Design & Experimental Modulation of Pitman Arm

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ABSTRACT

In this paper an investigation attempt is made to optimize the steering link (Pitman's Arm). Number of iterations were prepared using FEA Structural Analysis followed by Topology optimization to minimize mass from the existed part. With the emerge in technology for cost saving methods ANSYS plays an important part to enroll the strength with several optimization strategy. This paper elaborates the stress factors and fatigue parameters of pitman arm for the applied boundary condition, & also an attempt was be made to fabricate the optimize part and to validate the software results with experimental testing results. Both the results are approximation to the exact solution and are matching the values, hence the design parameters evaluated to optimize the link was successfully obtained thorough the software as well as experimental via UTM tensile testing.

Keyword: - *Steering link, Structural Analysis, optimization, boundary Condition & UTM tensile testing.*

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1. Introduction

Car manufacturing is now necessary due to the fall in vehicle mass demand. Customers' expectations in terms of durability, efficiency, and affordability are rapidly increasing. Vehicle components that are overly designed result in increased weight and decreased efficiency. The Pitman arm, which is used to steer the vehicle, can be changed and modified to reduce weight and hence cost. Using CATIA V5 software, existing pitman arm components will be reverse engineered and CAD modelled. Ansys will be used to perform finite element discretization and analysis. FEA will assist in identifying high-strain areas in components as well as indicating areas that can be changed. Strain gauging will be carried out in high-strain locations identified using FEA software.

In a car or truck, the Pitman arm is a steering component. It translates the angular motion of the steering box's sector shaft (see recirculating ball) into the linear motion required to guide the wheels as a linkage attached to it. The arm is supported by the sector shaft and has a ball joint that supports the drag link or center link. It sends the steering box's motion to the drag (or center) link, which causes it to move left or right to turn the wheels in the proper direction.

1.1 Objective

1. To optimize the pitman's Arm for minimized weight condition.
2. To Compare the results among the other materials.
3. To validate the feasible iteration with fabrication and UTM Tensile testing process.

1.2 Working or Methodology of the project

The project's working or methodology
1. The 3D model was created with the help of CATIA v5 software and part designing or surface wireframe modelling.
    a. CATIA v5 r20.00 software version

2. Structural transient analysis
   a. The term "transient" refers to a problem that is solved using time considerations.
   b. Material reduction strategy employing topology optimization for lower mass by density-based technique after solving for transient structural analysis system.
   c. Following topology optimization, the optimized component will be compared to alternative materials with reduced molecular weight.
   d. After analyzing all of the options, the most efficient one will be chosen, and manufacture of the part will begin, followed by testing on the UTM machine.
   e. Experimental Validation Comparison

2. Design

1. To create sub parts using CATIA v5 soft.
2. Open CATIA file, click on create Part and rename the save part.
3. Choose axis on which u want to create and draw the sketch to a required parameter using sketch command tool.
4. Exit sketcher and create it to solid using solid command on main page
5. Create sub parts of each part
6. Assemble each sub parts in product section using assembly tools like surface contact, offset, and coincide tools.
7. Finally convert it to a drafting file mention required parameters in it and print the blue print for manufacturing process
1. Optimized design for low costing and efficient spraying.

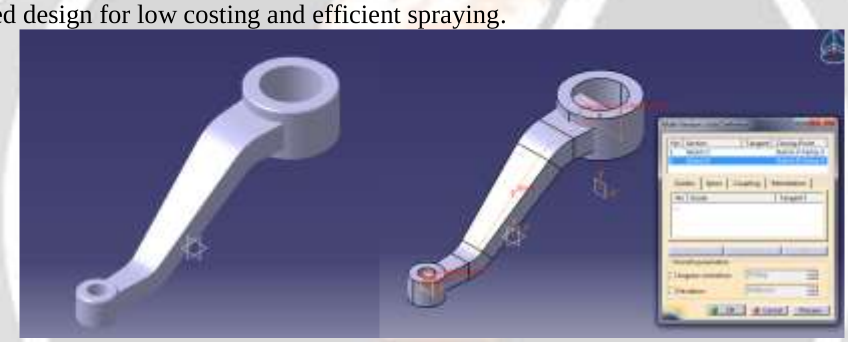


Fig 1: Pitman's Arm Catia v5 Design.

