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Analysis of Modified Front Suspension of Three Wheeled Passenger vehicle

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ABSTRACT

Three wheeled vehicles are used as public and cargo transport in India. These vehicles have the configuration as one front wheel and two wheels in the rear. The vehicle stability depends on various parameters like caster trail, camber and scrub radius etc.Stability analysis of three wheeled vehicle is done for straight line stability control. This dissertations work analyses front suspension for three wheeled passenger vehicle with improved straight line stability. The finite element analysis was carried out for modified front suspension to find out stresses at critical location. It is observed that the vehicle with modified front suspension has better straight line stability than existing and competitors vehicle.

Keywords- **A Three wheeler front suspension, Trailing Link, Caster trail, Straight line stability**

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I. Introduction

The three wheeled vehicle is a very common public transport vehicle in India, with a maximum speed of about 50 km/hr. An auto rickshaw is a three wheeled motor vehicle with one front wheel. Three wheeled vehicle is most commonly found in developing countries as they are cheap form of transportation due to low price, low maintenance cost, and low operational costs.Three wheeled vehicle has one front wheel with linkage (trailing or leading) suspension attached to the steering column and two rear wheels attached to corresponding swinging arms that are pivoted to the frame. The steering system construction and wheel sizes are similar to a scooter, and the caster trail is less than that of motorcycle.

Three wheeled vehicles are used in traffic areas, so they require stability with ride comfort to reduce driver fatigue (steering efforts). The basic problem arises in vehicle handling is the control of the vehicle to a desired path. Effect of front suspension parameter on straight line stability of three wheeled vehicle is analyzed and investigated. Three wheeler front suspension with improved straight line stability is designed and analyzed in this dissertation.

II.LITERATURE REVIEW

A R. P. Rajvardhan, S. R. Shankapal, S. M. Vijaykumar [1] studied steer-ability and handling characteristics of the vehicle. The purpose is to improve the steer-ability and handling of the vehicle by avoiding the steering pull and wheel traveling problems. The steering effort, steering wheel return capability and the lateral forces produced by the tires were obtained in order to predict the behavior of the vehicle for different wheel geometry parameters.Figure shows the dissimilarity of pinion torque acting at the pinion of rack and pinion steering system for altered values of caster angles. The caster angle was varied from +5° to -5° to detect its effect on the variation of steering effort. It can be seen that the torque acting at the pinion, a measure of steering effort, is lower for negative caster angle and increases as the caster angle is changed from maximum negative to maximum positive. For negative caster angles, the aligning torque, instead of trying to push the wheels to straight ahead position, pushes the wheels out of away from it. This fails the wheel path, giving rise to wheel traveling problems. Hence, it is preferred to have positive caster angles.From the results, that positive caster angles increase the steering wheel return capability but increase the steering effort. Negative caster angles reduce the steering power but create wheel traveling problems. Steering Axle Inclination angles help in increasing the steering wheel return ability and decreasing the steering power as well. Negative camber angles help in creating higher lateral forces to improve the corner ability of the vehicle. Toe-in angles help in improving the straight-line stability whereas toe-out angles help in improving the cornering. Negative scrub radius looks to have stabilizing effect on vehicle handling.

M. A. Saeedi, R. Kazemi [2] studied stability controller of a three-wheeled vehicle with one wheels on the front axle, a three-wheeled vehicle with two wheels on the front axle, and a standard four-wheeled vehicle are compared. For vehicle dynamics control, the direct yaw moment control is considered as an appropriate way of controlling the lateral motion of a vehicle during a simple driving exercise. 3 wheeler 1 rear wheel and 4wheeler Cars become highly unstable, but the three-wheeled vehicle with front single wheel remains steady. It is presented that for lateral stability, the three wheeled vehicle with single front wheel is more steady than the four wheeled vehicle, which is in turn more steady than the three wheeled vehicle with single rear wheel. Turning radius which is a kinematic property shows that the front single three-wheeled car is more under steer than the other cars.

