IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 05-10

Design and Analysis of Zero Turning Radius Robotic Vehicle

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Abstract : *In this research work, design and analysis of zero turning radius robotic vehicle is presented. In this study various kinematic links are arranged to form the mechanism of vehicle. Electric motor is used for the required direction of vehicle in such a way that radius of rotation is equal to partial length of car. Vehicle rotates exactly at the same place without taking traditional circular turn. Designs of zero turning cars are useful in narrow roads where turning of cars are difficult. Static Analysis of chassis is done using FEA simulation. It is concluded that design of chassis is safe for 10 kg load.*

Keywords: *Kinematics Links, Prototype Design, Steering, Turning Radius, Worm and Worm Wheel*

I. Introduction

Primary function of the steering system is to attain angular motion of the front wheels to cope with a turn. It's done through linkage and steering gear which transfer the rotary motion of steering wheel in to angular motion of the front road vehicles. Secondary functions of the steering system are to cater directional stability of the vehicle when going straight and perfect steering condition i.e. perfect rolling motion of the road wheels at all times to minimize tire wear. In traditional two wheel steering mechanism, steering is only connected to front two wheels. Hence, only front two wheels are steered and rear wheels will only spin axially. In present condition, many new vehicles including trucks, trailers, cars have adopted four wheel steering mechanism. In most four-wheel steering systems, computer and actuators are used to steer the rear wheels. The rear wheels cannot turn as far as the front wheels. Systems like Delphi's Quadra steer and the system in Honda's Prelude line allocate for the rear wheels to be steered in the opposite direction as the front wheels at minimal speeds. This grants the vehicle to steer in a smaller radius which can be critical for large trucks and vehicles with trailers.

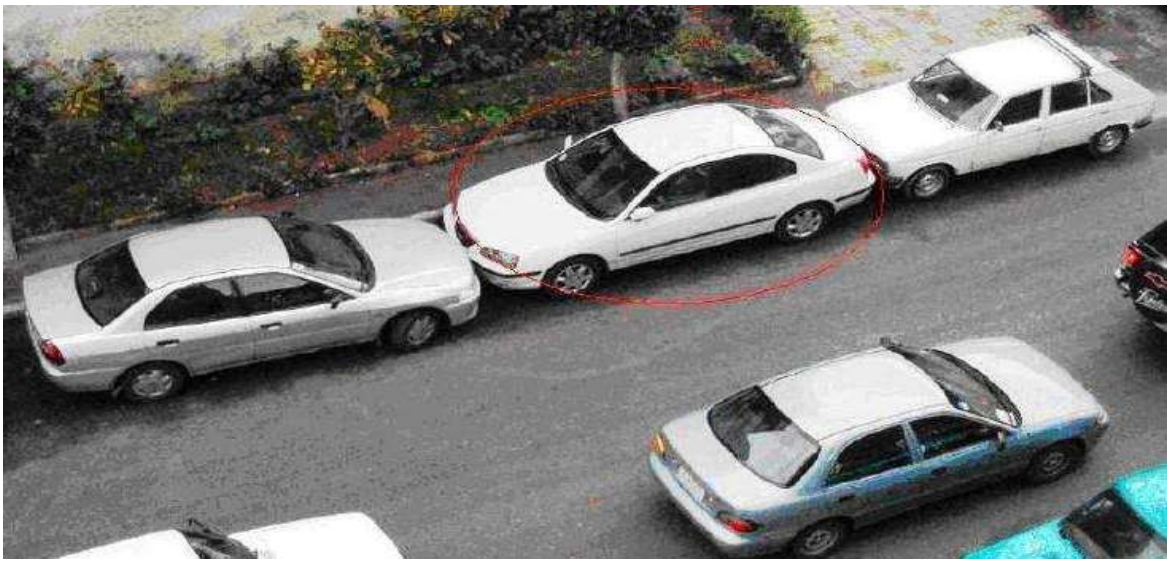

Fig.1 Parking Problem [1]

1.1 ZERO TURNING RADIUS VEHICLES

Fig. 2 JCB Excavator [11]

Zero turning radius of a vehicle means the vehicle rotating about an axis going through the centre of gravity of vehicle instead of describing a circular path. Due to zero turning radius vehicle takes the path equal to length of vehicle. So vehicle turns easily. The concept of zero turning vehicles exists in heavy JCB Excavator.

