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Design and Weight Optimization of Mahindra Tractor Steering Arm using FEA and Strain Gauge Technique

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Abstract: The current off-highway vehicle market demands low value and lightweight weight elements to satisfy the requirement of a value effective vehicle with fuel economical. This in turn offers the increase to more effective use of materials for vehicle components which may cut back the weight with increased utility of the car for varied applications. In tractor business, several casting parts continually suffer dynamic load with less frequency and really high amplitude which can cause the potential danger. Thanks to brittle behavior of the material, such components will break suddenly with no apparent caution. The steering mechanism is needed to control the direction of motion of the Mahindra tractor. This can be done through a series of links to convert the rotation of the wheel into an amendment of the angle of the axis of the steering wheels. Another operation of the steering mechanism is to supply directional stability. Once the operator turns the wheel, the motion is transmitted through the steering shaft to tire angular motion of the pitman arm, through a group of gears. The angular movement of the pitman arm is transmitted to the steering arm through the drag link and tie rods. Steering arms square measure keyed to the several kingpins that square measure integral a part of the stub shaft on that wheels square measure mounted. The movement of the steering arm affects the angular movement of the front wheel. For weight optimization of tractor Steering arm topology optimisation module use. Three-dimensional CAD model is intended using CATIA V5R20. Finite part Analysis (FEA) software ANSYS Version nineteen.0 is used to work out the total deformation and equivalent stresses. . Experimental investigations are going to be done by strain gauge technique and UTM. Conclusion and future scope are going to be suggested.

Keyword: Design optimization, Steering Arm, Strain gauge, UTM.

I. INTRODUCTION

The steering system is needed to regulate the direction of motion of the vehicle. This can be done through a series of links that convert the rotation of the hand wheel into modification of the angle of the axis of the steering wheels. The steering lever link is an integral part of a tractor mechanism it facilitates the conversion of movement given at the wheel to angular motion at the road. Steering lever link is mounted on the rigid beam shaft connected to 1 of the wheels of the tractor and it's positioned by means of kingpin. The motion of the vehicle being steered has to become straight ahead once the force on the hand wheel is removed. Once the operator turns the steering wheel, the motion is transmitted through the steering shaft to the angular motion of the pitman arm, through a collection of gears. The angular movement of the pitman arm is more transmitted to the steering arm through the drag link and tie rods. Steering arms area unit keyed to the various kingpins that area unit integral a part of the stub shaft on that wheels area unit mounted. The movement of the steering arm affects the angular movement of the front wheels. In another style, rather than one pitman arm and drag link, 2 pitman arms and drag links are unit used and also the use of a rod is avoided to attach each steering arm. The Pitman arm may be a steering element in an automobile or truck. As a linkage hooked up to the steering box (see recirculating ball) sector shaft, it converts the angular motion of the world shaft into the linear motion required to steer the wheels. The arm is supported by the world shaft and supports the drag link or centre link with a ball joint. It transmits the motion it receives from the steering box into the drag (or centre) link, inflicting it to maneuver left or right to show the wheels within the applicable direction. The nonworker arm is hooked up between the other facet of the centre link from the Pitman arm and also the vehicle's frame to carry the centre or drag link at the right height. A worn ball joint will cause play within the steering, and should intensify over time. Rigid bodies have wide ranging applications across fields together with molecular dynamics, robotics, machine assembly, human motion, and special effects for video games and films. In several applications, the main focus is on mechanics or inverse mechanics, and dynamic behaviour is of secondary or restricted interest with solely a number of instances of certain contact and collision, e.g. consider manipulating a robotic arm in an exceedingly controlled surroundings. Multi body simulation consists of analyzing the dynamic behaviour of a system of interconnected bodies composed of versatile and/or rigid elements. The bodies could also be strained with relation to one another via a kinematic ally admissible set of constraints modelled as joints. These systems will represent an Associate in Nursing automobile, a craft as an assemblage of rigid and flexible components, a mechanism with manipulator arms, and so on. In such cases, the elements could endure large rotation, large displacements.

II. LITERATURE REVIEW

The kinematic models of planetary stuff set and directing stuff are set up, in light of the examination of the transmission instrument of point superposition with Active Front Steering framework (AFS). A regulator of variable guiding proportion for Active Front Steering framework is planned, and virtual street tests are made in Car Maker driver vehicle-street reenactment climate. The consequences of recreation tests approve the regulator execution and the benefit of variable controlling proportion work, likewise show that the driving solace is improved at low speed particularly, because of the Active Front Steering framework adjusts the guiding proportion as per the driving circumstance [1].

