ISSN (e): 2250 – 3005 || Volume, 08 || Issue, 5|| May – 2018 ||

International Journal of Computational Engineering Research (IJCER)

Vibrational Analysis, Life Prediction and Optimization of Pitman Arm Using FEM

Pradeep B Patil[1], P.D.Darade[2]

[1](P.G Student, M.E Design Engineering, Sinhgad Institute of Technology and Science, Narhe, Pune
[2](HOD Mechanical Engineering department Sinhgad Institute of Technology and Science, Narhe, Pune
Corresponding Author: Pradeep B Patil

ABSTRACT

Steering system is used to steer the front wheels corresponding to the inputs provided by the driver in order to achieve overall directional control of the vehicle. Thus, in vehicle handling characteristics steering system plays very important role. Pitman arm transmits the steering movement to the wheel. The Pitman arm is a linkage attached to the steering box, sector shaft, which 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 on one side and on the other side to 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. A performance study will be carried to analyze fatigue life and vibrational behavior of pitman arm using FEA tools. The structural optimization will be done on the pit man arm using Optistruct, changing the structure of pitman arm by adding ribs or slots to the structure which will increase its strength. The meshing and boundary conditions will be applied using Hypermesh 12.0 and analysis will be carried out using ANSYS. The testing of Pitman arm is carried out for fatigue analysis and the result will be validated with the simulation results.

KEYWORDS - Ansys, Catia, Fatigue analysis, Modal analysis, Pitman arm

---

Date of Submission: 28-04-2018 Date of acceptance: 14-05-2018

I INTRODUCTION

The Pitman arm is a steering component that is used in an automobile or truck. It is a linkage between sector shaft of the steering box and drag link. It transmits the angular motion to the linear motion that is required to steer the wheels in desired direction. The arm is attached to 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. The idler arm is attached between the opposite side of the center link from the Pitman arm and the vehicle's frame to hold the center or drag link at the proper height. A worn ball joint or a sudden failure of pitman arm can cause severe damage and may get worse over time.

II OBJECTIVES

The main objective of the study is to analyze fatigue life and vibrational behavior of pitman arm using FEA tools under various loading conditions and structural optimization for better model which will have better performance.

III LITERATURE SURVEY

Sijith PM, Prof. Shashank Gawade, Prof. S.S Kelkar[1]: Performance study is carried out followed by static structural analysis and optimization to minimize the weight of the pitman arm and thereby reducing the material cost. Optimized model is then verified by physical testing.

Pavel Podany, Petr Martinek, Jana Miskova[2]:A failure investigation of fracture was conducted on pitman arm of stamping press. Fracture area was investigated by means of scanning electron microscope. Detailed investigation of microstructure on the locality of fracture initiation was performed. Article shows how crucial the heat treatment of the weld is for prevention of the failure. Further examples of other failure analysis show the most often cause of failures due to non-conforming microstructure of material.

Srilekha Aurulla , G. Gopala Krishna[3]: This paper presents the static and modal analysis of steering lever link of a tractor to check its deformation, maximum stress and natural frequencies by using three materials.
Kazem Reza Kashyzadeh, Mohammad Jafar Ostad-Ahmad-Ghorabi, Alireza Arghavan[4]: In the present paper, predict fatigue life of suspension component and package of automotive suspension are the main purposes. First, using MATLAB software, road roughness according to the intercity roads for constant vehicle velocity (100Km/h) has been studied. After that frequency response of components has been analyzed, its critical points determined to calculate the fatigue life of the part, and the amount of critical stress obtained based on Von Misses, Tresca and Max Principle criterion for a quarter car model (passive suspension System in 206 Peugeot).
AniketKolekar, Mr. Shubham R. Gound, Mr. Mahesh S. Ban [5]: this paper is about the design and fabrication of fixture which is used in the manufacturing of Pitman Arm of steering system. The design of fixture is done by using software CATIAV5R21.The purpose of the fixture is to provide strength, holding, accuracy and interchangeability in the manufacturing of product. The main purpose of a fixture is to locate and in the cases hold a work piece during an operation.

IV ANALYSIS OF PITMAN ARM

Finite element analysis is a computational technique that is used in engineering to obtain approximate solutions of boundary value problems.
The following are the steps for pre and post processing in FEM. [1]

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.