William A. Podgorski, Allan I. Krauter, Richard H. Rand [3], studied the motion, these are resulted for single wheel steerable air-filled tire systems are a built in wheel vibrate and wheel tire irregularities which produce swinging of the normal load. Special importance is placed on the dynamics classification of the tire cornering force and aligning torque. Figure shows for a given trail, the amplitude points at a certain velocity. The height of peak depends on the trail (height decrease as trail increase). The shaking of wheel will decrease as trail increase.

E. Esmailzadeh, A. Goodarzi, G.R. Vossoughi, [4]studied new optimal control law for direct yaw moment control, to improve the vehicle handling, is developed. This can be considered as part of the grip control of a motor wheels electric vehicle, but the results of this study are quite universal and can be applied to other types of vehicles. Two different types of control laws are considered here and the performance of each version of the control law is compared with the other one. The numerical simulation of the vehicle handling with and without the use of the optimal yaw moment controller has been carried out. Results achieved from the computer simulation indicate that the vehicle, which governed by the optimal controller have a superior performance when compared with the uncontrolled vehicle. Therefore, addition of the optimal controller in vehicles can considerably improve the road handling and safety of vehicles. The time history diagrams of Figure illustrate that the steady state values of the lateral acceleration and the yaw rate for the optimal controlled vehicle are considerably less than those for the uncontrolled vehicle as well as for the neutral steering limit The time responses of the desirable and achievable values of the optimal yaw moment control are illustrated in Fig. 9d. It can be seen that there is quite a difference between the desirable value being calculated by the optimal yaw moment controller, and the achievable value generated by the electric motors.The optimal yaw moment control, those oscillatory responses have been rapidly converged to their steady state constant values and therefore, the vehicle performs a safe and controllable behavior. Simulation results obtained indicate that considerable improvements in the vehicle handling can be achieved.

Thomas Gyllendahl, David Tran[5] studied new automotive product in the current world one of the most important challenges is safety of the users. As for the automotive industries, this task has an importance since the outcome can be shocking. One important classification from the safety point of view is the vehicle suspensions, as the suspensions control the effort of the wheels and thus keeping the vehicle on the road. Hence a change of the suspension was carried out to analyze if the negative handling characteristics typical for a three wheeled vehicle could be enhanced in the auto rickshaw. So that develops a vehicle suspension proposed for an auto rickshaw. A variety of different suspension types were explored and estimated until two suspension types were chosen; one type for the front and one type for the rear. These suspension types were then simulated and tested in CAE in different critical situations to gain useful information.Steering torque defines the load needed to steer the vehicle. The steering torque is affected by the caster angle, trail and rake. In the case of motorcycle the steering will be heavier when the caster angle is high together with either high trail. For easier steering a low caster angle together with high rake or low trail is needed.

III. FRONT SUSPENSION SYSTEM OF EXISTING VEHICLE AND COMPETITOR VEHICLE

This chapter includes the three wheeled vehicle front suspension modeling and layout of front suspension at various loading condition and finite element analysis of existing and competitor front suspension to find out critical stress location and experimental analysis of existing vehicle front suspension for straight line stability.

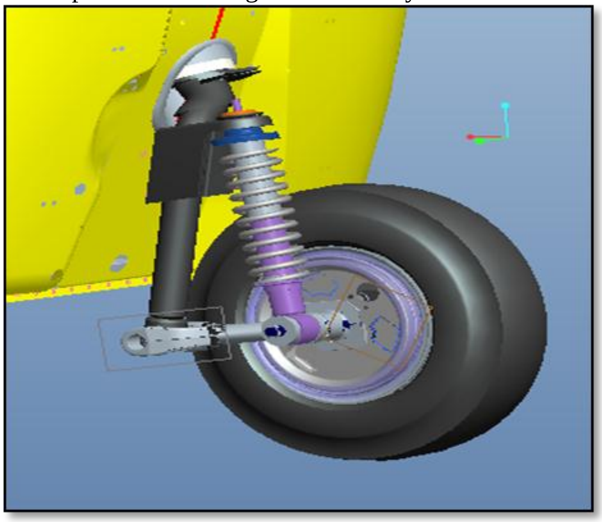


Fig 3.1: Leading Link Suspension (Existing Front Suspension)

Fig. 3.2: Competitor Trailing Link Suspension

Trail Lay Out of Wheel at Various Loading Condition

From Spring calculations, a layout of existing and competitor front suspension is drawn which shows the spring deflection, wheel travel and Trail values at various loading conditions, using AutoCAD.