A various leveled streamlining method for the ideal union of a twofold pivot guiding component utilized in truck with dynamic burdens is introduced. A multibody model of twofold hub guiding instrument is introduced to portray the leaf spring impact. The impacts of dynamic loads, the movement impedance of guiding linkage came about because of the flexible twisting of leaf spring, and the impacts of wheel slip points and the position errors of wheel speed turn focuses are concentrated methodically. A progressive enhancement technique dependent on track falling philosophy is proposed to characterize the plan factors of twofold pivot guiding instrument into four levels. A twofold hub guiding system for a rock solid truck is used to show the legitimacy of the proposed strategy. The recreation results demonstrate that the progressive improvement methodology is powerful and hearty. What's more, thus, it will certainly be generally utilized in designing [2].

Guiding framework is utilized to guide the front wheels because of driver contributions to request to give by and large directional control of the vehicle. In this manner, Steering framework assumes vital part in vehicle dealing with qualities. Pitman arm assumes a vital part in guiding framework as it sends the directing development to the wheel. The Pitman arm is a linkage joined to the area shaft of the controlling box and track bar, that changes over the rakish movement of the area shaft into the direct movement expected to guide the wheels. The Pitman arm is upheld by the area shaft and supports the drag connection or focus interface with a rotating conjuncture. It sends the movement it gets from the controlling box into the drag (or focus) connect, making it move left or right to turn the wheels the fitting way. Execution study is done trailed by static underlying examination and enhancement to limit the heaviness of the pitman arm and subsequently decreasing the material expense. Upgraded model is then checked by actual testing [3].

The thesis reports the plan project for the controlling framework and suspension of the 2005 Formula SAE-A racer vehicle made at the University of Southern Queensland. The paper incorporates a survey of current car directing and suspension frameworks followed by the audit of Formula SAE-A limitations and plan necessities. An intensive examination of 2004 USQ racer vehicle has been remembered for request to build up the spaces of plan adjustments followed by the real plan with every one of the specialized details required [4].

Venture work present inflexible multi body dynamic examination approach in plan. The use of this technique work on plan interaction and give right outcome. For the contextual investigation here work of configuration done on Ackerman directing instrument for tipper. In this initially as indicated by Ackerman conditions essential calculation is plan and afterward enhance it for static stacking, modular examination and afterward for dynamic powers created on guiding linkages while turning utilizing Rigid Dynamics apparatus in Ansys. The outcomes acquired from inflexible body dynamic examination are utilized for testing singular parts and if vital, remedial moves are made in plan to support that heap. Results shows unbending elements approach for configuration lessens time for streamlining, recreation and give the opportunity to make a most restorative move. Unbending elements approach is utilized in present day plan procedures for different spaces [5].

The controlling methodology and directing execution are combined with one another. Along these lines, how to consider the impact of the guiding methodology on the directing execution and further develop the framework's general exhibition is important to the controlling framework. This work brings the guiding methodology into the investigation of the controlling framework, and consolidates the elements model with the actual model to explore the exhibition of directing feel, directing affectability and guiding methodology. In view of the unique model of the vehicle and directing framework, the exchange elements of controlling feel, guiding affectability and directing strength are determined. Also, the regular recurrence is gotten by joining of plan of analyses (DOE) plan technique and reaction surface strategy. Then, at that point the improvement numerical model of the controlling framework is set up and the multi-target advancement is done by molecule swarm streamlining (PSO) calculation and non-ruled arranging hereditary calculation II (NSGA-II) separately. The streamlining results show that the controlling framework enhanced by NSGA-II calculation can more readily stay away from the reverberation with the motor out of gear condition, and further develop the framework's general exhibitions [6]

This paper depicts vigorous directing help force control of electric-power-helped controlling (EPAS) frameworks for an objective guiding wheel force following. The guiding help force control calculation has been created to defeat the significant weakness of the traditional technique for tedious tuning to accomplish the ideal directing feel. A reference guiding wheel force map was planned by post-handling information got from target execution vehicle tests with a profoundly evaluated directing feel for both sinusoidal and progress controlling data sources. Versatile sliding-mode control was embraced to guarantee heartiness against vulnerability in the controlling framework, and the same snapshot of idleness damping coefficient and successful consistence were adjusted to further develop following execution. Powerful consistence assumed a part in remunerating the mistake between the ostensible rack power and the real rack power. The exhibition of the proposed regulator was assessed by directing PC reenactments and an equipment on the up and up reproduction (HILS) under different guiding conditions. Ideal directing wheel force following exhibitions were effectively accomplished by the proposed EPAS control calculation [7].

