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Failure Analysis and Re-Design of Tractor Brake Actuating Link

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Abstract

This article solves the customer complaint of poor performance of brake in certain tractors. This failure was reported particularly in Tractor which is predominantly used for puddling application. After prolonged usage, breakage was occurring in certain area of the actuating link. In order to overcome this problem, analysis has been carried out by using finite element method along with optimization technique. To obtain the best result various link designs have been created in CATIA and optimized with an optimization tool called OptiStruct solver in Hypermesh. The stress and deflection plots of existing and modified link were compared. Then the fatigue life of the optimized model is obtained from Nastran in order to know the life of the actuating link. In the same way fatigue life of the existing and modified link were analyzed and discussed.

Keywords: Actuating Link, Failure Analysis, Finite Element Method, Optimization, Redesign

1. Introduction

In recent scenario most of the agricultural tractor finds its application in puddling operation. It is very much needful for a vehicle to have an effective braking system which provides a safe drive. Tractor brakes are completely differing from conventional braking system in which all other vehicles, the braking system controls the wheels which offer a declaration. But in a tractor, the braking system directly controls the drive shafts[1]. In the thermal behavior of oil-immersed brakes was analyzed and discussed the factors that influence the friction surface temperature and performance. Finally he recommended the use of wet brakes in road vehicles[2]. Found that, Oil-immersed Multiple Disk Brakes provide different combinations of torque and sliding velocities with respect to the friction material. He also added that a maximum resistance to all failure modes does not appear practical due to limitations in performance and papermaking technology[3]. Developed a neural model of the disc brake cold performance in neural network architectures with the five different learning algorithms and studied its performance[4]. Studied a ring shaped force transducer, commonly used for force measurement in various applications like verification of material testing machines, monitoring force components in different cutting tools, agriculture related applications, hardness testing machines using finite element analysis. The study provides scope for the effect of nominal quantities over the design of ring shaped force transducers[5]. Explained that the operation of a high speed modern agricultural tractor with high-efficiency brakes coupled with a low braking- efficiency trailer will lead to the accelerated wear and premature damage of the brake[6]. They found that multiple disc brakes shows promise for greater tolerance for the selection of friction materials to solve braking problems such as noise, fade, energy capacity, and torque capacity[7]. They simulated the various braking configurations parameters including brake system parameters at each wheel and they have compared the simulated and full scale test result[8]. Studied both the theoretical and practical aspects of braking in a tractor and single axle trailer combination were examined[9]. Created the computer modeling program in which they have analyzed critical speed variations with respect

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to Wheel base, Unstrung mass, Longitudinal damping, Vertical Damping, Longitudinal stiffness, Lateral Stiffness, Vertical stiffness, Position of COG and Wheel track and Wheel radius for the LCV(cargo). They found that the following parameters such as Wheel base, Unstrung mass, Vertical damping, Lateral stiffness, Wheel track, Position of Centre of gravity and Wheel radius have more influence on critical speed variations, and can be easily analyzed with computer modeling10. Described the Classical methods of brake analysis and the role of computer analysis methods, especially the finite element (FE) method. The design parameters like brake factor, specific torque and their sensitivity to changes in the coefficient of friction were explained and discussed.

2. Problem Identification

2.1 Aim of the Paper

The objective of this paper is to study and analyze the stress, displacement and Fatigue life of a tractor brake actuating link using the Finite Element Method (FEM). Based on the study of the stress, displacement and fatigue life, further improvements will be recommended to the design of the tractor brake actuating link.

2.2 The Issue

The Tractor brakes which act on the axles, work via linkages. (i.e.) brake pedal, brake cross shaft, Turn buckle, Actuating lever, Pull rod, Link plates and the actuator disc. The breakage occurs in about 5 in 100 tractors sold after 500 hrs of continuous Tractor usage in puddling application. When analyzing the customer complaints, it was found breakage happened at exact same point on the actuating lever – around the corner of the pivot hole which is mounted with the Brake Housing Lug. Because of this problem, Brake is not functioning properly. This breakage may be due to great stress acting at that point when the braking load is applied at certain force acting on the brake pedals. This great stress could be due to offset loading, design errors, material defects, etc. To find a solid solution to this problem, analysis needs to carry out.

