DESIGN AND FABRICATION OF LEANING QUAD BIKE

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Abstract - *This project outlines and describes the introduction and preliminary development of Team "LEANING QUAD" Vehicle Suspension Prototype. We explore the many engineering and non-engineering aspects of starting and managing a sizable mechanical project. Our project is to design and fabricate a concept vehicle which incorporates a new, leaning suspension. This new suspension will reduce lateral acceleration felt while a cornering, increase vehicle performance, and make driving more dynamic and exciting. Our research shows that many similar vehicles achieve tilting by using active hydraulic actuation, which limits the spontaneity of the leaning action and puts additional parasitic losses on the engine. Instead, we will design the vehicle to lean passively.*

Key Words: Leaning, Suspension, Quad bike, Hydraulic actuation, Tilting, Lateral acceleration

1. INTRODUCTION

An all-terrain vehicle (ATV), also known as a quad bike, three-wheeler, or four-wheeler, is defined by the American National Standards Institute (ANSI) as a vehicle that travels on low-pressure tires, with a seat that is straddled by the operator, along with handlebars for steering control. As the name implies, it is designed to handle a wider variety of terrain than most other vehicles. By the current ANSI definition, ATVs are intended for use by a single operator, although some companies have developed ATVs intended for use by the operator and one passenger. These ATVs are referred to as tandem ATVs

Everybody who rides a two wheeler leans. That is because a vehicle in a turn experiences inertia that is proportional to the momentum of the vehicle. This is very similar to the centrifugal effect that a body in a circular motion experiences i.e., the body in the circular motion tends to develop a centrifugal force pushing it outwards from the centre of the circular path, the force being proportional to the momentum of the body. Similarly the vehicle in a turn experiences a centrifugal force which tends to push the vehicle away from the turn tangentially. When the biker turns the bike without any lean, the inward force due to friction, will create a torque at the bike's center of gravity, acting outwards the curve. This will cause the bike and the rider to tip over. When the biker leans inwards the curve, as he turns, there will be an inward torque due to gravity.

This torque, depending on the angle of lean, will balance the outward torque created by the centrifugal force. As far as the biker balances the two torques throughout the curve, he will make a proper and stable turn.

By incorporating this principle to a quad bike we arrived at a mechanism which is known as "LEANING SUSPENSION MECHANISM". This mechanism allows the rider to lean to a particular angle so that effective negotiation of curves will be possible. Turning radius is reduced on the application of this suspension mechanism. Also it stabilise the whole vehicle due to lowering the centre of gravity**.**

2. LITERATURE REVIEW AND OBJECTIVE

2.1 Literature Review

Elizabeth et al 2012:Serious injury secondary to all terrain vehicle usage has been widely reported since the 1970s. All-terrain vehicles (ATV) or 'quad bikes' are four wheeled vehicles used for agricultural work, recreation and adventure sport. Data collected in the U.S. indicates that ATV related injury and fatality is increasing annually. Journal discuss about unstable design of quad bike with a narrow wheelbase, high centre of gravity and the accidents caused by it.

From this journal we found that the quad bike have stability problems and roll over tendency. So there is a need for a better suspension systems for quad bike .

The leaning suspension element is clearly described in **Subash et al 2017** . The mechanism fully narrated for the practical application.But actually this mechanism were before.The concept of tilting suspension came into existence during the 21st century. On 18th Mar 2008, **Lawayne Matthias** implemented it in three wheeled vehicle and filed a patent on same (US 7,343,997). He had used active tilting (i.e. it have computer-controlled power mechanism). He had implemented his mechanism on rear wheel. We got our basic design about the leaning mechanism from his patent. Generally vehicles are rear wheel drive so according to Davis steering mechanism they have to implement differential on rear wheel so that outer wheel travel with higher speed than the inner wheel. By implementing it the design become very complex and