Ergonomic plan prerequisites are expected to foster ideal vehicle interfaces for the driver. Most of the current particulars think about just anthropometric conditions and emotional assessments of solace. This paper inspects explicit biomechanical angles to work on the current ergonomic prerequisites. Thusly, an examination which included 40 subjects was done to get more information in the field of directing development while driving a vehicle. Five diverse shoulder-elbow joint setups were investigated utilizing a driving test system to discover ideal stance for driving in regard of controlling exactness and directing speed. Thusly, a 20 s accuracy test and a test to evaluate greatest controlling speed over a scope of 90 directing movement have been led. The outcomes show that driving exactness, just as greatest directing speed, are essentially expanded in mid-positions (elbow points of 95 and 120) contrasted with more flexed (70) or broadened (145 and 160) stances. We presume that driver wellbeing can be upgraded by carrying out these information in the auto plan measure in light of the fact that quicker and exceptionally exact directing can be significant during hesitant activities and in mishap circumstances. Moreover, emotional solace rating, broke down with surveys, affirmed trial results [8].

An uprooting and power coupling control plan for dynamic front controlling (AFS) arrangement of vehicle is proposed in this paper. To research the dislodging and power qualities of the AFS arrangement of the vehicle, the models of AFS framework, vehicle, and tire just as the driver model are presented. Then, at that point, considering the nonlinear attributes of the tire power and outside unsettling influence, a hearty yaw rate control technique is planned by applying a controlling engine to create a functioning guiding point to change the yaw strength of the vehicle. In view of blended H2/H1 control, the framework vigor and yaw rate following execution are implemented by H1 standard limitation and the control exertion is caught through H2 standard. Likewise, in view of the AFS framework, a planetary stuff set and a help engine are both added to understand the street feeling control in this paper to excuse the impact of additional guiding point through a repaying strategy. Assessment of the general framework is cultivated by reproductions and analyses under different driving condition. The recreation and analysis results show the proposed control framework has amazing following execution and street feeling execution, which can further develop the cornering dependability and mobility of vehicle [9].

III. PROBLEM STATEMENT

Now a day's automotive OEM are concentrating on vehicles efficiency and cost effectiveness to reach out with competitors. Pitman arm seems to be an overdesigned part. Hence to achieve cost effectiveness optimization of less critical components is necessary.

IV. OBJECTIVES

- To study and perform static analysis on tractor steering arm under steering load.
- To propose an optimized model which will have better or same performance and reduced weight.
- CAD modelling of tractor steering arm in Catia V5R20 software.
- To perform static structural Analysis of optimized tractor steering arm in ANSYS 19 workbench.
- To perform topology optimization of tractor steering arm for weight optimization.
- Comparative Analysis between Experimental & Analysis results.

DESIGN:
CAD: -

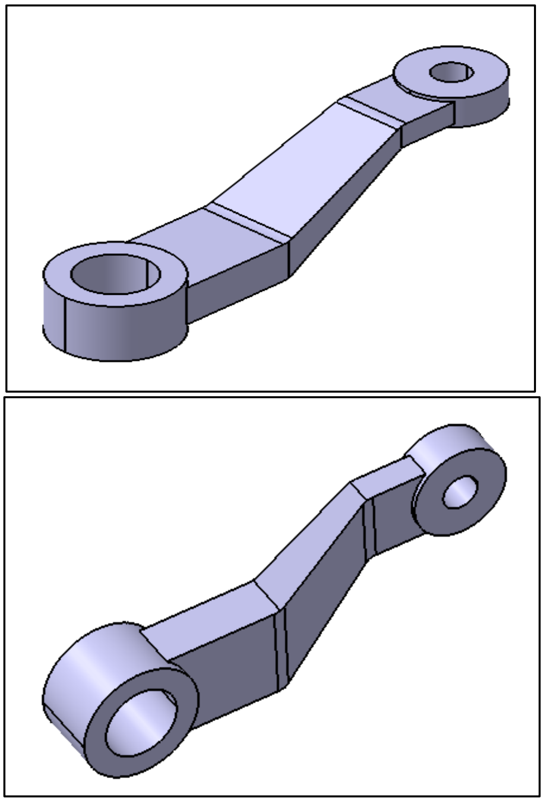


Fig. CAD model of pitman arm using reverse engineering

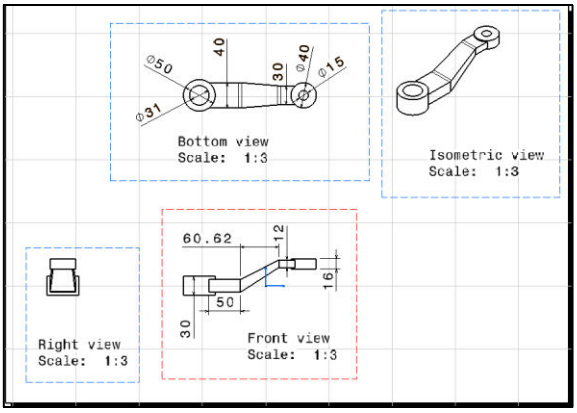


Fig. 1: CATIA and drafting of pitman arm

ENGINEERING MATERIALS – STRUCUTRAL STEEL

Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	1.2E-05	C^-1
6	Isotropic Elasticity		
7	Derive from	Young's Mod...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa

Fig. 2: Details of engineering material

MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Metaphysics solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.

