Design Optimization and Fatigue Analysis of Indian Railway Draft Gear Housing

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Abstract— The draft gear housing is used to connect railway cars. Hence it is continuous subjected to buff and drag forces. These forces cause the failure of draft gear frequently due to fatigue loading. This work aims in analysing the draft gear housing assembly under service load conditions and finding the stresses, number of cycles to failure respectively. And also finding the more stress concentration regions and studying the effect of these on elements with duration. Finding and analyzing the reason for failure of these components and finding the corrective measures by modifying design to required extent. If the design is failing under the service load (2500kN, 2000kN, 1500kN) conditions, design needs to be modified and improve the fatigue life of the component by understanding the stress concentration zone, load distribution etc. There are two types design modification of the component i.e. Without undercut draft gear housing (at load 2500kN, 2000kN, 1500kN) and With undercut draft gear housing (at load 1500kN), after geometry modifications to reduce the stress levels and finally comparing the FEA results with a analytical calculated values to validate and also comparison a S-N curve for without undercut and with undercut of a draft gear housing and find the number of cycles. CATIA V5 used for the modelling, HYPERMESH is used for meshing, ABAQUS is used for analysis and FE-safe is used for finding the fatigue life of component.

Key words: Draft Gear Housing, Fatigue Life, Multiple Loading Conditions, S-N Curve, Etc

I. INTRODUCTION

Introduction of draft gear housing, Indian Railways are facing problem of longitudinal jerks. Though various measures were taken in the past to deal with the problem of jerks, no significant improvement was observed. Research design and standards organization (RDSO) has done a complete analytical study on causes for Longitudinal jerks and based on the findings, it has been recommended to use balanced type of draft gear housing for coaching stock. A new specification of draft gear housing with balanced type draft gear has been prepared. The specification has been made to meet Indian Railways specific requirement. Draft gear housing important for safety and commercial concern.

Draft gear housing is the most significant component of the coupler, this type of draft gear housing is the mainly railway connection in the Australian and North American railways. This type of auto coupler with draft gear housing using in the Indian railways. Draft gear housing is the two types of roles in the train operation, transmitting and damping of in buff and drag forces. There are draft gear housing is the male and female part are connected to the front and back end of the train (railway cars). As shown below figure of male and female connector of draft gear.

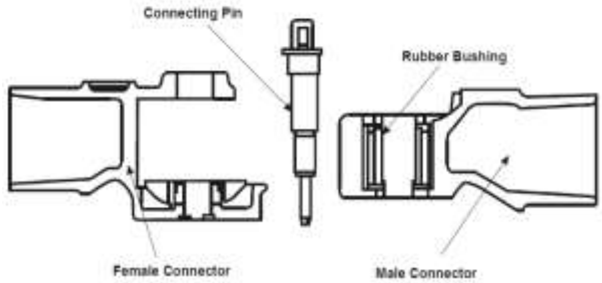

Fig. 1: Male and female connector of draft gear

A. Process Methodology

Following methodology involved in this project,

1) The solid model of this draft gear housing is developed in CATIA V5 software.
2) Creation of FE model using appropriate meshing tool.(hyper mesh)
3) After meshing the model to analysis of component, applying loads and boundary conditions as per the service load.(abaqus)
4) To understand the stress concentration region.
5) To calculated fatigue life of component.
6) Compare with requirements.
7) Suggest design modification and re run to achieve fatigue life.
8) Conclusion.

B. Fatigue

Progressive damage under the repetitive load is called Fatigue and Failure occurs under the condition of dynamic loading are called fatigue failures. It is found that for most equipment there is a limiting stress below which a load may be repetitively applied for an indefinite period large number of time without causing failure. This type of limit stress is called Endurance limit. The stress at which a metal fails by fatigue is herein termed the Fatigue strength. Fatigue failure is always start from surface.

Some formulas for calculated fatigue life of component and finding range of stress, mean stress, alternating stress, stress ratio and amplitude ratio.

