

# Design and analysis of upright in All Terrain Vehicles

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## Abstract

Upright is an important part of All Terrain Vehicle (ATV) which links suspension, steering, and braking system. Suspension, steering, and braking systems are mounted over the upright. Therefore, upright should have sufficient strength under various loading conditions. Uprights used in commercial vehicles are too heavy and traditionally designed to fulfill the need. When vehicle becomes off-road or ATV, upright should have optimized design and satisfy all aspects of design and performance. In this article we proposed a basic design of upright in terms of optimize weight, strength, and size of upright. The CAD model of upright is prepared in PRO-E 4.0 and the selected design is analyzed in workbench module of ANSYS12.1. Robustness of the proposed optimized design of upright is validated by using different loading conditions of ATV.

## 1. Introduction

Upright is an important part of All Terrain Vehicle (ATV). Upright is attached to the suspension components, wheel hub and tie rod end. Brake caliper is also attached on the Upright. It is also known as spindle or steering knuckle. Wheel assembly is attached to the hub where the tire/wheel rotates while it is held in stable plane via upright assembly. Figure1 shows double-wishbone suspension where knuckle is attached to the upper A-arm at the top and the lower A-arm at bottom. Wheel is mounted with the help of struts on the hub which is attached to Upright. One of the arms of upright is attached to the steering rack which turns the knuckle and wheel.

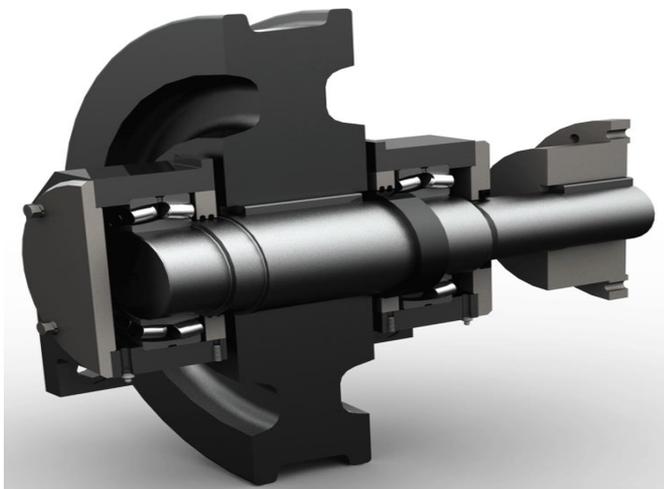


Fig 1: Sectional view of wheel assembly

Knuckle is the medium which connects wheel assembly to the chassis via hub. Upright serves following purposes in a vehicle:

- It connects A- arms in case of double wishbone suspension system, steering arm and tire
- It carries spindle and bearing assembly
- It also holds the brake caliper in appropriate orientation with rotor
- It makes possible to adjust the caster and camber

Upright performs all the above functions in every automotive vehicle. But, the design and material is varied for different types of vehicles. But, for an ATV or off road racing cars, upright should possess minimum weight as possible, maximum strength as required for both shocks and fatigue loading. Therefore, we are going to suggest a design of upright for double suspension system.

## 2. Literature Review

Chakradhar *et al.* [1] have explained the design and analysis of upright human powered vehicle (HPV). The fabricated HPV of

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Chakradhar *et al.* follows the norms of American Society of Mechanical Engineering (ASME). Optimal design of suspension system for ATV is discussed by Shijil *et al.* [2]. Static and dynamic process variables of suspension system for ATV is optimized and fabricated by Shijil *et al.* 2016. Shrivastava [3] have suggested that 4130 Chrome Moly Steel is the best suitable material for ATV. They have critically examined the design, analysis, and manufacturing process of ATV.

Milliken and Milliken [4] explained the concept of upright for race car. They were mainly concentrated on the dynamics of race car vehicle and proposed the optimal design of upright for race car. Smith [5] explained how to optimize upright and hub design in his book Engineering to Win. Fuganti [6] suggested that aluminum could be a good material to make upright of ATV.

Although, a lot of researchers and practitioners have suggested their own viewed but still design, analysis, and manufacturing of upright for ATV is a challenging task. Therefore, this article proposed a design, and analysis of upright in ATV.

## 3. Modeling of Upright/ Knuckle

CAD model of an upright is shown in figure-2 which is designed on PRO-E 4.0 according to the required dimensions. Material used for knuckle is Al6061-T6 because of its good strength and light weight. Parameters of wheel geometry are as follows for the Upright:

Kingpin inclination	: 7°
Caster angle	: +5°
Camber angle	: Adjustable
Toe-in & Toe-out	: Adjustable



Fig 2 : PRO-E Model of Upright

When the ATV is in motion, the magnitude of forces acting on upright is very high and fluctuating. Design analyzed for static and fatigue loading through ANSYS 12.1 Workbench.

