes. Keeping the frame as light as possible is the key parameter in determining the vehicle performance and making sure that its performance is optimum in the endurance test. Design methodology consist of minimizing the total number of structural members without compromising the rigidity of the frame. I initiated with designing a basic CAD model on SOLIDWORKS 15 software and later analysed the design on ANSYS 14.5 software. The Finite Elemental Analysis (FEA) aided the material selection decision process. FEA helped to study whether a member was under high or low stresses in different conditions taken into consideration simultaneously. Based on the results obtained by the analysis I modified the design various times so as to arrive at the final design which is light weight, rigid and safe under all the conditions. The main, side two structures of the frame is being made by one complete bent pipe. The weld joints are avoided in the main supportive structure. The position of the mounting points are specifically adjusted so that they are welded at the nodes of the frame. Due to this the forces on the mounting points is distributed and intense pressures on a single member is avoided. Only the A-arm Mountings are not situated at the nodes.

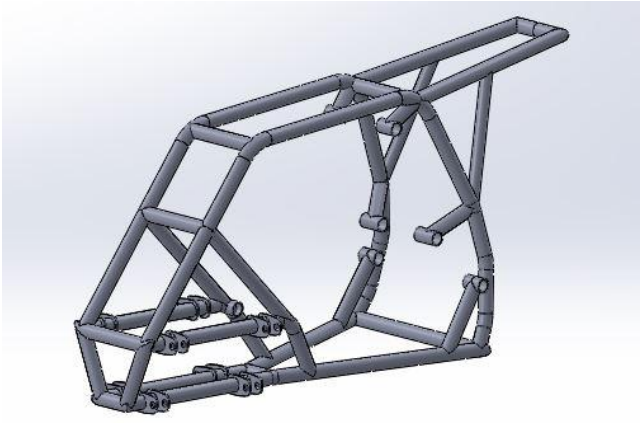

Fig - 1: Final Frame Design

Table - 1: Frame Specification

FRAME DESUGN SPECIFICATION	
Overall length	55 inch
Overall width	50 inch
Overall height	19.2 inch

3. MATERIAL SELECTION

Material selection is one of the key parameter for manufacturing the frame. To ensure that I select the correct material for the frame, I shortlisted a few materials based on the strength, weight, cost and availability. The three materials shortlisted were AISI 1018, AISI 4130 and AISI 1040. Finally, I had to choose one from all the three.

Table - 2: Physical Properties of the Materials

PROPERTY	AISI 1018	AISI 4130	AISI 1040
Tensile Strength	440 MPa	560 MPa	620 MPa
Yield Strength	370 MPa	460 MPa	415 MPa
Modulus of elasticity	205 GPa	190-210 GPa	190-210 GPa
Bulk Modulus	140 GPa	140 GPa	140 GPa
Shear Modulus	80 GPa	80 GPa	80 GPa
Poisson's Ratio	0.290	0.30	0.27-0.30
Elongation at break (in 50mm)	15 %	21.5 %	25 %

Finally on the basis of requirement, the above properties and most importantly availability AISI 4130 was chosen for the frame manufacturing. The material AISI 4130 (chrome molybdenum alloy steel) has low carbon content (0.280%) which increases its weld ability. Welding of AISI 4130 can be performed by all commercial methods. It is easy to machine using conventional methods and available in market according to required specification. The AISI 4130 tube of 1 inch outer diameter and 2 mm thickness is selected. Thinner walls require to be welded using TIG (Tungsten Inert Gas) welding process which make the members stronger and efficient. Also all the necessary equipment and facilities are available with me for carrying out this welding process.

Table 3: Chemical Properties of AISI 4130

Contents	Percentage
Iron, Fe	97.02 – 98.22
Chromium, Cr	0.80 – 1.10
Manganese, Mn	0.40 – 0.60
Carbon, C	0.280 – 0.33
Silicon, Si	0.15 – 0.30
Molybdenum, Mo	0.15 – 0.25
Sulphur, S	0.040
Phosphorous, P	0.035

4. FRAME SAFETY ANALYSIS

The final weight of the frame measured on the software is 13.21 kg and the gross final weight of the Quad Bike with all the subsystems and driver sitting on it is assumed to be 220 kg. Structural integrity of the frame was verified by comparing the analysis result with the standard values of the material. Theoretically calculated load were placed on the wireframe model of the frame at critical points to simulate the amount of force that the vehicle would undergo due to its own weight and the driver at the event of collision. Analysis was conducted using Finite Elemental Analysis (FEA) on ANSYS 14.5 software.