1) *Range of stress:*

$$\sigma_r = \sigma_{max} - \sigma_{min}$$

2) *Alternating stress:*

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

3) *Mean Stress:*

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

4) *Stress ratio:*

$$R = \frac{\sigma_{min}}{\sigma_{max}}$$

5) *Amplitude Ratio:*

$$A = \frac{\sigma_a}{\sigma_m}$$

C. *Strategies in fatigue Design*

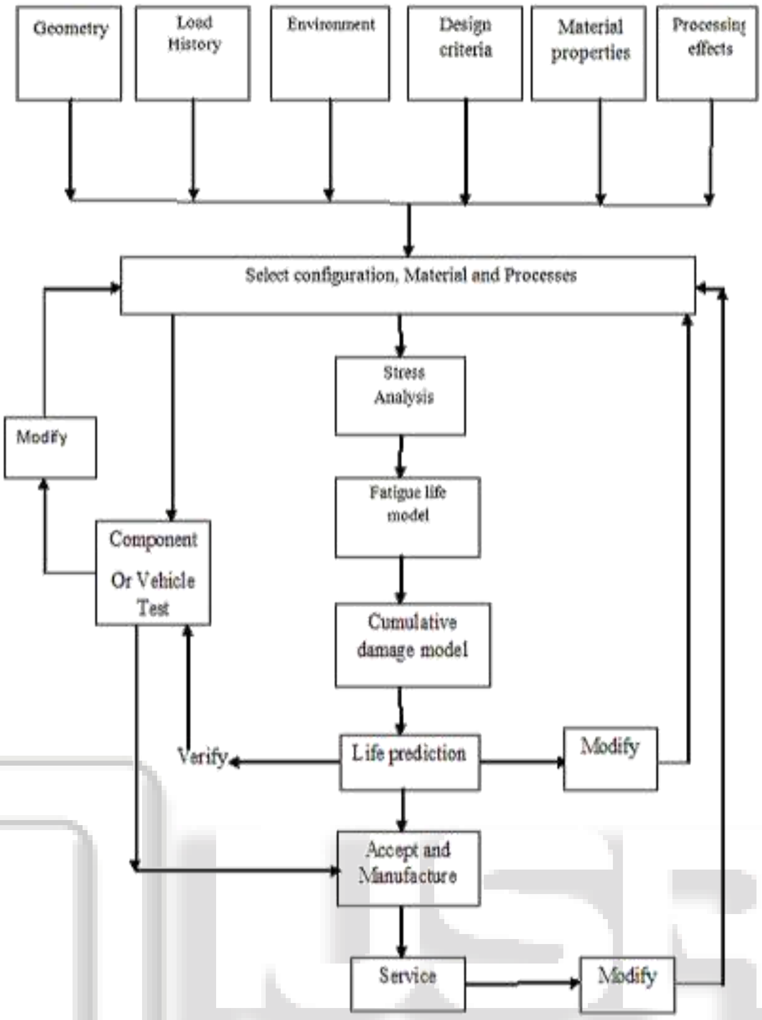

Fig. 2: Strategies in fatigue design

D. *Properties of Material*

Steel alloy material used in the draft gear housing. There are two parts in draft gear housing i.e. frames (upper frame and lower frame) and blocks. Frames are using to the AAR-M201-GR-E material, blocks are using to the IS-2062 materials for steel alloy. Show below table for n the properties of steel alloy materials.

Material	Density (δ)	Young's modules (E)	Poisson Ratio (ϒ)
	Kg/m^3	MPa	
AAR_M201_GRADE_E (Frame)	7800	1.9×10^5	0.3
IS 2062 (Block)	7850	2×10^5	0.3

Table 1: Material Properties for steel alloy

E. *Model for draft gear housing*

The solid model of this draft gear housing is developed in CATIA V5 software and generating 3D model. There are two types of 3D model created i.e. without undercut and with undercut draft gear housing. Draft gear housing is involved two part i.e. frame and block. The quantity of frame and block is two. Frame is involved a hole, fillet, sluts and undercut etc. As shown in below figures for without undercut draft gear housing and with undercut draft gear housing.

