Performance Analysis of Swing Machinery Using Root Cause Analysis

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***Abstract: -* Root cause analysis(RCA) is a method of problem solving used for identifying the root causes of faults or problems. RCA is a methodology to identify and correct the root causes of events, rather than to simply address the symptomatic result. Focusing correction on root causes has the goal of entirely preventing problem recurrence. Conversely, RCFA (root cause failure analysis) recognizes complete prevention of recurrence by one corrective action is not always possible.RCA is typically used as a reactive method of identifying events, causes, revealing problems and solving them. Analysis is done after an event has occurred. RCA can be used to forecast or predict probable events even before they occur. RCA comprises many different tools, processes and philosophies. CATIA V5 R20,3D-Tetramesh,ANSYS 14.**

This paper presents root cause analysis of swing machinery carried out theoretically and obtained results were validated using ANSYS 14 software.

***Keywords:* Swing machinery, failure analysis, performance characteristics, bearing failure.**

I. INTRODUCTION

The swing machinery is an element of the hydraulic excavator that is responsible for swivelling the upper structure of the excavator through 360^0, so that digging work and loading dump trucks can be done without moving the machine.

RCA is typically used as a reactive method of identifying events, causes, revealing problems and solving them. Analysis is done after an event has occurred. Insights in RCA make it potentially useful as a primitive method. In that event, RCA can be used to forecast or predict probable events even before they occur. While one follows the other, RCA is a completely separate process to incident management [1].

Rather than one sharply defined methodology, RCA comprises many different tools, processes and philosophies like Safety-based, production-based, process-based, failure-based, and system-based[2].

The steps involved in root cause analysis are

- Modelling the components using CATIA V5 R20.
- Importing the CATIA model into HYPERMESH.
- 3D-Tetramesh-volume tetra by means of quads and trias in HYPERMESH.
- Importing the meshed component in to ANSYS 14 for displacement and stress analysis.
- Numerical computation of theoretical maximum stress, gear ratio, output torque, interference is performed.
- Obtained results are compared with theoretical results for validation.

II. PROBLEM STATEMENT

To identify and correct the root causes of events, rather than to simply address the symptomatic result. Focusing correction on root causes has the goal of entirely preventing problem recurrence. Conversely, RCFA (root cause failure analysis) recognizes complete prevention of recurrence of problems when one corrective action is not always possible. [3]

III. OBJECTIVES

- Our aim is to reduce the speed of the input motor shaft and hence increases the torque at the output shaft of swing machinery.
- Production-based RCA had roots in the field of quality control for industrial manufacturing.
- Process-based RCA, follow on to production based RCA, broadens the scope of RCA to include business processes.
- Failure-based RCA originates in the practice of failure analysis as employed in engineering and maintenance.

The swing machinery (Fig.1) is an element of the hydraulic excavator that is responsible for swivelling the upper structure of the excavator (bucket, boom and arm) through 360 degrees so that digging work and loading dump trucks can be done without moving the machine .The swing machinery consists of two epicyclical gear trains that reduces the speed of the input motor shaft and hence increases the torque at the output shaft. The input to the swing machinery is provided by a fixed displacement of hydraulic motor.

Figure 1: Swing machinery

IV. METHODOLOGY

- Create a model in CATIA
- Hyper mesh
- Import the Modelled pinion shaft in STP format into HYPERMESH software
- Mesh the model
- Export the meshed model in CDB format to analyze it in Ansys
- File type-Ansys
- Template-Ansys
- Export options
- Export
- The exported file saves in CDB format

V. NUMERICAL COMPUTATION

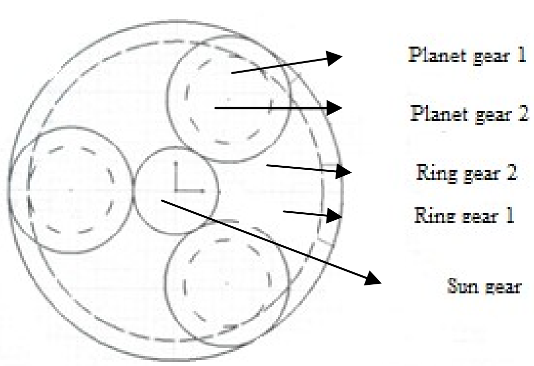


Figure 2: Gear Ratio

Zs = Number of teeth on Sun gear

Zp1 = Number of teeth on planet gear 1

Zp2 = Number of teeth on planet gear 2

X =Speed of the ring gear 1

Y = Speed of the ringgear 2

X+Y = Speed of the sun gear

Speed of the ring gear (Fig 2)

Speed of the ring gear2 = [Zs*Zp2/ (Zp1*Zr2] Y

$$= X-[(22*22)/(32*76)*Y$$

Reduction ratio = input speed/ output speed

Therefore the reduction ratio for the swing machinery is found to be 22.109

TORQUE

The power input to the swing machinery is given by fixed displacement hydraulic motor.