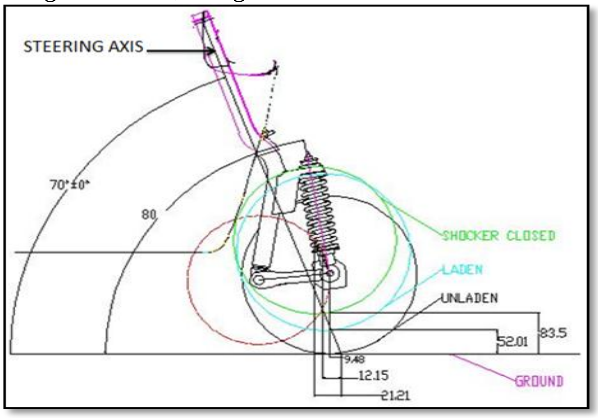


Fig 3.3: Lay-out of Existing Front Suspension

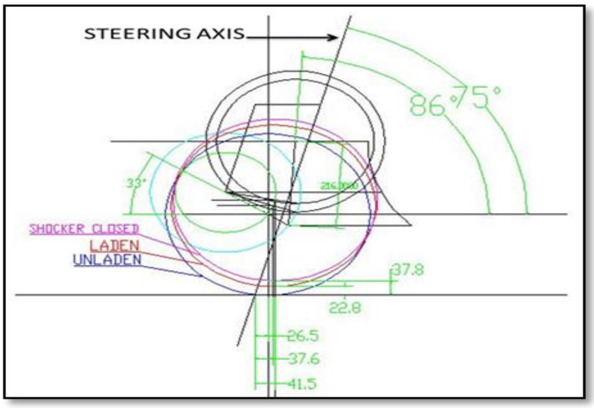


Fig.3.4 Lay-Out of Competitor Vehicle Front Suspension

Table 3.1Comparison between Suspensions System and Trail Value

	Trail (mm)		
	Unaden	Laden	Shocker-closed
Existing Suspension	9.48	12.15	21.21
Competitor Suspension	26.46	37.5	41.6

Finite Element Analysis of Steering Column Meshing

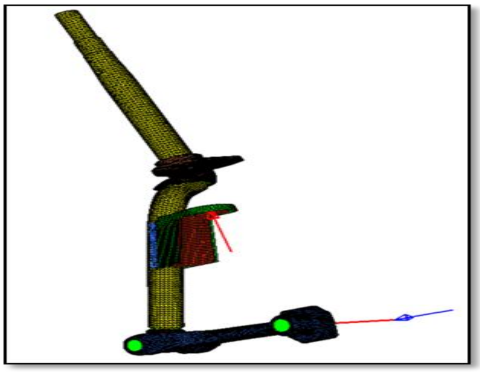


Fig.3.5Meshed Model of Existing Steering Column

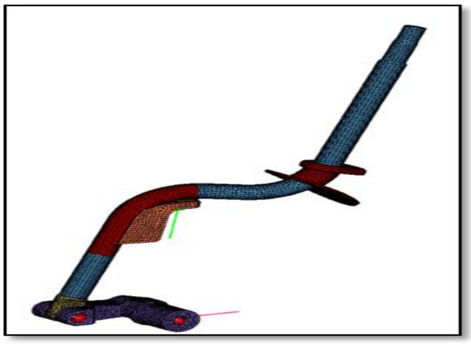


Fig. 3.6 Meshed Model of Competitor Steering Column

The steering column tube, suspension arm, casting these wear meshed in 2d by tria 3 elements was converted to 3D tetra 10 element