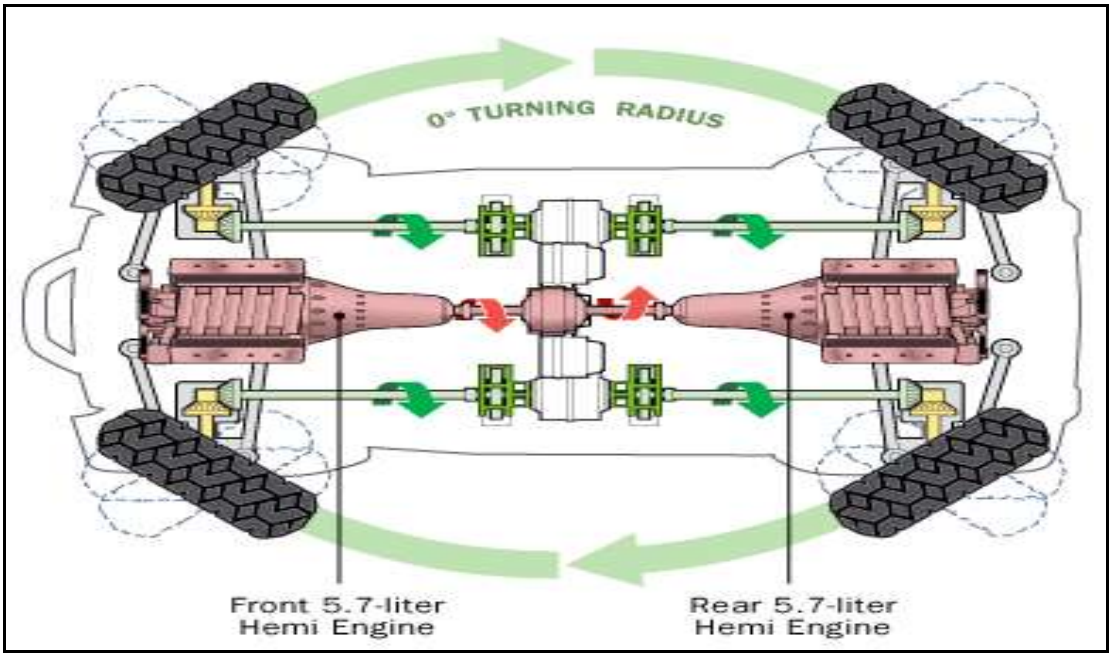

Fig. 3 Zero turning radius mechanism for jeep mechanism [12]

In Fig.3. Zero turning radiuses for jeep mechanism is shown. The vehicle consists of two turning mode. One is traditional turning and another is zero turning modes.

II. Design And Modeling

2.1 PROTOTYPE DESIGN

Each wheel of the vehicle is powered using 12 VOLT DC motors. The motors are controlled using double pole double throw (DP/DT) switches where as the point to point control is achieved using push buttons.

