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DESIGN & ANALYSIS OF DOUBLE WISHBONE SUSPENSION SYSTEM

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Abstract: *Vehicle suspension system is a linkage to allow the wheel to move relative to the body and some elastic element to support loads while allowing that motion. The suspension system of an all-terrain vehicle implements the vital role of damping undesired commotions and vibrations in the vehicle while maintaining ride quality and stability. The paper discusses design procedure of a double wishbone suspension system for an all-terrain vehicle(ATV). A 3D CAD model of the Double wishbone is prepared by using CAD Software for analysing the system capable of handling vehicle.*

Index Terms—*Roll centres, Spring, Strut, Sprung, Wishbone, Suspension.*

Literature Review
An investigation by Ashish Sangave and Chaitanya Aurangabadkar in the paper 'Design and analysis of an ATV suspension system' published in International Journal of Current Engineering and Technology
(12 Feb 2017) have shown the basic concept and terminologies associated with suspension geometry.

Another paper by Aniket Thosar 'Design, analysis and fabrication of rear suspension system for an all-terrain vehicle' published in International Journal of Scientific and Engineering Research discusses about the design considerations and calculations of roll centres of suspension system.

I. INTRODUCTION

Suspension system in an automobile is a system mediating the interface between the vehicle and the road, and their functions are related to a wide range of drivability such as stability, comfort and so forth. The suspension of modern vehicles need to satisfy a number of requirements whose aims partly conflict because of different operating conditions such as loaded/ unloaded, acceleration/ braking, constant/ variable terrain road, straight running/ cornering. For the purpose of ensuring the optimum handling characteristics of the vehicle in a steady state as well as in a transient state, the wheels must be in a defined position with respect to the road surface for the purpose of generating the necessary lateral forces. When a tire hits an obstruction, there is a reaction force and the suspension system tries to reduce this force. The size of this reaction force depends on the unsprung mass at each wheel assembly.
Double Wishbone Suspension System consists of two lateral control arms of unequal lengths (upper arm and lower arm) along with a coil over spring shock absorber

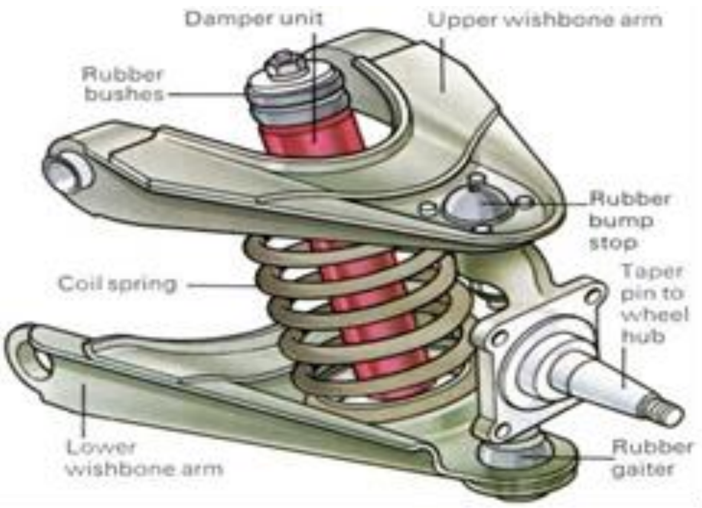

Fig: Double Wishbone Suspension System

It is popular as front suspension mostly used in rear wheel drive vehicles. Design of the geometry of double wishbone suspension system along with design of spring plays a very important role in maintaining the stability of the vehicle.

The upper arm is usually shorter which induces a negative camber as the suspension rises, and this arrangement is often known as Short Long Arms suspension. When the vehicle is taking a turn, body roll results in positive camber gain on the lightly loaded inner wheel, while the heavily loaded outer wheel gains negative camber.

The Four bar link mechanism formed by the unequal arm lengths causes a change in the camber of the vehicle as it rolls, which helps to keep the contact patch square on the ground, increasing the ultimate cornering capacity of the vehicle. It also reduces the wear of the outer edge of the tire.