a) Boundary conditions

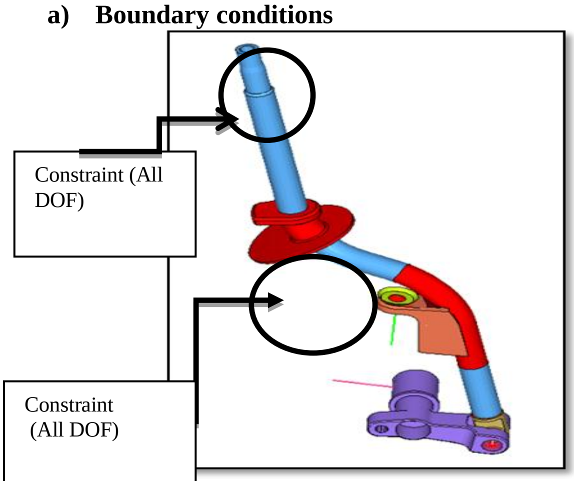


Fig. 3.7: Boundary Conditions Applied on the Steering Column

Loading for static calculations

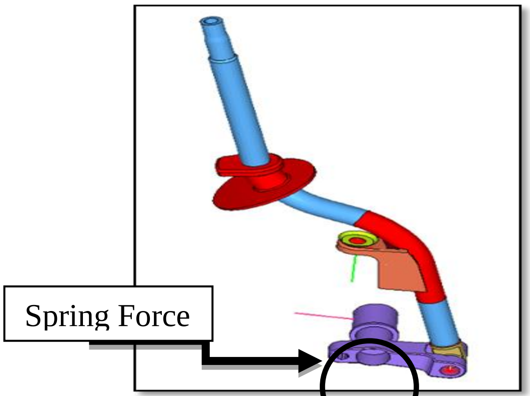


Fig. 3.8: Load Case for Steering Column

Load case 1) Spring force: F.A.W x 2g= 5619.16N. The vertical load wear applied on the wheel center.
Load case 2) Braking force: taken from experience 0.7 times of vertical load= 4214.37. The cornering loads wear applied on the wheel center.
Steering column was constraint as per above and 5619.16 N in vertical at wheel center and 4214.37 N longitudinal and load applied at the center of the top mounting bracket as shown.

SOLUTION

1) Existing front suspension:-

Spring Force Case Result:-

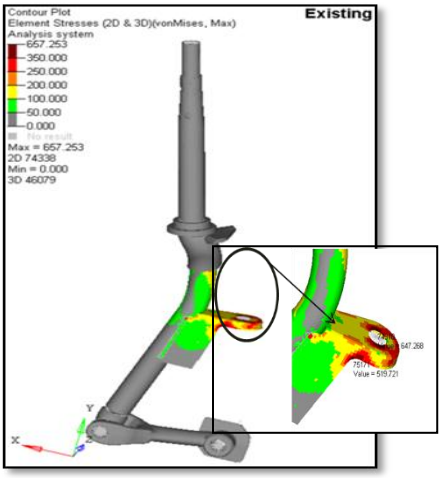


Fig. 3.9: Stress Plot for spring force

Spring force analysis shows in fig. 3.9. The above figure shows the stresses at critical locations.

Braking force Case Results:-

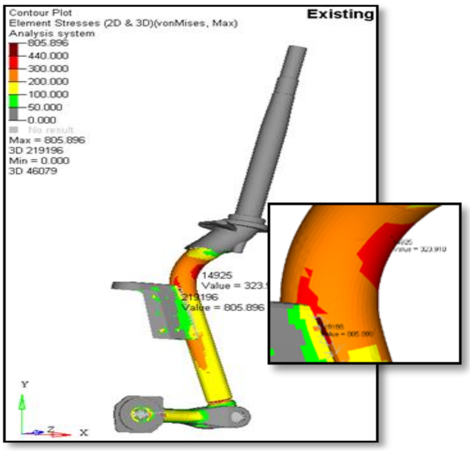


Fig 3.10: Stress Plot for Braking Force

Braking force analysis shows in fig. 3.10 the above figure shows the stresses at critical locations.