GEOMETRY

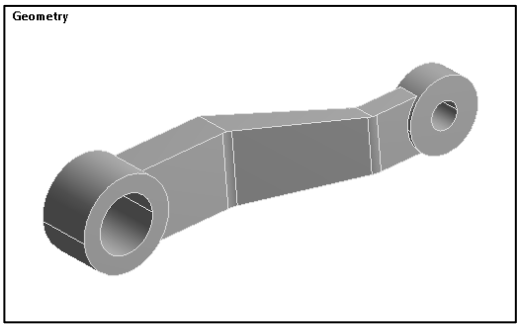
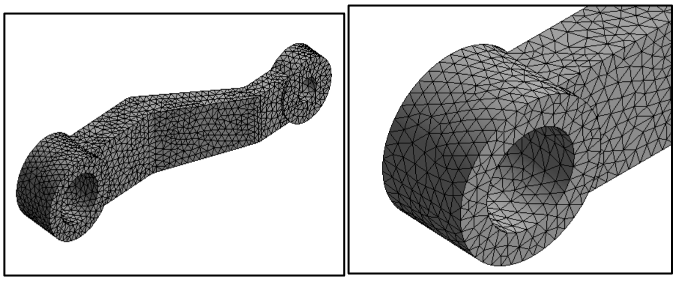


Fig.3: Original CATIA Model imported in ANSYS



Details of "Body Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	4.0 mm
Advanced	
Defeature Size	Default
Behavior	Soft

Properties	
Volume	1.3002e+005 mm^3
Mass	1.0207 kg
Scale Factor Va...	1.

Statistics	
Nodes	28550
Elements	18373

Fig.4: Meshing of original Pitman Arm/ steering arm

Boundary Condition

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both.

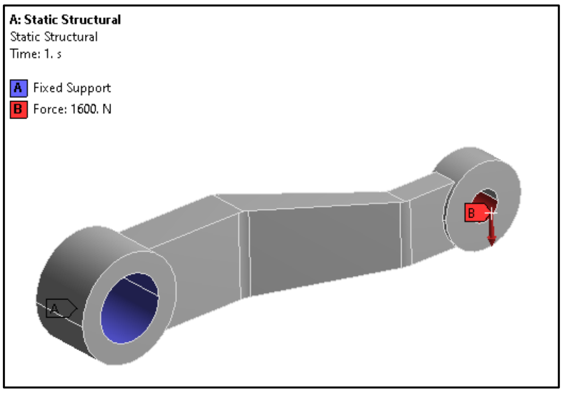


Fig. 5: Boundary Condition of existing steering arm

Total Deformation

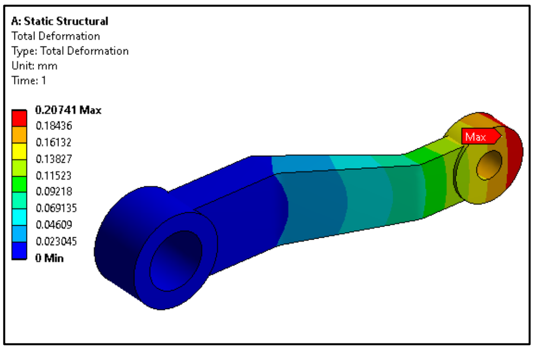


Fig. 6: Total Deformation of existing steering arm

Equivalent Stress

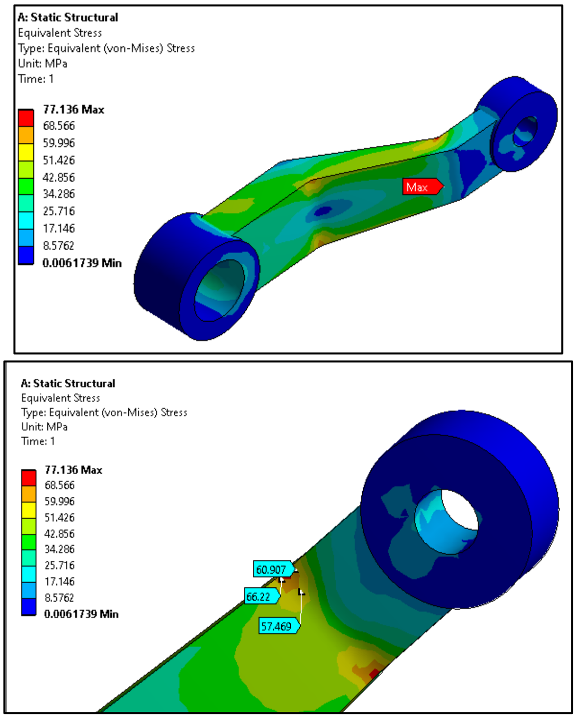


Fig. 7: Equivalent Stress of original model

- Maximum stress is observed around 77 MPa.