II. DESIGN PROCEDURE

The design procedure for the chosen suspension system has been divided into two stages:

2.1. Primary design:

- Basic design and development of suspension system components.
- Modified design parameters based on approximation of dynamic condition.
- Static testing and analysis.

2.2. Secondary design:-

- Dynamic testing and analysis on ANSYS.
- Modification of design parameters based on dynamic testing results.

The following components are to be designed:-

1. Suspension spring
2. Wishbones or A arms

III. TEOROTICAL ANALYSIS AND RESULTS OF SUSPENSION SYSTEM COMPONENTS

3.1. Suspension Spring:

The spring which has been selected is a helical compression spring with square and grounded ends. These types of springs are easy to manufacture and are highly reliable. The deflection of spring is linearly proportional to the forces acting on spring.

Let us consider an ATV with sprung mass of 250kg and has a mass distribution of 40:60 (Front: Rear), so mass on each front wheel would be 50 kg and that on each rear wheel would be 75 kg.

Motion ratio is defined as the ratio of total spring travel upon total wheel travel. Generally for an ATV spring travel is 4 inch and wheel travel of 6 inch is sufficient. So the motion ratio as per definition comes to be 0.667

3.1.1 Front spring

Let us take the length of lower wishbone for front side is 17 inch. This is calculated on the basis of wheel track and ground clearance needed. For motion ratio to be 0.667 the ratio of distance of strut from chassis end to total length of arm should be 0.667.

As per this formulation the distance of strut from the chassis end comes to be 11.22 inch.

Calculating the spring stiffness

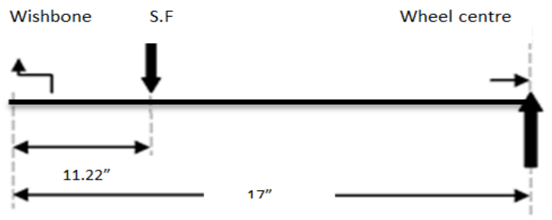

Fig. Free Body Diagram of front lower A arm

Point of attachment of strut = 11.22" (285mm) from chassis end …. (from suspension geometry)

Reaction force acting from the ground on the wheel =

(Mass per wheel * 9.81) N

= (50kg * 9.81) N

= 490.5 N

Considering wishbones are hinged at chassis end, taking moment about this point, we get,

490.5 * 17.00 = Spring Force * 11.22

Spring Force = 743.1818 N

Considering the dynamic factor as 2.5

Dynamic force acting on the spring = 1857.95 N

According to the ride conditions and road conditions, it is concluded that the optimum spring travel should be approx. 4" (101.6 mm)

Hence, Required Spring Stiffness

=Dynamic Spring Force / Spring Deflection

= 1857.95/ 101.6

= 18.2869 N /mm ≈ 20 N/mm

From the above calculations we get,

Stiffness = 20N/mm

Maximum spring force =1857.95 N

Material: Oil hardened steel wire of grade 4

Ultimate tensile strength = 1100N/mm^2

Modulus of rigidity= 81370 N/mm^2

According to Indian Standard 4454-1981,

Shear stress=0.5*Ultimate tensile strength

Shear stress (□) = 550N/mm^2

Taking spring index (C) =8

By Wahl's factor,

$$K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C}$$

= 1.184

So,

$$\tau = K * \frac{8PC}{\pi d^2}$$

So, d = 10 mm

Mean Coil Diameter = C*d = 80 mm

No. of active coil

$$\delta = \frac{8PD^3N}{Gd^4}$$

So, N = 10 coils

Assuming that the spring has square and ground ends

N_t = N+2 = 12 coils

Solid length of spring = Nt*d

= 120 mm

Total axial gap = (Nt – 1) *1

= 11 mm

Free length = (Solid length + Gap + deflection)

= 232.6 mm

3.1.2 Rear spring

Same as that of front spring calculations let us consider the length of lower wishbone as 18 inches and motion ratio as 0.667