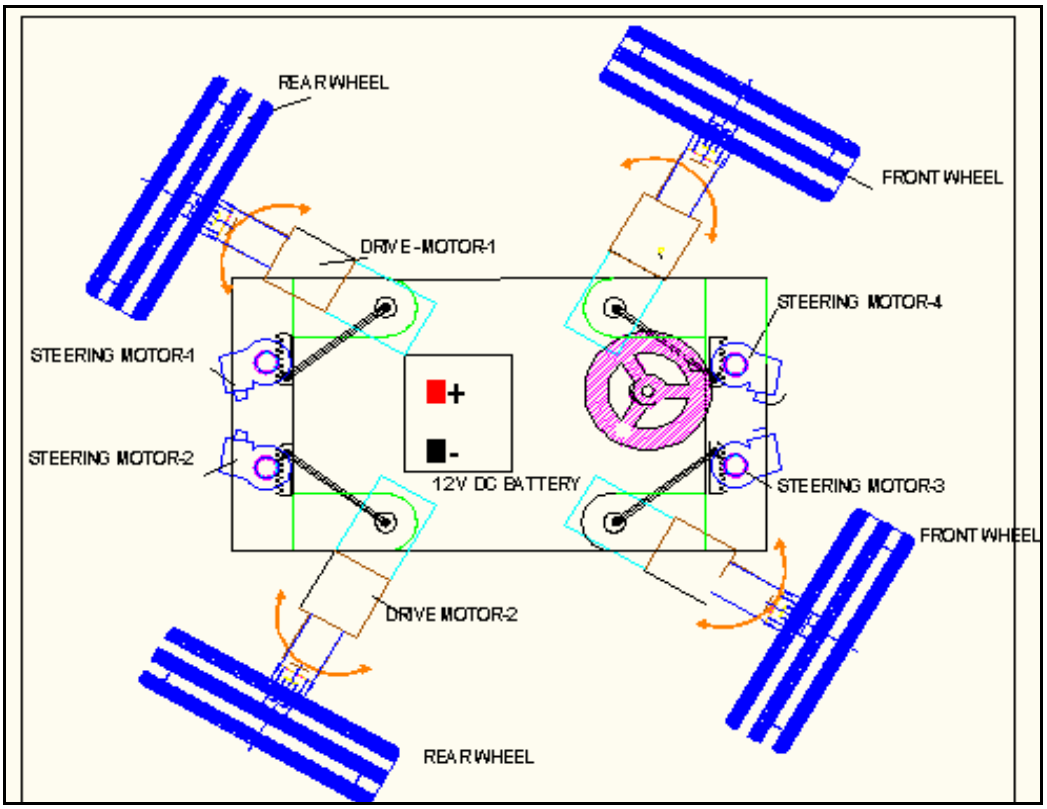

Fig.4. Prototype design

2.2 SIMULATION OF CHASSIS

The simulation is based on the condition of the robotic vehicle being stationary. The chassis was treated as simply supported beam and the loads were applied to the beam. For analysis it is considered that loads applied on chassis are supported on the four supports provided on the chassis as shown in Fig. 4. The weight of components which are supported by chassis is considered as point load. Total load of components supported by chassis is 10 kg.

Software used for static analysis of chassis is ANSYS 14.0. ANSYS mechanical software is a FEA (finite element analysis) tool for structural analysis. This engineering simulation product gives a set of elements behaviour, material models and equation solvers for a varied range of mechanical design problems. The model of geometry of chassis was created in PRO-E.