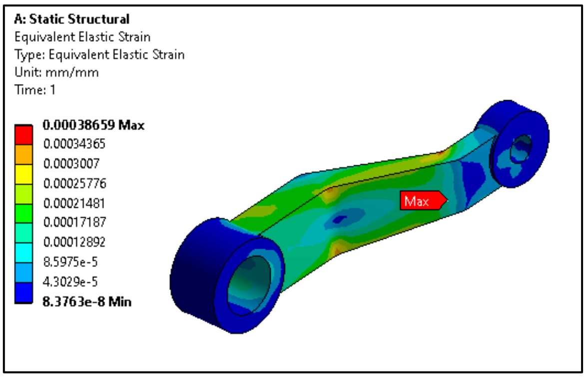


Fig. Elastic strain

Steps in Topology Optimization

The topology optimization consists of the following sequence of steps.

• Define the design space
• Define optimization parameters
• Material removal process and detail design

➢ Defining the Optimization Parameters

The aim of topology optimization in this project is to minimize the volume without affecting the bracket stiffness and strength compared to base bracket, so the design objective is taken as to minimize the volume. Following parameters are defined as constrains:

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1. Allowable stress limit value is defined as stress constraints from durability point of view
2. Single draw direction is defined as manufacturing constraint.

➢ Material Removal Process and Detail Design

The optimization process took some iteration to remove the unnecessary material from the design space. The output of the topology optimization, an intermediate model which may be called a topology based model, is constructed by removing unnecessary materials from the rough conceptual model.

- Additive Manufacturing

Without manufacturing constraints, optimized components often have complex geometries. Recent developments in Additive Manufacturing (3D printing) enable the fabrication of these optimized designs without compromise. Topology optimization forms the natural design technology for Additive Manufacturing, as it fully exploits its potential.

- Shape Optimization

Where topology optimization excels at automated concept generation, shape optimization allows for efficient final fine tuning of designs. However, every fabrication technique has its shape/property accuracy limitations, particularly at the micro scale. Our activities on shape optimization concentrate on dealing with fabrication inaccuracy, and optimizing for robustness.

Boundary condition for topology

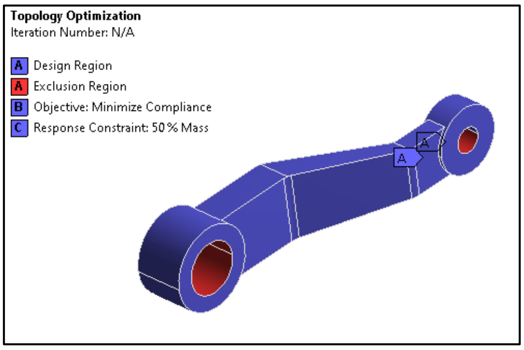
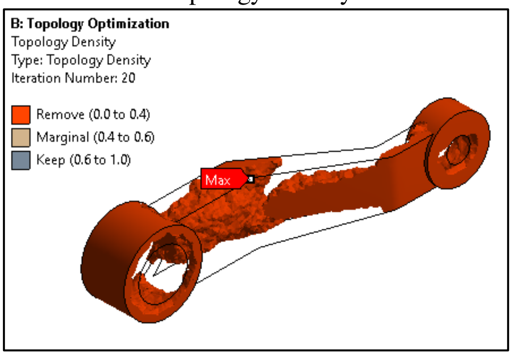


Fig. 10: Boundary condition for topology optimization

Topology Density



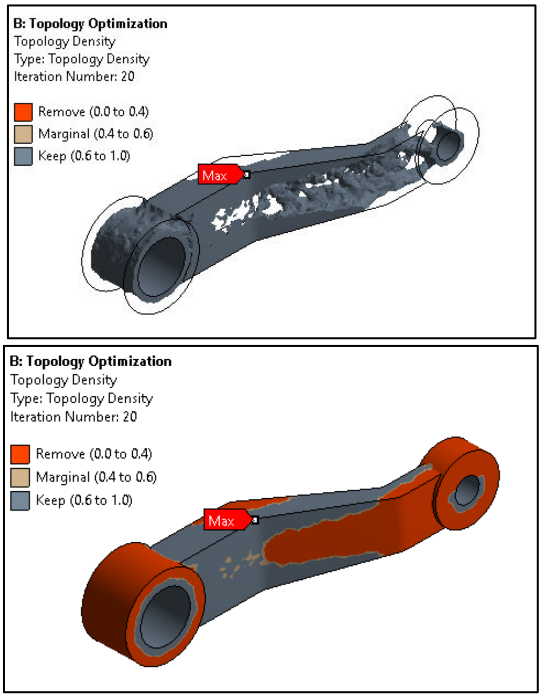


Fig. 11: Topology optimization results

- It is observed from above figure that red region indicates material removal region so, it is beneficial to removal material with proper design. So, it must sustain existing boundary condition load.