Figure 1 shows the breakage of the actuating link in the tractor brake. Triangular lever plate are cracked/angle of plate increased or hole is worn out from the position where pin is fitted resulting into poor brake efficiency is observed.

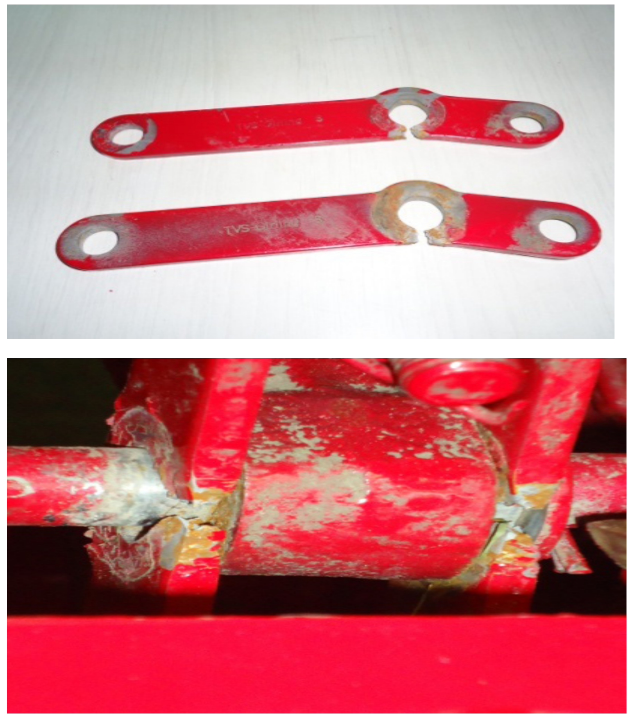

Figure 1. Actual field photograph of the link.

2.3 Scope of the Investigation

In this paper the mechanical behaviors as well as the performance of the brake actuating link under specific loading conditions are studied. This is done by simulating the loading conditions that the lever is predicted to undergo and analyzing the results. The primary focus of this work is to arrive at the optimized design of Brake actuating link using OPTISTRUCT solver in HYPERMESH software and simulate its performance using NASTRAN software. As the load acting on both the actuating links is equal, only one link was taken into consideration during the FEA study. The ability of the existing actuating link was examined, with different loading conditions and their weaknesses and strengths are discussed.

3. Optimization Analysis

In optimization analysis the CAD geometry model is build using CATIA software and imported to Hyper Mesh software. It is then meshed in Hyper Mesh as a 4-noded, tetrahedral element. Altair Hyper Mesh is a high-performance finite element preprocessor for popular finite element solvers. It allows engineers to analyze product design performance in a highly interactive and visual environment. Hyper Mesh is a user interface and it is easy to learn and supports a number of CAD geometry and finite element model file formats, thereby increasing interoperability and efficiency. The Solver used in optimization analysis is OPTISTRUCT 11.0. The material property considered in the analysis is listed in table 1. In the optimization analysis certain assumptions were made such as connecting pins in the lever were assumed as rigid structures and appropriate interactions were defined between actuating lever and connecting pin. The main objective of the analysis is to bring down the stress magnitude and tried to maintain the same mass of the existing lever.

Table 1. Material properties

S.NO	PROPERTIES	VALUE
1	Material	Fe330
2	Young's Modulus	21000 N/mm^2
3	Poisson's Ratio	0.29
4	Yield Strength	205 N/mm^2
5	Ultimate Tensile Strength	330- 410N/mm^2
6	Density	7.85 g/cm

3.1 Design Drawings

For optimization purpose the design of the existing model is created along with the four lever designs apart from the modified lever which are shown in the figures. Figure 2 and 3 shows the drawing of lever design 1, 2, 4 long with existing and modified lever.

