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Tilt Suspension System for Three Wheelers and Reverse Trikes

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Abstract: **The load incurred on the suspension system of a vehicle is the maximum when it makes a turn or runs around a corner due to the centrifugal/centripetal forces acting on it. If the vehicle could lean by a certain angle when making a turn, it could retain its tyre grip and stability as it was during a straight road run. It is very effective for a suspension system to offer maximum damping efficiency without compensating the vehicle's stability and grip. Tilt suspension system is the most efficient design for a 3-wheeler suspension system and a vehicle has to lean if it's going to feel like a motorcycle. A front Trike conversion also puts more traction up front, improving cornering and braking. The main concept behind the tilt suspension system is that the two front wheels remain at the exact same angle as of the vehicle when it is leaning or taking a corner. When the vehicle tilts the contact patch of the tyres remain with the same area, hence there is no change in the dynamics of the wheel unless they are loaded. With tilt suspension system we can ensure 50% added stability and traction to the wheels on cornering with the same thrill and fun of riding a motorcycle. The only things that we need to consider are those trikes and other three wheelers don't do sharp turns like bikes and we will face larger turning circles. Though there is only one rear wheel, the turning geometry of the vehicle is as described by Ackermann.**

***Keywords:*—suspension, stability, traction, lean, Ackermann.**

I. INTRODUCTION

Motorized tricycles are three-wheeled vehicles based on the same technology as bicycles or motorcycles, and powered by electric motors, motorcycle, scooter or car engines. Depending on the design of the vehicle, motorized trikes may be categorized as motorcycles, motor scooters, or simply the three-wheeled counterpart to a motorized or electric bicycle. The main difference between a motorcycle trike and a scooter trike is that motorcycles are sat on in a "saddle"-style seating (as with a horse), with the legs apart, and motorcycles have manual transmissions. Scooters have a "step-through" seating style, in which the driver sits on a more chair-like seat, with the legs together; as well, scooters have automatic transmissions. While laypersons often associate the engine size as a dividing line between motorcycles and scooters, since a typical scooter has a small 50 cc engine, engine size is not one of the dividing lines, because some scooters such as the Burgman have 638 cc engines. A motorized tricycle's wheels may be arranged in either configuration: delta or tadpole. A delta trike has one wheel in front and two in back, and the tadpole trike has two wheels in front and one in back. Occasionally, rear wheel steering is used, although this increases the turning circle and can affect handling (the geometry is similar to a regular trike operating in reverse, but with a steering damper added). Tadpoles are more stable under braking and more likely to slide instead of roll; front braking hard on a delta requires the vehicle to steer almost straight to avoid tipping. The balance of friction patches and rolling resistance also means that tadpoles tend to over steer and deltas under steer. Motor trikes are attractive for those with mobility or balance problems. Under some local regulations, while riding a three-wheeled vehicle, it may be possible to carry multiple passengers with a motorcycle driving license, to ride a motorcycle-style vehicle with a car license, or to avoid motorcycle helmet use regulations

A.TILT SUSPENSION SYSTEM

A tilting vehicle can't work properly unless it has correct suspension action. A motorcycle has correct suspension movement. In a motorcycle the wheel always moves in the plane of its inclination. This system can be called "in the plane suspension". Many people fit laterally running parallel wishbones to tilting vehicles because they have observed this style on racing cars but this can result in a less than ideal suspension when applied to a tilting vehicle. They have experimented with all forms of suspension and has reached clear conclusions that the parallel wishbone types are flawed. When parallel wishbones move while inclined they cause the wheel to move dramatically out of its inclined plane. Imagine a wheel rolling from a flat surface then onto an undulation/bump. There is a "natural rolling path" that this wheel will follow and this path is only possible if the suspension of the wheel is arranged to move in the inclined plane. The N.R.P. (NATURAL ROLLING PATH) is the path on the surface of the bump/hollow that shows when a cut is made through the profile of the irregular surface at the

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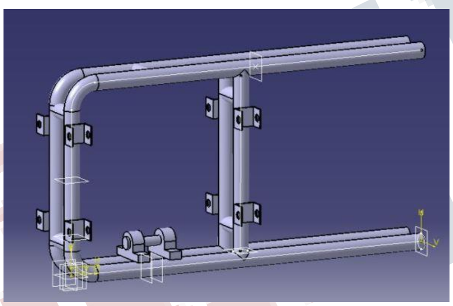
inclined angle of the rolling wheel 3 that is passing over it. If the N.R.P is not maintained then the slip angle of the wheel will be instantaneously loaded as the wheel is scrubbed across the surface sideways. In a real event the mass of the vehicle has inertia that wants to resist any sideways displacement so the wheel is forced to scrub sideways across the surface and so causes loss of traction and poor feedback characteristics. On the other hand if the suspension is performed properly "in the inclined plane" then this does not occur. Many large corporations who are ignorant of tilting vehicle requirements have proposed tilting vehicles with parallel wishbones and many individuals have built such vehicles.