3. Analysis

3.1 Iteration 1 Ansys Transient Structural Analysis

Loading condition NON-linear types

3.1.1 Force Calculations

Total Mass of the vehicle, M1= Curb weight + Passenger's weight + other weight

Toyota Glanza/Curb weight 890 to 935 kg = 922 kg

Consider 5 people are sitting inside the car =5*100 = 500 kg

M1= 922 + 500 +50= 1472 Kg

This weight must be divided into front axle weight and rear axle weight. 52% of the total weight is taken by front axle and 48% is by rare axle.

Front axle weight = 0.52*1472 = 765.5 N

Rare axle weight = 0.48*1472 = 706.56 N

Therefore, Mass on the front axle, M1 = 735.8 kg /2

Mass on one of the front wheels, M = 382.75 = 382.72 kg

Coefficient of friction, μ = 0.7

F = u * m

= 0.7 * 382.72 = 267.9kg = 267.9*9.81

= 2628.099 = 2625N

3.1.2 Results Material Structural Steel.

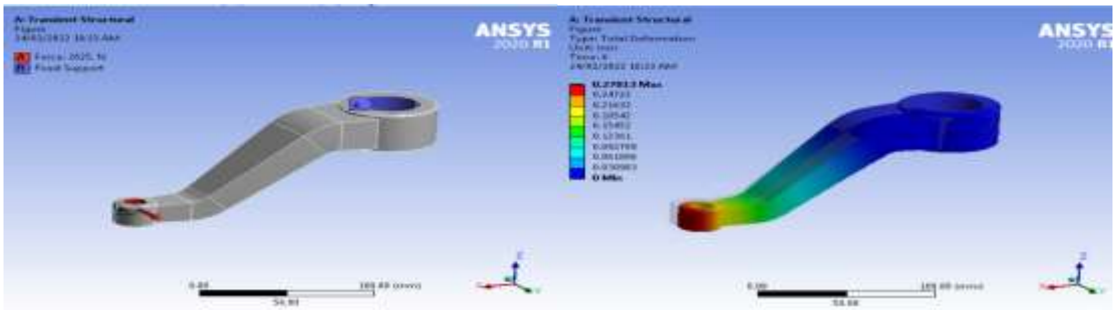


Fig -2: a. Boundary Condition & Total Deformation

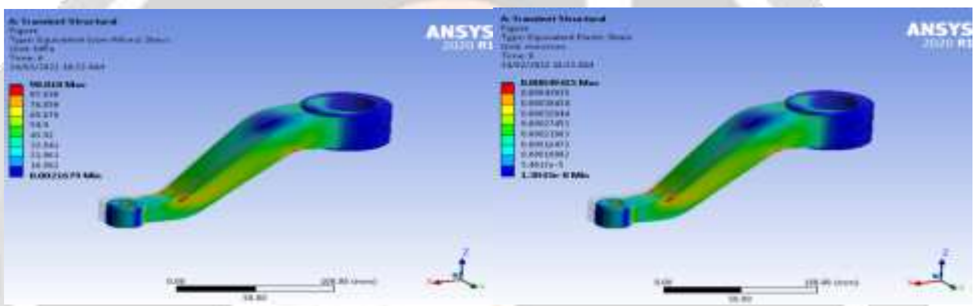


Fig -3: a. Stress b. Strain

3.1.3 Discussion of iteration 1

- In this iteration the 3D model of pitman arm is imported to ANSYS workbench and structural analysis is carried out and result were noted.
- Using time definition Transient solution is selected for 6 sec first 3 sec applies the load in negative Y direction and 3 more sec in positive Y direction, this time setup helps in solving a structural FEA in a complete loading condition.
- The maximum total deformation in all direction observed is 0.27813 mm
- The maximum Von-Misses stress induced due to loading is 98.6 MPa
- The maximum tensile strength of the material 250 Mpa Hence, design is safe.
- The observed design Factor of safety crises 0.87231 with span of life cycle minimum 4.55e5 cyclic loading.
- In Next Iteration
- Hence the solution has been satisfactorily safe from the boundary condition applied to it, hence the stress is low and material used has a much higher density, so inversely the weight is also more, so let's try to optimize an arm for topology optimization in the next strategy. And I'll take off as, much as unwanted material from the arm or linkage.