also the control system on frame can be complex. So the main drawback was that he implemented the mechanism on rear wheel. On 22nd SEP 2009, **Ryan J. Suhre** and co. worked with **Harley Davidson Motor Company** and filed a patent (US 7,591,337).They had implemented their design on front wheel. The limitations of Lawayne was overcome. But the Ryan and co. had used hydraulic actuators to force the bike into leaning position while turning and back to upright position while tracking a straight line. The vehicle, which will be described herein as a trike, includes a frame, a rear drive wheel, conventional gasoline-fueled internal combustion engine, and two front wheels with a leaning suspension system. The suspension system includes one or more lean actuators configured to extend and retract to force-tilt the front wheels and to lean the motorcycle, responsive to a driver's pivotal rotation of the steering mechanism, e.g. the handle bars, through a corner. The actuators "are controlled by the leaning suspension control system that monitors at least one characteristic of the trike such as handlebar position (i.e. Steering angle), speed, acceleration, etc." Thus, the leaning of the trike described in the recent publication is understood to be actively controlled by the trike's leaning suspension control system, with said system applying a force to push the vehicle's centre of gravity in the direction of the turn, thus leaning the vehicle into a turn, hereinafter referred to as "forced-leaning". On 19th JAN 2010, **Daniel Mercier** implemented the leaning mechanism on vehicle. According to his design, vehicle has a frame pivotally connected to the lower end of a shock tower, the pivotal connection defining a frame leaning axis wherein the frame is adapted to lean to a right side and to a left side relative to the shock tower about the frame leaning axis. The leaning vehicle includes an actuator operatively connected to the frame and to the shock tower which is adapted to impart a leaning motion to the frame relative to the shock tower about the frame leaning axis. Another aspect of his present invention is to provide a leaning vehicle comprising an electronic control unit ECU electrically connected to at least one sensor adapted to detect a direction and magnitude of a torque applied to the steering column and the ECU being operatively connected to the actuator; Yet another aspect is to provide a vehicle speed sensor electrically connected to the ECU and adapted to send signals to the ECU. From his patent we came to know that 0o to 50o is the optimal range of tilting.

Stephen et al.(2010) describes the application of leaning attachment in an un motorised vehicle inheriting static and dynamic stability. Finally we arrived at the leaning suspension for a quad bike.

2.2 Objective

The literature review outlines that the conventional (non-leaning) quad bike is unstable, rolls over and causes accidents.

Also that there is room for improvement in existing tilting mechanisms and if successfully incorporated in a 4 wheeler, its disadvantages can be overcome.
Main objectives include:

- Economically design, analyse and fabricate a quad bike with a tilting suspension mechanism.

- Lower the centre of gravity of the vehicle.

- Reduce the turning radius.

3. METHODOLOGY

3.1 Cad Modeling Of The Mechanism

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. By choosing the optimum mechanism for the leaning mechanism the CAD model of the device is created with suitable dimensions obtained through engineering drawing.
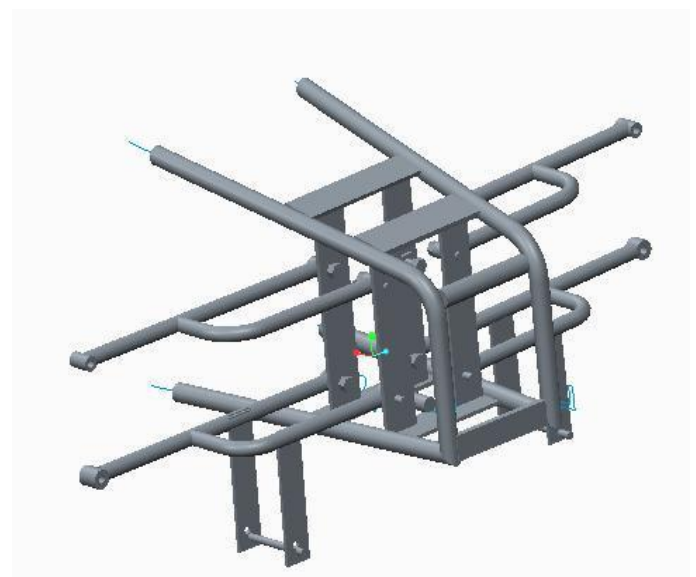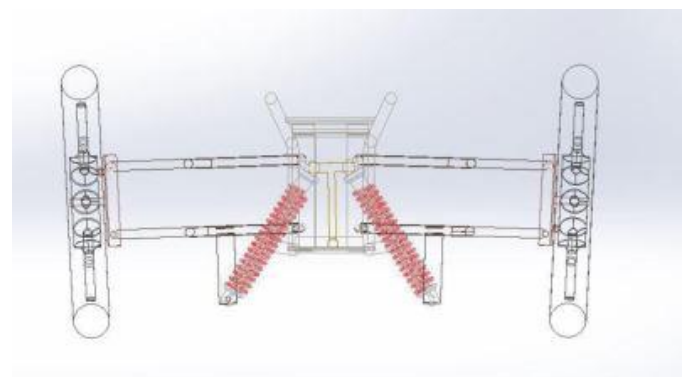

Figure-1:CAD model of Leaning Mechanism

Figure -2: Wireframe model of mechanism

3.2 Calculations

3.2.1 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.

