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FINITE ELEMEMNT ANALYSIS OF PITMAN ARM

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***Abstract*— Steering system control the front wheels movement in response to driver inputs in order to provide overall directional control of the vehicle. Thus, Steering system plays key role in vehicle handling characteristics. Pitman arm plays a vital role in steering system as it transmits the steering movement to the wheel. The Pitman arm is a linkage attached to the sector shaft of the steering box and track rod, that converts the angular motion of the sector shaft into the linear motion needed to steer the wheels.**

The Pitman arm is supported by the sector shaft and supports the drag link or center link with a ball joint. It transmits the motion it receives from the steering box into the drag (or center) link, causing it to move left or right to turn the wheels in the appropriate direction. Performance study is carried out followed by static structural analysis of the pitman arm under steering load done by numerical method and there by check the stress values comparison to prove the boundary conditions, and verified the FEA with hand calculation and proved the feasibility for topology optimization of the pitman arm by comparison of FEA stress value with yield strength of the material.

***Index Terms*— Linkage; Pitman arm; Steering System; Structural analysis;**

I. INTRODUCTION

The pitman arm is also called steering arm, it is a linkage which is attached at one side to the steering box (through sector shaft) at the bottom of the steering wheel shaft and on the other side to the track rod which is attached at the other end to the idler arm. When the steering wheel is turned left or right, a worm gear at the bottom of the steering shaft turns a set of teeth. That action moves a gear that activates the pitman arm, causing the steering linkage to move the wheels. The steering arm is part of an older recirculating ball steering system which is still used primarily in some full-size SUVs and trucks as compared with the smoother-handling rack and pinion steering mechanism more commonly used in automobiles.

A properly functioning pitman arm, 1) precisely directs the movement of all the other steering links, 2) limits wheel wobble on bumpy surfaces, 3) assures full wheel turning radius and 4) helps to reduce steering wheel vibration.

II. OBJECTIVES OF THE WORK

1. To study and perform static analysis on pitman arm under steering load.
2. To propose an optimized model which will have better or same performance and reduced weight.

III. SCOPE OF THE WORK

1. Numerical analysis: Static analysis and topology optimization is performed on the existing pitman arm model using FEA tools.
2. Theoretical verification: Verifying the FEA analysis using hand calculation.

IV. MODELLING AND ANALYTICAL TOOLS USED

1. 3D Modelling of the pitman arm is made using Creo Parametric 2.0.
2. Finite element analysis is performed using Hypermesh 12.0 and Optistruct tools.

V.PITMANARM ASSEMBLY

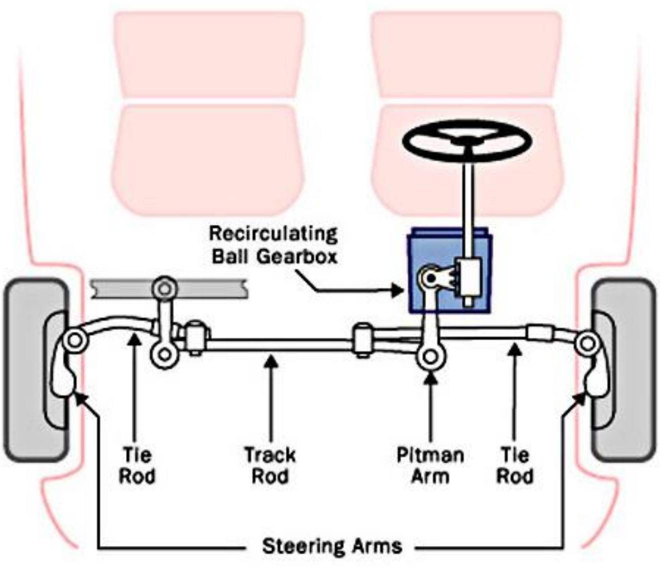

Fig.1. Steering Linkage Components [2]