3.2 Topology Optimization

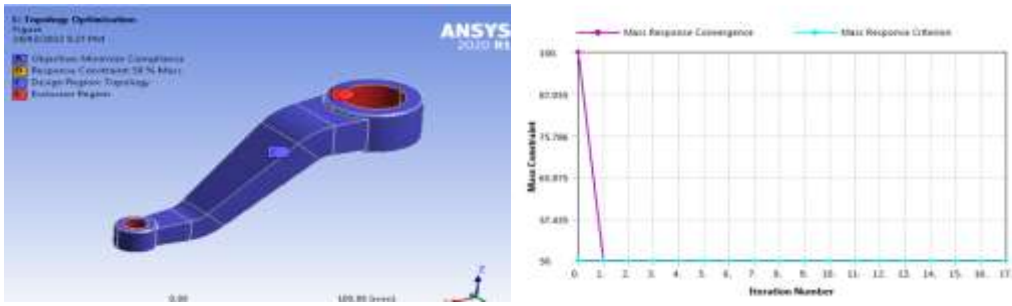


Fig – 4: a. response constraint b. Graph Mass Constraints vs/ Iterations performed

3.2.1 Discussion of iteration 2

Topology optimization has been conducted and mass reduction results were noted.

After the optimization 3D model is redesigned according to the solution, remove 0.0 to 0.4 it is a rate of mass reduction from which the material can be removed in order to minimize the mass constraints, as shown in the figure. The marginal rate is rate either the material can be removed or can be kept and it does not affect too much towards the failure for the applied boundary condition. Keep rate is rate were the material or mass cannot be removed from the region this directly affects the life span.

Remove	0.0	-	0.4
Marginal	0.4	-	0.6
Keep	0.6	-	1.0

3.3 Iteration 3 redesigning strategy

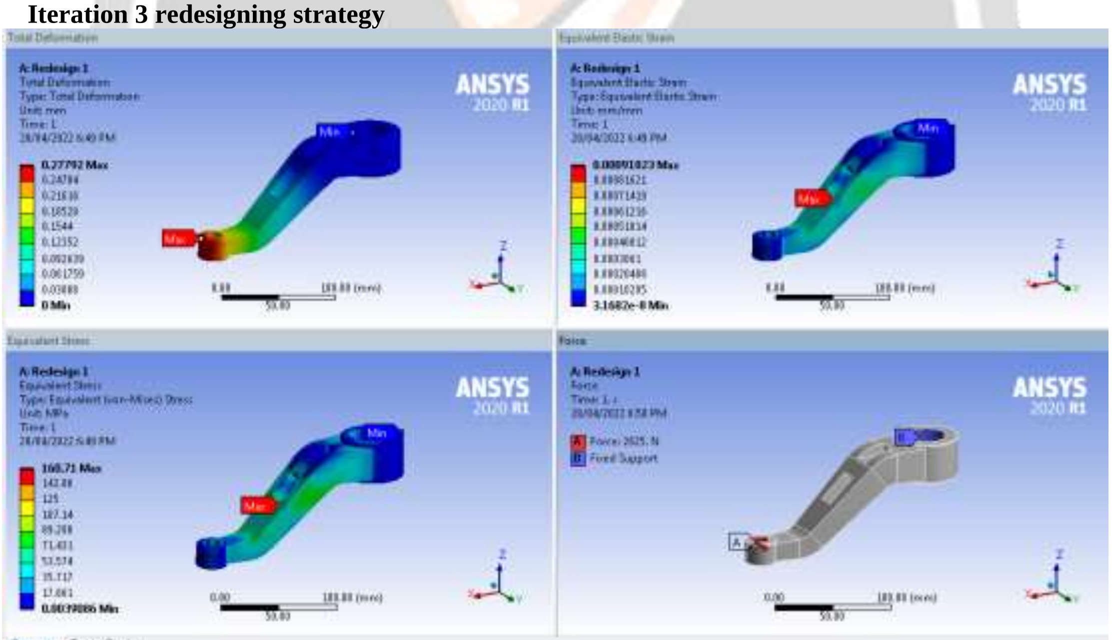


Fig – 5: a. total Deformation b. Strain c. Stress d. boundary Condition.