Table 1 Material properties Alloy Steel

Property	Value
Young's modulus, E	2.110^{9}Mpa
Poisson's Ratio ,ν	0.2
Density, ρ	7.9×10^{-9} tonne/mm^{3}
Yield Strength	520MPa

V FORCE CALCULATION:

Total Mass of the vehicle,
M1= Curb weight + Passengers weight
M1= 1600+600= 2200kg
This weight must be divided into front axle weight and rare axle weight. 52% of the total weight is taken by front axle and 48% is by rare axle.
Therefore, Mass on the front axle, M2=1144kg
Mass on one of the front wheel, M= 572kg
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*μ*□ ((B2/8) + E2)
T=Torque required to rotate one wheel (torque at king pin),
T= 557967.351 N,
F = T/L1 = 3848.05 N,
Since single steering arm will be handling two wheels so force on steering arm will be doubled
F= 7696.1 N

VI FINITE ELEMENT ANALYSIS OF PITMAN ARM

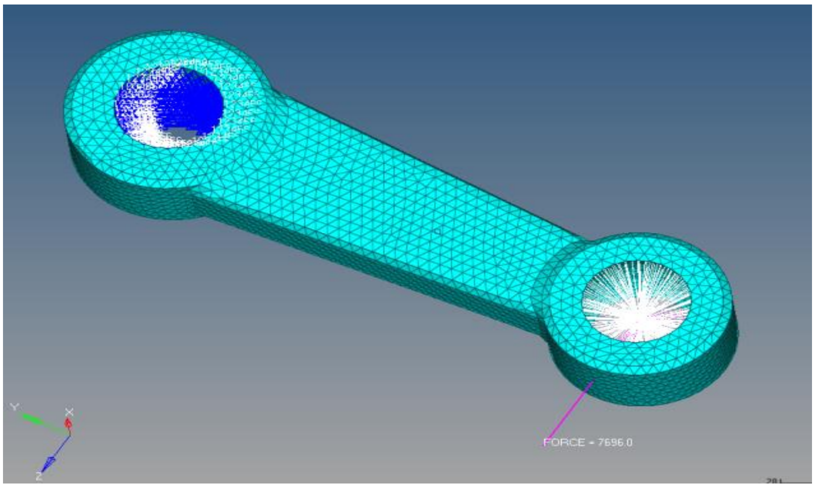

Fig.1 Meshed model with boundary conditions

Deformation plot

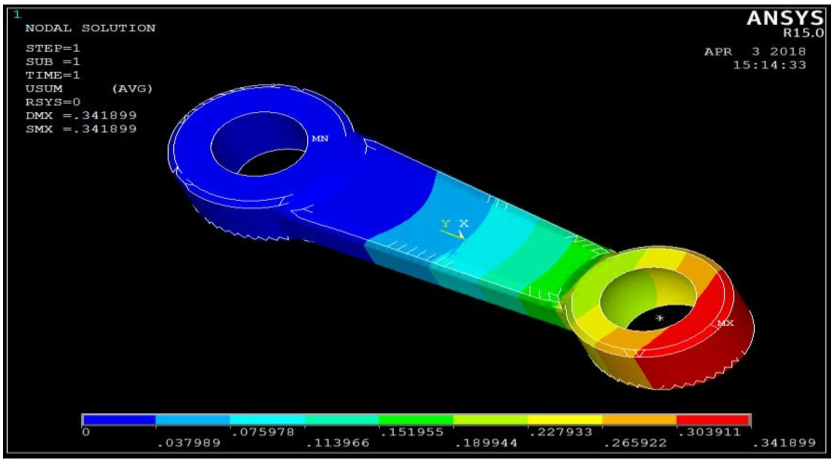

Fig.2 Displacement result for pitman arm Maximum deformation is 0.30 mm Stress plot