ASSUMPTIONS

1. Only the frame members and the mounting members are considered and no other items on the chassis is studied.

2. The frame is fixed at the mounting points of the front and the rear suspension arms.

3. All the weld joints are perfect.

4. The material has no imperfections.

5. The maximum velocity of the Quad Bike is 60 kmph.

GOALS

1. The frame must withstand the calculated force applied directly on the members.

2. The maximum deformation of the main frame members must be 1 mm - 10 mm.

3. The factor of safety obtained must be at least 1.5.

4.1 Front Impact Analysis

The frontal impact is considered to be an elastic collision. The linear velocity remains 60 kmph or 16.66 m/s. The value of force is calculated by the mass moment equation. Generally the collision takes place for very short duration of time. We assume this time to be $\Delta T = 1.01s$. The following calculations are done in order to design the frame in the best way.

The moment of the Vehicle at 60 kmph is given by,

$$P = M*V$$

$$P = 220*16.66$$

$$=3665.2 \text{ kgm/s}$$

And the frontal impact force is given by,

$$F = P/\Delta T$$
$$=3665.2/1.01$$
$$=3628.91 \text{ N}$$

Therefore the impact force by speed limit is 3628.91 N.

The Quad Bike will have maximum of 1.68G force under acceleration limit. Therefore the impact force is given by,

$$F = 1.68 * M * a$$
$$= 1.68 * 220 * 9.81$$
$$=3625.776 \text{ N}$$

The values of the force are practically comparable.

According to a research the body has to pass 6.8G force for extreme worst case collision. Therefore for static frontal analysis the force is calculated as;

$$F = 6.8 * m * a$$
$$= 6.8 * 220 * 9.81$$
$$= 14675.76 \text{ N}$$

Therefore the worst impact force = 3628.91 + 14675.76

= 18304.67 N

Now this calculated force was placed on the front part of the frame on ANSYS. The result obtained along with the image is as follows.

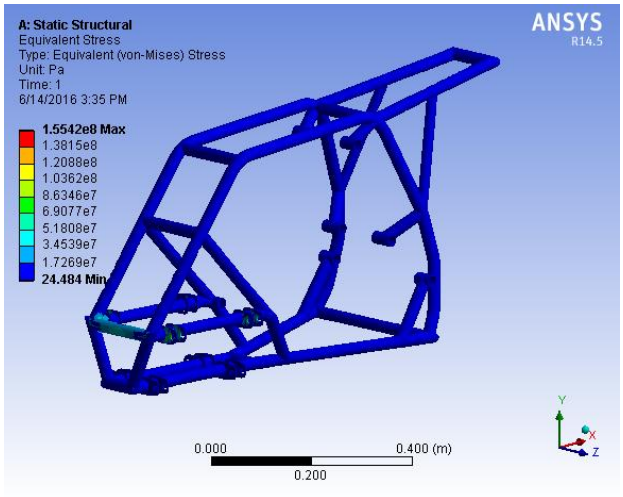

Fig - 2: Stress in Frontal Impact

Maximum Stress Generated = 155.42 MPa

Maximum Deformation = 0.0533 mm

Maximum Strain = 0.00079 max

Factor of Safety = 1.60

4.2 Side Impact Analysis

In the case of collision by side impact the value of impact force is calculated in the same way as in the case of frontal impact. For the side impact the velocity of the vehicle is taken as 48 kmph or 13.33 m/s according to ENCAP (The European New Car Assessment Program) standard and hence the force is calculated as,

$$F = P/\Delta T$$

Where,

$$P = M * V$$
$$= 220 * 13.33$$
$$=2932.6 \text{ kgm/s}$$

The side impact force is given by,

$$F = 2932.6/1.01$$
$$= 2903.56 \text{ N}$$

Therefore the side impact force by speed limit is 2903.56 N.

The Quad Bike will have maximum of 1.35G force under acceleration limits. Therefore the impact force is given by,

$$F = 1.35 * 220 * 9.81$$
$$= 2913.57 \text{ N}$$

The values of the force are practically comparable.

According to a research the body has to pass 2G force for extreme worse case collision for side impact. Therefore for static side impact analysis, the force is calculated as,

$$F = 2 * m * a$$
$$= 2 * 220 * 9.81$$
$$= 4316.4 \text{ N}$$

Therefore the worst impact force,

$$F = 2903.56 + 4316.4$$
$$\textbf{=7219.96 N}$$

Now this calculated force was placed at the side part of the frame on ANSYS. The result obtained along with the image is as follows.