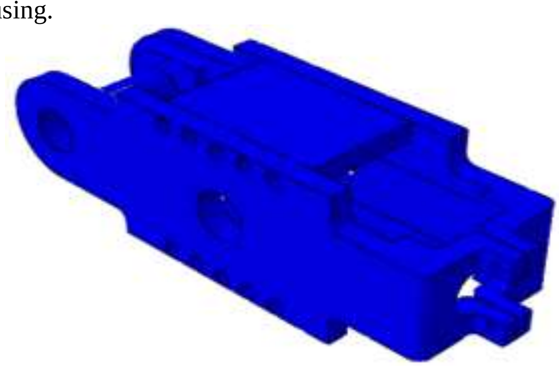

Fig. 3: Without undercut draft gear housing

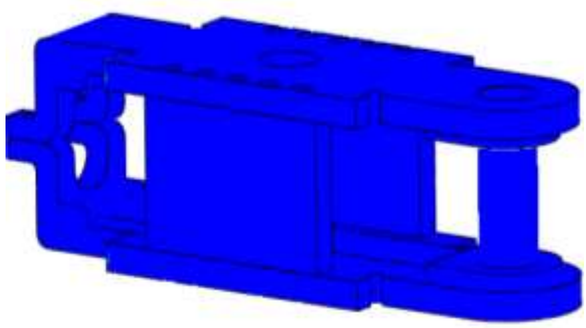

Fig. 4: With undercut draft gear housing

F. Meshing (2D & Tetra mesh)

In computational solution of partial differential equation, meshing is a separate representation of the geometry that is involved in the problem. Essentially, it partitions space into elements (cells or zones) over which the equations can be free to create computationally best shaped zones, or they can be fixed to represent internal or external boundaries with in a model. Draft gear housing is the meshing of 1^{st} order element (C_3D_4). Meshing is convert infinite element to finite element i.e. called meshing.

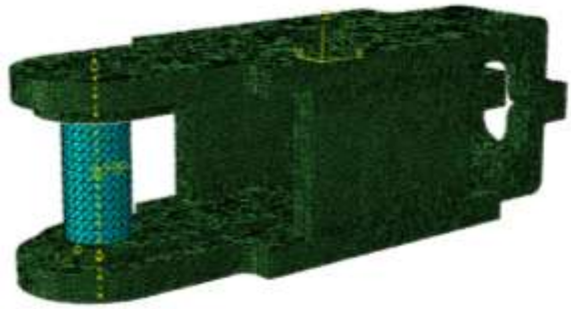

Fig. 5: Mesh view of without undercut draft gear housing

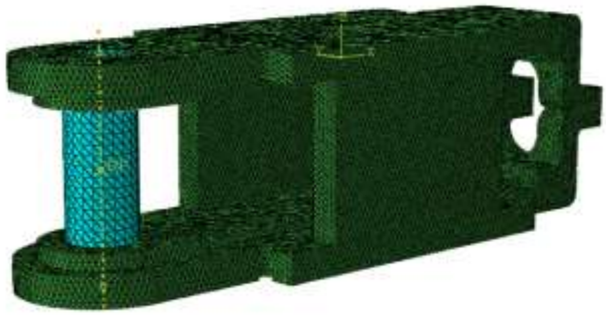

Fig. 6: Mesh view of with undercut draft gear housing

II. RESULTS AND DISCUSSION

The analysis carried out for different load condition and many modification of the component. For many loads are applied to the draft gear housing (1500kN, 2000kN, 2500kN). And there are two types are modification, i.e. without undercut (fillet) and with undercut draft gear housing.

A. Without Undercut Draft Gear Housing

The without undercut or fillet region of draft gear housing is the applied drag mode and buff mode load condition. The applied a tensile load in drag mode and compression load in buff mode. Check the stress concentration region for draft gear housing. Stress concentration is high in fillet region and Stress is increase in number of load, the component is automatically fail in fillet region. There are two types of load is applied on draft gear housing i.e. drag mode and buff mode. As shown below results for drag mode and buff mode of draft gear housing.

1) Drag mode (Tensile load)

In drag mode, the draft gear housing was constrained in XYZ direction on the faces of four of the gear housing which rest on the vehicle. A frictionless support on the two faces where the coupler is placed. The applied load 1500kN on a draft gear housing in drag mode, to increasing the stress concentration in fillet region. To check the stress concentration region, displacement, von misses stress, reaction force, max and min principle stresses and strain. As shown below figure for von mises stress in drag mode.

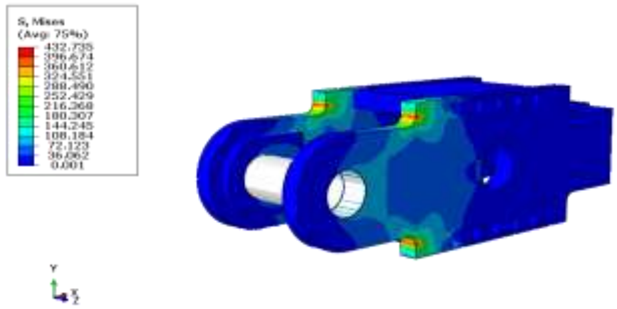

Fig. 7: Von mises stress for drag mode

2) Buff Mode (Compression Load)

In buff mode, the draft gear housing was constrained in XYZ direction on the faces of four of the gear housing which rest on the vehicle. A frictionless support on the two faces where the coupler is placed. To applied a compression load at 1500kN in draft gear housing in buff mode to check the stress concentration region, displacement, von misses stress, reaction force, max and min principle stresses and strain. As shown below figure for von mises stress in buff mode.