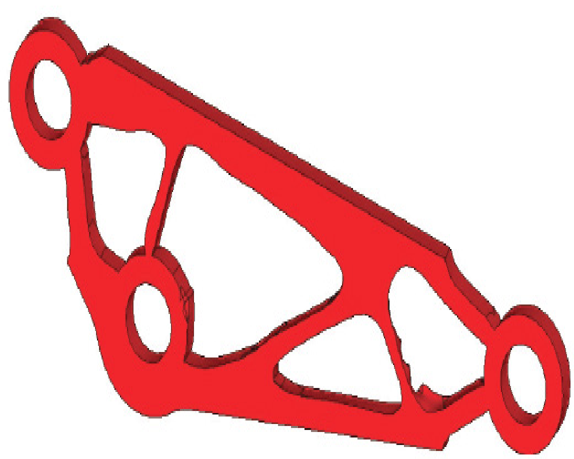

Figure 2. Drawing of the lever design-1.

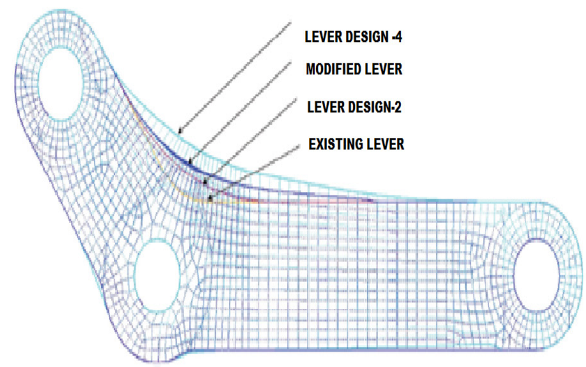

Figure 3. Superimposed details drawing of lever design.

3.2 Result Analysis for Optimization

The Table 2 shows the consolidated FEA results of different actuating levers. Of the above levers Modified lever is considered to replace the existing design so as to avoid the field failure. The stress magnitude in modified lever is reduced by 48% while comparing to the existing lever.

3.2.1 Existing Lever

It is being supplied at present and faces the field failure problem. Figure 4 shows the stress and displacement plot of the existing lever in which the stress is 320Mpa and deflection is 0.501mm.

3.2.2 Lever Design-1

Modified design generated is better than the existing one. It reduces stress magnitude by 32%. The stress and deflection plots are shown in Figure 5.

3.2.3 Lever Design-2

This design brought stress magnitude and mass by 27% and 37% respectively. As this model demands different manufacturing process, so this design was neglected. The stress and deflection plots are shown in Figure 6.

3.2.4 Lever Design-3

(Geometry model delivered by optimized tool)

This design was also arrived with above said objectives and also considered not to change the existing manufacturing process. This design brought down the stress magnitude by 42% and marginally increased the mass by 4.5% from existing lever.

Table 2. Comparison of various optimized model

S.NO.	LEVER DETAILS	MASS (gms)	MATERIAL	LOAD (N)	STRESS (Mpa)	DEFLECTION (mm)	CHANGE IN MASS(gms)
1	Existing Lever	155	Fe 330	1140	320	0.501	–
2	Lever Design-1	158	Fe 330	1140	218	0.425	3(2%) ↑
3	Lever Design-2	100	Fe 330	1140	233	0.219	58(37%) ↓
4	Lever Design-3	162	Fe 330	1140	187	0.337	7(4.5%) ↑
5	Lever Design-4	168	Fe 330	1185	166	0.35	13(8%) ↑
6	Modified Lever	162	Fe 330	1140	166	0.361	7(4.5%) ↑