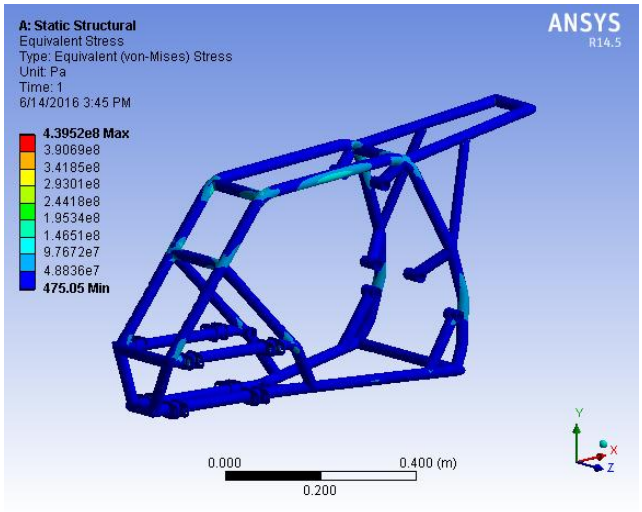

Fig - 3: Stress in Side Impact

Maximum stress generated = 439.52 MPa

Maximum Deformation = 1.5 mm

Maximum Strain = 0.0021976 max

Factor of safety = 1.59

4.3 Rear Impact Analysis

The rear impact force is calculated in the same way as the above two cases. In this case the velocity of the Quad bike is considered to be 50 kmph or 13.88 m/s by calculation and by the ENCAP standards. The calculations are as,

$$F = P/\Delta T$$

Where,

$$P = M * V$$
$$= 220 * 13.88$$
$$= 3035.6 \text{ kgm/s}$$

The rear impact force is given by,

$$F = 3035.6/1.01$$
$$= 3023.36 \text{ N}$$

Therefore the impact force by speed limit is 3023.36 N

The Quad Bike will have maximum of 1.35G force under acceleration limits.

Impact Force is given by,

$$F = 1.35 * 220 * 9.81$$
$$= 2931.57 \text{ N}$$

The values of the forces are practically comparable.

According to a research, the body has to pass 2G force for extreme worse case collision for rear impact. Therefore for static rear impact analysis, the force is calculated as,

$$F = 2 * M * a$$
$$= 2 * 220 * 9.81$$
$$= 4316.4 \text{ N}$$

Therefore the worst rear impact force,

$$F = 2931.57 + 4316.4$$
$$\mathbf{= 7247.97 \text{ N}}$$

Now, this calculated force was placed on the rear part of the frame on ANSYS. The result obtained along with the images is as follows.

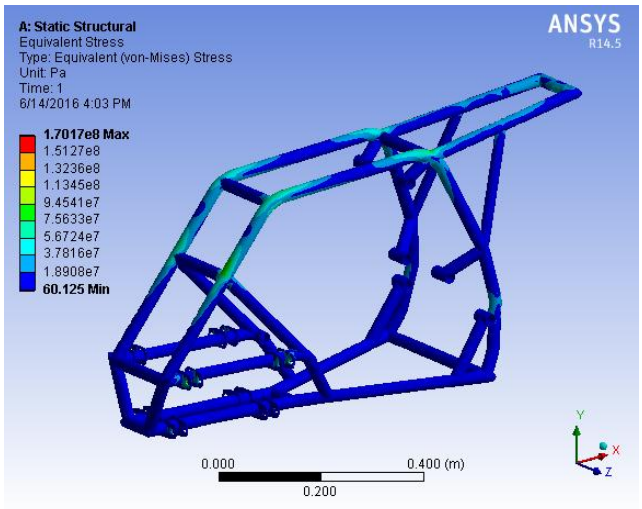

Fig - 4: Stress in Rear Impact

Maximum Stress generated = 170.17 MPa

Maximum Deformation = 0.84 mm

Maximum Strain = 0.00085087

Factor of safety = 1.52

5. CONCLUSION

In this paper, analysis is carried on the frame designed for a Quad Bike made of AISI 4130. The FEA analysis demonstrated the structural superiority while maintaining lower weight to strength ratio. The design of the frame was kept compact and simple so that it is easy to manufacture. The complete analysis was done on the ANSYS simulation software. The results obtained were

dependable and dynamically stable for the Quad Bike frame. The stresses obtained for all the conditions were under the limit of the material properties. The minimum FOS obtained was 1.52 for rear impact analysis which is safe as the maximum stress was 170.17 MPa. The design, development and fabrication of the frame was carried out successfully.

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