3.3.1 Discussion

In this iteration the weight is negligibly reduced from 1.2841 Kg to 1.2425 kg which is less. In order to bring the optimized weight second time redesign was prepared in further process.

3.4 Redesign topology 2

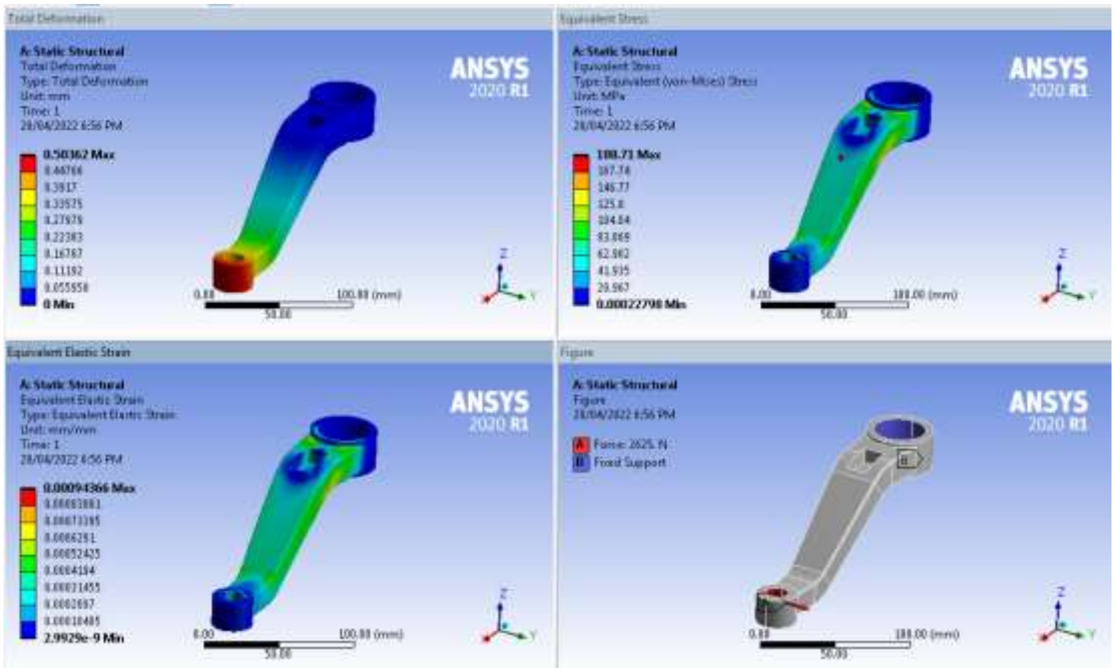


Fig – 6: a. total Deformation b. Strain c. Stress d. boundary Condition.

3.4.1 Discussion

Finally, the mass has been brought to the final retention stage.

Before 2nd redesign weight = 1.2425 Kg

After 2nd redesign weight = 0.76531 Kg

But the redesign part has a higher stress factor, but which is less then yield strength of material Structural Steel. In next iteration Material comparison will be made on for different constraints.