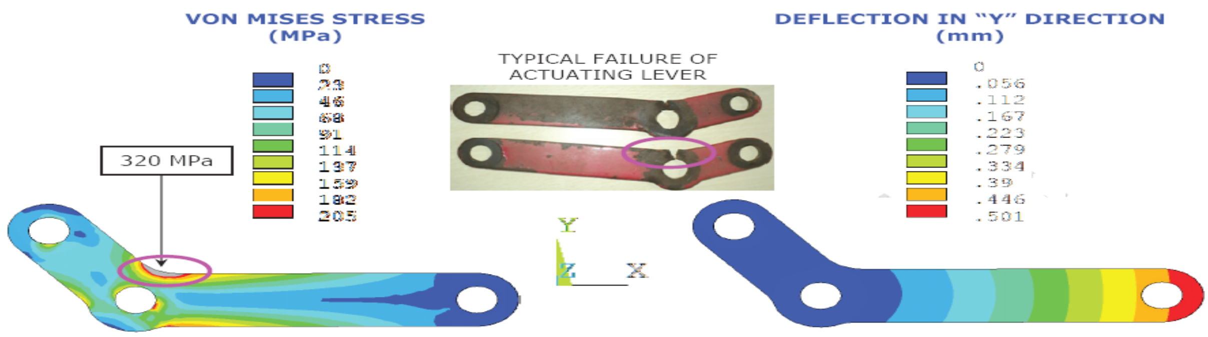

Figure 4. Stress Plot and Deflection Plot-Existing lever.

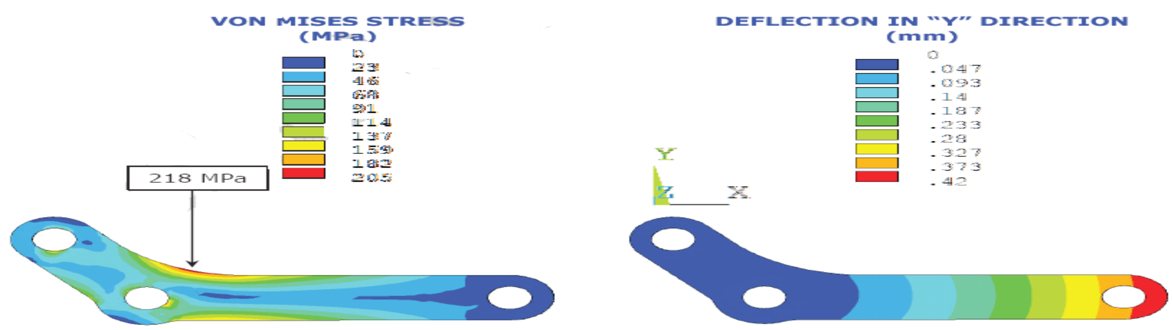

Figure 5. Stress Plot and Deflection Plot- Lever design-1.

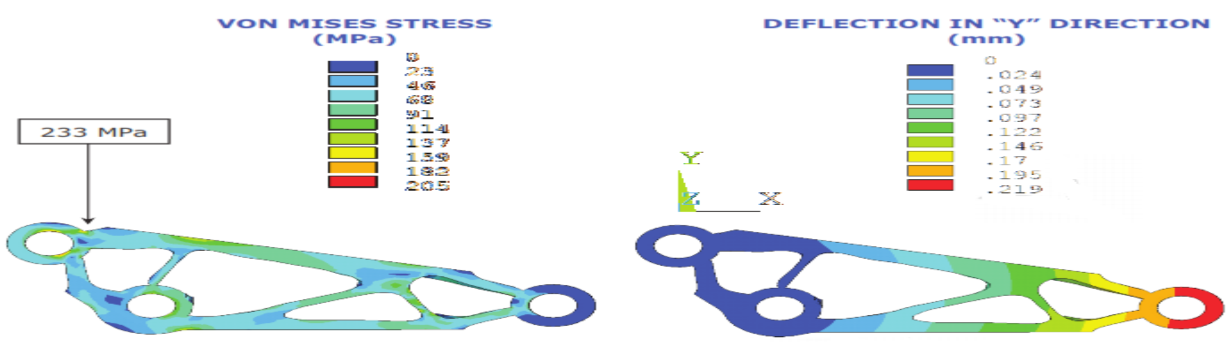

Figure 6. Stress Plot and Deflection Plot- Lever design-2.

