Design and Analysis of Precesion Steering Mechanism using FEM Method

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Abstract: In this work, the direct-indirect steering mechanism is used in which direct steering mechanism helps to rotate the wheel and an indirect steering mechanism is rotating up and down or pulls and push. Twin lever steering mechanism is push and pulls type and controlled mainly by bi-articular muscles, making use of advancements in science and technology. To perform the analysis on steering arm, we choose Ansys software to validate the design of steering arm for applied steering to from the steering wheel. In this mechanism, steering arm is directly connected to wheel hub and rotate the wheel directly. Finally, the kinematics simulation and error analysis of the avobe mentioned steering mechanism are carried out for two different materials such as structural steel and akuminum, and the results show that the steering mechanism with structural steel can meet the steering requirements of the vehicle.

Keywords: Ackerman Principle, Steering Geometry, Rack and pinion , Design, Ansys.

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INTRODUCTION

The most of the four wheel vehicles are working using four-bar linkages steering mechanisms [1, 2] which are often called Ackermann-type steering mechanisms [4, 5]. In this mechanism, the input motion from the driver at the steering wheel is transmitted via gear box assembly and the steering control linkage to one of the steering knuckles and then transmitted to the driver through the Ackermann steering linkage [6]. The main kinematic requirement of the steering linkage of a vehicle is to provide the steerable wheels, a correlated pivot such that their axes intersect at a point on the rear wheel axis [7]. Steering systems are used to change the direction of the vehicle. These are essential to provide vehicle safety, steering quality and steering control and used to turn the vehicle without loss of traction and also used to maintain the directional stability of the vehicle. The most commonly used steering geometries are Davis and Ackermann. The structure of Ackermann steering wheel is as shown in Fig. 1. Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different rdii. The intention of Ackermann geometry is to avoid the need for tires to slip sideways when following the path around a curve.

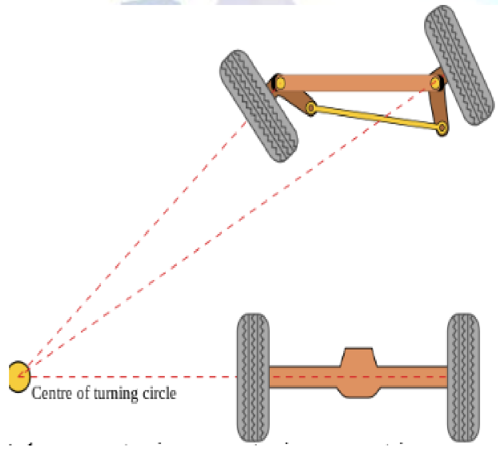

Fig 1: Ackermann steering wheel

The types of steering systems are trapezoidal; double trapezoidal and Rack & pinion etc. The design of steering system has effect on the directional response behaviour of a motor vehicle that is not fully appreciated. The function of steering is to steer front wheel with respect to driver command input in order to provide overall directional control of the vehicle. The steering System plays an important role for the vehicle as it is the "interface" between the driver and the vehicle. The driver turns the steering wheel which will rotate the steering column and give further movement in the steering rack. The motion is then transmitted to the wheels by the tie rods. The design and type of the steering rack depends on the system chosen. The steering systems used are divided into power assisted and manual steering systems, each designed to help the driver to turn easily for optimal performance with different configuration of the vehicle. Since the steering system is directly operated by the driver it is essential to take human comfort into consideration while designing the steering. The effort required by the driver in handling the steering is an important factor.

OBJECTIVES

To design such a light weight steering system, the modified four bar mechanism is used which will also reduce the overall weight of the vehicle.

- To minimize the turning radius, so that the vehicle can take turn in minimum required space with full precesion.
- To provide better safety to the driver.
- To provide more comfort to the driver.
- To increase the strength of rack & pinion.
- To maintain the better steering ratio.

