Failure Analysis of Shackle Bracket Used In Airbus Suspension System

Dr. M. Nataraj[1], S. Aswinkumar[2]
[1]Professor Dept of Mechanical Engineering
[2]Dept of Mechanical Engineering
[1, 2] Government College of Technology, Coimbatore-13.

Abstract- *In the air suspension system of commercial passenger bus, the shackle bracket which holds the leaf spring deforms and cracks after a certain period of usage under actual road conditions. If replacement is required when the shackle bracket is failed, then it is a costlier at the customer end. In this paper, shackle bracket was analyzed under real conditions with generalized force elements using Failure Mode Effect Analysis to find the root cause of the bracket failure. In this finite element analysis, forces such as Bump force, Brake Force, Corner Couple, Bump Couple and Corner pretension acting on the bracket was applied to find out the stress value for all these forces. Further, the life cycle of the bracket was estimated. The design was modified, and the same condition of the forces applied to the modified bracket to observe the new stress and the corresponding life cycle was arrived for comparative analysis and the factor of safety was arrived at the optimized safe design.*

Keywords- Leaf spring bracket, Bump Force, Brake Force, Couple force, Commercial vehicle suspensions, Vehicle dynamics. FEAs

I. INTRODUCTION

The Suspension system supports the weight of the vehicle and provides a smooth ride for driver and passengers. Also, suspension systems protect your vehicle from damage and play a critical role in maintaining safe driving conditions. Failure damage assessment of a mechanical system is an important for design stage. A shackle bracket present in the commercial passenger bus must be strong enough to withstand loads imposed by vehicle mass during cornering, accelerating, braking and uneven road surfaces. The failure of shackle bracket acting under variable amplitude loading condition it's a complex phenomenon and is difficult to assess, particularly due to the load interactions. The significant acceleration or retardation in a crack growth process can occur as a result of this type of load interactions. The tensile over load cycles in retarded and under compressive loads in accelerated the fatigue crack growth rates.

The air suspension system of shackle brackets transfers all controls, braking and acceleration forces from the axle to the vehicle frame. These shackle brackets have adjustable air suspension, short with integrated shock absorber mounts, reduce weight make installation easier and cut the torsional load on the vehicle's frame. One end of the air suspension brackets is fixed to the chassis and other end connected to double stand leaf spring. Air suspension system in the middle portion of the leaf spring is fixed with a shock absorber. The shock absorber is a dual tube gas charged shock absorber. This shock absorbers with stands high stress and are highly durable. It also has temperature resistant sealing system.

The air suspension system consists of four primary parts. These components are mounted in the chase except leaf spring. The component of air bag (bellow), shock absorber and bracket, is mounted on the chases of the vehicle. The other end of the bellow and shackle bracket is connected by using double stand leaf spring. The other end of the shock absorber is fixed along with axle. This is arrangement of fixing air suspension system is shown in the figure 1&2. The candidate product for the research reported in this paper is RTS 6-U SERIES HKmodel manufactured by wheels India.

In this research, the working of suspension systems through a design modification of failure bracket, when subjected to dynamics forces acting on it were studied. The shackle bracket is analyzed by using Failure mode effect analysis and finite element analysis (FEA) is the root cause of system to find out the new safe stress value and corresponding life cycle value is calculated. The FEA techniques is an ideal tool to provide a solution for this kind of problem. All these concerns the safety of the vehicle.

Fig. 1Air bag arrangement

II. METHODOLOGY

The main objective of the research reported in this paper is to reduce the vertical vibrations bumps, impacts due to road irregularities by means of variations in the stress and deflection of a Bracket of the suspension system.

III. PROBLEM INVESTIGATION

Whenever force exerted on the system, the shock absorber and bellow absorb the force using leaf spring. One end of leaf spring is mounted on the bellow and another end is fixed to shackle bracket. So, whenever force exerted on the system, it is also absorbed by the shackle bracket. The same process repeated when the vehicle is moving on the road due to road irregularity. Due to repeated cycle process, which bracket under goes fatigue. This leads to bend in the bracket and crack formation. The failed component is shows fig.2. It shows the bending over the leaf spring fixing area and Fig 2 shows the crack formation in the bracket at fixing with chases. It is observed that the damaged shackle bracket has presumed the failures due to fluctuating loads with uneven road surface conditions.