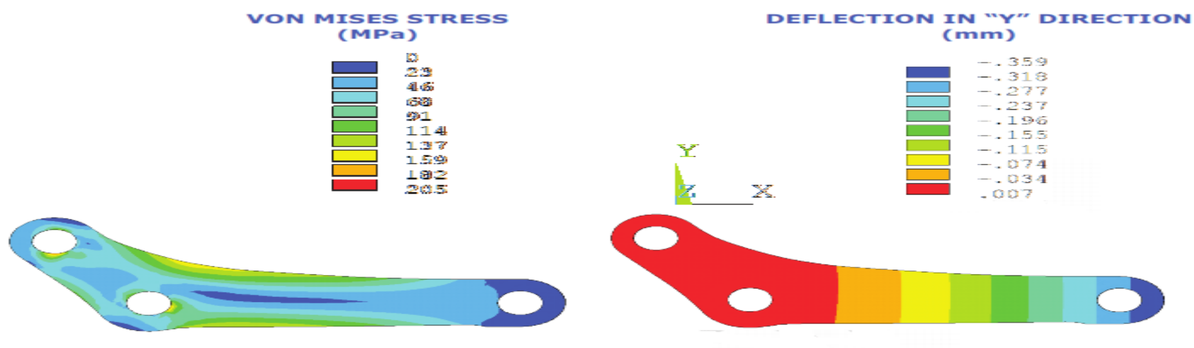

Figure 7. Stress Plot and Deflection Plot- Lever design-4.

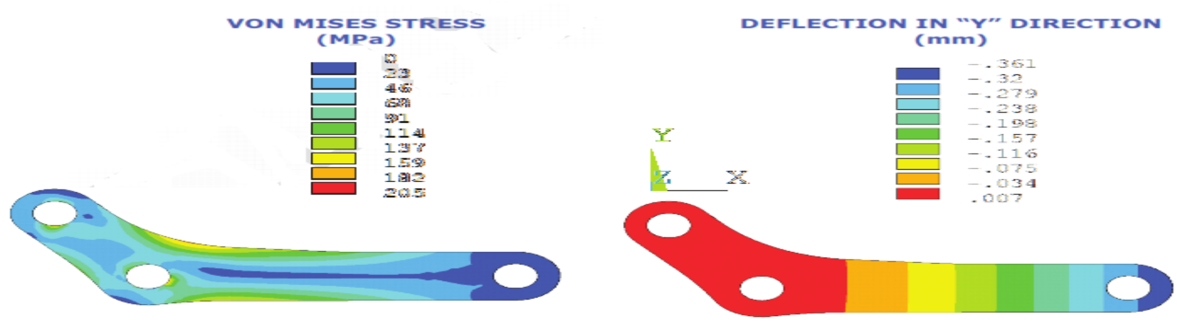

Figure 8. Stress Plot and Deflection Plot-Modified lever.

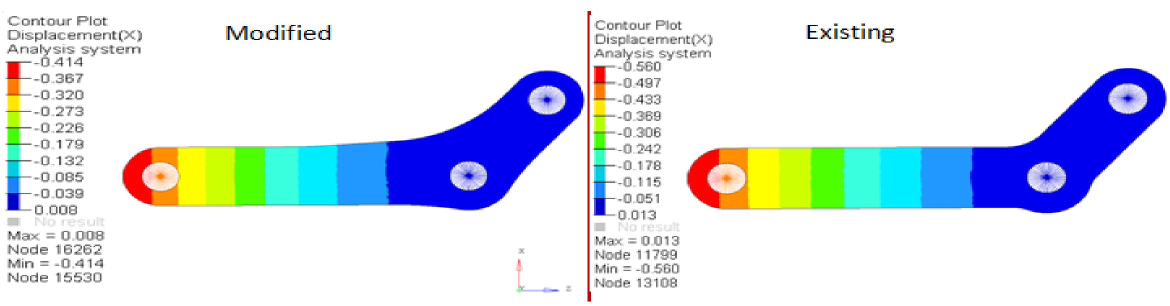

Figure 9. Displacement plot for load 140kg.