3.2.2 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,

$P = M*V$

$P = 220*16.66$

$=3665.2$ kgm/s

And the frontal impact force is given by,

$F = P/\Delta T$

$=3665.2/1.01$

$=3628.91$ 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, $F = 1.68 * M * a$

$=1.68 * 90 * 9.81 = 1483.272N$

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;

$F = 6.8 * m * a$

$=6.8 * 90 * 9.81$

$=6003.72N$

Therefore the worst impact force = 1483.272+6003.72 N

$=7486.992N$

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.

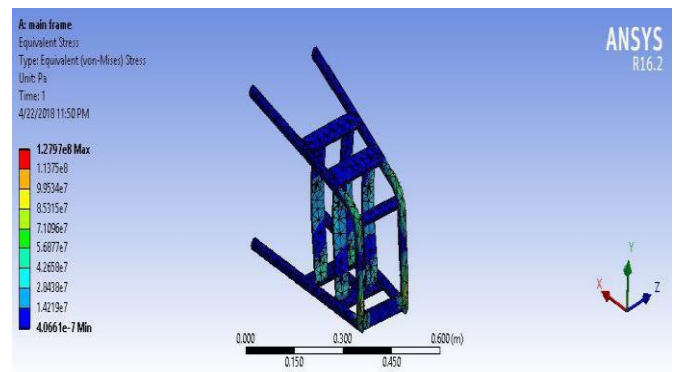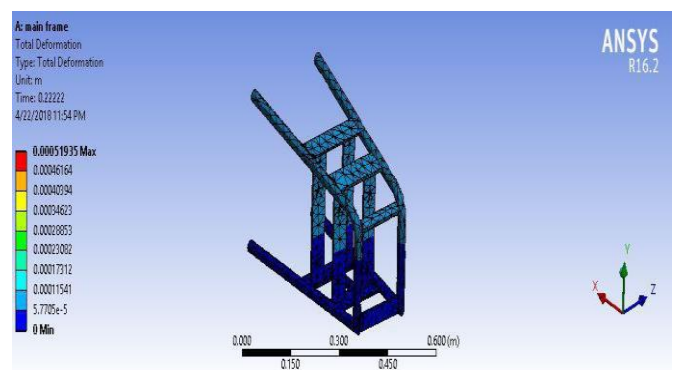**Figure-3**: Front Impact Stress

