Selection, Modification And Analysis of Steering Mechanism For An All Terrain Vehicle

Chetan Dhuri, Aditya Masur, Aniket Warang & Aditya sudhir

Guided by Aqleem Siddiqui & Nitin Gurav
Department Of Mechanical Engineering,
Fr. C. Rodrigues Institute Of Technology, Vashi

Abstract **– This project aims at studying the designing of the steering system of an ATV (All Terrain Vehicle). The steering system is the most vital element in any automobile. It helps the driver in obtaining complete control on the manoeuvring 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. The steering system is in direct contact with the tyres hence it is subjected to extensive forces. Hence it is imperative that the design is tested for failure under such conditions. In this project we have modified the steering system implemented in Maruti Suzuki Esteem to meet our design requirements. We have successfully tested our steering mechanism in the ATV (All Terrain Vehicle) fabricated in the workshop by obtaining values from the various calculations we performed..**

I. INTRODUCTION

Mechanical Engineering is one of the broadest disciplines in engineering which overlaps many other disciplines. It provides a choice of innumerable field of interest and development for a student. Automobile Design was a common interest of the members of the project team.

Our interest led us to become members of the automotive society, SAEINDIA Collegiate Club of our college, through which we were introduced to the event BAJA SAEINDIA.

BAJA SAEINDIA is a competition involving teams from all over the country wherein each team has a goal to design and build a rugged single seat, off-road recreational four-wheel vehicle intended for sale to a non-professional, weekend off-road enthusiast.

The design analysis and fabrication of the various systems in the All Terrain Vehicle (ATV) was divided amongst the 4 groups consisting of 4 members each. Our project is the Steering System of an All Terrain Vehicle (ATV).

II. AIM AND OBJECTIVE

Study and analysis of a modified steering system according to the constraints provided by the RULEBOOK OF BAJA SAEINDIA 2013 to be used in single seat All-Terrain Vehicle.

III. PROBLEM DEFINITION

After considering all the advantages and disadvantages of the types of steering systems it was found that the rack and pinion steering system is suited to be implemented in an all-terrain vehicle. However manufacturing of the entire system would have been very costly and difficult.

Therefore it was decided that a standard steering system available in the market would be modified to meet the required constraints.

Since all standard steering systems available are right hand drive the actual problem definition of our project is ***to convert the standard right hand drive steering system into centrally aligned steering system***. The standard steering system chosen was **Maruti Suzuki Esteem**.

Following are the specifications.

- Right hand drive.
- Dimensions –
  - Tie rod – 10 inches
  - Rack arm - 25.5 inches
  - Steering ratio – 2.5

IV. SCOPE

In this project the conditions satisfying true rolling will be calculated from Ackermann steering law. Then the calculated values would be used to design the rack rod. The modified rack would be tested on software (Inventor/Ansys) for various modes of failure. Changes in the design would be made according to the test results. The rack housing would be modified accordingly. The length of the steering column will be varied according to the roll-cage dimensions. Mounting points for steering system on the roll-cage would be designed.

Finally the steering system would be mounted on to the vehicle.

V. DESIGN METHODOLOGY

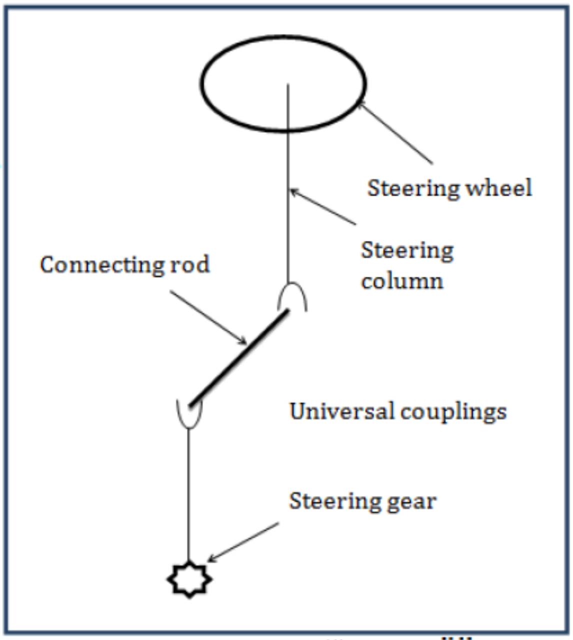

Fig. 1 steering linkage [1]

There are two ways in which the right hand drive could be converted into a central drive either by modifying the length of the steering column or by modifying the length of the rack rod as showing in Fig. 1.