Table 3.2: Stresses due to loading in Existing Steering Columns

	Spring Stress (MPa)	Breaking Stress (MPa)
Existing front Suspension	323.9	324.74

2) Competitor front suspension:-

In the fig below the steering column on the competitor steering column, the results are as follows

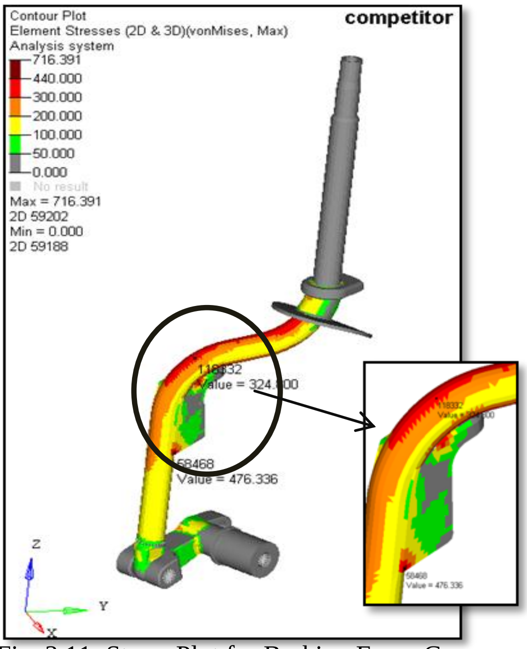


Fig. 3.11: Stress Plot for Braking Force Case

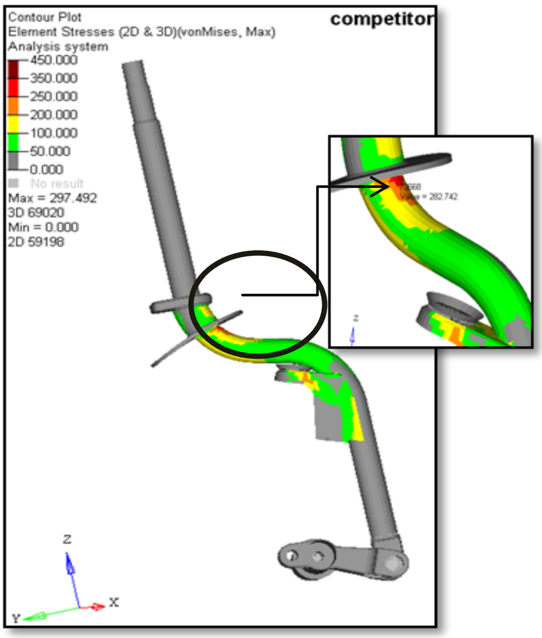


Fig. 3.12: Stress Plot Spring Force Case

Braking and spring load analysis shows in figures.
The above figure shows the stresses at critical locations.

Table 3.3: Stresses Due To Loading in Competitor Steering Columns

	Stress due to spring force (MPa)	Stress due to Braking force (MPa)
Competitor Front Suspension	287.74	324.74