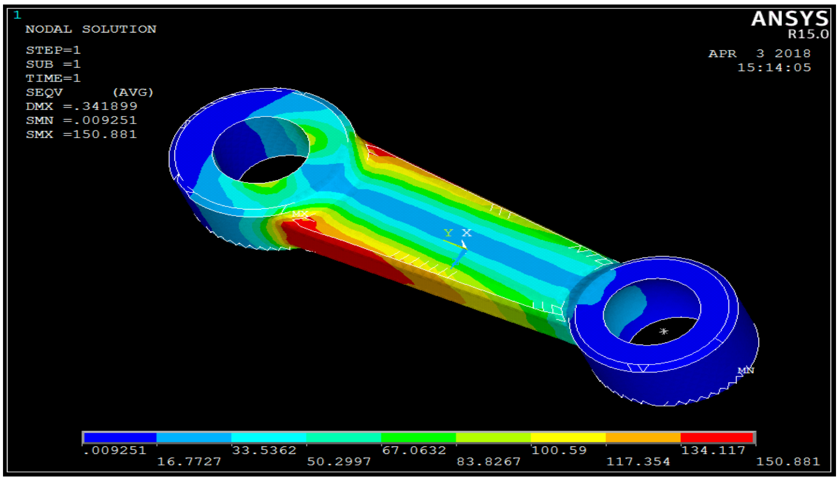

Fig.3 von-mises stress for pitman arm

Maximum Stress obsreved is **132.94 Mpa.**
As stress is well within the limit and deformation is less hence there is scope for optimization.

VII VIBRATIONAL ANALYSIS AND FATIGUE ANALYSIS

After this we have done vibrational analysis(Modal analysis) and fatigue analysis of existing pitman arm.Natural frequencies of pitman arm are 1248.09 Hz, 1625.5 Hz, 4918.69 Hz, 5772.23 Hz, 5798.34 Hz, 9270.32 Hz for 1^{st} to 6^{th} mode respectively.

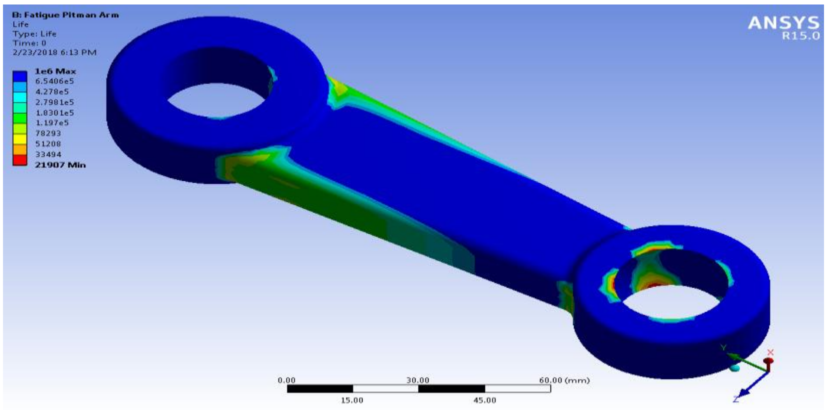

Fig.4 Fatigue life of specimen Life of specimen – 10, 00,000 cycles

VIII TOPOLOGY OPTIMIZATION METHODOLOGY

It uses highly advanced optimization algorithms; OptiStruct can solve the most complex optimization problems with thousands of design variables in a short period of time. OptiStruct advanced optimization engine allows users to combine topology, topography, size and shape optimization methods to create better and more alternative design proposals leading to structurally sound and lightweight design. Manufacturing requirements can also be defined as input to the simulation to create design proposals that are easier to interpret and to manufacture.

For topology optimization we create a 6 mm depth slot on both sides of the pitman arm.

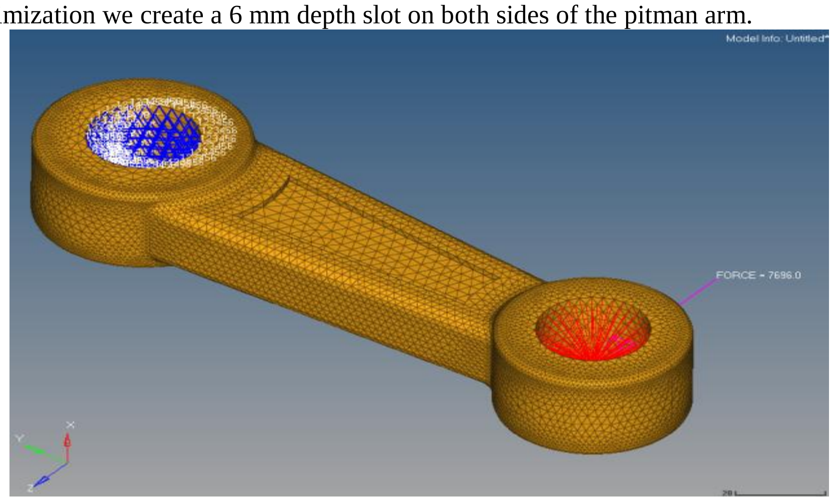

Fig.5 optimized pitman arm with applied boundary conditions in Hypermesh

IX RESULTS FOR STRESS AND DEFLECTION OF PITMAN ARM WITH 6 MM SLOTTING:

