Finite Element Analysis & Weight Optimization of Steering Idler Arm

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Abstract- *As we know the steering system control the front wheels movement in response to driver inputs in order to provide overall directional movement of the vehicle. Thus, Steering plays a key role in vehicle handling during running as well as static condition. Idler arm plays a crucial role in steering system as it transmits the steering movement to the road wheel. The Idler arm is a linkage connected to the tie rod, which transmits linear motion of the tie rods to the road wheels. If the linkage were not supported on the side of the Vehicle opposite the pitman arm, the linkage would flex instead of moving the wheel on that side. To prevent unwanted flexing, an idler arm is installed on the frame across from the pitman arm. One end of the idler arm is attached to the frame through a metal bushing, which allows the arm to turn. The other end of the idler arm is attached to the relay rod through a ball socket. Some large vans and pickup trucks have two idler arms. The idler arm will usually have grease fittings on both the ball socket and the bushing ends. Some vehicles have two idler arms.*

Performance exercise is carried out followed by static structural analysis of the idler arm under maximum 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 idler arm by comparison of FEA stress value with yield strength of the material.

***Keywords*-** Idler arm, Linkage, Steering System, Structural analysis

I. INTRODUCTION

The steering system components are a common source of driver complaints. Tire wear is almost completely dependent on the condition and adjustment of the steering components. In steering system if the linkage were not supported on the side of the vehicle opposite the pitman arm, the linkage would flex instead of moving the wheel on that side. To prevent unwanted flexing, an idler arm is installed on the frame across from the pitman arm. One end of the idler arm is attached to the frame through a metal bushing, which allows the arm to turn. The other end of the idler arm isattached to the relay rod through a ball socket

A properly functioning idler arm,

1) Precisely directs the movement of all the other steering links,
2) Limits wheel wobble on bumpy-irregular surfaces
3) Assures full wheel turning radius and
4) Helps to reduce steering wheel vibration.

Fig 1 shows an idler arm as it is installed on most vehicles. Some large vans, pickup trucks& tractors have two idler arms. The idler arm will usually have grease fittings on both the ball socket and the bushing ends. Some vehicles have two idler arms

II. LITERATURE SURVEY

Following studies have been carried out to understand Pitman arm function and load condition.

V.D.Thorat and S.P.Deshmukh[1] analyzed rigid multi body dynamic analysis approach in design and Results shows rigid dynamics approach for design reduces time for optimization, simulation and provide the chance to take most corrective action. Rigid body dynamics approach is used in modern design techniques for various domains

Girish Rane and K.M. Narkar[3] investigated the steering arm and pitman drag link ball joint affects these parameters and prove that the location of the steering arm ball joint affects vehicle directional stability in severe brake applications

Malge Sangeeta Ganesh, G. P. Patil B and N. A. Kharche[2] analyzed various structural analyses such as static-structural, modal Analysis of a steering rod are done. Static-structural analysis is capable to find out deformation in body in which Von-mises stress are calculated and this state that up to what extent the deformation in the rod occurs.

Cristina Elena Popa[6] investigated the current automotive steering and suspension systems followed by the review of Formula SAE-A restrictions and design requirements. A thorough analysis of 2004 USQ sports car has been included in order to establish the areas of design modifications followed by the actual design.

III. OBJECTIVES

1. To study and perform static analysis on idler arm under steering load in various operating condition.
2. To propose an optimized model idler arm this will have better or same performance and reduced mass.

IV. SCOPE OF THE WORK

1. Numerical analysis: Static analysis & topology optimization is performed on the tractoridler arm model using FEA tools.
2. Theoretical verification: Verified the FEA result analysis using hand calculation.