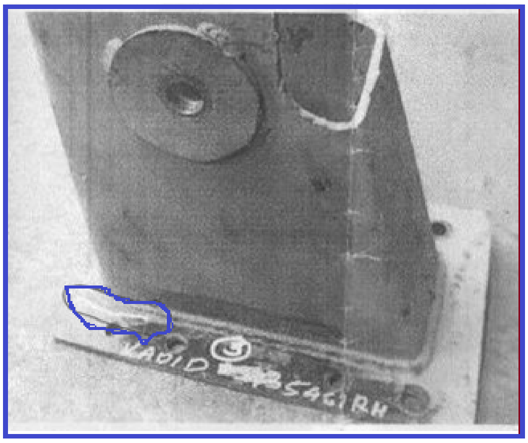
Fig.2 Crack formation

IV. MATERIAL AND GEOMETRY

The preliminary steps in failure analysis are identification of material. Normally material used for shackle bracket for plain carbon steel-grade C25, it has 0.90 -1.0% of carbon. The bracket materials composition used for 50 Cr 1 V 23. The materials are used in hardened and tempered state. The chemical compositional analysis of the bracket was carried out by the results are presented in table 1 composition in percentage.

Table 1 Material Composition

Steel	50 Cr1 V23
Grade	2
C	0.51-0.59
Si	1.6-2.0
Mn	0.50-0.80
Pmax	0.03
Smax	0.03
Cr	0.55-0.85
Mo	----

V. FAILURE MODE EFFECTIVE ANALYSIS

In order to identify the real-time problem, we can use the Failure mode effect analysis (FMEA). FMEA is a methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome these issues, thereby enhancing reliability through design. Here an air suspension system of leaf spring bracket has failed. In this case, the causes of failure of bracket is deformation and crack formation. The nature of failure causes and effects of failures were studied with the help of design FMEA chart. There is no design controls to check the system to identify or simulate the problem. So in order to check the stress distribution of the existing system over leaf spring bracket, the life cycle of the component is to be increased. The corrective actions that need to be taken in order to eliminate or mitigate the risk and then follow up on the completion of those recommended actions has to be identified. The table 2shows the typical FMEA chart for the bracket failure. By using this chart, we can fix the ranking for the priority for the problem.

VI. MODELING AND ANALYSIS

In order to analyze the system, the dynamic forces which are acting on the bracket has to be considered. The main forces acting on the body are listed below. Each of these forces were considered individually and results were obtained. The main factors considered for analyzing shackle bracket are the various dynamic forces acting on the bracket.

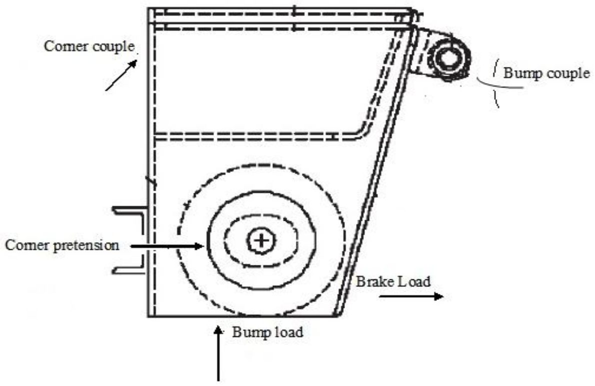

Fig. 3 Load Factors consider in bracket

For a level roadway, braking vehicle experiences only for horizontal acceleration. Therefore, according to Newton's laws of motion, the sum of the vertical forces acting on the vehicle must be zero. The vertical forces on an vehicle are the normal forces of the roadway pushing up on the tires to counteract the effect of gravity pulling down. Gravity effectively acts at the vehicle's center of gravity (C.G).

The two normal forces N1 and N2, center of gravity, and the braking forces f1 and f2, along with the horizontal braking forces of the roadway on the tires, are displayed in Fig.7.If one labels the normal forces acting on the front and rear tires as N1 and N2 respectively, and "W" represent the weight, or force of gravity, then Newton's law equation is,

$$N1 + N2 - W = 0 \quad (1)$$

Since there is no appreciable forward rotation of the vehicle, Newton's laws require the sum of the torques (lever arm time's force) must also add to zero. If the C.G is used as the point of rotation, then the roadway's vertical or normal force on the front tires produces a clockwise torque with lever arm b1 as shown in the figure, while the normal force on the rear tires produces a counterclockwise torque with lever arm b2 (note that b1 + b2 = B, the wheel base). The braking forces on both the front and rear tires produce counterclockwise torques with lever arm h, the height of the C.G from the roadway. Adding clockwise torques and subtracting counterclockwise torques (where f1 and f2 are Coefficients of friction)