Result for Deflection:

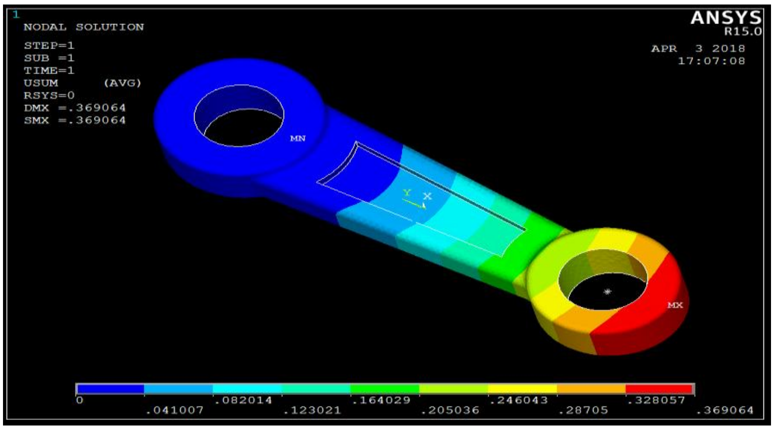

Fig.6 Displacement result for pitman arm

From fig.6 it can be seen that the deformation is 0.369 mm

Result for Stress

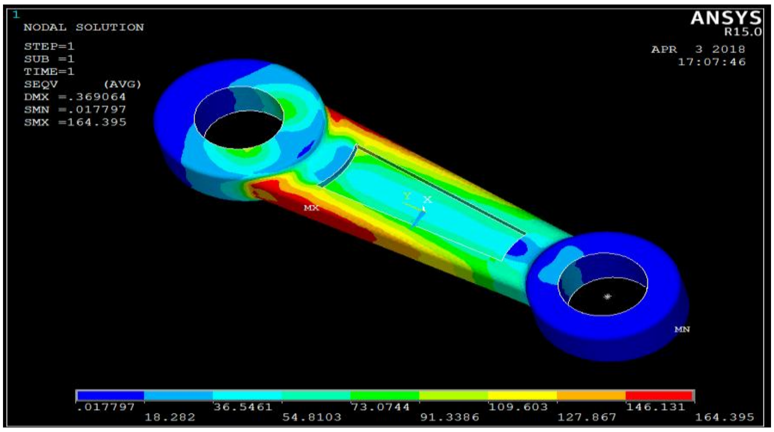

Fig.7 von-mises stress for pitman arm

From fig.7 it can be seen that the maximum stress is164.39 MPa.
As the stress induced is **164.39** MPa, which is well below the critical limit. Hence, Iteration-3 pitman arm with 6 mm slotting is considered in optimization.

X VIBRATIONAL ANALYSIS(MODAL ANALYSIS) AND FATIGUE ANALYSIS

After this the vibrational analysis and fatigue analysis of this optimized pitman armis carried out. The natural frequencies of optimized model are 951.19 Hz, 1464.43 Hz, 3654.77 Hz, 5446.25 Hz, 6179.35 Hz and 8733.91 Hz for 1^{st} to 6^{th} mode respectively.