3.5 Material Comparison – Material SAE 1022

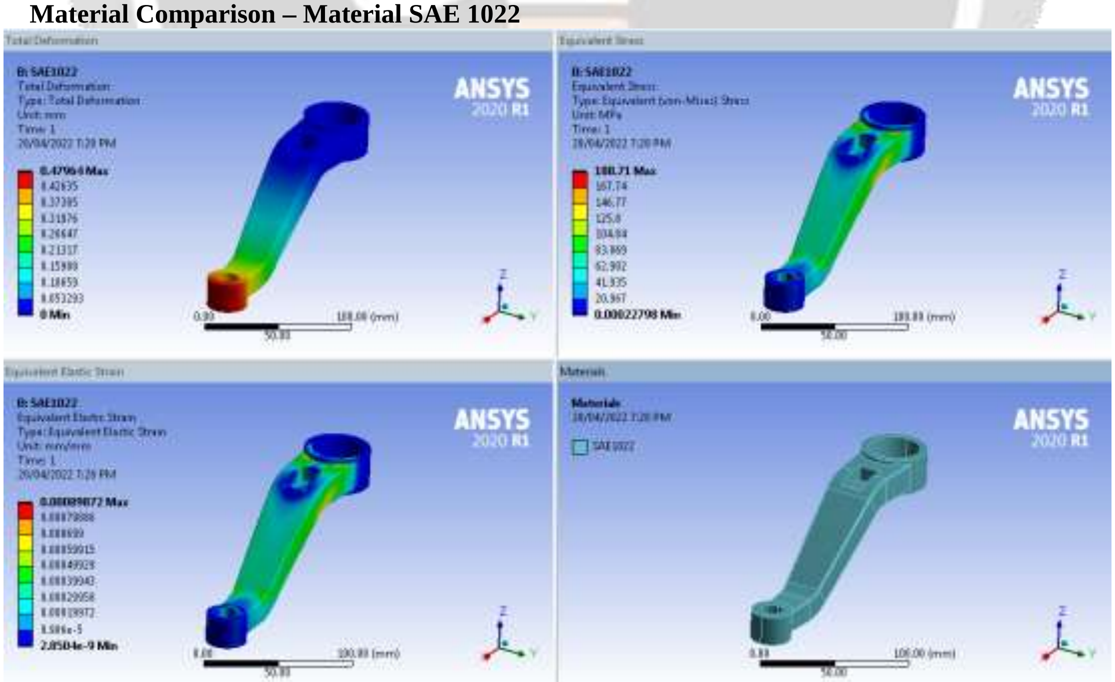


Fig – 7: a. total Deformation b. Strain c. Stress d. Material

Properties

Volume = 97492 mm³ , Mass = 0.77409 kg

3.6 Material Aluminum 5052

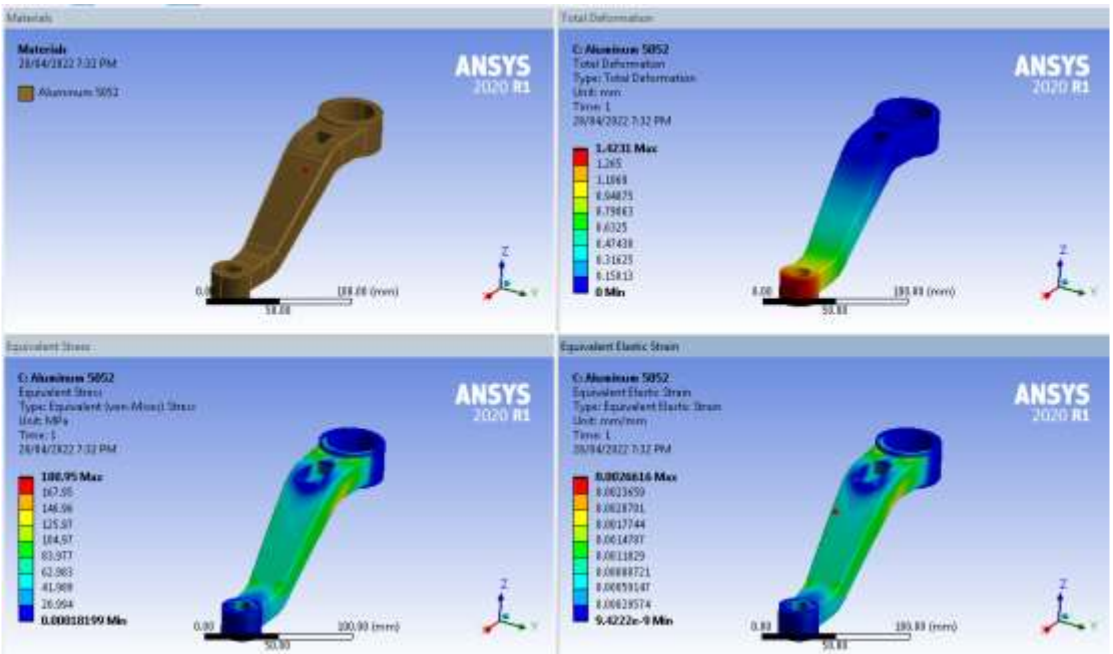


Fig – 8: a. Material b. total Deformation c. Stress d. Strain

Properties
Volume 97492 mm³
Mass 0.26128 kg

Note: Stress factors are more in the designed part so an iterative part without cuts is propagated and analyzed in a hope to reduce stress factors.