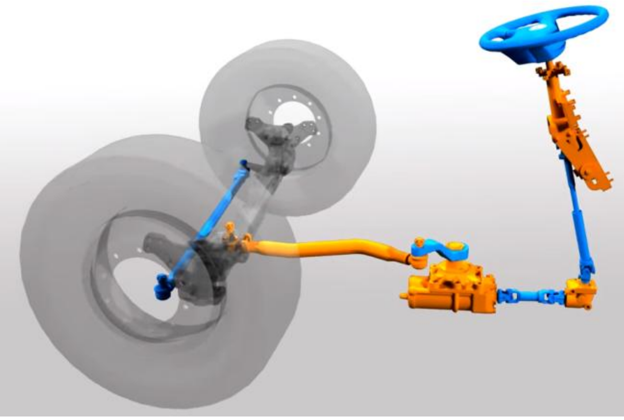

Fig.2. Pitman arm vehicle assembly

VI. COMMON MATERIAL USED FOR PITMANARM

1. Alloy steel
2. Iron
3. Carbon steels

VII. ADVANTAGES OF PITMANARM

1. Higher turning Ratio
2. Less Sensitive to errors in assembly
3. Simple in Design
4. Provides mechanical advantage to the driver
5. Pitman arm combined with power steering mechanism could be better than a rack and pinion mechanism

VIII.INTENDED APPLICATION

1. Passenger Car Steering
2. Truck Steering
3. Heavy Duty Equipment
4. Recreational Vehicles

Fig.3. Pitman Arm side View

IX. FEM ANALYSIS OF PITMAN ARM

Finite element analysis is a computational technique used to obtain approximate solutions of boundary value problems in engineering.
These are the steps for pre and post processing in FEM

1. Define the geometry of the problem.
2. Discretize the model by meshing.
3. Define the element type(s) to be used.
4. Define the material properties of the elements.
5. Define the element connectivity.
6. Define the physical constraints (boundary conditions).
7. Define the loadings.
8. Solve the analytical problem.
9. Result evaluation.

Element Type- Hexahedron & Wedge (Prism)
Element Order- First Order (Linear)
Node Population Count- 23887.
Element population count- 19750.

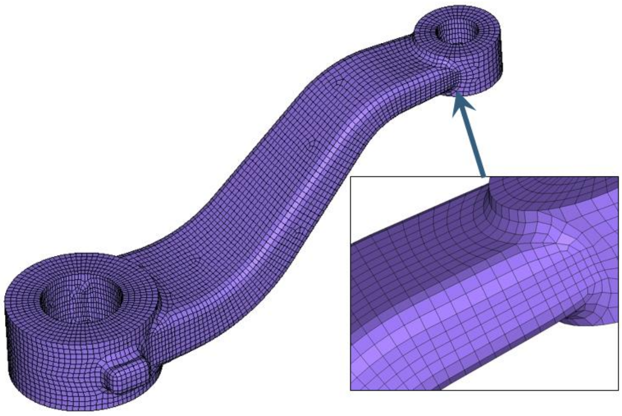

Fig.4. Meshing

X.MATERIAL PROPERTIES

Material used for Pitman Arm is Alloy Steel – 4140, and manufactured by forging

TABLE 1
MATERIAL PROPERTIES

Density of Material	7.85e-6 kg/mm^3
Modulus of Elasticity	210 GPa
Poisons Ratio	0.3
Yield Strength	520MPa

XI. BOUNDARY CONDITION AND LOADING

Total Mass of the vehicle, M1= 1640+680+200 = 2520kg
Mass on the front axle, M2=1008kg
Mass on one of the front wheel, M= 504kg
Width of tire, B= 215mm
Center of rotation (king pin) to wheel, E= 120mm
Co-efficient of friction, μ= 0.7
Distance from king pin center to tie rod center, L1= 145mm.