B. PROCESS

- Design of Components.
- Assembly of Components.
- Fabrication of suspension system.
- Analysis of spring on different loads.

I. Design of Components

Central Frame:



Central Frame

The central support frame of the vehicle consists of two U-shaped tubes which is attached to the frame of the vehicle. This frame is the main support for mounting suspensions and A-Arms.

A-Arms:

A-Arms

In automotive suspension, a control arm, also known as an A-arm, is a hinged suspension link between the chassis and the suspension upright or hub that carries the wheel. The inboard (chassis) end of a control arm is attached by a single pivot, usually a rubber bushing. It can thus control the position of the outboard end in only a single degree of freedom, maintaining the radial distance from the inboard mount. Although not deliberately free to move, the single bushing does not control the arm from moving back and forth; this motion is constrained by a separate link or radius rod. This is in contrast to the wishbone. Wishbones are triangular and have two widely spaced inboard bearings. These constrain the outboard end of the wishbone from moving back and forth, controlling two degrees of freedom, and without requiring additional links. Most control arms form the lower link of a suspension. A few designs use them as the upper link, usually with a lower wishbone. The additional radius rod is then attached to the upper arm.

Wishbones:

Wishbones

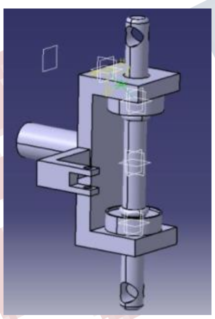
In automobiles, a wishbone suspension is an independent suspension design using two (occasionally parallel) wishbone-shaped arms to locate the wheel. Each wishbone or arm has two mounting points to the chassis and one joint at the knuckle. The shock absorber and coil spring mount to the wishbones to control vertical movement. Double wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel, controlling such parameters as camberangle, casterangle, toe pattern, rollcenter height, scrub radius, scuff and more.

Mid-Suspension Support:

Mid-Suspension Support

The mid-suspension support frame is the T-shaped tubular member welded together to hold the suspensions at their right place. It is independent to move with respect to the central frame.

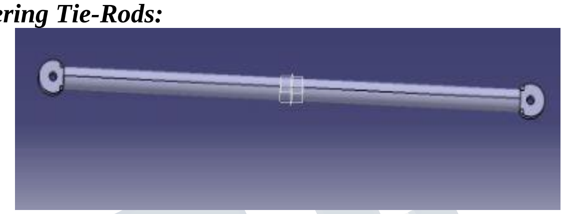
Steering Knuckle:



Steering Knuckle

Steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension components. It is variously called a steering knuckle, spindle, upright or hub, as well. The wheel and tire assembly attach to the hub or spindle of the knuckle where the tire/wheel rotates while being held in a stable plane of motion by the knuckle/suspension assembly. Steering knuckles come in all shapes and sizes. Their designs differ to fit all sorts of applications and suspension types. However, they can be divided into two main types. One comes with a hub and the other comes with a spindle. In a non-drive suspension, the knuckle usually has a spindle onto which the brake drum or brake rotor attaches. The wheel/tire assembly then attaches to the supplied lug studs, and the whole assembly rotates freely on the shaft of the spindle. In a drive suspension, the knuckle has no spindle, but rather has a hub into which is affixed the bearings and shaft of the drive mechanism. The end of the drive mechanism would then have the necessary mounting studs for the wheel/tire and/or brake assembly. Therefore, the wheel assembly would rotate as the drive shaft (or half-shaft) dictates. It would not turn freely by itself, but only if the shaft was disengaged from the transaxle or differential. A driven suspension as described may also be steerable. This is often called a drive/steer arrangement.