3.7 Iteration without cut

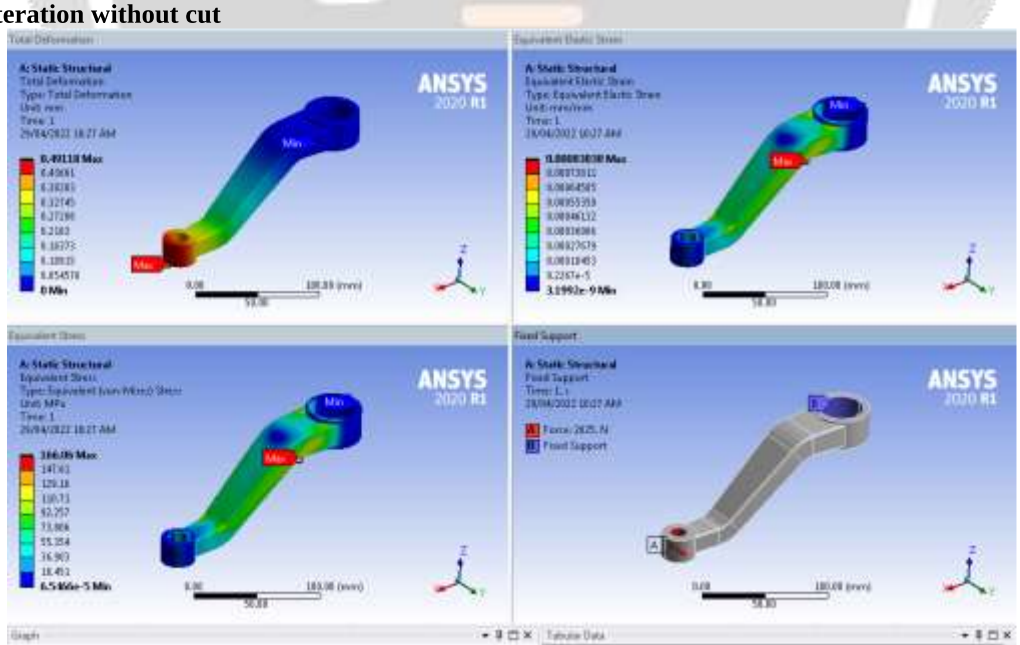
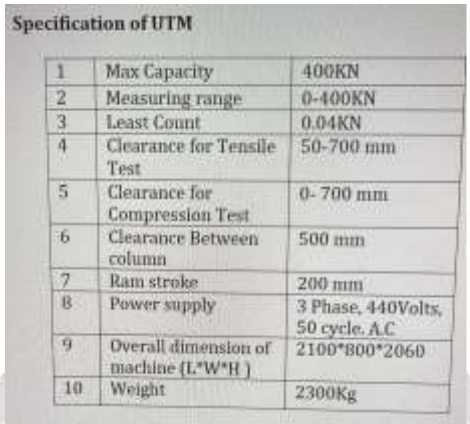


Fig – 9: a. total Deformation b. Strain c. Stress d. boundary Condition.

4. Validation

Machine Specification



Specification of UTM

1	Max Capacity	400KN
2	Measuring range	0-400KN
3	Least Count	0.04KN
4	Clearance for Tensile Test	50-700 mm
5	Clearance for Compression Test	0- 700 mm
6	Clearance Between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase, 440Volts, 50 cycle. A.C
9	Overall dimension of machine (L*W*H)	2100*800*2060
10	Weight	2300Kg

Fig – 10 :Specification of UTM

Fabrication process

- Replica casting & machining.