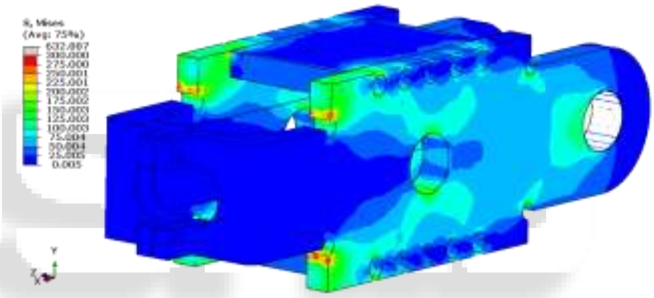

Fig. 8: Von mises stress for buff mode

B. With Undercut Draft Gear Housing

After failure of the component to changing modification of geometry and reduced the load. To changing fillet region for draft gear housing to cut the fillet part for undercut 12.5mm, because stress concentration high. After modification of geometry to applied load at 1500kN in drag mode and buff mode condition. . As shown below results for drag mode and buff mode of draft gear housing.

1) Drag mode

The applied tensile load on a draft gear housing in drag mode, to increasing the stress concentration in undercut region. And check the reaction force, max principle stress, min principle stress, displacement, strain. As shown below figure for von mises stress in drag mode.

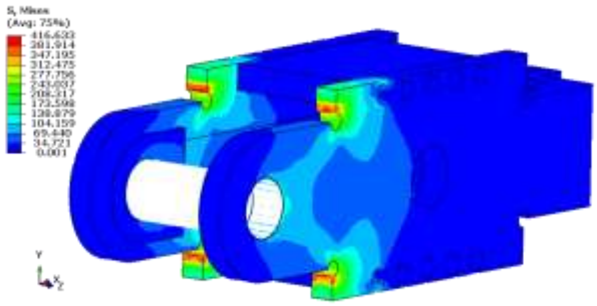

Fig. 9: Von mises stress for drag mode

2) Buff mode

Applied to compression load on a draft gear housing in buff mode to check the stress concentration region, displacement, von misses stress, reaction force, max and min principle stresses and strain. As shown below figure for von mises stress in drag mode.

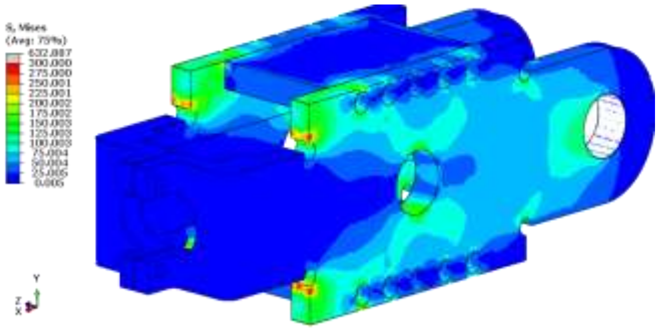

Fig. 10: Von mises stress for buff mode

III. VALIDATION

A. Calculation for Without Undercut

Type	Load (kN)	Node no.	S, von mises (Mpa)	Max princ (Mpa)	Min princ (Mpa)
			Without Undercut		
Drag mode	1500	126357	271.174	285.42	3.22143
		126356	257.593	283.68	15.0394
		119837	22.1882	23.1305	0.44415
		117520	19.8581	21.058	0.6998
Buff mode	1500	126357	128.926	-2.78054	-134.725
		126356	136.09	-7.058	-147.965
		119837	153.765	-3.3355	-159.965
		117520	130.02	-7.012	-163.147

Table 2: Few von misses stress, max principle stress and min principle stress for without undercut in drag mode and buff mode.