$$b1N1 - b2N2 - hf1N1 - hf2N2 = 0 \quad (2)$$

These two equations are solved for N1 and N2, with the following results:

$$N1 = (b2 + hf2)\, W/b1 + b2 + h(f2 - f1) \quad (3)$$

$$N2 = (b1 - hf1)\, W/b1 + b2 + h(f2 - f1) \quad (4)$$

For calculation purpose the following parameters are considered, table.3 shows the specification of the Airbus system. Below the table.2 shows in specification of airbus suspension system of model was considered.

Table.2 Specification of Airbus

Total weight of vehicle(Without loaded condition)	10360 Kg
Total weight of vehicle(With loaded condition)	15660 Kg
Front axle weight	650 Kg
Rear axle weight	1020 Kg
Total load acting on the CG (W)	15660 Kg
Distance between front wheel to CG (b1)	1827 mm
Distance between rear wheel to CG (b2)	2523 mm
Distance between ground level to CG (h)	975 mm
Coefficient of friction for front wheel(μ)	0.2
Coefficient of friction for rear wheel(μ)	0.5
Unsprung weight= Front axle weight + Rear axle weight Total sprung weight=Total weight – Unsprung weight	

VII. BUMP LOAD

Bump load is the load acting on the wheels. When the vehicle is moving over the road, unevenness like speed breakers, pits occurs. When the vehicle is moving over this unevenness, the wheel axle absorbs more loads due to a transfer of dynamic forces. The forces are converted in to work with the help of suspension system. So in that time, the suspension system needs to transfer a lot of loads.

VIII. BRAKING LOAD

In general, when a brake is applied to the vehicle 60% of the sprung mass is acting on its front axle. The force acting on the front axle is calculated. Consider a vehicle is moving 55 km/hr,and applied the brake and dropped to 0 km/hr in 3 seconds, and assumed a constant braking force, we could calculate that force (given the weight of the vehicle, and ignoring air resistance and miscellaneous frictional decelerators).

Deceleration= (Initial speed – Final speed) / Total time taken (5)

Braking force = m*a (6)

m --> Mass of the body (C.G)
a --> Deceleration

1)

IX. COUPLE FORCE

In that suspension system, consider two types of couple as like, bump couple and corner couple. In both cases, one side of the wheel is to transfer a force to another wheel side. So, the one end loses weight and other end absorb that weight, this is explained in the figure. 8a shows the normal road surface. So, both the axis is in parallel in shape. But in the figure 8b, is shown that one wheel is moving over the uneven road surface. At that time on right hand side of the wheel exerts an upward force; at the same time in the left-hand side absorbs the load. So, it forms a couple of force.

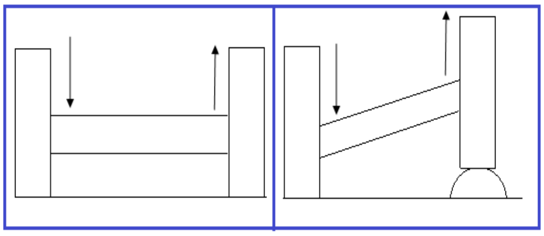

Fig.4 Corner Couple load

X. FINITE ELEMENT ANALYSIS OF SHACKLE BRACKET

A complete solid structure of the shackle bracket (Figure 9&10) is created by using CATIA V5 software package. This model is saved in IGES file format to import it in ANSYS14.0 without any distortion to carry out the analysis of part component. The finite element analysis of the bracket was conducted for a static structural analysis problem.

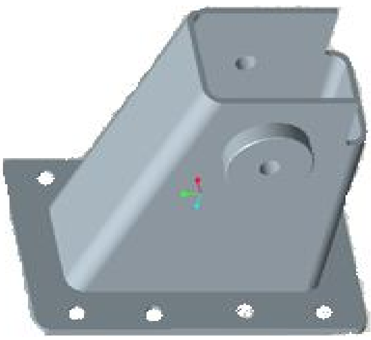

Fig. 5 CAD model without rib

The SOLID 45 element type was selected for analysis, since the element model groups has quadratic displacement behavior in addition to plasticity, swelling, creep, large deflection, stress stiffening and large strain capabilities. Above features was consider selected for SOLID 45 element type model, it has irregular meshes. The model used free meshing for analysis and the element used is solid element. Total no of element used for meshing is 72802 and the node is 583216.The element is defined by ten nodes having three degrees of freedom at each node: translation in the nodal x, y and z directions.