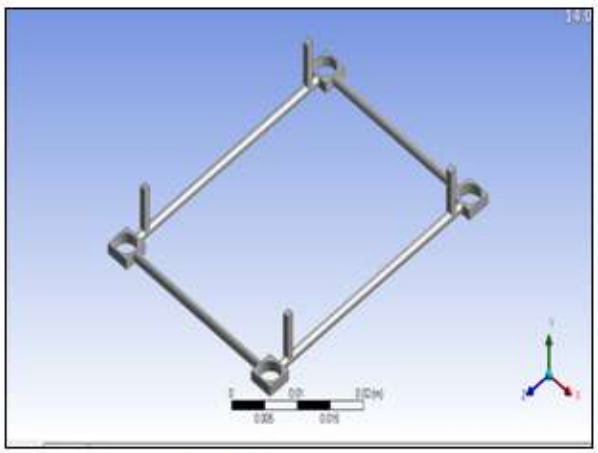

Fig 5 Model of chassis

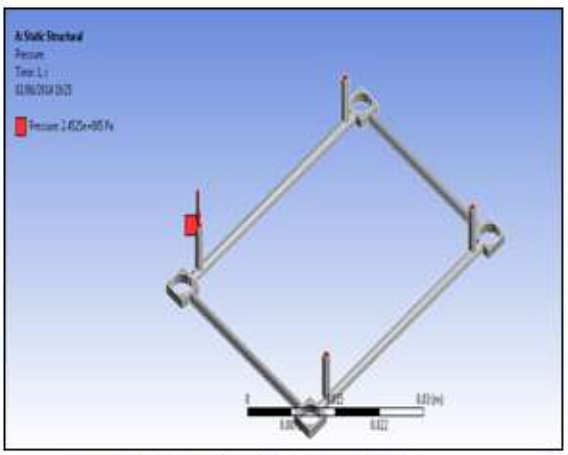

Fig 6 Applied pressure on support

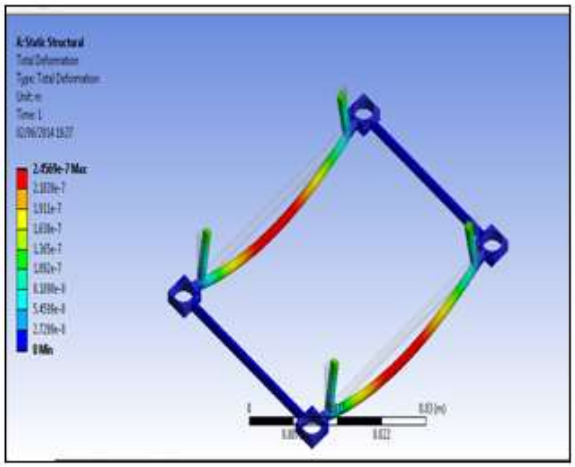

Fig 7 Total deformation of chassis

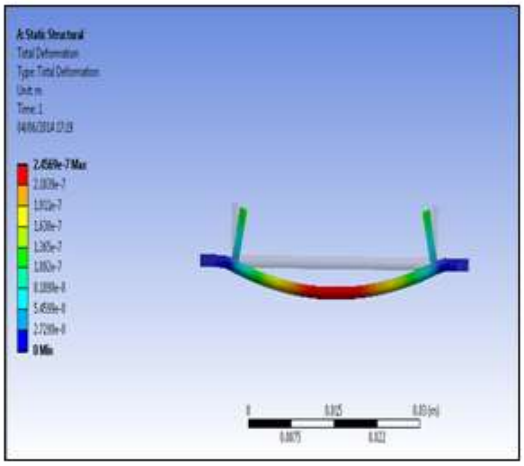

Fig 8 Front view of chassis for deformation

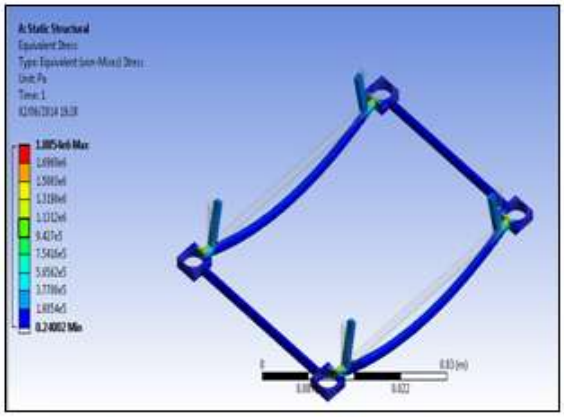

Fig 9 Equivalent (von-mises) stress induced in chassis

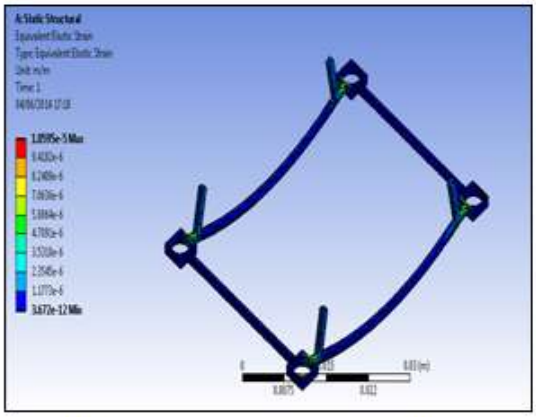

Fig 10 Front view of chassis for deformation

III. Working Of Circuit

3.1 MICROCONTROLLER CIRCUIT FOR STEERING

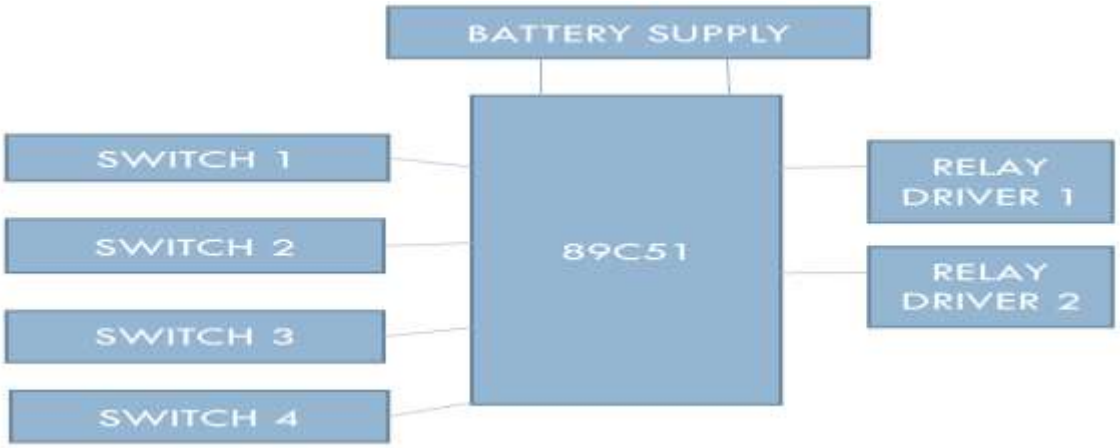

Fig 11. Block diagram of electronic circuit

In this device 89C51 microcontroller is used. This 8 –bit 4 Kbytes microcontroller is provided with four input switches that is switch 1, switch 2, switch 3 and switch 4 and 2 output relays named relay driver 1 and relay driver 2.

