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Review of shaft failure in Coil Car Assembly

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Abstract - *A spinning machine component known as a shaft transfers power from one place to another. Power transmission causes the shaft to receive torque, and reactions to the members it supports cause the shaft to receive a bending moment. The shaft was modified to include a discontinuity for crucial functional requirements. The shaft supports a variety of loading situations while it is in use (torsion, bending, axial, and combinations of these). In order to better understand failure and find ways to prevent it, a coil car shaft study was done. A visual inspection, hardness measurement, and investigation were carried out to determine the integrity of the failed axle shaft. The findings indicate that reversed bending fatigue caused the axle shaft to fracture and that fractures occasionally happened as a result of misalignment. A common cause of failure for many rotating equipment components is fatigue fracture.*

We first check the load capacity of our existing shaft utilising theoretical and analytical techniques and typical shaft design calculations. Calculate the new shaft diameter in light of the findings. The load on the shaft considerably lowers as shaft diameter grows. The S-N curve is used to theoretically and analytically calculate the fatigue life of a shaft that is subject to cyclic bending stresses. Stress levels in the shaft steps were found to be greater during the shaft investigation. We examine the effects of fillet and chamfer on shaft life and use them to disperse load. Also, the effect of a larger load acting area on shaft life is examined in this study.

***Key Words*: shaft failure, maintenance techniques, heavy loading, industrial application, analytical solution**

1.INTRODUCTION

A coil car is a material-handling device. This coil car instrument is frequently used in the steel and vital industries. The middle function of this type of material management tool is to load and sell off coils from mandrels. Transporting coils (or rolls) of sheet metal, most notably steel, is done with the help of coil cars, a type of rolling stock. The transport surface can be flat with support plates or specific elements, such as double-wedge cradles to support rounds such as ferrules or coils in the travel direction or also transverse, and one or more coils or rolls of straps with an anti-roll system can be included. These vehicles first appeared in the 1960s. Early examples include the Pennsylvania Railroad G40 and G41 class cars, which were built in 1964-1965[1]. The G41 has a capacity of 2000 LBS and can carry 6 coils in a single rack system. This G41 coil car has a self-weight of 59200 LBS. The G41 coil car has a total of eight wheels. G41 has a total length of 39 feet 2 inches and a width of 9 feet 8 inches. The central distance between the two wheels is three feet.

2. LITERATURE SURVEY

2.1 Deepan Marudachalam M.G, K.Kanthavel, R.Krishnaraj:

A shaft used in a spinning machine frequently fails, as discussed by Deepan Marudachalam M.G. Failure took place close to the shaft's change in cross section, where a relief groove is present. The forces and torques acting on the shaft are computed using the drive system to estimate the stresses occurring at the failure region. The findings of stress analysis using the finite element technique (FEM) are compared to the calculated values[2]. The least square approach is used to determine the stress concentration factors at the failure cross section from the fatigue stress concentration factors. According to Deepan Marudachalam M.G., changing the position of the support and increasing the shaft's fillet radii reduce the stress concentration factor while raising the endurance limit and fatigue factor of the shaft's safety.

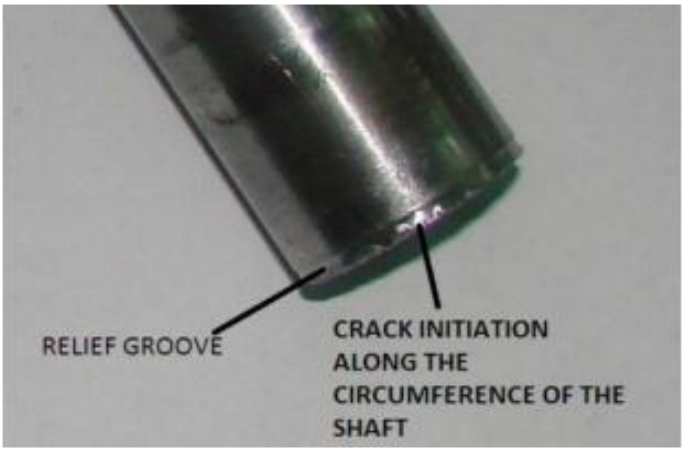

Fig-1: Shaft Failed

Osman Asi discusses the failure analysis of a rear axle shaft from a car that was involved in an accident. The axle shaft had split into two pieces, which was discovered. The investigation sought to determine whether the failure caused or contributed to the accident.

2.2 A. Göksenli *, I.B. Eryürek

An elevator drive shaft failure analysis is carefully examined. Properties of the shaft's microstructure, mechanics, and chemistry are identified. After visually examining the fracture surface, it has been determined that the fracture was caused by torsional-bending fatigue. At the keyway edge, a fatigue crack has started. The shaft's forces and torques are calculated, and stresses at the fracture surface are estimated. The endurance limit, the fatigue safety factor, the shaft's fatigue cycle life, and the fatigue analysis are all computed. Due to poor keyway manufacturing or design (low radius of curvature), a high notch effect resulted from the shaft's fracture. Finally, the use of FEM to describe the impact of changing the radius of curvature on stress intensity and distribution clarifies the safety measures that must be done to avoid a failure of a similar nature.