V. MODELLING AND ANALYTICAL TOOLS USED

1. CATIA V5 R20 for solid modeling of Idler Arm.
2. Ansys 18.0 for Finite element analysis is performed

VI. IDLER ARM ASSEMBLY

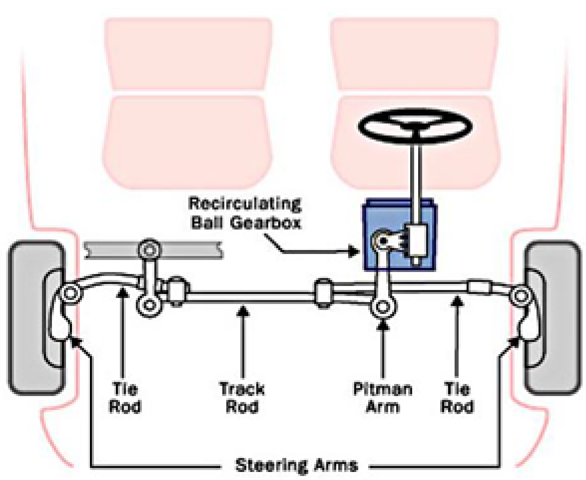


Fig.1. Steering Linkage Components [1]

VII. COMMON MATERIAL USED FOR IDLER ARM

1. Alloy steel
2. Iron
3. Carbon steels

VIII. ADVANTAGES OF IDLER ARM

1. Higher turning Ratio
2. Less Sensitive to errors in assembly
3. Simple in Design
4. Provides mechanical advantage to the driver

IX. APPLICATION OF IDLER ARM

1. Passenger Car Steering
2. Truck Steering
3. Heavy Duty vehcicles
4. Off-Road and constructional Vehicles

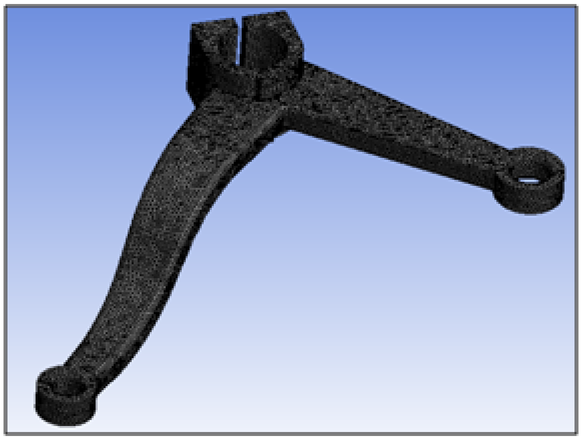
Fig.3. Idler Arm side View

X. FEM ANALYSIS OF IDLER 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- Tetrahedron, Element Order- Second Order (Linear) Node Population Count- 327819. Element population count- 225659.



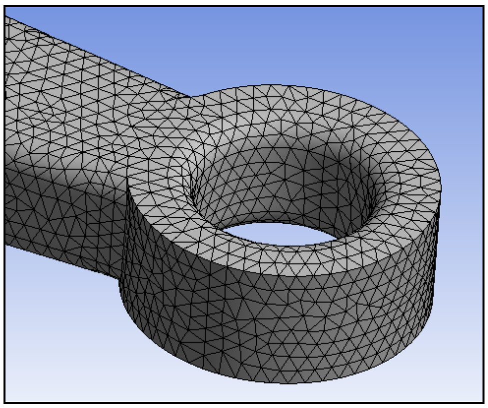


Fig.4. Meshing

XI. MATERIAL PROPERTIES

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

TABLE 1

Density of Material	7.85e-6 kg/mm3
Modulus of Elasticity	210 GPa
Poisons Ratio	0.3
Yield Strength	520MPa