So the distance of strut from chassis would be 11.88 inches

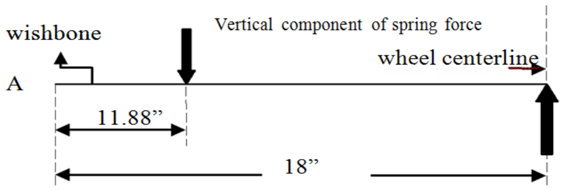

Fig. Free Body Diagram of Rear lower A arm

Reaction force acting from the ground on the wheel

= (Mass per wheel * 9.81) N

= (75 kg * 9.81) N

= 735.75 N

By taking moment at hinge point A

735.75 * 18 = Spring Force * 11.88

Spring Force = 1114.77 N

Considering dynamic factor 2.5

Dynamic force acting on the spring = 2786.9318 N

The required spring stiffness would be

=Dynamic Spring Force / Spring Deflection

= 2786.93/ 101.6

= 27.430 N /mm

~28 N/mm

From the above calculations we get,

Stiffness = 28N/mm

Maximum spring force =2786.93 N

Material: Oil hardened steel wire of grade 4

Ultimate tensile strength = 1100N/mm^2

Modulus of rigidity= 81370 N/mm^2

According to Indian Standard 4454-1981,

Shear stress=0.5*Ultimate tensile strength

Shear stress ( ) = 550N/mm^2

Taking spring index (C) =8

By Wahl's factor,

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

= 1.184

So,

$$\tau = K * \frac{8PC}{\pi d^2}$$

So, d = 11 mm

Mean Coil Diameter = C*d = 88mm

No. of active coil

$$\delta = \frac{8PD^3N}{Gd^4}$$

So, N = 8 coils

Assuming that the spring has square and ground ends

N_t = N+2 = 10 coils

Solid length of spring = Nt*d

= 110 mm

Total axial gap = (Nt – 1)*1

= 9 mm

Free length = (Solid length + Gap + deflection)

= 220.6 mm

3.2. Wishbone or A arm:

Double wishbone suspension system consist of two wishbones or A arms, usually of unequal length and form a four bar kinematic chain with chassis end as a fixed link, knuckle as rotating link and wishbones as levers of kinematic chain. Generally the length of knuckle is kept more than the length of fixed link i.e chassis end link.

The lengths of wishbones are decided by the wheel track of the vehicle and the position of the strut on wishbone is obtained from the motion ratio decided.

Shown below are some images of the cad models of upper and lower wishbones of the designed suspension system.

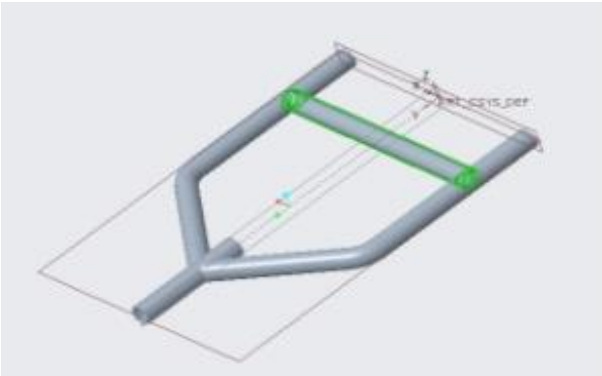

Fig. CAD model of lower A arm

Fig. CAD model of upper A arm

Material selected for the wishbones is AISI 4130 Chromoly pipes, for front knuckle material is EN 8 and for stub axle, the material is EN 24.