Fig – 11 : Pit Man's Arm

Fig-12. Standard Specimen

Result

The proposed pitman arm was failed on 20.68 KN load,

Sample Identification	PITMANS ARM							
Test Required	**TENSILE TEST**							
Test Method	IS 1608 :2018				**Reference Standard**		---	
Material Specification	---							
	TEST PIECE DIMENTIONS:							
	Dia. mm	Thickness mm	Initial Area mm²	Gauge Length mm		Final Gauge Length mm		Final Dia. mm
	5.01	---	19.72	25.00		28.40		3.38
	TEST RESULTS:							
		Yield Load kN	Ultimate Load kN	Y.S. N/mm²	UTS N/mm²	% Elongation	%Reduction in Area	Fracture
	SPECIFIED	---	---	---	---	---	---	---
	ACTUAL	17.98	20.68	911.69	1048.60	13.44	54.48	W.G.L

Fig-13: Test Results

FEA analysis for optimized pitman arm using ANSYS for the failed load condition to validate
Same boundary Conditions & Meshing Sizes are maintained to part body

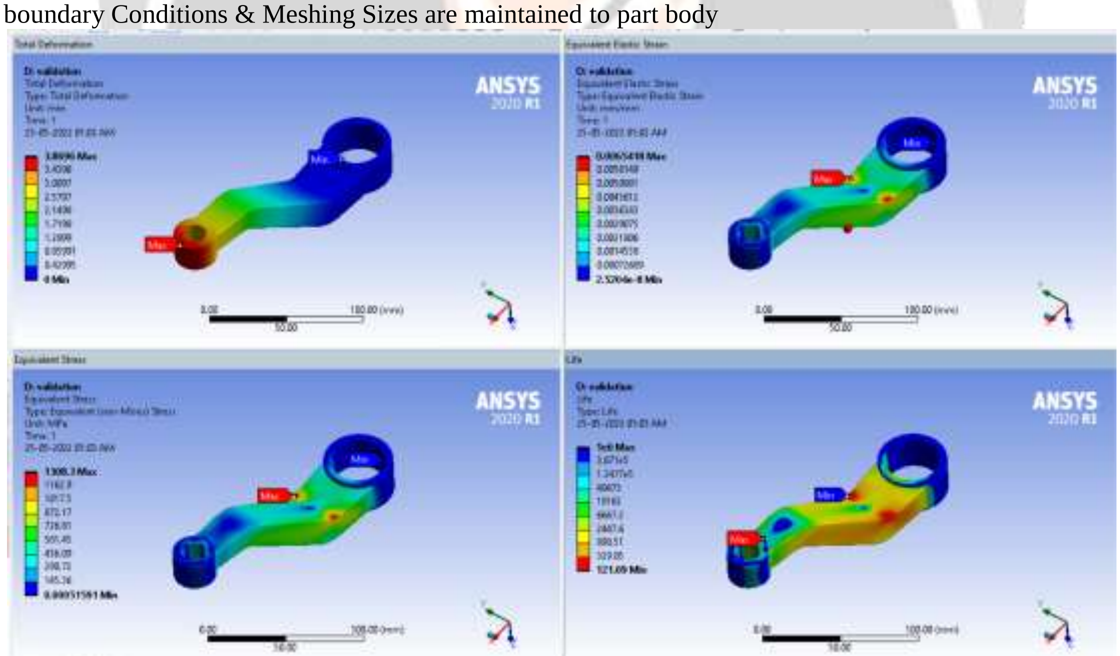


Fig – 14: a. total Deformation b. Strain c. Stress d. Life

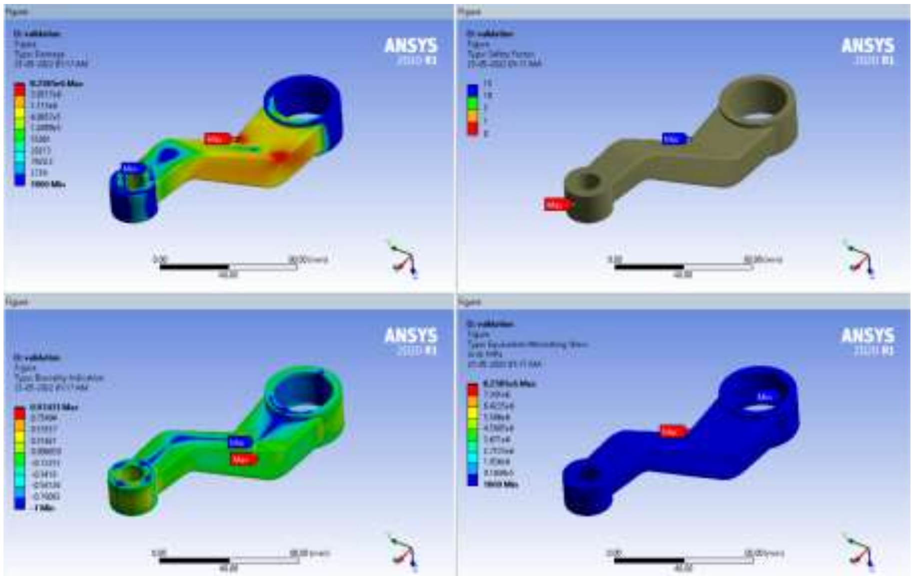


Fig-15: a. Damage b. Safety c. Biaxiality Indication.

- Hence one can observe the maximum failure is on the slant edge end of arm so, as the failed part is exactly on the edge end.
- Hence the deformation Observed is 3.86mm in the software.

Sl No	Material	Type of validation	Deformation in mm
1.	Structural Steel	Experimental UTM Tensile Testing result.	3.4
2.	Structural Steel	FEA Static Structural Ansys software result.	3.8

Table-1: Validation Results

Difference Between FEA analysis and Experimental Result = 0.4 mm difference in deformation

Fig-16 : Broken Part

4. CONCLUSIONS

FEA analysis was successfully conducted on the proposed Pitman's arm or steering link arm. First the modal was solved using transient system with varying loading condition to its time dependency followed by topology optimization to reduce the weight, Material Comparison & vibrational Modal Analysis. Following results were recorded.

1. The force is applied on the larger end of the pitman arm, deformation, stress & strain Plotting have been done.

Result Section

Sr. No	Material	Type of Iteration	Optimization Mass Reduction Percentage	Total Deformation in mm	Strain	Stress in Mpa