OPTIMIZED DESIGN ITERATION 1

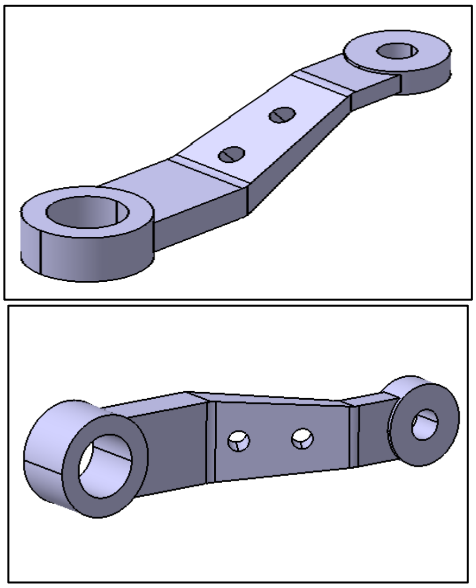
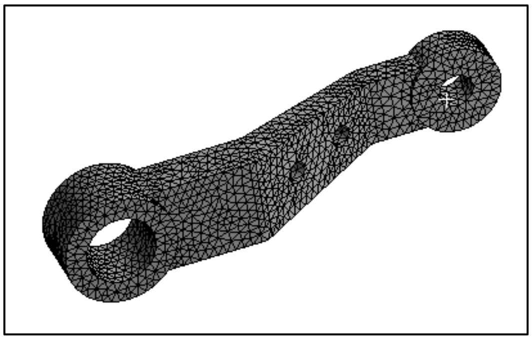


Fig. cad model for optimized design



Details of "Body Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	4.0 mm
Advanced	
Defeature Size	Default
Behavior	Soft