Experimental data:-

- Existing Vehicle Test Results

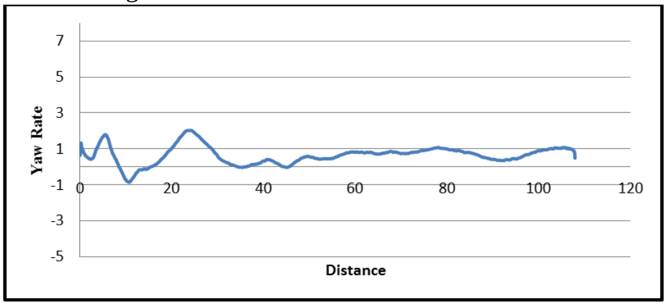


Figure 3.13: Existing Vehicle Straight Line Handling

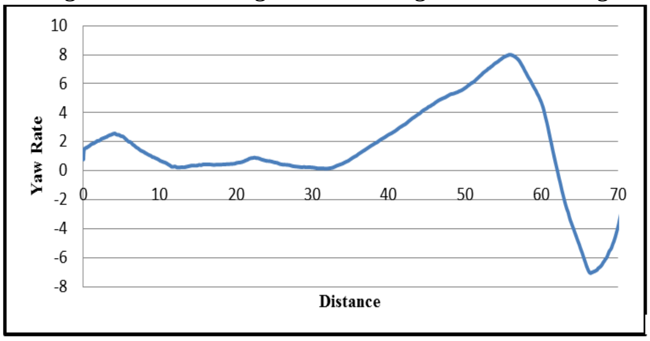


Figure 3.14: Existing Vehicle Hands off Handling

Observation

The straight line stability of the vehicle should be analyzed properly.Above figure shows the experimental analysis of existing vehicle in hands off and straight line stability.

- **Competitor Vehicle Test Results**

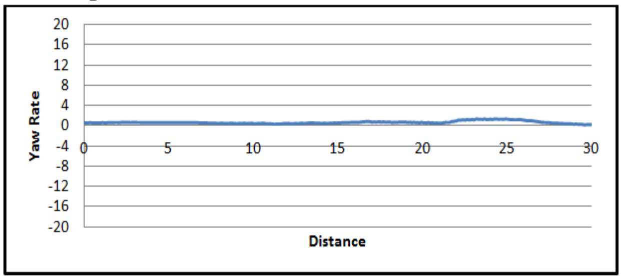


Figure 3.15: Competitor Vehicle Straight Line Handling

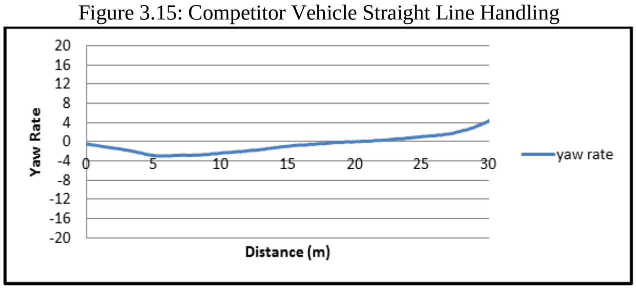


Figure 3.16: Competitor Vehicle Hands off Handling

Observation

It is required that the vehicle should obey a straight line handling unless and until the steering input is given by the driver. Driver has to continuously exert force on the steering handle bar to keep the vehicle handling in straight line. Compared to existing vehicle, the competitive vehicle is good in straight line stability.

IV. FRONT SUSPENSION SYSTEM OF MODIFIED VEHCLE

As per above definition, the front suspension of three wheeler vehicle with improving straight line stability is redesigned. Straight line stability is mainly depending on caster trail of front suspension as discussed in section 4.2.6. This is done by converting leading link to trailing link front suspension and studying advantages and disadvantages of trailing link front suspension as discussed in section 3.3. In new suspension only steering column is modified but all the remaining components are same. In modified front suspension link should be placed at 20^0 from horizontal plane in unladen condition and shock absorber should be as it is positioned (80^0) from horizontal plane same as existing front suspension. So that load is directly transferred to steering column but gives maximum caster Trail values. Spring deflection, wheel travel and Trail values at various loading conditions are shown in layout diagram.

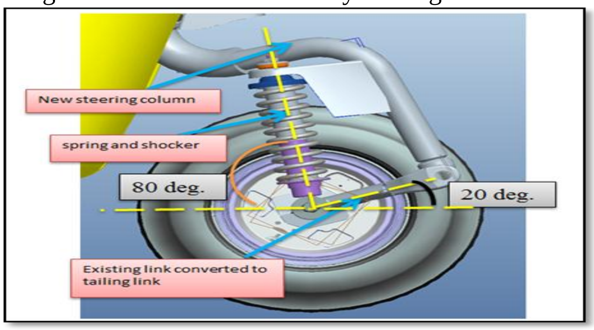


Fig. 4.1: Modified Trailing link suspension (CAD MODEL)

- **Trail Lay Out of Wheel at Various Loading Condition**

From above spring calculations, drawn a layout of front suspension and shows the spring deflection, wheel travel and Trail values at various loading conditions using AutoCAD.