An average man can turn a simple steering wheel with an average force of 300N with an average 18 rpm. Therefore,

$$P = \frac{2\pi NT}{60}$$

$$P = \frac{2\times\pi\times18\times(300\times0.015)}{60}$$

$$P = 8.84 \text{ watts}$$

Efficiency of coupling is assumed to be 90%

Therefore,

Power to connecting rod= 7.63 watts

Now,

$$P = \frac{2\pi\times18\times T}{60}$$

$$T = 4.05 \text{ N-m}$$

Checking for standard dimensions,

We know,

$$T = \frac{\pi}{16}\times d^3 \times (\zeta)$$

$$4.05\times10^3 = \frac{\pi}{16}\times 15^3 \times (\zeta)$$

$$\mathbf{(\zeta)=6.11 N/mm^2}$$

$$\mathbf{(\zeta) < [\zeta] = 87.5 N/mm^2}$$

Therefore, the design is safe.

Now to finding permissible angular deflection

Consider the shaft in twisting,

$$\frac{T}{J} = \frac{G\theta}{L}$$

$$\frac{4.05\times10^3}{\frac{\pi}{32}\times d^3} = \frac{2.15\times\in5\times\theta}{150}$$

This shows that the connecting rod is now designed to deflect in angular direction.

Now, if we increase the length of connecting rod, we will have to simultaneously increase the diameter or the modulus of rigidity to keep the angular deflection zero.

But it is not possible to vary either of the two parameters as the connecting rod is a critical member in the geometric assembly of the system.

So we prefer to modify the rack arm, which is fairly simple.

5.1 ACKERMANN'S LAW OF CORRECT STEERING

The law states that to achieve true rolling for a four wheeled vehicle moving on a curved path, the lines drawn

perpendicular to the four wheels must be concurrent.

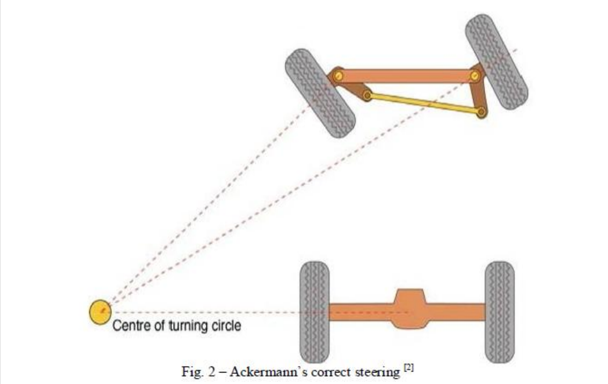

Fig. 2 – Ackermann's correct steering [2]

However in Ackermann steering mechanism this condition is not achieved for all angular positions of the wheel. This condition is met only for a single angle of turn.

The length of the teeth on the rack = 6.5 inch Initially, when the steering position is neutral the pinion is in the center of the rack teeth. That means it can move 3.25 inch on either side.

Taking Maximum angle of turn = 45^o
Obtaining correct steering using the formula

$\cot \varphi - \cot \theta = c / b$

Where,

c = 35inch
b = 72inch
$\theta = 45^o$

'φ' was found out to be **33.946^o**

Using geometry the length of the rack rod was found out the required length of the rack rod is **14.30 inches**

Turning radius = 2273.3 mm

Fig..3 – Correct steering condition [3]

5.2 CONVERSION TO ADJUSTABLE STEERING

To make the steering system easy to handle the inclination of the steering column should be made adjustable.

Keeping in mind the comfort of the driver a mechanism has been devised to rotate the steering column for a range of angular position in the longitudinal plane with respect to entire vehicle.