RELATED WORK

Rudolph Ackermann invented the steering mechanism first time across the world, which allow the vehicle to turn along the flow of the path in early 1800's, called as Ackermann steering. Later the parallelogram steering mechanism was developed in late 1800's. In most of the research paper, the major studies showed the design of steering mechanism of all four wheel vehicles using either by manual formulaes based or the matlab software. The almost work was reported based on the performance of steering mechanism by considering the steering geometry optimizations. In most of the academic research work, many authors are reported the optimizations of steering geometry of four bar linkage mechanism. Recently, Hardikkumar Gadher, Tejashkumar Patel, Chirag Modi, Zeel Bhojani
Chandubhai S Patel Institute of Technology, Charusat, Gujrat, India [1] reported in 2017 on Design and

Optimization of Steering System with maximum Ackerman angles in steering system. In this work, they demonstrated Ackerman steering system usually achieves around 25^0 inclinations at inside wheel and 18^0 outside wheels. It governs by steering geometry and steering mechanism from the steering wheel to vehicle wheels. In another work, Mohammad Kristamto et al [2] reported about "the measure geometri and kinematic of steering system to disign steering axis to angle turn of the electric golf car" in 2nd International Conference on Sustainable Energy Engineering and Application, ICSEEA 2014. In this work, they reported the maximum turning angle of the car is limited by 30^o and the car has R at 372 cm. Saket Bhishikar, Vatsal Gudhka, Neel Dalal, Paarth Mehta, Sunil Bhil, A.C. Mehta [3] also reported the design and simulation of four wheel steering system in a most important journal named as International Journal of Engineering and Innovative Technology (IJEIT), Volume 3, Issue 12 in 2014.

Similarly, R.S. Khurmi, J.K. Gupta [4] has been demonstrated and published one reference book as a tittle of "Theory of Machines", S Chand & Company Pvt. Ltd., Vol 1, 14th Edition, in 2014. In this book they demonstrated many basic concept, theorey and design principle of steering system. In another reference book, the renounce author named S.K. Gupta [5] also reported about various parametric design consideration of steering system based on four bar mechanism and they published in 2014 for the first time to all interested reader. Similarly, Dr. Kirpal Singh also published one text book on detals design procedure of four wheel steering system with different condtions. The tittle of this book is published to tha name of "Automobile Engineering", Volume 1 in 2013.

ANALYSIS BY ANSYS WORKBENCH

Once the design is done by using some design software like solid works, the design underwent for analysis by using software's like CATIA, ANSYS. Now we are using ANSYS version 16.0 software for design analysis of various components of steering system. Analysis is done by applying various conditions like load, temperature etc.., and results were taken and analyzed.

PROPOSED DESIGN METHODOLOGY

We are using rack and pinion mechanism because of oblivious advantages of reduced complexity, ease of construction and less space requirement compare to other steering mechanisms.

DESIGN METHODOLOGY:

The step by step procedure for design methodology of steering wheel is as shown in Fig. 2. The flow charts involved various parametric designs which have to follow for the current design and analysis of steering mechanism for all the light and heavy weight vehicles. Those design parameters are: the selection of track width and wheel distance, turning radius, Ackermann conditions, turning angle, wheel geometry, and selection of linkage in four bar mechanism. Then the whole design is analsed by ANSYS software under CAE packages. The error calculation has been determined. Finally, the fabrication of feasible designed product of precesion steering mechanism has been reported.