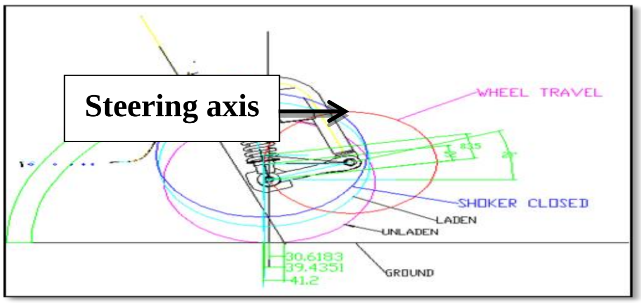


Figure 4.2: Lay Out of Modified Trailing Link suspension

Table 4.1: Trail Values of Modified Suspension at Various Loading Condition

Vehicle	Spring Deflection	Trail (mm)

Condition	(mm)	
Unladen	22.4	30.61
Laden	52	39.43
Overload	83.5	41.2

Finite Element Analysis of competitor vehicle front suspension system

Meshing

The components like re-enforcement and top spring mounting bracket as in steering column are meshed at the mid- surfaces using quad4 shell element and having an element size of 5. The other component such as steering tube, casting and link wear solid components. Because required them to be mesh in 2d by using tria 3 elements having an element size 5. The connections between the different components wear given by bolt connection's by rigid elements and welding connections by quad elements.

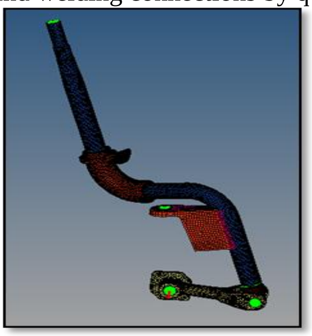
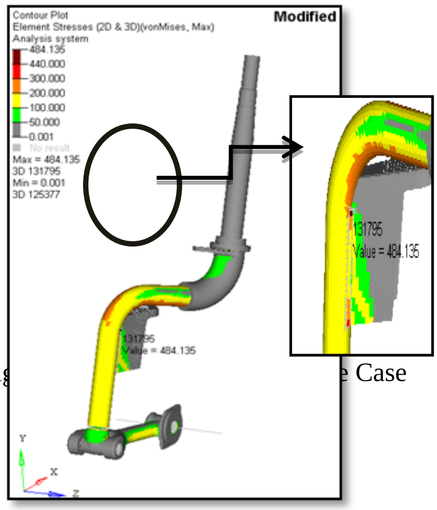


Fig 4.3 Meshed Model of modified Steering Column

Boundary conditions same as existing and competitor vehicle.

Solution:-

In the fig below the steering column on the modified steering column, the results are as follows



Fi e Case

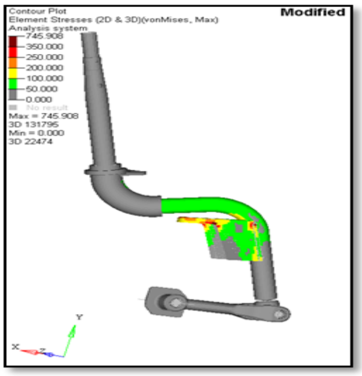


Fig. 4.5: Stress Plot Spring Force Case

Braking load analysis shows in fig. 4.4 the above figure shows the stresses at critical locations.