Torque input = $P*VD/2\pi$

Assumed values based on gear ratio

Volume displacement VD= 90e-6m3/rev

Pressure P = 31.392 Mpa

Torque input = $(90e-6*31.392e-6)/2\pi$

$= 449.65$ N-S

Model the component by using the software CATIA. Fig 3

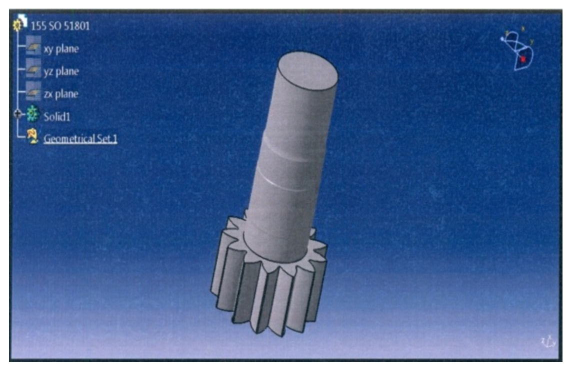


Figure 3: Modelling the Pinion Shaft

Hyper Mesh is a high-performance finite-element pre-processor. It allows analysing product design performance. Fig 4

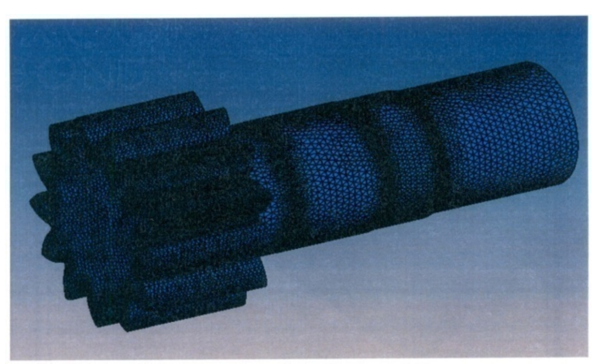


Figure 4: Meshed Component

The nodal solution of X displacement is 1.2329 so the stress is maximum in mid position of swing machinery. Fig 5

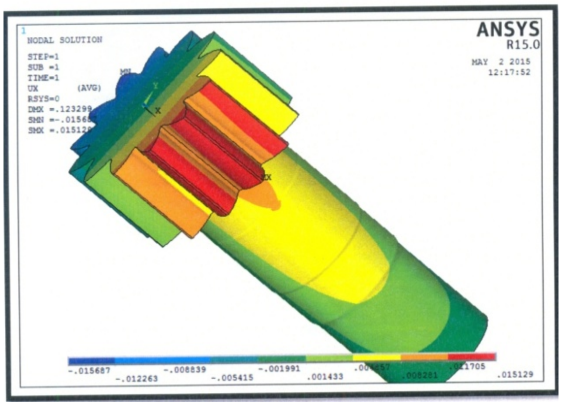


Figure 5: Analysis in X displacement

The nodal solution of Y displacement is 0.772 so the stress is maximum in end position of swing machinery. Fig 6

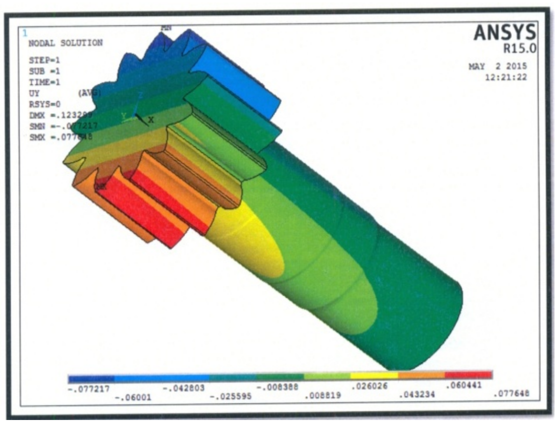


Figure 6: Y displacement

The nodal solution of Z displacement is 0.432 so the stress is reduced in mid position of swing machinery. Fig 7

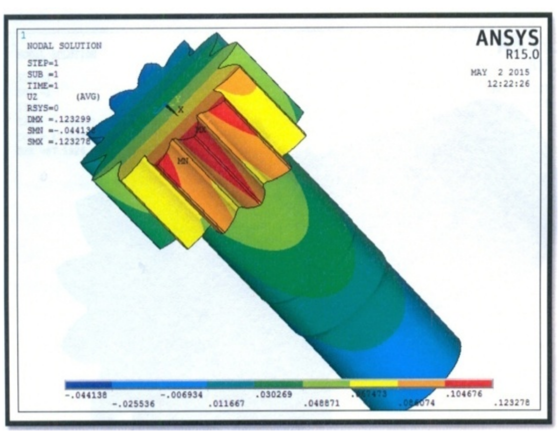


Figure 7: Z displacement

When the swing machinery rotates the stress distributes through the pinion shaft. Fig 8