Properties	
Volume	1.2782e+005 mm³
Mass	1.0034 kg
Centroid X	39.758 mm

Statistics	
Nodes	28657
Elements	18374

Fig. meshing details

. Boundary condition

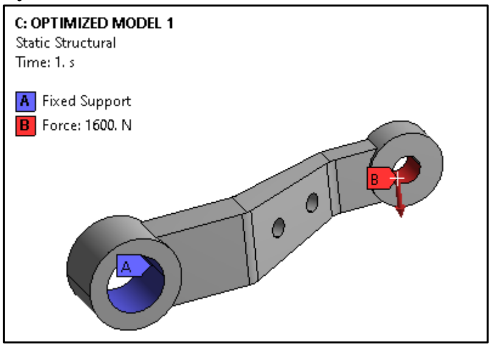


Fig. boundary condition for optimized model

Total deformation

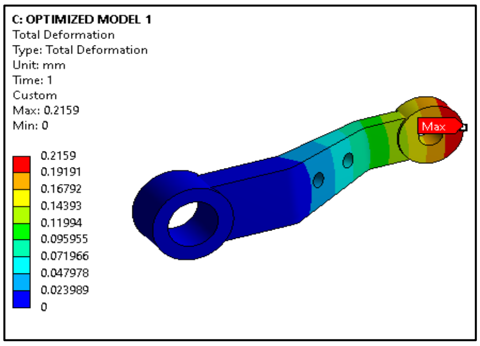


Fig. Total deformation for optimized model

Equivalent stress

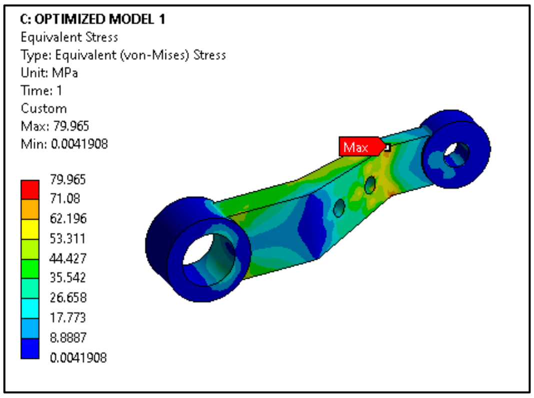


Fig. Equivalent stress

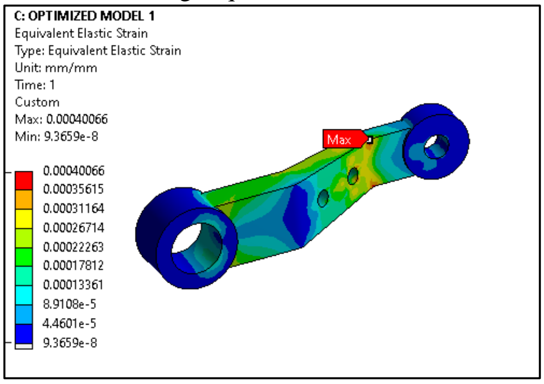
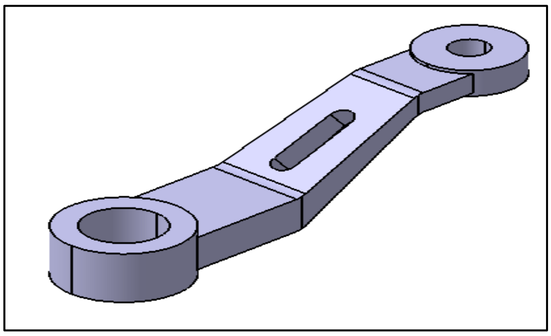


Fig. Equivalent elastic strain

OPTIMIZED MODEL 2



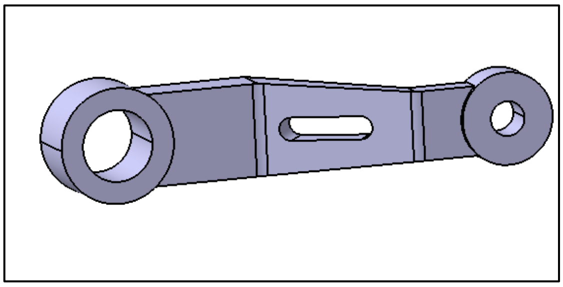
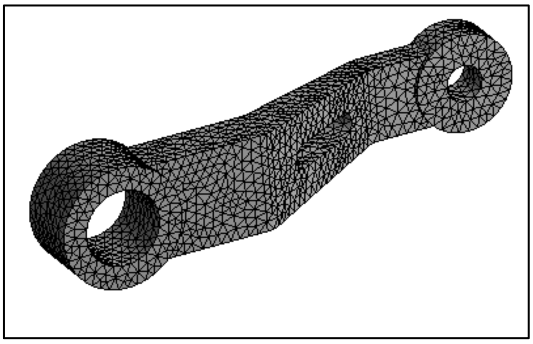


Fig. Optimized model 2



Details of "Body Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	4.0 mm
Advanced	
Defeature Size	Default
Behavior	Soft