$T=M*g*\mu*\sqrt{((B^2/8) + E^2)}$
T=Torque required to rotate one wheel (torque at king pin),
T= 491629.6N,
F = T/L1 = 3390.5 N,
Since single steering arm will be handling two wheels so force on steering arm will be doubled
F= 6781 N,
F= Force on steering arm.
Maximum Bending Moment (M) calculation:
Thickness t = 15mm
Width b= 35mm

Length L = 120mm
I= Moment of Inertia

$I = (t*b^3) / 12$
$I = 53.59e3\ mm^4$
M =F * L
=6781*120
=813720 N-mm
$M/I = \sigma/y$
Maximum Bending Stress σ = 258 MPa

The hole which is connected to sector shaft of steering box is fully constrained. Load=6781N is applied (from the side) at the other end of the pitman arm.

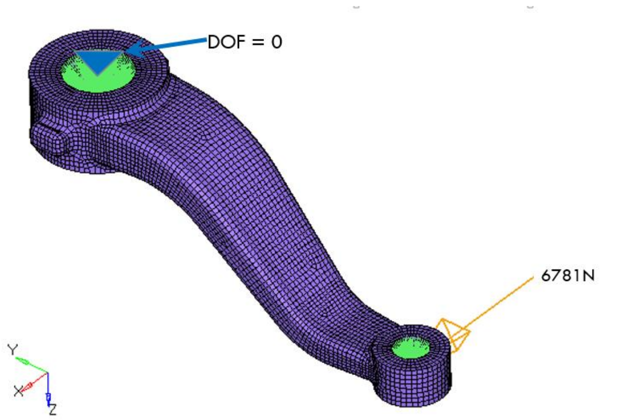

Fig.5. Boundary Condition and Loading

Von Mises stress observed from the FE analysis = 255 MPa which is very close to the calculated value (258MPa).

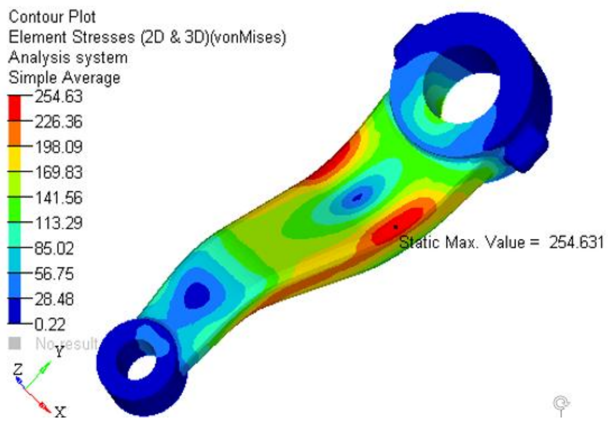

Fig.6.Von Mises Stress Plot

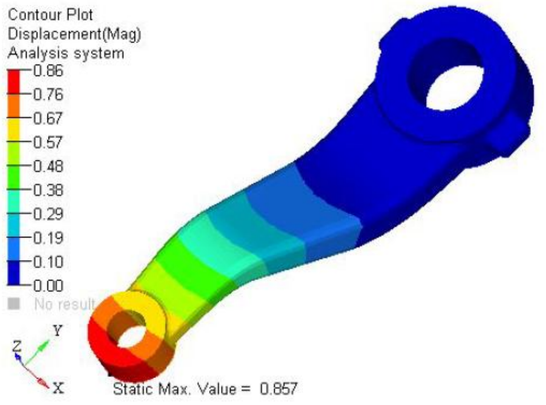

Fig.7.Maximum Deflection Plot

XII. CONCLUSIONS

Scope to optimization of the pitman arm proved based up on the Finite Element Analysis and below are the conclusions from the analysis:

1. Finite Element analysis result and calculated stress values are closely matching which shows that the boundary conditions and force calculations were right.
2. Also the static analysis result of the model 254.6 MPa was just half of the Yield strength of the material is 520MPa so it shows the scope for the topology optimization of the existing pitman arm.

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