Figure4: Front impact strain

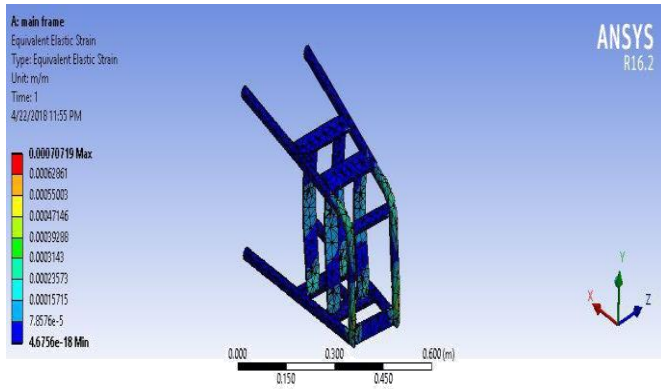**Figure-5**:Front impact deformation

Maximum stress obtained =127.97Mpa

Maximum strain=..000707

Maximum deformation=.519mm

3.2.3 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,

$P = M * V$
$=90 * 13.33 =1199.7$ kgm/s

The side impact force is given by, $F = 1199.7/1.01$
$=1187.821N$

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,

$F = 1.35 * 90* 9.81$

$= 1191.95$ 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,

$F = 2 * m * a$

$=2 *90 * 9.81$

$=1765.8$ N

Therefore the worst impact force,

$F = 1187.821+1765.8$

$=2953.621N$

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.
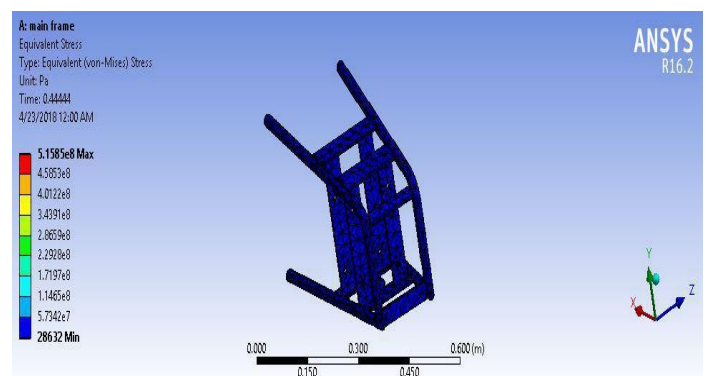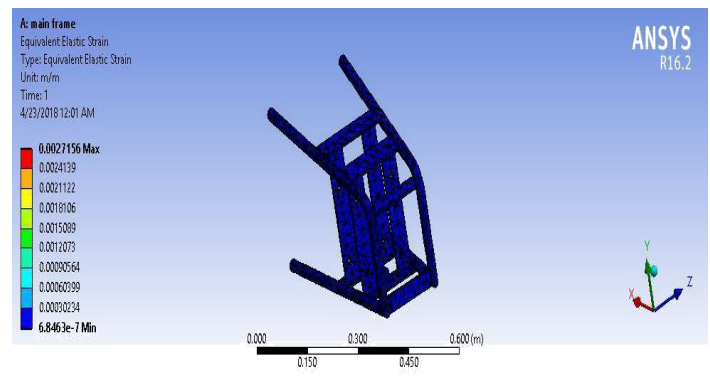

Figure-6:Side impact stress
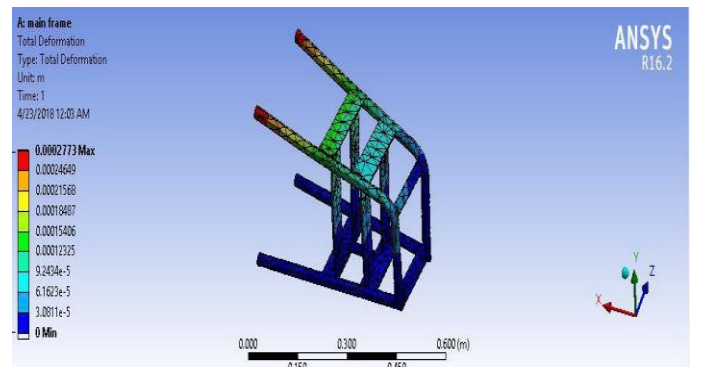

Figure-7:Side impact strain

Figure-8:Side impact deformation

Maximum stress obtained =171.4Mpa

Maximum strain=0.00271

Maximum deformation=0.277mm

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 171.17 MPa. The design, development and fabrication of the frame was carried out successfully.

3.2.4 Suspension Analysis

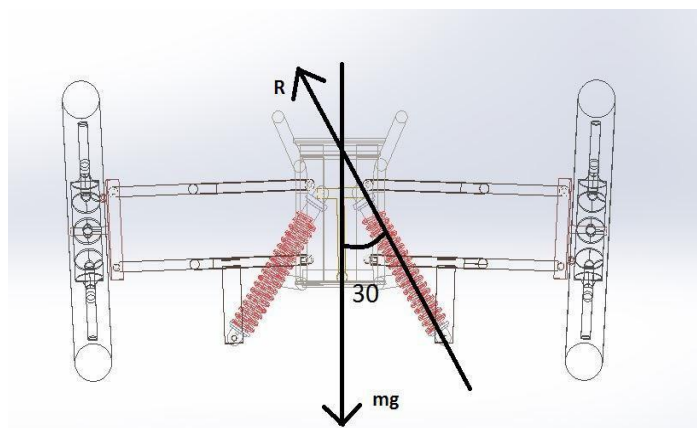Stationary condition of leaning mechanism

Figure-9 :suspension analysis (normal condition)

From the free body diagram, the horizontal components of the two springs on either side of the chassis will cancel each other out and vertical components balances the total weight of the vehicle.