Statistics	
Nodes	28200
Elements	18016

Properties	
Volume	1.2472e+005 mm³
Mass	0.97903 kg
Centroid X	40.473 mm

Fig. Meshing details

Boundary condition

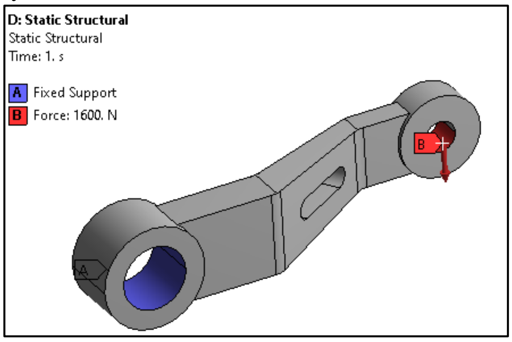


Fig. Boundary condition of Optimized model 2

Total deformation

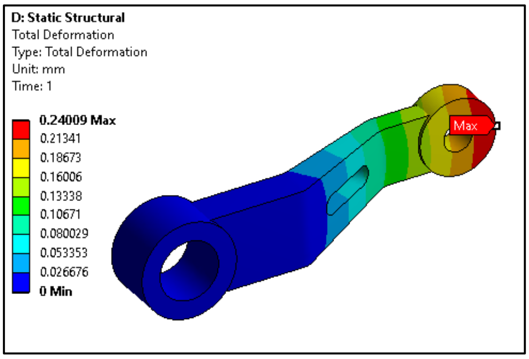


Fig. Total deformation of Optimized model 2

Equivalent stress

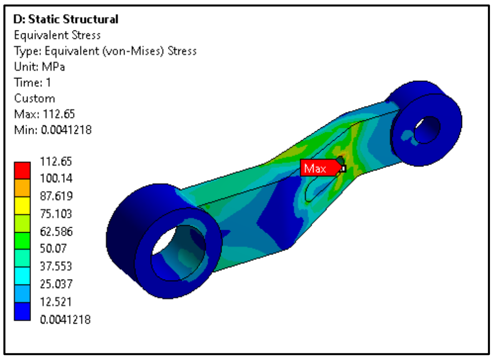


Fig. Equivalent stress

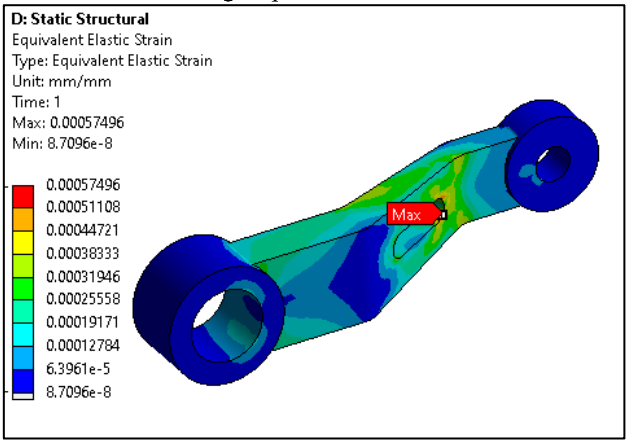


Fig. Equivalent elastic strain Optimized model 2

V. RESULT AND DISCUSSION

SR NO	COMPONENT	EQUIVALENT STRESS (MPa)	TOTAL DEFORMATION (mm)	WEIGHT (kg)
1	EXISTING MODEL	77.13	0.207	1.0207
2	OPTIMIZED MODEL 1	79.96	0.21	1
3	OPTIMIZED MODEL 2	112.65	0.24	0.97

Topology optimization is one of the important process is automobile industry. It mainly effects on the efficiency of the vehicle. Perform static analysis on pitman arm and find out maximum stress generate on it. Then perform topology optimization to find out material removal density form pitman arm to reduce the weight of the pitman arm. After removing material from the pitman arm perform static analysis to check rather stress generated on optimized pitman arm is less than material yield point that is 250 MPa.

VI. CONCLUSION

- In present research pitman arm static and topology optimization analysis is performed to determine stress and deformation.
- In topology optimization red region is observed so it predicts to removal of material from that area.
- Static structural analysis of pitman arms is performed to determine deformation and equivalent stress. It is observed that around maximum deformation is 0.207 mm and equivalent stress is 77.13 MPa. An optimized model is obtained from topology optimization technique.
- In our case original mass is 1.02 kg but removal of material is to 0.97 kg as per software. But it depends on us to removal of material by proper design and reanalysis as per existing conditions to sustain boundary condition.
- Static structural analysis of optimized model 2 pitman arms is performed to determine deformation and equivalent stress. It is observed that around maximum deformation is 0.21 mm and equivalent stress is 79.96 MPa.
- Static structural analysis of optimized model 2 pitman arms is performed to determine deformation and equivalent stress. It is observed that around maximum deformation is 0.24 mm and equivalent stress is 112.65 MPa.
- Weight reduction of around 5 % is observed.

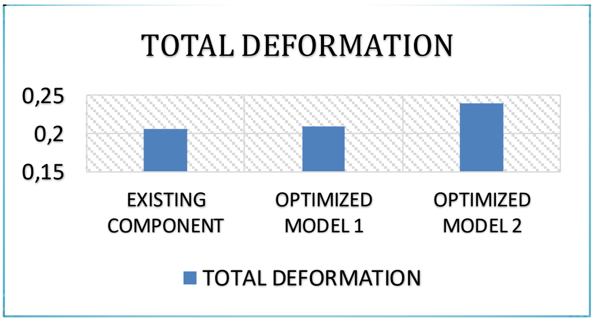


Fig. Total deformation comparison

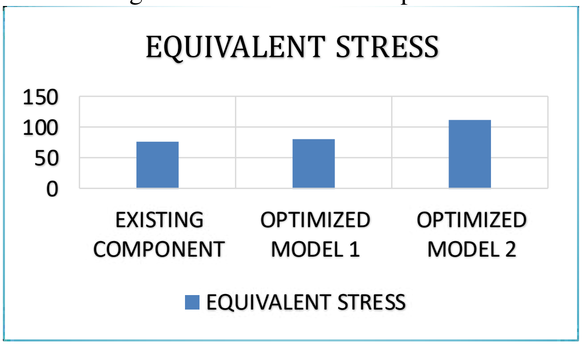


Fig. Equivalent stress comparison

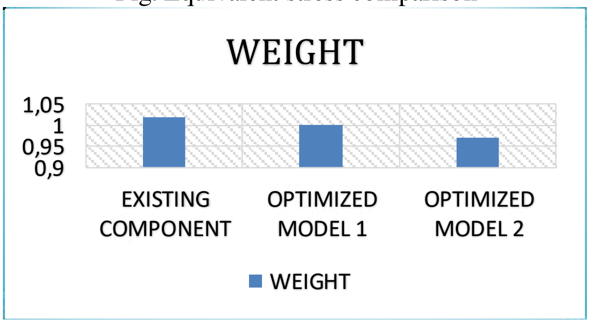


Fig. Weight comparison

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