At Load=1500kN

At node number 126356

1) Range stress:

$$\sigma_r = \sigma_{max} - \sigma_{min}$$
$$\sigma_r = 283.68 - (-7.058)$$
$$\sigma_r = 290.738\text{MPa}$$

2) Alternating stress:

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$
$$\sigma_a = \frac{283.68 - (-7.058)}{2}$$
$$\sigma_a = 145.369\text{MPa}$$

3) Mean stress:

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$
$$\sigma_m = \frac{283.68 - 7.058}{2}$$
$$\sigma_m = 138.311\text{MPa}$$

4) Stress ratio:

$$R = \frac{\sigma_{min}}{\sigma_{max}}$$
$$R = \frac{-7.058}{283.68}$$
$$R = -0.0248$$

5) Amplitude Ratio:

$$A = \frac{\sigma_a}{\sigma_m}$$
$$A = \frac{145.369}{138.311}$$
$$A = 1.051$$

Calculation procedure is same for the remaining nodes.

B. Calculation for with undercut

Load=1500kN

At node number 109741

1) Range Stress:

$$\sigma_r = \sigma_{max} - \sigma_{min}$$
$$\sigma_r = 246.19 - (-2.622)$$
$$\sigma_r = 248.81\text{MPa}$$

2) Alternating stress:

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$
$$\sigma_a = \frac{246.19 - (-2.622)}{2}$$
$$\sigma_a = 124.405\text{MPa}$$

3) Mean stress:

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$
$$\sigma_m = \frac{246.19 - 2.622}{2}$$
$$\sigma_m = 121.705\text{MPa}$$

4) Stress ratio:

$$R = \frac{\sigma_{min}}{\sigma_{max}}$$
$$R = \frac{-2.622}{246.19}$$
$$R = -0.0106$$

5) Amplitude Ratio:

$$A = \frac{\sigma_a}{\sigma_m}$$
$$A = \frac{124.405}{121.784}$$
$$A = 1.0215$$

Type	Load (kN)	Node no	Von mises (MPa)	max principle (MPa)	min principle (MPa)
			With Undercut		
Drag mode	1500	109741	244.239	246.19	-12.315
		110292	209.698	131.087	-107.283
		83902	23.566	23.8197	-0.67059
		83976	20.8825	21.4754	-0.4232
Buff	150	10974	152.011	-2.622	-161.47

mod e	0	1			
		110292	93.4204	-11.15	-88.474
		83902	163.443	-5.311	-171.36
		83976	160.012	-5.13	-168.86

Table 3: Few von misses stress, max principle stress and min principle stress for with undercut in drag mode and buff mode.

Calculation procedure is same for the remaining nodes.

C. Comparison Fatigue life of component

1) S-N Curve for without undercut

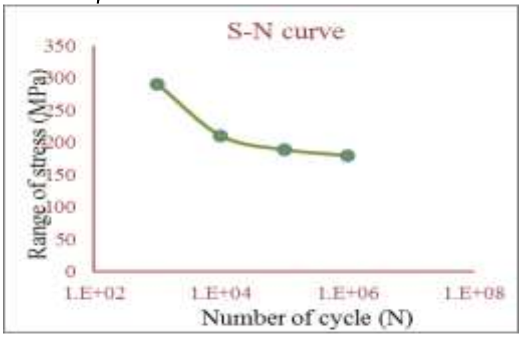

Fig. 11: S-N curve for without undercut

2) S-N Curve for with undercut

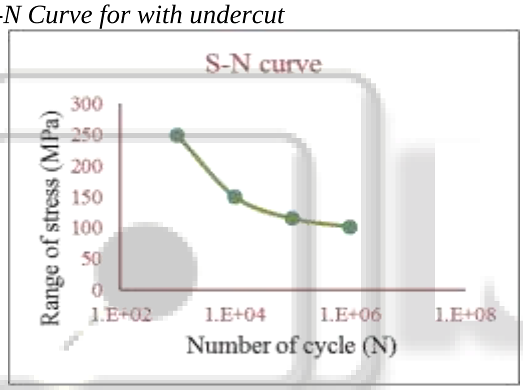

Fig. 12 S-N curve for with undercut

3) S-N Curve for AAR-M201-GR-E Material

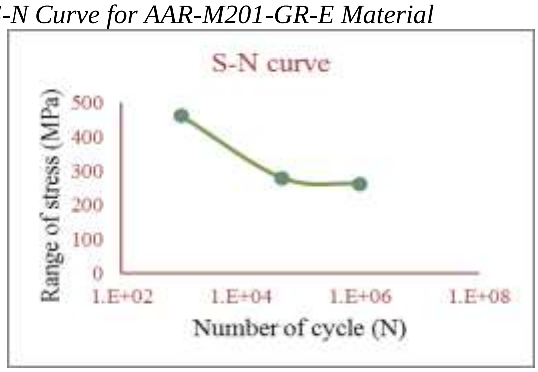

Fig. 13 S-N curve for AAR-M201-GR-E (FE-safe tool)