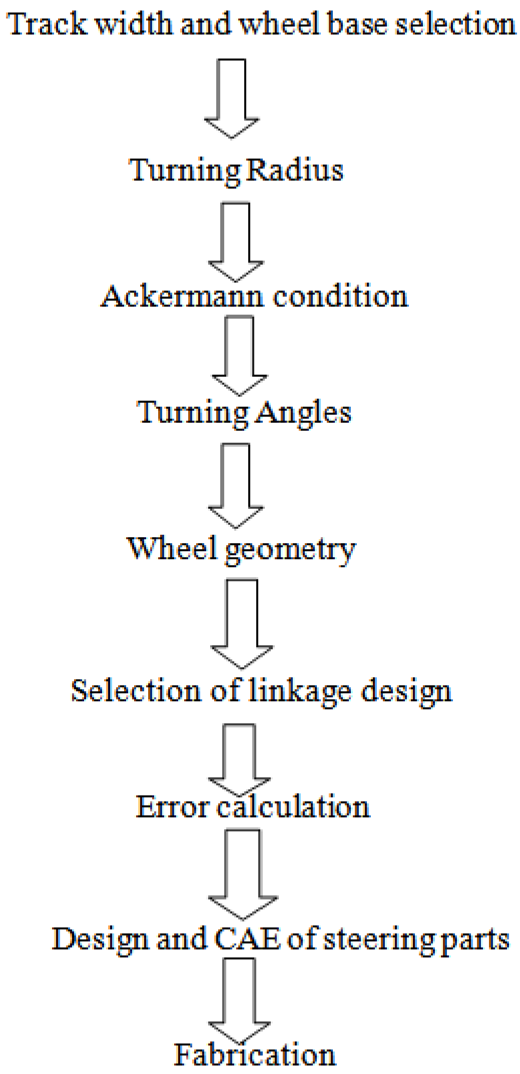

Fig 2: Flow chart for Design methodology of steering wheel

SELECTION OF TRACK WIDTH & WHEEL BASE:

As per our design requirement for the design vehicle, we selected a suitable parameters of track width and wheelbase.

TURNING RADIUS CALCULATIONS :

As per driver ergonomics and driver comfort while driving the vehicle we have selected the track width and wheelbase of the vehicle. Turning radius is fixed as 2.3 metres for the vehicle taken on the basis of track width and wheel base.

Where T = (pivot-pivot distance)

T= 1060mm

R_1 = 2260.566 mm

a = 424mm

Tan(δ_i) = wheel base/(R_1-T/2)

Tan (δ_i) = 1060/ (2260.5-1060/2)

$\delta_i = 34.01^0$

Tan (δ_0) = wheel base/(R_1+T/2)

Tan (δ_0) = 1060/(2260.5+1060/2)

Then, $\delta_0 = 22.67^0$

ACKERMANN'S CONDITION:

Cotδ_0 –cotδ_i = (Distance betweenpivots)/(wheel base)

Cot (22.67)-cot (34.01) = 1060/1162

0.9120=0.9125

Thus Ackermann condition is approximate

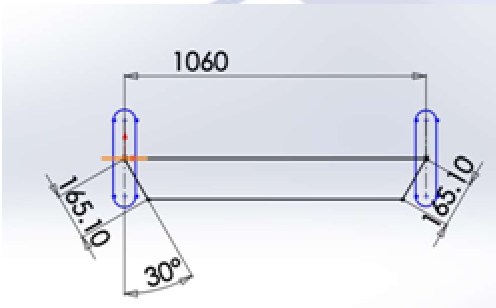

Fig 3: Ackermann's condition for steering wheel

CALCULATION OF ACKERMANN ANGLE AND STEERING ARM LENGTH FOR MINIMUMERROR:

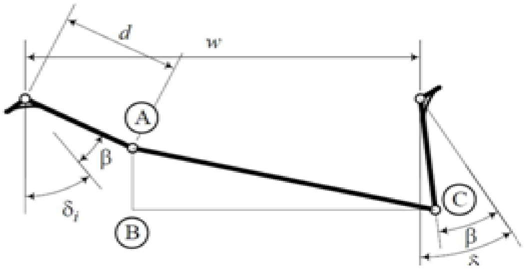

Fig 4: Ackermann angle and steering arm length for steering wheel

Derivation:

From the above figure

AB = dcos(β−δo)−dcos(β + δi)

BC = w−dsin(β + δi)+dsin(β−δo) AC= w−2dsinβ

Applying Pythagoras theorem:

$AC^2 = AB^2 + BC^2$

$(w-2d\sin\beta)^2=(w-d\sin(\beta+\delta i)+d\sin(\beta-\delta o))^2+(d\cos(\beta-\delta o)-d\cos(\beta + \delta i))^2$

The minimum error at β = 30^0 d=165.1mm, Ackermann angle (β) = 30° Steering and arm length(d) = 165.1mm is achieved.