XII. BOUNDARY CONDITION AND LOADING

Mass of the Tractor (m1) = 1500kg

Mass of Occupant (m2) = 100kg

Weight of the vehicle acting at its center of gravity

$$G = 9(m1+m2).g = 15696N$$

Load on front axle

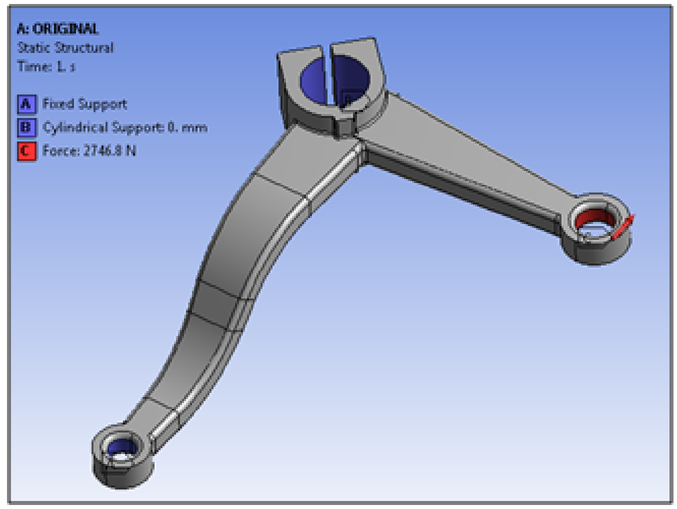
$$GFA = G/2 = 7848N$$

Load on Wheel of front axle

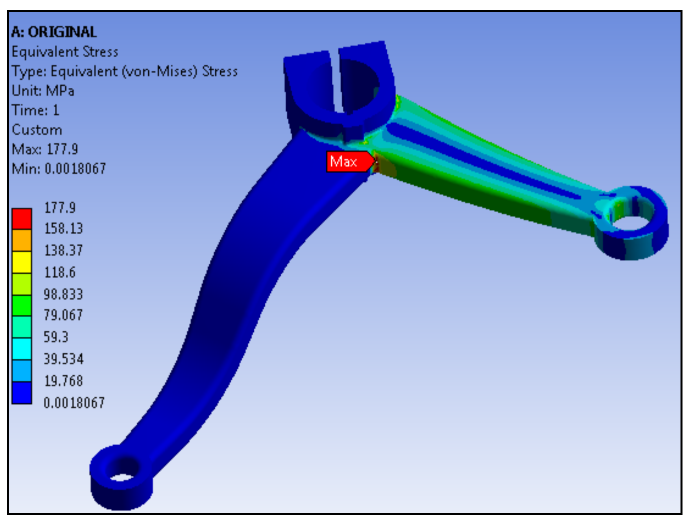
$$GFAW = GFA/2 = 3924N$$

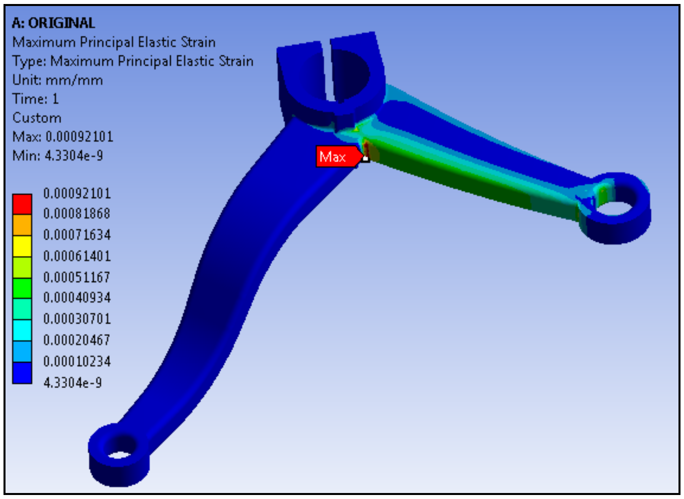
Force acting to pull steering arm =
Reaction force * (coefficient of friction between road and tyre)
=3924*0.7= 2746.8N

The idler arm is fixed at two cylindrical support and load 3924N is applied at other end



The maximum von mises stress observed is 177N/mm2 under pull force of 2746.8 N.