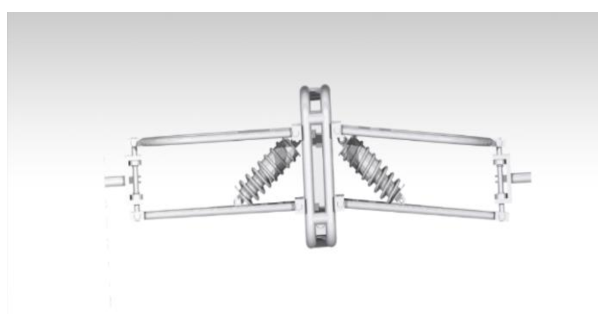
Steering Tie-Rods:



Steering Tie-Rods

A tie rod is a slender structural unit used as a tie and (in most applications) capable of carrying tensile loads only. Tie rods are generally used to steer the vehicle. Tie-rods connect the rods steering column and the knuckle. It converts the rotatory movement of the steering column into sliding movement, which helps to steer the vehicle. Usually tie-rods have ball and socket joints at its ends, in some cases hemi joints are used.

II.ASSEMBLY OF VARIOUS COMPONENTS



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The final assembly shows all individual components of the tilt suspension system mounted at their respective positions. The assembly shows the position of the helical springs mounted between the A-arms, wishbone and the mid-suspension support. The design shows the spatial freedom offered between each moving component such that their degree of freedom and movements are not disturbed.

III.FABRICATION OF SUSPENSION SYSTEM

MATERIALS CHOSEN FOR EACH COMPONENT

COMPONENT	MATERIAL	PROPERTIES	COMPOSITION %
1. FRAME 2. A-ARMS 3. SUSPENSION CLAMPS	**AISI 4130 Seamless tube** Outer diameter: 24.7 cm Inner diameter: 24.4 cm Wall thickness: 1.5 mm	Tensile strength(ultimate)=400 Mpa Tensile strength (yield) = 300 Mpa Modulus of elasticity= 190-210 Gpa Poisson's ratio = 0.27-0.35 Elongation at break = 21.5% Brinell hardness= 217 Density = 7.85 g/cm2	Fe – 97.03 – 98.01 Cr – 0.8 – 1.1 Mn – 0.4 – 0.6 C – 0.280 – 0.330 Si – 0.15 – 0.30 Mo – 0.15 – 0.25 S – 0.040 P – 0.035
1. KNUCKLE HUB 2. BEARING HOUSING 3. ROTARY SUPPORT SHAFT	**EN 08** **Medium Carbon Steel Block**: 50x120x12mm 50x176x12mm **Rod**: diameter-20 mm, length- 380 mm	Tensile strength(ultimate)= 700-850 N/mm2 Tensile strength (yield) = 465 N/mm2 Poisson's ratio = 0.27-0.35 Elongation at break = 16% Brinell hardness= 201 – 255	C – 0.25 – 0.45 Mn – 0.60 – 1.00 Si – 0.05 – 0.35 P – 0.015 – 0.06 S - 0.015 – 0.6

MACHINING OPERATIONS PERFORMED

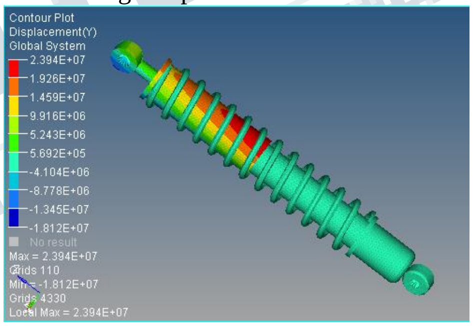
- Milling
- Turning and Phasing
- Drilling, Boring.
- Welding (MIG)
- Screw Thread cutting.

FULLY ASSEMBLED REVERSE TRIKE WITH TILT SUSPENSION SYSTEM

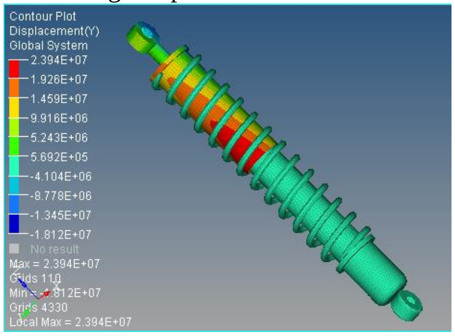
IV.ANALYSIS OF SPRING AT DIFFERENT LOADS

SOFTWARE USED: HYPERMESH OPTI-STRUT 14.0

Load applied = 50kg = 490.5 N
Maximum displacement = 2.394 cm
Minimum displacement = 1.812 cm
Average displacement = 2.103 cm