Θi	Θo	18	20	24	26	28	30	32	34	36
5	4.632	4..847	4.827	4.786	4.763	4.740	4.716	4.691	4.665	4.637
10	8.637	9.400	9.325	9.168	9.086	8.912	8.821	8.821	8.725	8.626
15	12.152	13.666	13.504	13.169	12.815	12.815	12.630	12.439	12.241	12.037
20	15.284	17.642	17.364	16.793	16.498	16.196	15.887	15.569	15.243	14.907
25	18.117	21.314	20.893	20.033	19.593	19.144	18.6880	18.221	17.744	17.255
30	20.717	24.664	24.073	22.875	22.267	21.652	21.027	20.391	19.745	19.085
35	23.138	27.664	26.878	25.300	24.505	23.703	22.893	22.073	21.242	20.398
Error		1.914	1.720	1.319	1.124	0.723	0.2891	0.454	0.8191	1.031

CALCULATION OF TIEROD LENGTH:

The procedure for calculation of tierod lengthfoe this steering mechanism is in detail as shown in Fig. 5.

Pivot to pivot distance = 1060 mm Ackermann angle = 30^0

x = 165.1*2Sin (30^0)

= 165*2(0.5)

= 165 mm

Then, 2x = 165mm Therefore:

Tierod length = (pivot to pivot distance) – (2x)

= 1060 mm – 165.1 mm

=894.9 mm

Tie rod length= 894.9 mm

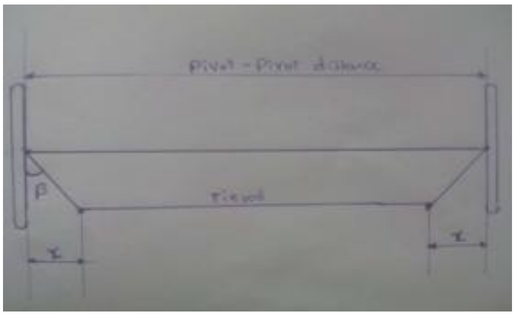

Fig 5: The procedure for calculation of tierod length

GRAPHS:

The graph between inner, outer and ackermann angle is as shown in Fig. 6. This error graph describes the procedure of proper mountings of steering arms for the clamps to get perfect steering condition for the vehicle.

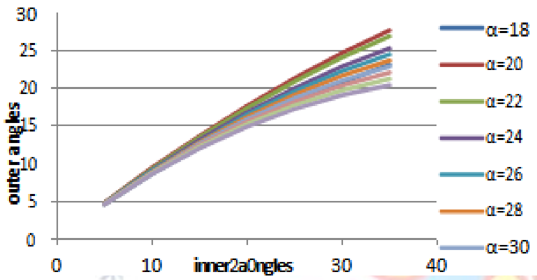

Fig 6: The graph showing design error against various ackermann angles

CALCULATION FOR CRITICAL VELOCITY:

Formula for critical velocity is given by

$V=(fRg)^{1/2}$

Where,

f = coefficient of friction

R = Turning radius of vehicle while Turning

g = Acceleration due to gravity let us consider R=2.3metres

$v = (o.6x2.3x9.81)^{1/2}$

=3.6m/s

DESIGN AND ANALYSIS OF STEERING ARM:

Designing of Steering Arm

Design of steering arm has been done in Fusion 360 software and is shown in Fig. 7 and Fig. 8. Fig. 7 shows the 2D solid model of steering arm where as Fig. 8 shows the front view of steering arm.