3.2 WORKING PROCEDURE

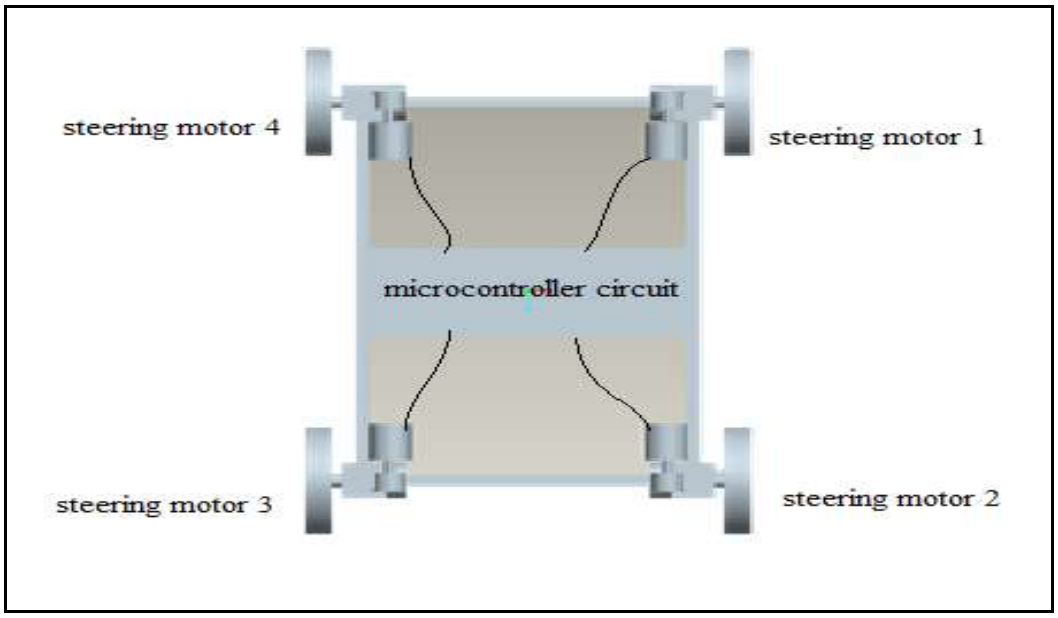

Fig. 12. Prototype

Steering of the vehicle is controlled by using a microcontroller circuit. Two relays are used along with the micro controller to steer the wheels of the vehicle to the required angle. Steering motor-1 and steering motor-3 are connected to relay-1 and steering motor-2 and steering motor -4 are connected to relay-2. Relays are used for switching operation. Relays are used where it is necessary to control a circuit by low power signal or where several circuits must be controlled by one signal. They are also used to perform logical operations in computers.

When switch-1 is pressed, relay-1 gets activated which in turn rotates steering motor-1 and steering motor-3 in clockwise direction. When switch-2 is pressed, it operates relay-1 to rotate steering motor-1 and steering motor-3 in anti-clockwise direction. When switch-3 is pressed, relay-2 gets activated which in turn rotates steering motor-2 and steering motor-4 in clockwise direction. When switch-4 is pressed, it operates relay-2 to rotate steering motor-2 and steering motor-4 in anti-clockwise direction.

IV. Conclusion

After over all analysis it is concluded that design is safe for 10 kg loads. Zero turning radius vehicles have lots of advantages such as effective parking at narrow space, easy removal of cars from jam. The system can be design using hydraulic system which provides rapid response with shorter distance. In table 1 Deformation and various stress values are shown.

Table 1 Properties evaluated

PROPERTIES	MAXIMUM VALUE	MINIMUM VALUE
DEFORMATION	2.4569e-007 m	0 m
EQUIVALENT (VON-MISES) STRESSES	1.8854e+006 Pa	0.24002 Pa
EQUIVALENT ELASTIC STRAIN	1.0595e-005 m/m	3.672e-012 m/m
MAXIMUM SHEAR STRESS	9.9963e+005 Pa	0.12493 Pa

Maximum equivalent stress induced in chassis = 1.8854 MPa
Allowable tensile stresses for chassis material = S_{yt} / F.O.S.
Take F.O.S. = 2
σ_{all} = 250 / 2 = 125 N/mm^2
Since $\sigma_{all} > \sigma_{max}$.
Therefore design of chassis is safe for 10 kg load.

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