Load applied = 55kg = 539.5 N
Maximum displacement = 3.715 cm
Minimum displacement = 2.812 cm
Average displacement = 3.263 cm



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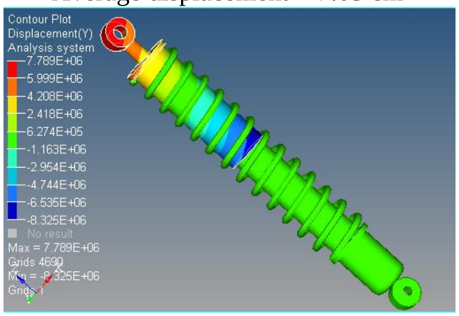
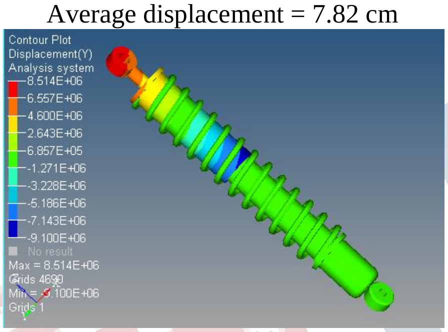
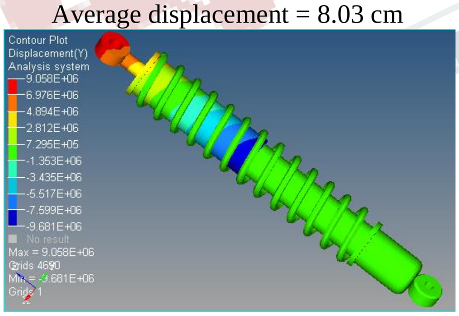
Load applied = 60kg = 588.6 N
Maximum displacement = 7.789 cm
Minimum displacement = 6.325 cm
Average displacement = 7.05 cm



Load applied = 65kg = 637.6 N
Maximum displacement = 8.514 cm
Minimum displacement = 7.143 cm
Average displacement = 7.82 cm



Load applied = 70kg = 686.7 N
Maximum displacement = 9.058 cm
Minimum displacement = 7.596 cm
Average displacement = 8.03 cm



II.RIDER ERGONOMICS

- The reverse trike fitted with a tilt suspension system does not affect the vehicle's geometry like the ride height; handle bar position and seat position.
- Altering the vehicle's geometry will drastically change the overall handling and riding features of the trike.
- The overall kerb weight of the trike is 120kgs which is quite easier to handle without a pillion rider since with a pillion rider the overall weight of a normal motorcycle will be around 200kgs.
- The tilt suspension system offers 30deg of angular freedom for leaning around curves in the road, this 30deg of tilt is sufficient for off-road riding purposes also.
- The maximum lean angle for a street motorcycle is found to be 15deg where as in trike it offers 30deg, hence the reverse trike will be functional in every way a motorcycle would be.

III.CONCLUSION

The project deals with the development of a suspension system for a three-wheeled vehicle that is capable of tilting like a conventional two-wheeled vehicle. This reverse trike with the tilt suspension system has proved its capabilities in off-road terrains with improved stability and riding performances.

1. The turn radius of 1.75 m helps the trike to take sharp turns and makes it very easy to maneuver around both on-road and off road tracks.

2. The reverse trike is capable of tilting to a maximum of 30 degrees which is the nominal lean angle for an amateur rider.

3. After 30 degrees of tilt, the vehicle is constrained to maintain that lean angle which prevents the trike from falling to its sides.

4. The handle bar of the trike offers 32.5 degrees of steering arm angle on either direction, which is the same for any conventional motorcycle.

5. The vehicle has a track width of 1110mm and a wheelbase of 1270mm, the broad track width helps to maintain the center of mass of the vehicle within the wheels even at maximum tilted position.

6. The total weight of the vehicle is found to be 120 kgs which is just 15 kgs more than that of a regular motorcycle, thus it helps in improve handling and stability.

7. The three drum brakes offers good braking performance and minimal stopping distance of two meters.

Thus all these parameters prove that the reverse trike offers improved riding characteristics than any conventional motorcycle and the tilt suspension system proves its efficiency in any terrain.

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