Curb weight of Pulsar 150 bike = 144kg

Average weight of two persons = 75+75 = 150kg

Total weight, W =294kg

Weight acting on front suspension = 40% of total weight =117.6kg The shock absorber is kept at an angle 70 degree to the horizontal.

$R\sin70 = 117.6 \times 9.81$

where, R = spring force = 1227.7N
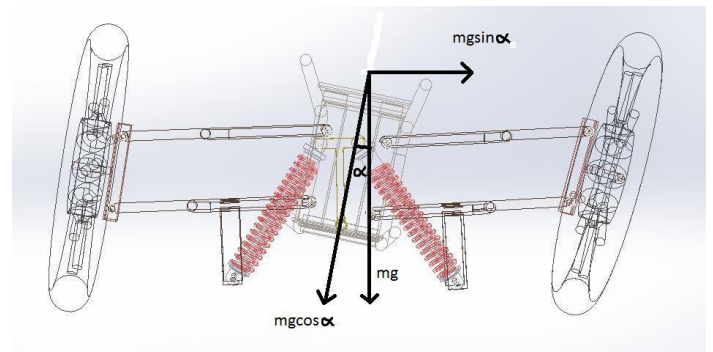
On Tilted Condition

Figure-10:Suspension analysis (tilted condition)

At this condition, the chassis is given a moment by the rider with respect to the center of mass.

Center of mass of the vehicle is assumed to be near to seat

Ground clearance = 155mm
Overall height = 1065mm
From figure, moment $T = xmg\sin\alpha$
x = 1065-155 = 910mm
therefore, $T = 0.910 \times 294\sin40 = 171.971$Nm

Hence the moment required to tilt the quad bike is 171.971Nm.

Calculation of helical coil spring

Material: Structural steel (G=78600 N/mm^2)

Mean diameter of coil, D= 32mm

Total no. of coils,n1= 15

Height, h=210mm

Outer diameter of spring coil,Do=D+d=40mm
No. of active turns, n=13

Weight of the bike=144kg

Average weight of one person=75kg

Total weight of vehicle (bike+2 person)=144+150=294kg

Weight acting on the front suspension=40% of total weight=117.6kg

Since we consider dynamic load, weight will be double of actual value.

Therefore, W=117.6 x 2=235.2kg=2307.312N

For a single shock absorber = W/2 =1153.656N

Deflection,δ = (WxD^3xn)/Gd^4= (1153.656x32768x13)/(78600x4096)=36.27mm Spring index,c = D/d = 32/8 = 4
Solid length,Ls = n1xd = 15x8 = 120mm

Free length of spring, Lf = solid length + maximum compression + clearance between adjacent coils = 120 + 36.27 + 36.27x0.5= 174.405mm Stiffness,K= W/δ = 1153.656/36.27= 31.807N/mm

Pitch of coil,P = ((Lf-Ls)/n1)+d = ((174.4-120)/15)+8 = 11.62mm

Stress in helical spring

Maximum shear stress induced in wire,T = Ks x (8WD/(3.14xd^3))

where, Ks = shear constant = 1.3105

T= 1.3105 x 8 x ((1153.656 x 32)/(3.14 x 512))= 240.620N/mm

From engineering data sources for structural steel the maximum allowable stress is 250N/mm.
So the designed helical spring has stress in safe limit for the worst condition.

KL = 0.1 for hinged end spring

Buckling of compression spring

Buckling load, Wcr = K x KL x Lf = 31.807 x 0.1 x 174.40= 554.71N

Now this calculated force was placed on the suspension system in ANSYS. The result obtained along with the image is as follows.
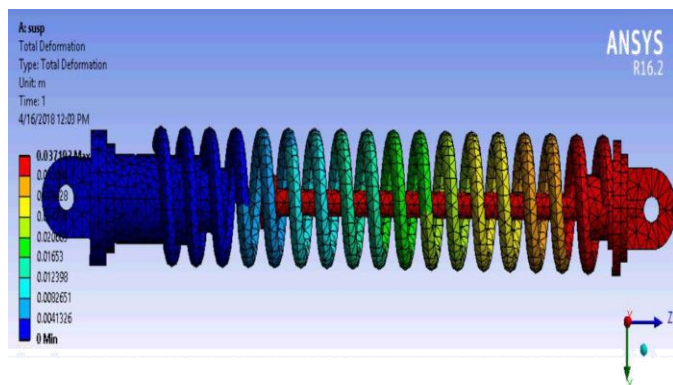