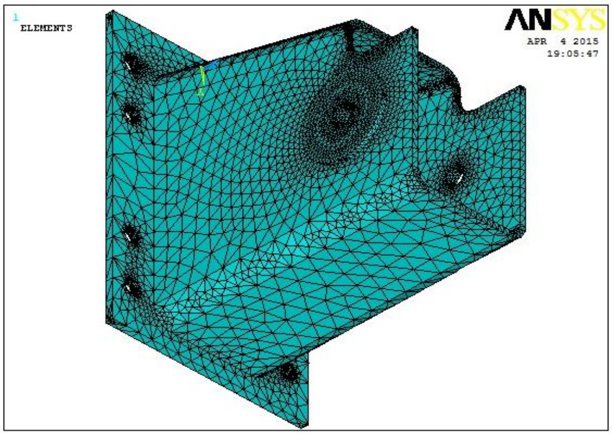

Fig.6 Meshed Model with out rib

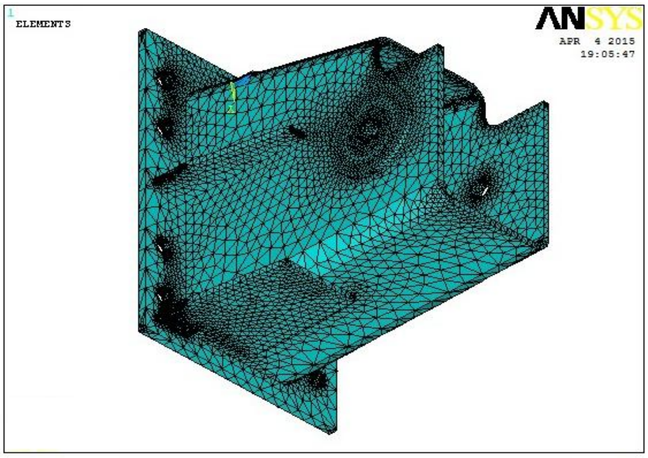

Fig.7 Meshed model with rib

XI. RESULT OF AN EXISTING SYSTEM

As per the procedure all the parameters are given in the ANSYS and the results are obtained for different type of cases. The results are shown below and Refer Fig 8 to12. table 3 shows the stress values of the existing bracket.

Table 3 – Stress value of existing bracket

Cases	Stress value (N/mm^2)
Braking load	311.81
Bump load	87.270
Bump couple	221.78
Corner couple	254.89
Corner pretension	199.869