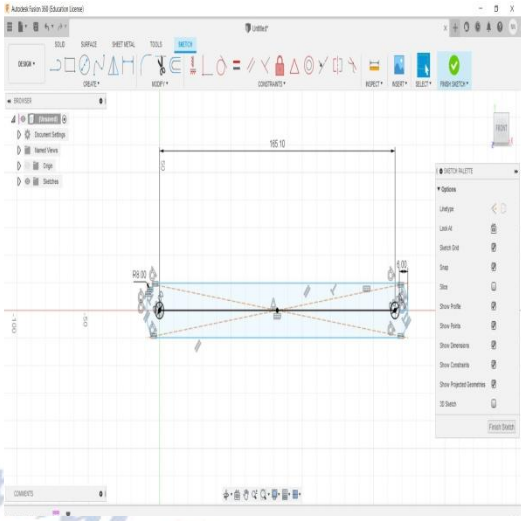

Fig 7: 2D Solid model of steering arm

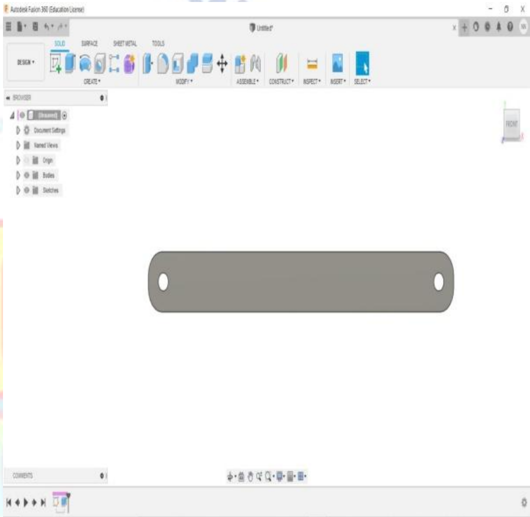

Fig 8: Front View of the Steering Arm

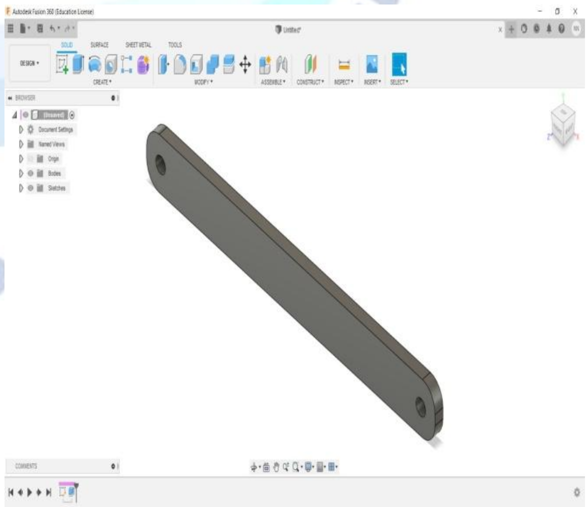

Fig 4: Isometric View of the steering arm

Analysis of steering arm

Ansys Inc. is an American company based most important analysis tool design for any type of structural material and is established by Canonsburg, Pennsylvania. It develops and markets multiphysics engineering simulation software for product design, testing and operation and offers its products and services to customers worldwide. Ansys was founded in 1970 by John Swanson. Swanson sold his interest in the company to venture capitalists in 1993. Ansys went public on NASDAQ in 1996. In the 2000s, Ansys acquired numerous other engineering design companies, obtaining additional technology for fluid dynamics, electronics design, and other physics analysis.The input parameters for analyzing of steering arm as meshing, boundry conditions, and loading conditions for steering arm has been applied and as shown in Fig. (9), (10) and (11) respectively.