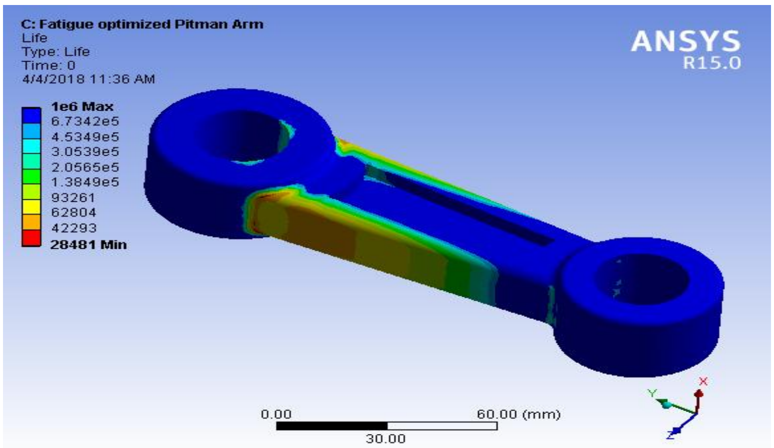

Fig.4 Fatigue life of specimen Life of specimen – 10, 00,000 cycles

XI RESULT AND DISCUSSIONS

Table 2 Comparison of structural analysis results

Material Steel	Existing Model	Optimized 6 mm slot
Deformation (mm)	0.34 mm	0.369
Stress (Mpa)	150.88 Mpa	164.395 Mpa
weight	1.073 Kg	0.976 Kg (9.04% weight reduction)

Table 3 Comparison of vibrational (modal) analysis results

Sr. No.	Mode	Frequency (Hz)	
		Existing	Optimized 6 mm slot
1	1	1248.08	951.19
2	2	1625.5	1464.43
3	3	4918.69	3654.77
4	4	5772.23	5446.25
5	5	5798.34	6179.35
6	6	9270.32	8733.91

Table 4 Comparison of Fatigue life

Fatigue Life	Minimum (cycles)	Maximum (cycles)
Existing steel Model	21907	1000000
Optimized 6 mm slot model	28481	1000000

XII CONCLUSION

Based on FEA it can be concluded that the optimized pitman arm has infinite life because it can withstands above 10,00,000 cycles. Weight reduction of 9.04 % is obtained without compromising the strength of pitman arm. Natural frequency of both conventional and optimized pitman arm are extracted.

REFERENCES

[1]. Sijith PM, Prof. Shashank Gawade, Prof. S.S Kelkar "*CAE Analysis and Structural Optimization of Pitman Arm"* International Engineering Research Journal Page No 1-5

[2]. Pavel Podany, Petr Martinek , Jana Miskova *"Failure Analysis of Pitman Arm, Influence of Microstructure on Failure"*Materials Science and Technology (MS&T) , Pittsburgh, Pennsylvania, USA, 2014 October Page No.12-16, 2014

[3]. Srilekha Aurulla , G. Gopala Krishna "*Modeling and Analysis of Steering Lever Link of a Tractor"* IJIRSET Vol. 5, Issue 11, November 2016 Page No. 19801-19808.

[4]. Kazem Reza Kashyzadeh, Mohammad Jafar Ostad-Ahmad-Ghorabi, Alireza Arghavan *"Fatigue life prediction of package of suspension automotive under random vibration based on road roughness"*Med. J. Model. Simul. 04 (2015) Page No. 037-050

[5]. AniketKolekar, Mr. Shubham R. Gound, Mr. Mahesh S. Ban "*Design of Fixture for Manufacturing of Pitman Arm"* IRJET, Volume: 04 Issue: 05 (May -2017) Page No.1714-1720.

[6]. P. D. Darade,Bimlesh Kumar,*"Employing Artificial Bee Colony In Mathematical Modeling Designing For Predicting Settling Time",* Materials Today: Proceedings Journal, Volume 4, Issue 8, 2017, Pages 7554-7561.

[7]. P. D. Darade, Bimlesh Kumar,*"Predicting Minimized Settling Time Corresponding Piezolocalization Displacement and Velocity",* Materials Today: Proceedings Journal, Volume 4, Issue 8, 2017, Pages 8469-8477.

[8]. P.D. Darade, Bimlesh Kumar, Sagar Bhopale, "Displacement Control of Photostrictive Actuators for Vibration Control with the Aid of Fuzzy Logic Control along with PSO Algorithm", Materials Today: Proceedings, Volume 4, Issue 2, Part A, 2017, Pages 3642-3651.

[9]. P. D. Darade, Bimlesh Kumar, *" Optimization Based on Evolutionary Algorithm in Vibration Control Process- A Review "*, International Journal of Research and Scientific Innovation (IJRSI) International Peer Reviewed Refereed Journal, Volume II, Issue IX, September 2015, IJRSI ISSN 2321 – 2705, pp 57-60.

Pradeep B Patil. "Vibrational Analysis, Life Prediction and Optimization of Pitman Arm Using FEM." International Journal of Computational Engineering Research (IJCER), vol. 08, no. 05, 2018, pp. 18-23.