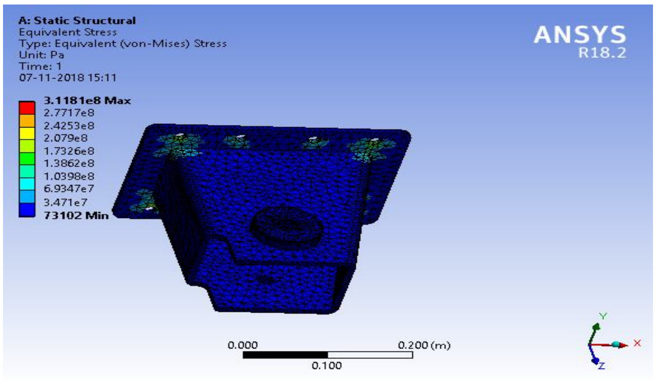

Fig 8 - Deflection Due to Brake load

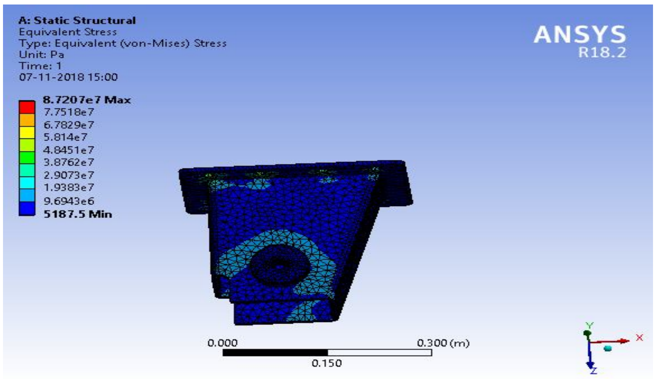

Fig 9 - Deflection due to bump load

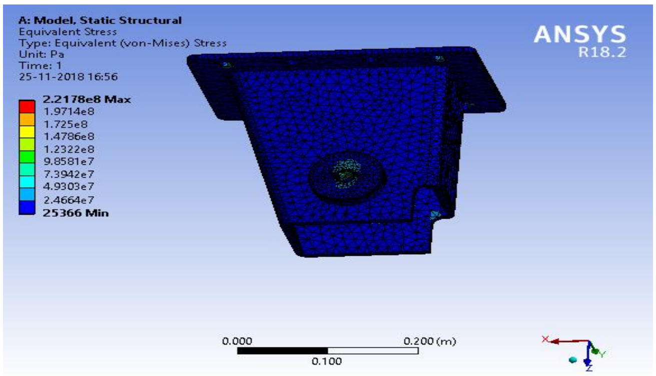

Fig10 - Deflection due to Bump couple

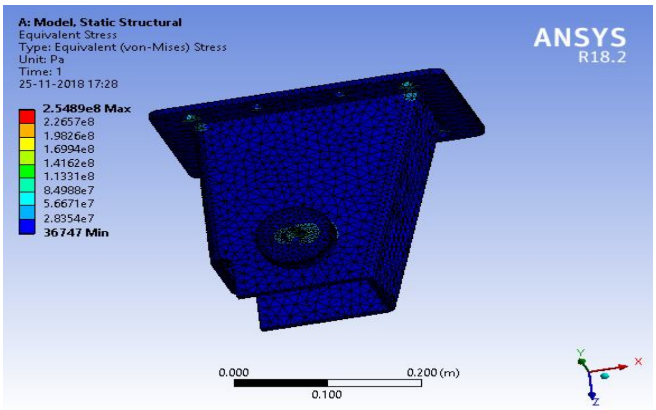

Fig 11 - Deflection due to corner couple

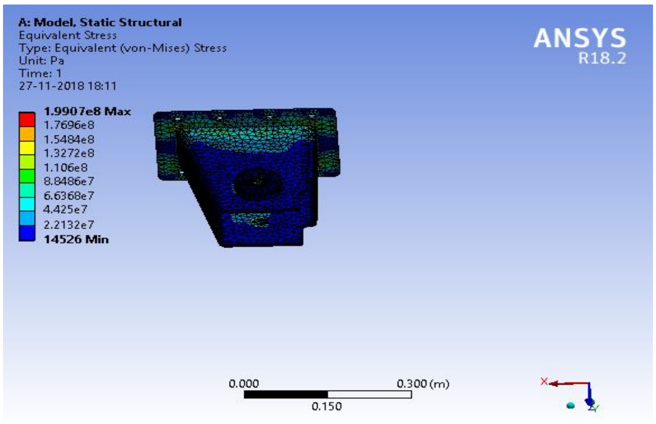

Fig 12 – Deflection corner pretension

XII. IMPROVEMENT IN EXISTING DESIGN

For improving the existing model, we need to reduce the stress vales in the leaf spring bracket. For that we can go for the material change. But if we suggested for new material then the concern have to maintain some inventory for the new type of material. Also, we should not disturb the existing process flow. And the new development can be fitted for the existing operation and the existing vehicle. By considering the stress strain distribution in the product we need to improve the section modulus of the bracket.

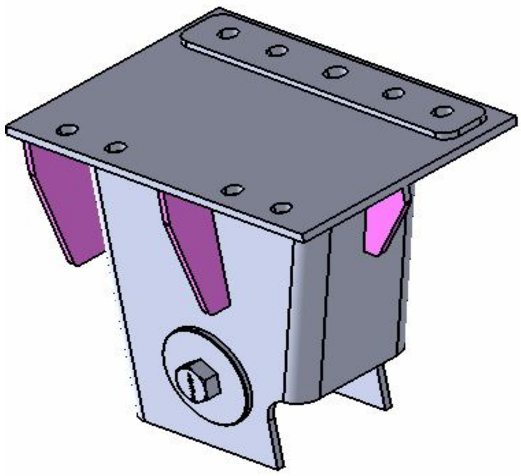

Fig 13 - Drawing and Model for Shackle Bracket with rib

XIII. RESULT FOR THE PROPOSED BRACKET

As for the existing bracket all the parameters and analyzing is done for the new modified system. The new modified bracket results for different loading conditions are shown below refer Fig14 to18. table 4 shows the stress values of the proposed bracket.