## 4. Calculations

There are four mountings of upright on which force is applied. First one is Caliper mounting, second is mounting for steering rack and mountings of two A-arms. Calculations of all mentioned given as:

1. Force applied on caliper mounting: force which provides impact on caliper mounting is Clamping Force. So calculations of Clamping force is given below:

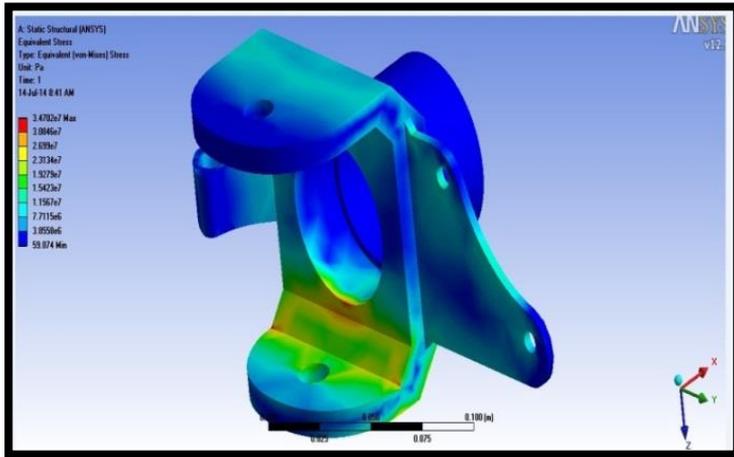
Clamping force = 3998.9 N

2. Force applied on steering knuckle on which tie rod of steering is connected, as shown below:  
 Force on steering knuckle = 812 N
3. Force applied by upper and lower A-arms of vehicle on upright after calculation are shown below:  
 Force on Upper arm=1083 N  
 Force on Lower arm= 4332 N

**5. Results and discussions**

Tetra meshing is done with size .0031 m<sup>3</sup>

- (1) **Von- mises Stress**  
 Stress =34.7 MPa

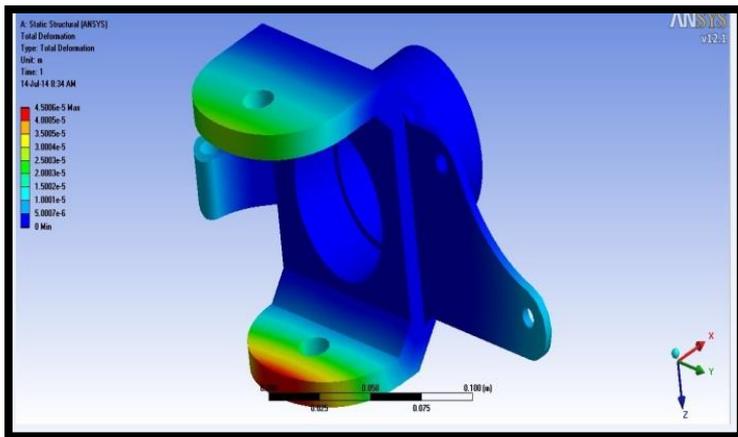


**Fig 3: Von- mises Stress**

Figure 3 shows von mises stress distribution of shell. Here the max stress produced is 34.7Mpa which is less than ultimate tensile strength of material selected by us. Hence our design is safe & it will not break or crack under worst loading conditions.

- (2) **Deformation**

Maximum Deformation= 0.045mm



**Fig 4: Deformation**

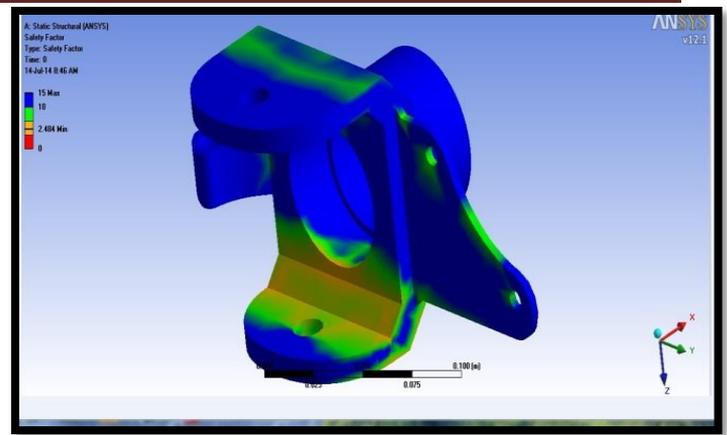
Figure 4 Shows the displacement diagram of shell. The maximum displacement produced is 0.045mm which is very small in magnitude and can be easily ignored. Thus, design of the upright is capable of bearing worst loading conditions with a very less deformation.

- (3) **Fatigue**

The knuckle is analyzed in ANSYS for the fatigue load of 10<sup>6</sup> cycles.

Safety factor of fatigue = 2.484

Steering knuckle is analyzed for fatigue loading is shown in Figure 4 to validate it for cyclic loading. The fatigue FOS of upright is 2.484 which indicate that design is capable to bear the torture of off-road conditions.



**Fig 4: Fatigue**

**6. Conclusions**

Conventionally used uprights are made of cast-iron, which has more weight for required strength or FOS but by analyzing the upright using Al 6061-T6, we can conclude that our upright is light weighted along with the required strength and parameters. It makes the vehicle to perform well in rough terrain.

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