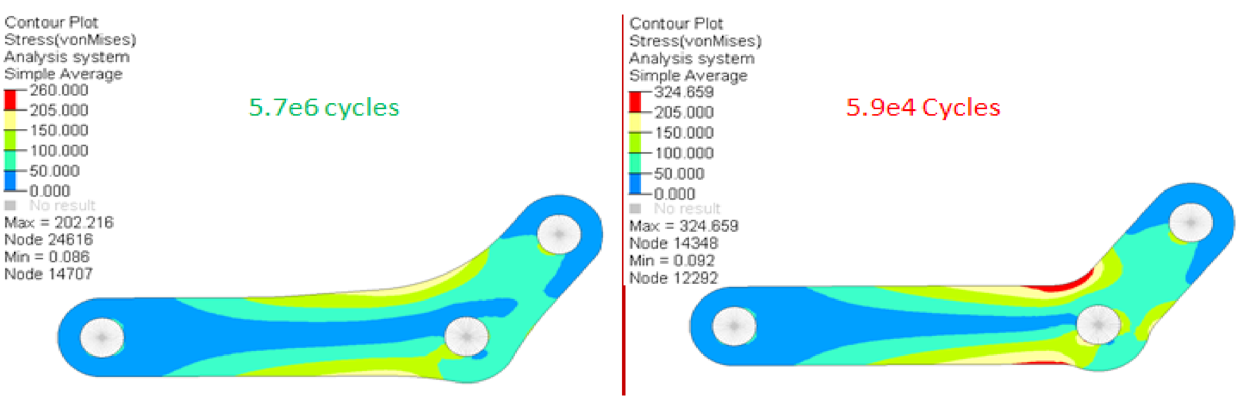

Figure 10. Stress plot for load 140 kg.

Table 3. Summary of fatigue life for existing and modified lever

Iteration No.	Load case	Key Result	Unit	Value	Acceptance criteria	Mass (kg)
Modified	140 kg load	Maximum Displacement	mm	0.414	--	0.161
		Maximum Stress	MPa	202.2	205	
		Life	Cycles	5.70E+06	1.00E+05	
Existing	140 kg load	Maximum Displacement	mm	0.56	--	0.154
		Maximum Stress	MPa	324.6	205	
		Life	Cycles	5.90E+04	1.00E+05	

3.2.5 Lever Design-4

This optimal design is arrived for the higher load of 1180N. This design shows much increase in mass so this design was neglected. The stress and deflection plots are shown in Figure 7.

3.2.6 Modified Lever

Lever design satisfies the objective of the optimization, but it was the rough design so with further modifications a lever was generated and named as modified lever design brought down the stress magnitude by 48%. Figure 8 shows the stress and deflection.

4. Appendix for Optimization Process

4.1 Fatigue Life Analysis

If a material is subjected to a cyclic loading then the progressive and localized structural damage occurs. The objective of doing Fatigue life analysis in this work is to evaluate the durability of the Brake Actuating link when the material is subjected to cyclic loading. Modified lever obtained from optimization process is used for analyzing the fatigue life. The finite element software used for fatigue life analysis is NASTRAN solver and results are viewed through HYPERVIEW 11.0.

4.2 Stress and Displacement Plot for Load 140kg:

4.2.1 Displacement Plot

From figure 9 it is clearly seen that the displacement of the modified lever is 0.414mm which is reduced from the existing lever which is 0.56mm.

It is needed that the lever has to meet up 1, 00,000 cycles throughout its entire life. Where from figure 10 it is seen that existing lever only meets up 5.9e4 cycles but the modified lever meets up 5.7e6 cycles. This shows that the modified lever satisfies the needed criteria.

5. Conclusion

- The optimized lever have satisfied the objective of the optimization that the lever have brought down the stress by 48%, on the other hand the mass of the lever does not show much variation.
- Table 3 gives the summary of the fatigue life analysis conducted for both existing and modified actuating link by using finite element software.
- The optimized model has passed the fatigue life that is needed. Thus the model can be replaced for the existing model.

6. References

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