Table 4 – Stress value of proposed bracket

Cases	Stress value (N/mm^2)
Braking load	285.331
Bump load	64.112
Bump couple	200.43
Corner couple	215.39
Corner pretension	178.25

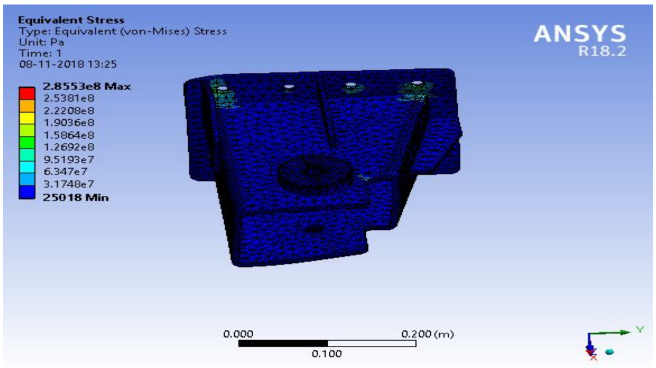

Fig 14 – Deflection due to braking load

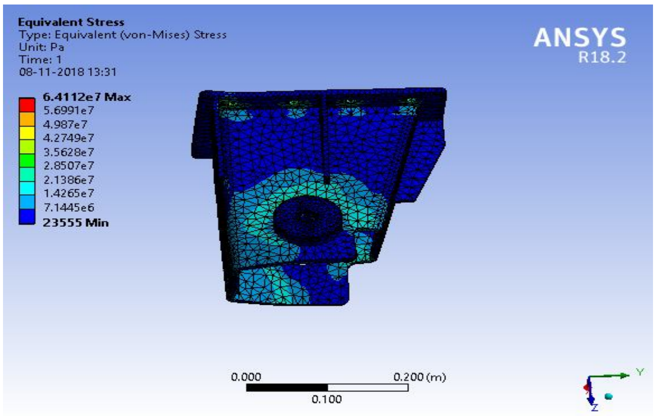

Fig 15 – Deflection due to bump load

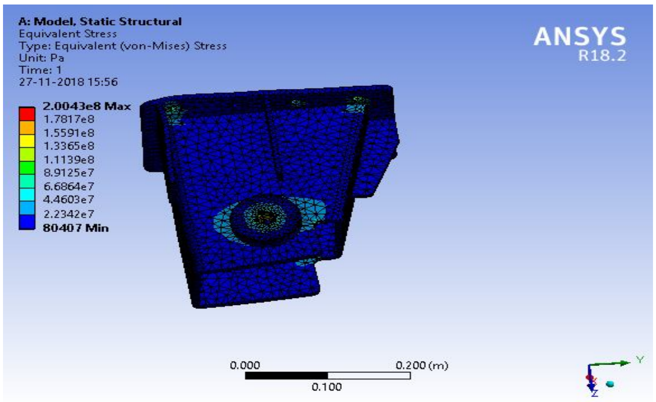

Fig 16 – Deflection due to bump couple

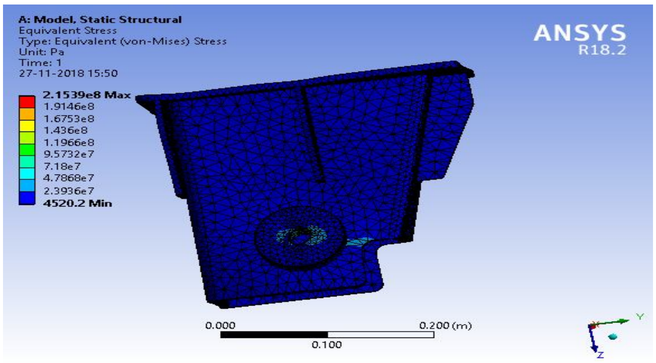

Fig 17 – Deflection due to Corner couple

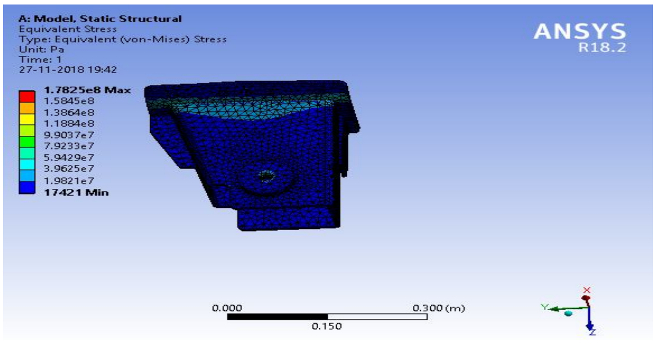

Fig18 – Deflection due to corner pretension

XIV. RESULTS AND DISCUSSION

Table: 5 Comparison of results

Loading condition	Existing bracket		Proposed bracket	
	Stress value (N/mm^2)	Life cycle	Stress value (N/mm^2)	Life cycle
Braking load	311.81	2X 10^4	285.331	5X 10^4
Bump load	87.270	1X 10^8	64.112	1X 10^8
Bump couple	221.78	4X 10^5	200.43	9X 10^5
Cornerco uple	254.89	1X 10^4	215.39	3X 10^4
Corner pretension	199.869	2X 10^4	178.25	3X 10^4

- The life cycle of the existing bracket is arrived using Finite Element Analysis.
- From table 5, Various possibilities of improving the life cycle of the bracket is studied finally the addition of stiffeners in the bracket gives the increment in the number of cycles in the bracket without disturbing the Fit, Form and Function.