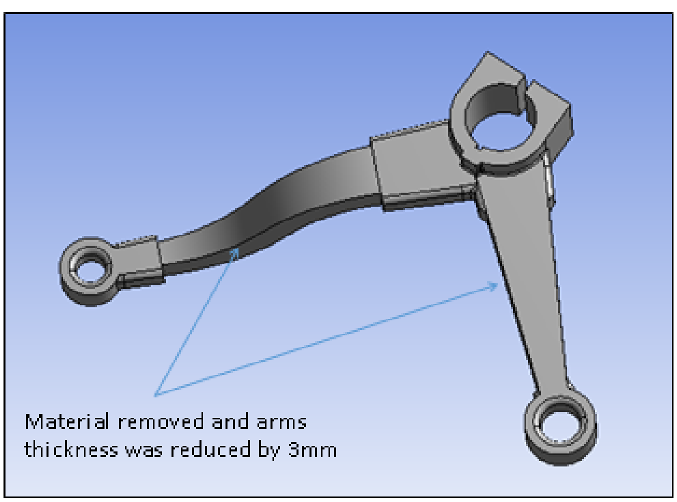
XIII. OPTIMIZATION

Optimization is a process to make a component possibly more effective with a optimizing design parameters, based on an objective function and subject to certain design constraints. There are many different methods that can be used to optimize a structure.

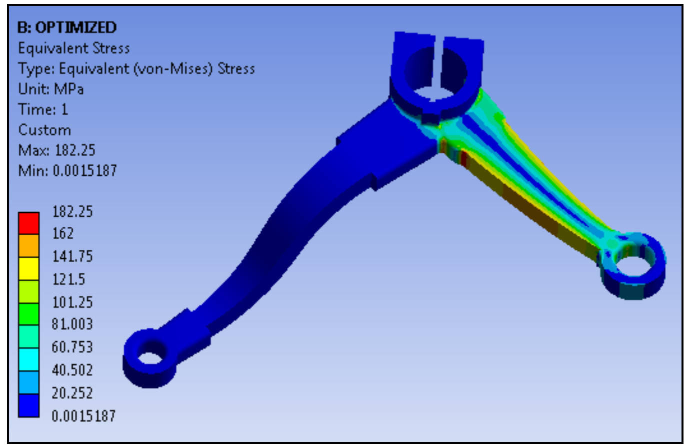
For idler arm optimization, we have selected Topology optimization as it is more suitable to apply design constraints as we needed.

Topology Optimization is a mathematical technique that try to optimize the material distribution for aexisting structure of idler arm within a given package space.

Optistruct tool is selected for the optimization as this software allows the use of numerous structural responses, calculated in a finite element analysis, or combination of these responses to be used as objective and constraint functions in a structural optimization.



After material removal the stresses observed is 182 N/mm2 is less than yield stress of alloy steel. So the design considered safe.



XIV. TESTING AND VALIDATION

Optimized Idler arm is mounted on testing through fixtures.

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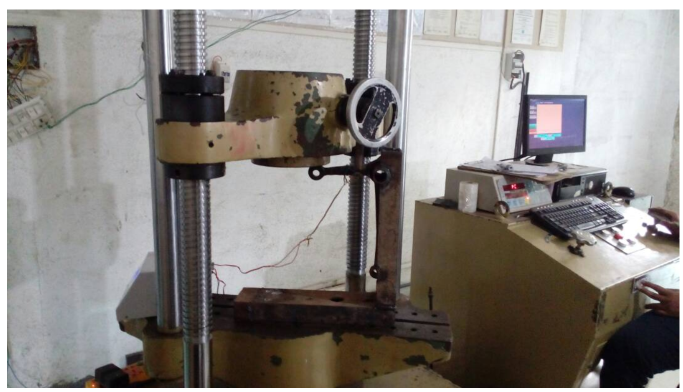

XV. CONCLUSIONS

Optimizations of the Idler arm are carried out and below are the conclusions from the analysis and testing:

1. Initial static 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 optimized model was well correlating with the test result which proves that the new Idler arm design could be used instead of the current one.
3. Through optimization, a percentage reduction is 13% achieved which saves the material cost.

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