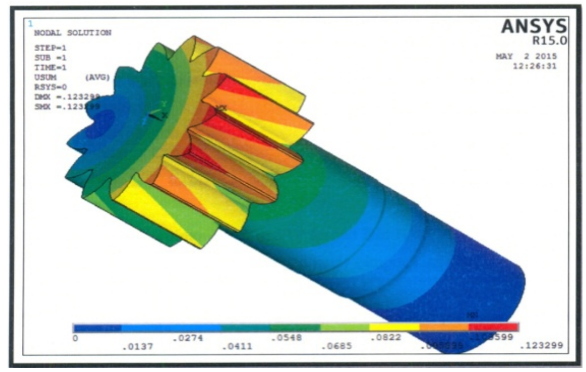


Figure 8: Rotational displacement

The stress reduces when it is subjected to displacement and when its titles down. Fig 9

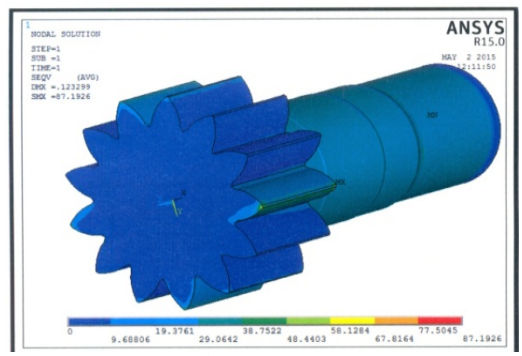


Figure 9: Stress

VII. EXPERIMENTAL AND RESULT ANALYSIS

The outcomes of root cause failure analysis suggested the probable reasons of failure is dirt, moisture, chemical attack, taking these reasons into account proper modifications were suggested. [4]

Modification 1(M1)

Changing the single lip seal in the original system to a double lip seal

Reason for implementing the modification:

Single lip seals have only one lip, hence, the possibility of foreign particles entering into the system is high resulting in the contamination of the lubricant.

Since external contamination (Dirt) is one of the root causes for the failure of the swing machinery. An additional sealing lip is provided to prevent moisture, dust, mud, and other fine solid contaminants from entering into the system and as well to hold the lubricant within the sun planetary gear system for effective lubricant.

Modification 2 (M2)

Change the sealing material from Acryl rubber to Ethylene Acrylic Elastomer.

Reason for implementing the modification

Acrylic rubber, known by the chemical name alkyl acrylate copolymer (ACR) or the trade name HyTemp, is a type of rubber that has outstanding resistance to hot oil and oxidation. It belongs to specialty rubbers. It has a continuous working temperature of 150°C and an intermitted limit of 180°C. ACM is polar and does not contain un-saturation. It is resistance to ozone and has low resistance to moisture, acids, and bases. It should not be used in temperatures below -10°C. it is commonly used in automotive transmissions and hoses. It is also used in shaft seals, adhesives, beltings, gaskets and O-rings. It is used in vibration damping mounts due to the damping properties. Since chemical attack by moisture, acids and bases is one of the root causes for the failure of the machinery and the seal material (Acryl rubber) has a poor resistance towards moisture, acids and bases, the seal material is changed to Ethylene Acrylic Elastomer.

Modification 3 (M3)

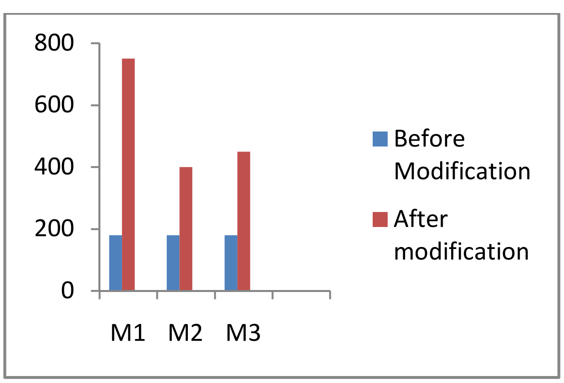
Elimination of the spacer and providing a step in the shaft in order to eliminate the O-ring from the assembly.

The seal wear and failure is particularly high in the O-ring of the spacer, hence the spacer is eliminated in order to eliminate the oil ring. By eliminating the space, a step of diameter 110mm is provided in the shaft. The increase in stresses due to stress concentration (since a step is introduced in the shaft) is calculated and is found to be within safe limits.

Results after implementing the suggested modifications

Table 1: Possibilities of modification

Sl No	Modification	Machine Hours	
		Before	After
1	Changing the single lip seal to double lip	180-250	700
2	Changethe sealing material from Acryl rubber to Ethylene Acrylic Elastomer.	180-250	400
3	Elimination of the spacer and O-ring by providing step in the shaft	180-250	450



Working hours Vs modification

VIII. CONCLUSION

Generally the machine working hours for a swing machinery of a hydraulic excavator is less when operated under extreme working conditions.

After identifying the root cause of failure of the swing machinery and implementing the recommended modifications considering the results of the root cause failure analysis, it is observed that the machine working hours is improved and the machine is still in good condition.

Hence it is inferred that the root cause for the failure of the swing machinery were properly identified and essential modifications were implemented.

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