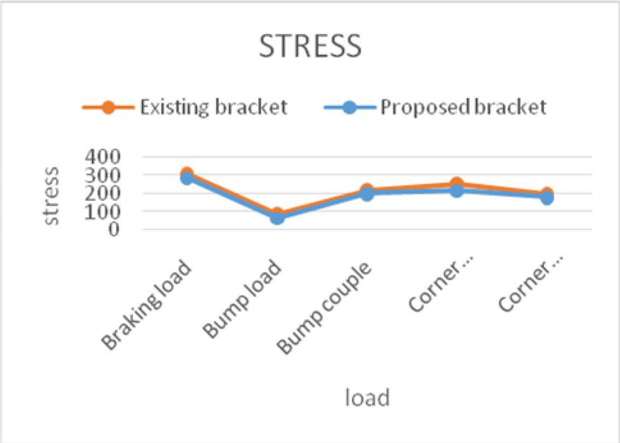

Fig 19 Load vs stress

From the above fig 19 stress for varying load condition is observed.then it shows stress in the proposed model iscomparitively lower than the exisiting model.

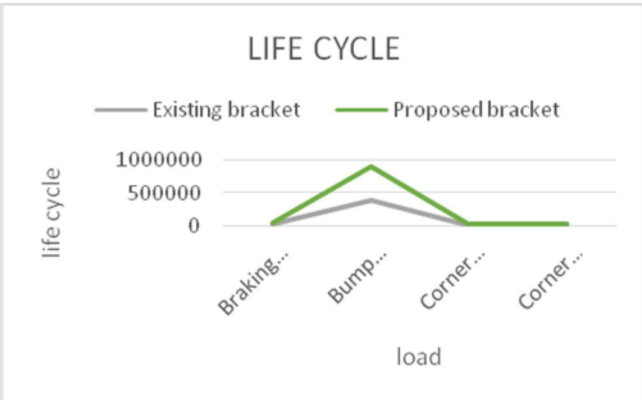

Fig 20 Load vs life cycle

From the above fig 20 life cycle of both the bracket is observed with respective load condition. The graph shows life cycle id improved in proposed bracket compare to existing bracket.

XV. CONCLUSION

Predicting fatigue life is a critical aspect of the design cycle because virtually every product manufactured will wear out or break down. These issues are whether the product component assembly will reach its expected life, and if damaged, whether the product component assembly will remain safety in service until the damage can be discovered and repaired. And as with most simulation analysis, the earlier fatigue analysis is deployed in the product development process, the more benefits will be realized, including safety and economic. The FEA tool were made a structural analysis was done. The deflection and stress an improving the life cycle of the product without disturbing the function and tolerance of model.

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