1.	Structural steel	Transient	Mass of arm 1.281 Kg	0.27813	0.00049415	98.818
2.	Structural Steel	Topology Optimization	50%	-	-	-
3.	Structural steel	Redesigned Part	Weight reduced after optimization 1.2425 Kg	0.277792	0.00091823	160.71
4.	Structural steel	Topology Optimization	50 %	-	-	-
5.	Structural steel	Redesigned	Weight reduced after optimization 0.76531 Kg	0.50362	0.00094366	188.71
6.	**SAE1022**	**Material Comparison**	**Mass 0.77409 Kg**	**0.47964**	**0.00089872**	**188.71**
9.	Aluminum 5052	Material Comparison	Mass 0.26128 kg	1.4231	0.0026616	188.5
10.	**Structural Steel**	**Investigation for without cuts**	**0.79225 Kg**	**0.49118**	**0.00083038**	**166.06**
11.	SAE1022	Material Comparison	Mass 0.7913 Kg	0.46779	0.00079084	166.06

Table-2: Result comparison

- From the above results SAE 1022 has lesser deformation compared to Structural steel, which is 0.49118-0.46779 = 0.02339 mm lesser then structural steel (low carbon steel).
- This minimum deformation can be neglected because it is in micron change.
- A final analysis has been done on the optimized design part but, all the cuts were neglected to know whether it reduces the local Von-Misses stress.
- Pitman arm without cuts has a reduced stress condition.
- With a minimize change in deflection and mass between SAE 1022 & structural steel. Structural steel (low carbon steel) is selected for Validation because of easy availability, lesser cost & equalized strength.

- To validate the proposed design, of pitman arm with structural steel material will be fabricated and tested on the UTM machine.
- The pitman arm which was failed at 20.68 KN load has a deflection of 3.4 mm
- So, as the analysis has a same Deflection when applied, hence the result has accuracy in all the results which was plotted for optimization of steering arm or pitman's arm are perfectly accurate to its result.

Future Scope

1. Different designs with minimized mass can improve the process of Industrial optimization.
2. Materials with Composite can provide with minimized mass.

5. REFERENCES

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