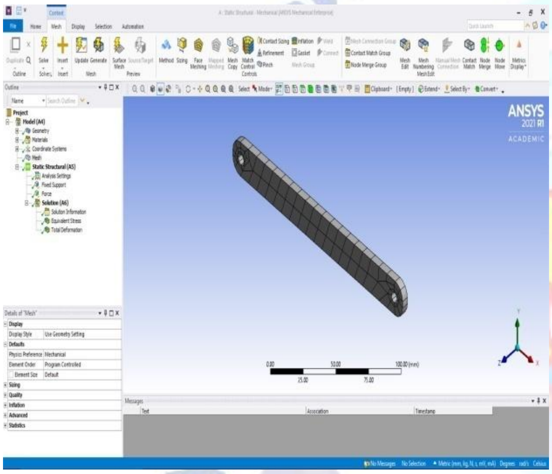

Fig 9: Meshing the Steering Arm

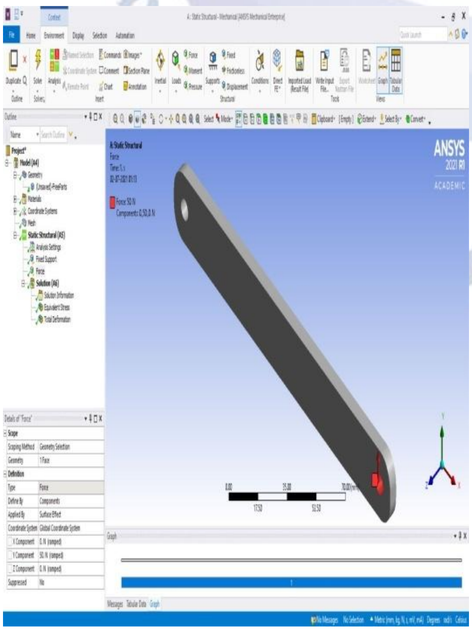

Fig 10: Applying force

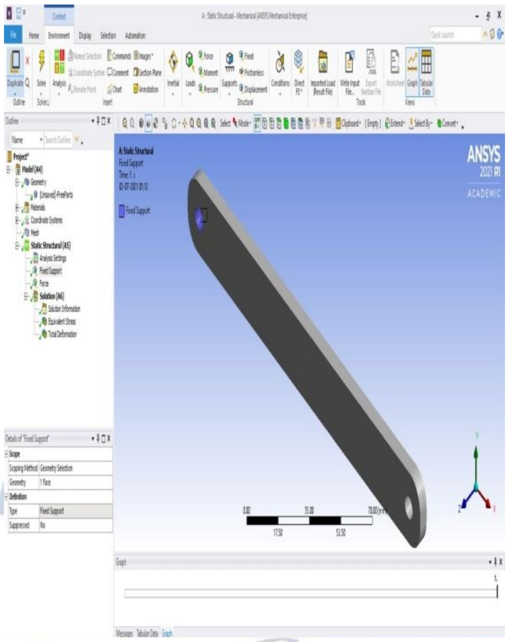

Fig 11: Applying Fixed Position

SIMULATION RESULTS

The simulation results for analysis of steering arm with two different materials structural steel and the aluminum is considered as the output of results and has been shown in Fig. (12), (13), (14) and Fig. (15). The Fig. 12 shows the Stress distribution Results of Structural Steel, Fig. 13 shows the total deformation result of structural steel, Fig. 14 shows the stress distribution results of grey cast iron, and Fig. 15 shows the total deformation result of grey cast iron.