4) S-N Curve for IS-2062

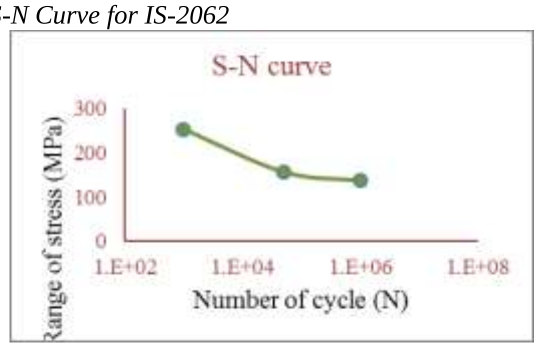

Fig. 14: S-N curve for IS-2062 material (in FE-safe tool)

5) Fatigue life of without undercut draft gear housing

Total number of cycles is 24758.389 of without under undercut draft gear housing. This type draft gear housing is successfully analysed. As shown in below figure.

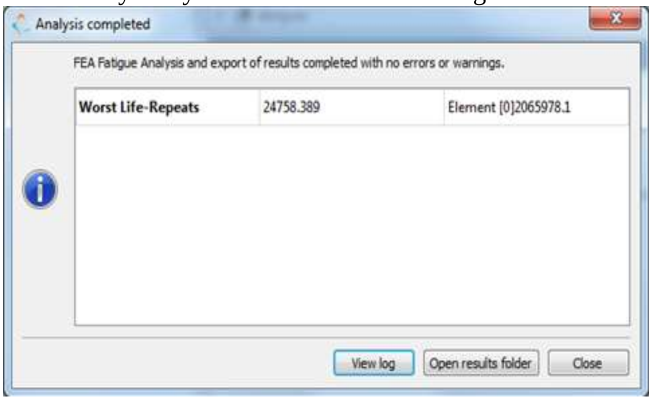

Fig. 15: Fatigue life of without undercut draft gear housing

6) Fatigue life of with undercut draft gear housing

Total number of cycle is 69654.734

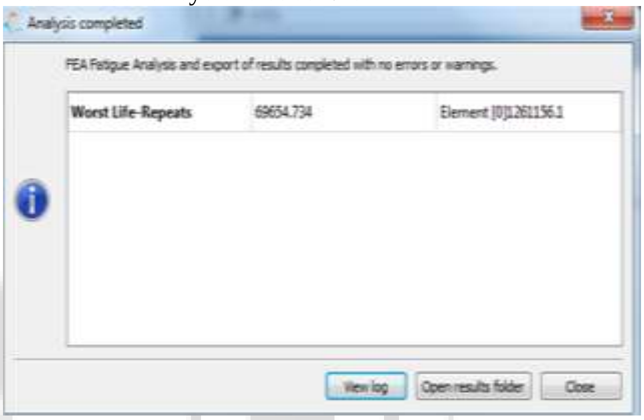

Fig. 16: Fatigue life of with undercut draft gear housing

IV. CONCLUSION

Draft gear housing analysis is carried out successfully by using ABAQUS. In this work considered various geometry modification of service load condition.

Two types of geometry modification is done i.e. without undercut and with undercut draft gear housing. Stress concentration ratio is more in case of without undercut. So the modified geometry with undercut is design and analysis is done.

In without undercut draft gear housing three different loads are considered i.e. 2500kN, 2000kN and 1500kN. For these different loading conditions stress concentration is calculated and found it is gradually decreasing with respect to load.

Now with modified design i.e. draft gear housing with undercut is analysed and checked for stress concentration region at different loading condition. Also found better results i.e. less stress concentration with respect to without undercut draft gear housing.

In further, for these two design at 1500kN fatigue life is estimated by using S-N Curve and found 24758.389 cycle for without undercut and 69654.734 cycles for with undercut draft gear housing.

Hence it is concluded that by modifying the design geometry of railway draft gear housing the service life of the component can be increased.

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