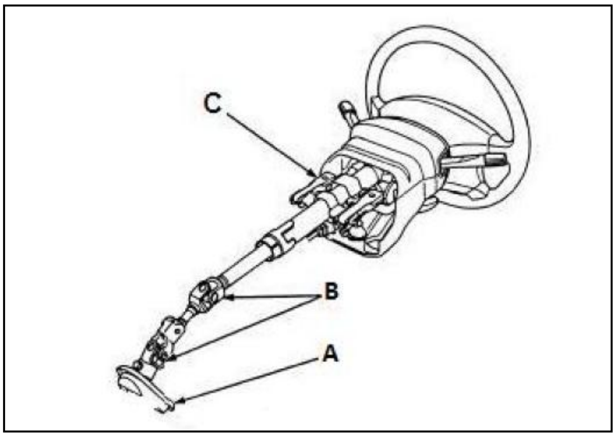

Fig. 4 – layout of steering column [4]

The above figure depicts the steering column. To make the steering column adjustable the bottom end of the steering column will be hinged to the roll cage. The adjustment latch will be mounted in the dash board as per requirement. A plate with holed arranged racially will be welded to the steering column.

A. Attachment to steering rack

B. Universal joints (hinge point)

C. Adjustment latching.

5.3 DESIGN OF LATCHING MECHANISM

Calculation of plunger diameter:

Material is Mild steel
Load on the plunger = 200N
Tensile strength = 130N/mm²
Shear strength = 65N/mm²
Factor of safety = 2
New shear stress = 32.5N/mm²
Single shear is taking place.

$$\tau = \frac{P}{A}$$

$$32.5 = \frac{200}{\frac{\pi}{4}d^2}$$

d = 2.97 mm

d= 9 mm(for consideration of shocks on the plunger during vehicle operation)

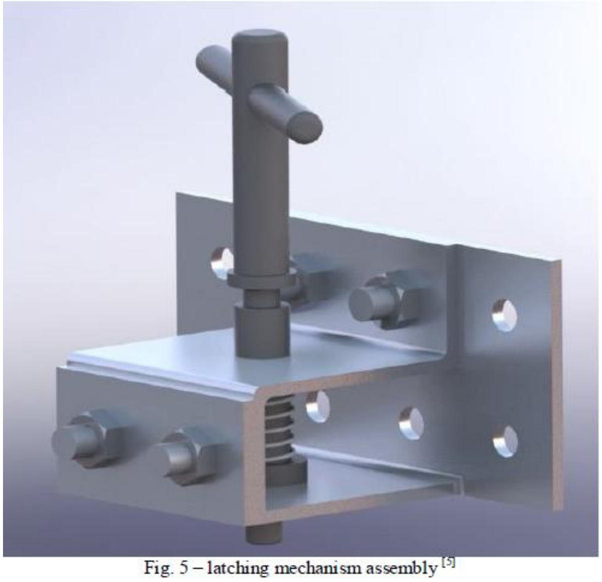

Fig. 5 – latching mechanism assembly [5]

VI. EXPERIMENTAL ANALYSIS AND FABRICATION OF STEERING SYSTEM FOR AN ATV

6.1 ANALYSIS OF CRITICAL COMPONENTS

All steering rack forces are calculated from the front wheels. Due to suspension geometry, the car will always want to 'unsteer' as it moves through a corner. This is known as restoring moment and it acts directly on the front tires. The restoring moment creates stress throughout the steering system and ultimately determines the input force required by the driver. Steady state turning conditions were analyzed in the experiment.

Several assumptions were made to simplify the calculations and appropriate factor of safety were applied.

Assumptions:

- All forces are distributed evenly: Under steady turning conditions, normal and lateral loads will be distributed among front and rear wheels equally.
- Ackerman effects are negligible: Because the front tires follow different radii throughout a turn, the inside wheel must turn farther.

6.2 MATERIAL SELECTION

The materials used in the steering system target precise operation and light weight components. Although precision and weight are the top priorities, cost, manufacturability, and reliability were also considered.

Precision in the steering system is derived from high manufacturing tolerances and minimal deflection.

Defection in any component leads to steer compliance, resulting in an unresponsive steering system.

The pinion, rack rod, and the steering column assembly were purchased. The material used for the manufacturing of the components is Mild Steel.