IV. ANALYSIS OF COMPONENTS USING ANSYS R18.2 SOFTWARE

4.1 Wishbones

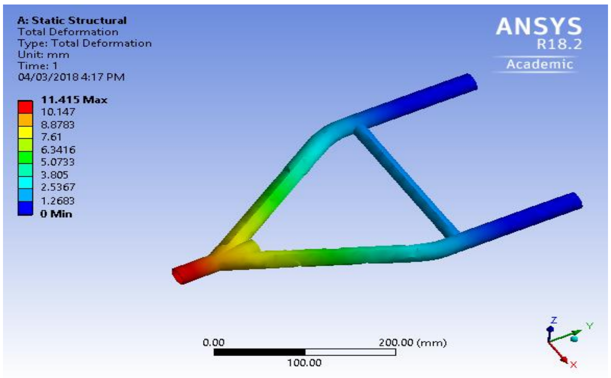

Fig: Total deformation of lower A arm

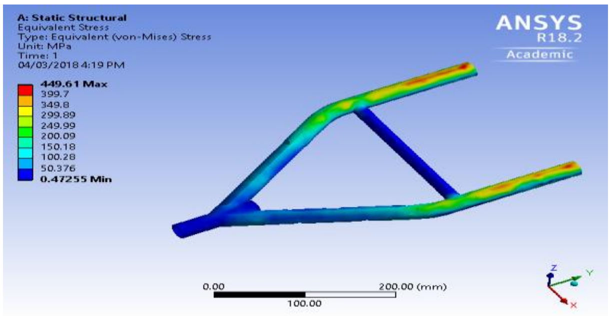

Fig: Stress analysis of lower wishbone

4.2 Knuckle

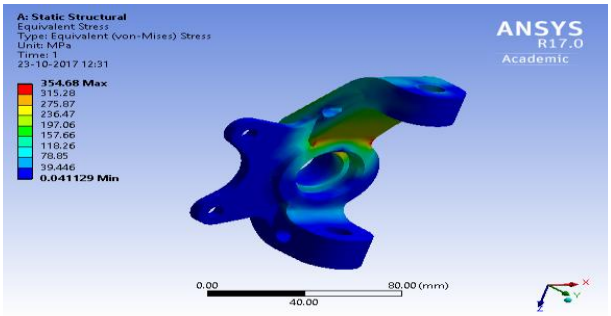

Fig: Stress analysis of front knuckle

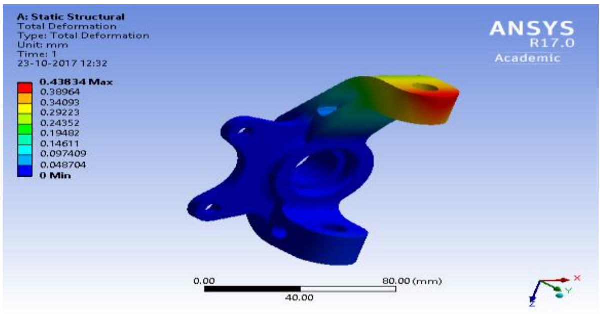

Fig: Total deformation in knuckle

4.3 Stub axle

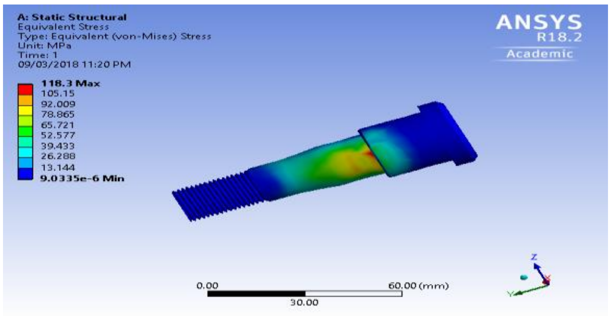

Fig: Stress in stub axle

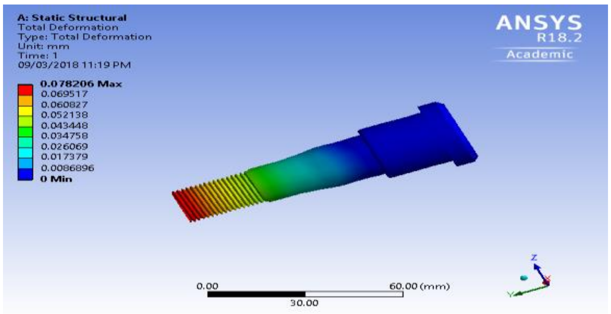

Fig: Total deformation in stub axle

V. CONCLUSION

We have designed the double wishbone suspension system and then followed by analysis of the system in the ANSYS; which gave following conclusions:

1. The design provided greater suspension travel, reducing the unsprung mass of the vehicle, maximizing the performance of the suspension system of the vehicle and better handling of vehicle while cornering.
2. The suspension spring design was found to be safe and was of desired condition of ride.
3. The quality of the design was assured by performing FEA which portrayed deformation and equivalent stresses well within the desired range.

VI. REFERENCES

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