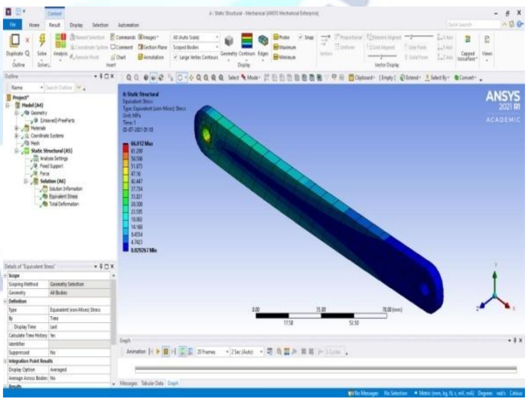

Fig 12: Stress Results of Structural Steel

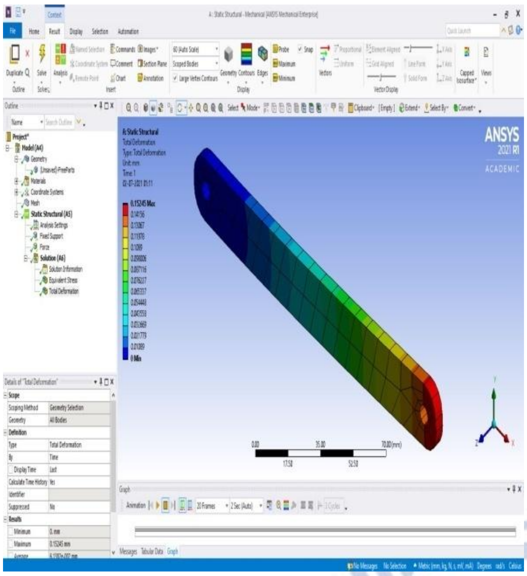

Fig 13: Deformation Result of Structural Steel

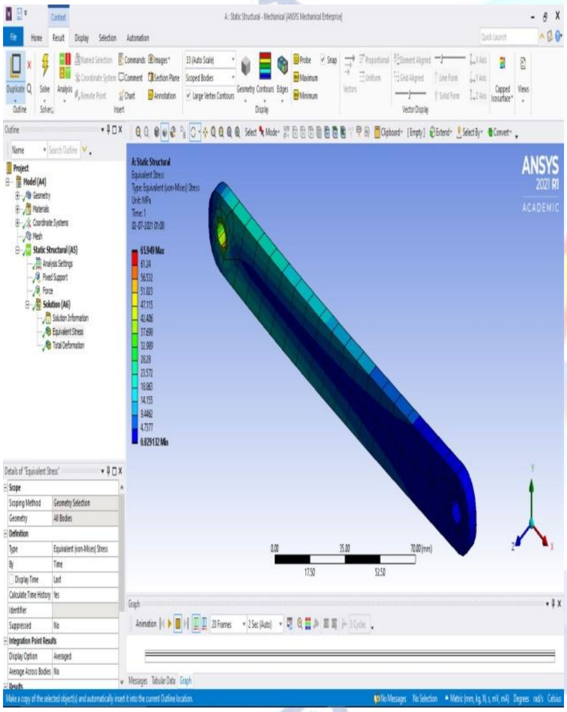

Fig 14: Stress Results of Grey Cast Iron

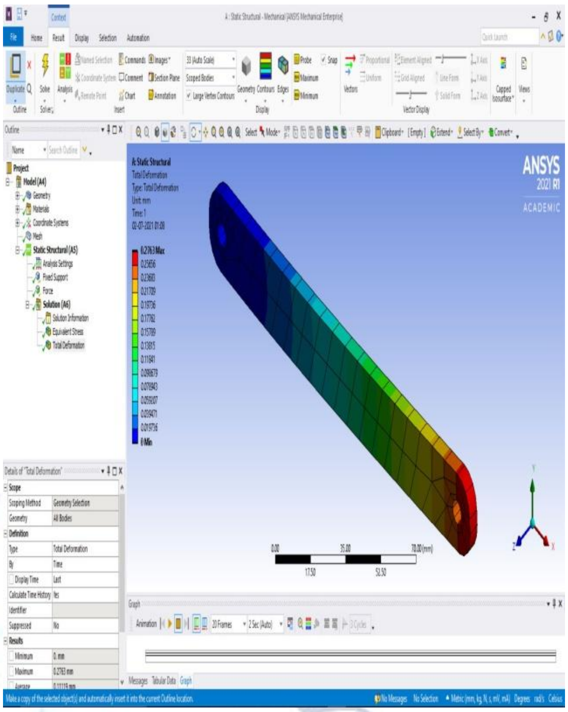

Fig 15: Deformation Result of Grey Cast Iron

CONCLUSION

A vehicle featuring low cost and user-friendly steering mechanism has been introduced. This focused on a steering mechanism which offers feasible solutions to a number of current maneuvering limitations. By this calculation we observed that at an angle of 30 degree with arm length giving minimum error. This prototype was found to be able to be maneuvered very easily in tight spaces, also making 360° steering possible. The prototype was tested to ensure the conformity with same. The steer forces required on each wheel was obtained and applied. The disadvantage associated with the current ackerman mechanism is due to turning pairs initially in the mechanism error exist. In conclusion, the performance of structural analysis of steering arm steering arm with two different materials such as structural steel and grey cast iron has been carried out. The results showed the structural steel is giving better results when compare to grey cast iron, where the deformation of structural steel is 0.15245 mm when compare to 0.2763 mm. Resulting stress is quite similar where the structural steel induces 66.012 and grey cast iron inducing 65.949.VBy observing the analysis results SS deforming less compare to grey cast iron.

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