Figure-11:Suspension analysis (ANSYS)

Maximum deformation obtained=0.0371m

The deformation obtained was in the range of safe as the maximum deformation for safety is .0500m(from engineering data book)

FRONT FRAME ANALYSIS

The result obtained from the above design calculations was placed at the whole body model, for the stationary condition and tilting condition as per the free body diagrams drawn above and the following result was obtained.
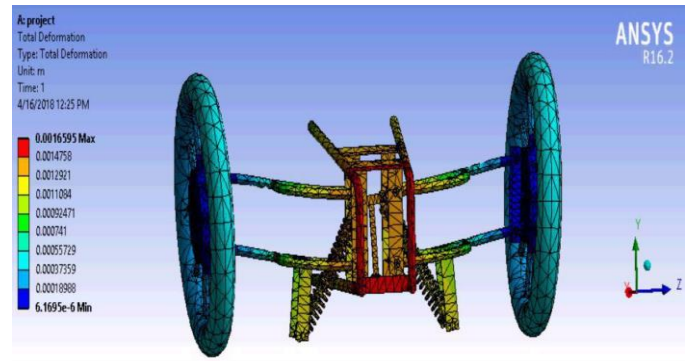

Figure-12: Front Frame analysis

The below figure shows the deformation occured while tilting

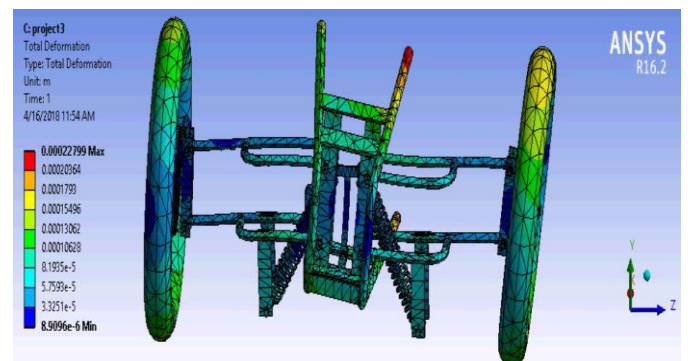Figure-13: Front Frame analysis(tilted condition)

From the front frame analysis the result obtained was about 1.25mm and 2.2mm which was in the permissible range of the goal that we have set before doing the analysis which was 1 to 10mm .the results obtained was between the limits hence the design is feasible in the range. hence the design is fixed to be the cad mode that we have made.

3.3Fabrication

By adopting suitable machine tools, machining processes and metal joining processes with the dimensions and values obtained from the design calculations with proper factor of safety fabrication was done .At initial stage we have encountered some difficulties during the fabrication.at that point of time we took suitable measures to solve them wheel alignment and other ergonomic factors was considered for rider comfort. Incorporating the frame to the chassis was a bit difficult as frame was of

a currently a existing model pulsar 150. Weight of the differential was a problem at the initial stage of fabrication as the incorporation of the differential was done after proper fixing of the back frame. At every stage we have ensured the strength of our ATV. Rear wheels were getting closer as the suspension was of independent type with independent arms so we welded a disc and a shaft to hinder the extra movement of the arms. with continuous hard work of 120 days the LEANING QUAD BIKE was fabricated. Later we have painted the whole body with black and orange enamel paints with fluorescent spray paint on the suspension and our final product is as shown

Figure- 14: Fabricated Model

4. CONCLUSION

The conventional (non leaning) quad bike had a lot of drawbacks regarding its instability and roll over tendency leading to many accidents. So we designed and manufactured a "LEANING QUAD BIKE" based on leaning suspension mechanism. The "LEANING QUAD BIKE" is working satisfactorily and we were able to achieve the set objectives such as higher stability and a lesser turning radius. We achieved a higher threshold velocity while negotiating a curve comparing with conventional (non leaning) quad bike.

We gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while doing this project work. We are proud that we have completed the work with the limited time successfully. The LEANING QUAD BIKE is working with satisfactory conditions. We are able to understand the difficulties in maintaining the tolerances and also the quality. We have done to our ability and skill making maximum use of available facilities. By using more techniques and a bigger budget, they can be modified and developed according to the applications.

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