Table 4.2: Stresses due loading in modified Steering Columns

	Stress due to spring force (MPa)	Stress due to Braking force (MPa)
modified front Suspension	240	295

Experimental Test of modified front suspension vehicle

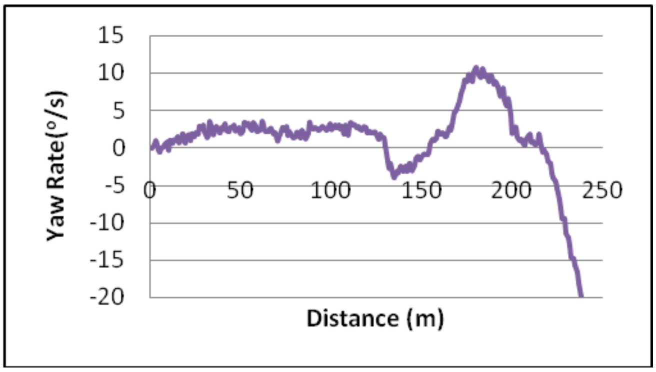


Fig.4.6: Results of Handoff Handling with Modified Caster Trail

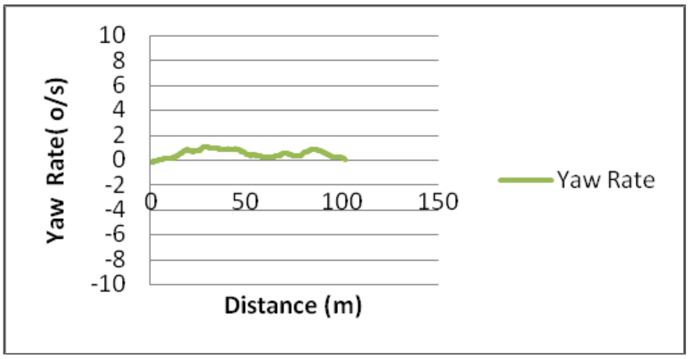


Fig. 4.7: Modified Vehicle Straight-Line Handling

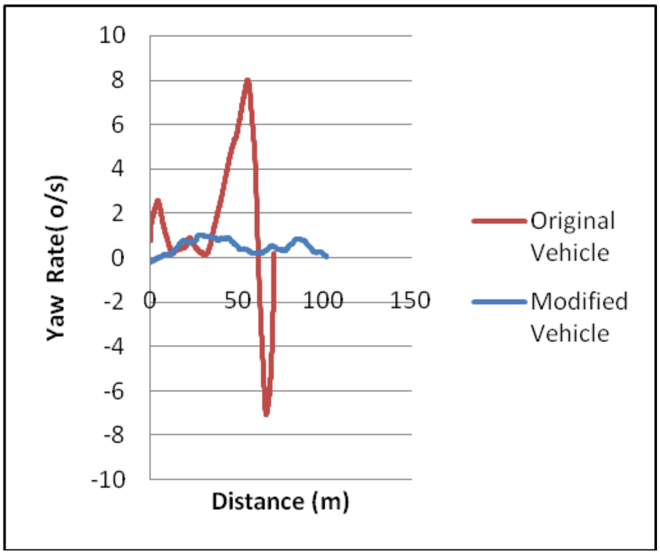


Fig. 4.8: Comparisons of Hands-off Handling Results

Table 4.3: Yaw Rate Results

Vehicle	Maximum Yaw Rate
Existing Vehicle	8
Competitor Vehicle	5.5
Modified Vehicle	1.45

Straight Line Stability Modification Results

From the above results the comparison of the yaw rate of the existing and the modified vehicle is done. The target to reduce the straight line deviation of vehicle is achieved. The yaw rate of the existing vehicle before and after modification is shown in table.

V.CONCLUSION

- The straight line stability of the front suspension of vehicle depends on caster trail.
- The finite element analysis shows marginal reduction in von-misses stress at critical locations.
- Load carrying capacity of the modified front suspension is maximum than other two vehicles.
- The straight line stability of the modified front suspension is maximum than existing and competitor vehicle.
- For further improving caster trail, link length of steering column suspension should be reduced.

VI.ACKNOWLEDGEMENT

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