6.3 FEA ANALYSIS

Finite Element Analysis was performed on many of the critical components in the modified steering system. This analysis was performed in Solidworks 2011 package. This software package is a very basic solver that automatically applies a 3D tetrahedral mesh to the part. Apart from the mesh only few parameters are required by the software as input for the analysis. Material properties were found out on www.matweb.com. The deflection characteristics were analyzed for each component under maximum expected loading conditions. The analysis for different components is shown below

Rack Rod:

Fig.6 Rack Rod [6]

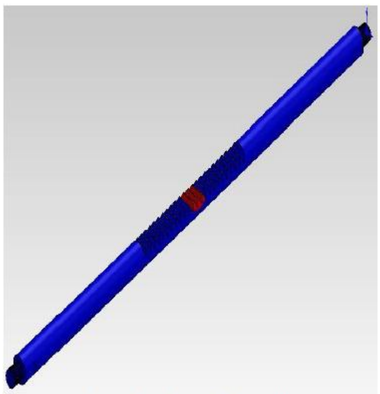

Fig. 7 Rack Rod FOS Result [7]

Force applied-200N

Pinion:

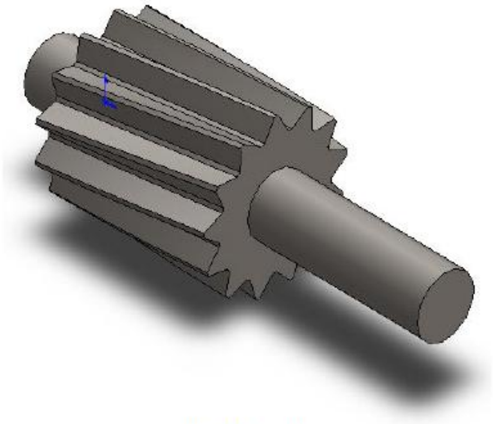

Fig.8 Pinion [8]

Force applied -200N

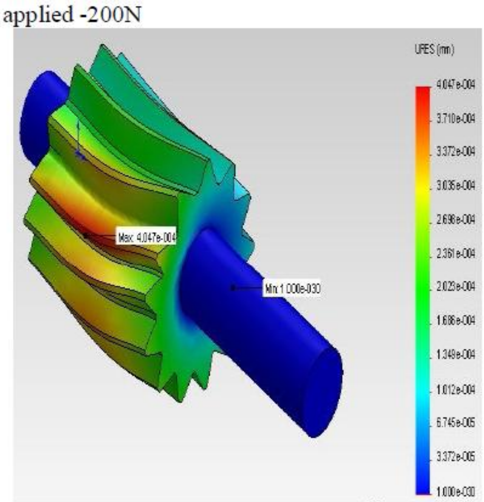

Fig.9 Pinion Deformation Result [9]

VII. CONCLUSION

The design and manufacturing of the system was completed as per requirement and is currently under testing.

VIII. ACKNOWLEDGMENT

We, the members of the group working on “SELECTION, MODIFICATION AND ANALYSIS OF STEERING MECHANISM FOR AN ALL TERRAIN VEHICLE”, would like to take this opportunity to thank all those who have sincerely and whole heartedly lend their support and contributed in our project. We express our gratitude and thankfulness to our professors for their valuable timely guidance and wholehearted co-operation in preparing this project.

We are also very much thankful to our project guide Mr. Nitin Gurav (Assistant Professor, Mechanical Engineering Department) and Mr. Aqleem Siddiqui

(Assistant Professor, Mechanical Engineering Department) for their inspiring guidance with helpful suggestions for our project whenever we approached them.

We are greatly obliged to the staff of Mechanical Engineering department and would like to extend our appreciation and gratitude to Prof. S.M.Khot (Head of Mechanical Engineering Department) and Dr. Rollin Fernandes (Principal, Fr.CRIT, Vashi) who helped us gain valuable insight into the topic Last but not the least; we would like to thank all those people who directly or indirectly contributed to our project.

IX. REFERENCES

[1] **Weblink:**http://www.google.co.in/search?q=steering+system+components+line+diagram

[2] **Weblink:**http://en.wikipedia.org/wiki/Ackermann_steering_geometry

[3] Prepared in PRO-E software.

[4] **Weblink:**http://en.wikipedia.org/wiki/column_steering_geometry

[5] Prepared in PRO-E software.

[6] Prepared in PRO-E software.

[7] Prepared in PRO-E software.

[8] Prepared in PRO-E software.

[9] Prepared in PRO-E software.

◈◈◈