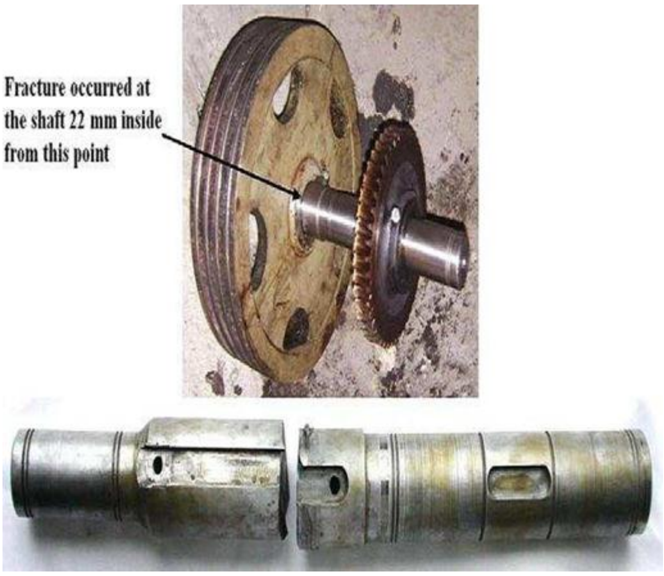

Fig -2:Elevator shaft failure

2.3 Jinfeng du Jun Liang Lei zhang

This essay examines the failure analysis of a power boiler's shaft-mounted induced draught fan. It compares the manufactured shaft to the real design and discovers that the chamfer is less than what is indicated in the drawing. This intensifies the focus of stress. Furthermore stated is that aberrant torsional vibration and increased stress concentration are caused by the shaft's incorrect balance. The induced shaft cracked as a result of the vibrations and alternate torsional loading, resulting in the ratchet-like profile. Two phases made up the full analysis.

1. Performance and fracture analysis of failed shafts

2. Study of the shaft's design, torsional resonance, and stress.

The shaft's material was determined to be typical. Although the material quality was good and failure was not caused by a material property, the average micro hardness, yield strength, and tensile strength were 157 HV, 349 MPa, and 527 MPa. While the actual radius was 2mm, FEA indicated a stunning 5mm stress concentration at the shoulder's chamfer. A micro crack started along the chamfer as a result of the higher stress concentration and torsional vibration, and it developed in size as a result of ongoing stress and torsional vibration.

3.SUMMARY OF LITERATURE REVIEW

SR. NO	AUTHOR	FAILURE REASON	Year
1.	Deepan Marudachalam M.G, K.Kanthavel, R.Krishnaraj	Shaft failed as a result of fatigue.	2008
2.	A Gokesenli ,I.B. Eryurek	Low radiusof the curvature of keyway	2009
3.	Jinfeng du Jun Liang Lei zhang	Actual radius of chamfer less than the design radius	2016

4.Design Calculation

After visual and stereoscopic inspection, we were able to determine that the failure of our coil car shaft was caused by **severe stress and rotational bending**. In order to reduce this shaft failure, we first verified whether our shaft design is appropriate. We compute the existing shaft design analytically and theoretically.

Theoretical Calculation of Existing Shaft

Data:

1. Motor Specifications:

OMS 315- Hydraulic ,RPM- 285 rpm , Power- 15 KW.

2. Diameter of the shaft:

68 mm (Smallest diameter of Shaft is consider core diameter of shaft)

3. Material:

EN-9 $S_{ut} = 600$ Mpa $S_{yt} = 310$ Mpa FOS =3 (Assume)

Step 1 - Permissible shear stress

$$\tau_{Max} = \frac{0.5 \text{ X } S_{yt}}{FOS} = \frac{0.5 \text{ X } 310}{3} = 51.66 \text{ Mpa}$$

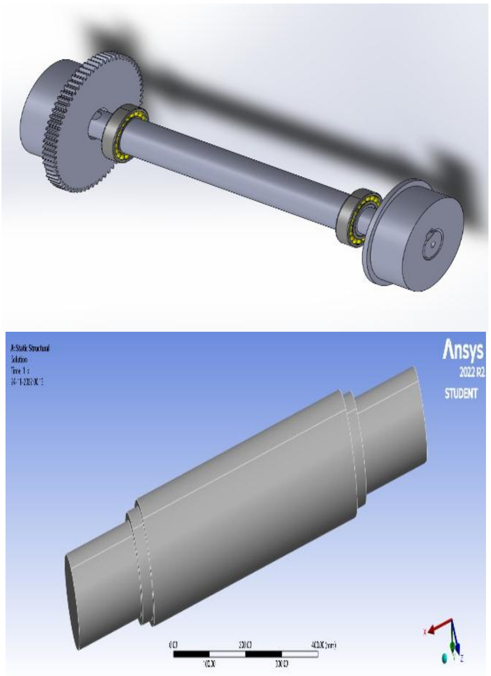

Fig 4.1.1 (a) Shaft wheel Bearing Assembly

(b) Shaft of Coil Car

Actual Loading Condition of Shaft

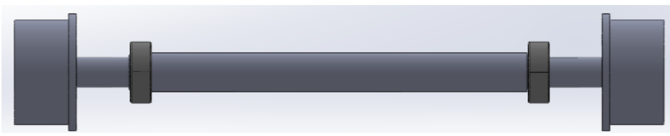

Fig 3.1.2 : Shaft Loading Condition

Free Body Diagram of Shaft

Fig 4.1.2 : Free Body Diagram Shaft

Bending Moment Diagram of Shaft

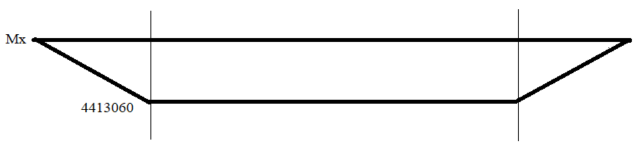

Fig 4.1.3 : Bending Moment Diagram Of Shaft

Step 2- Forces calculation

Forces act on point B – 24517 N

Forces act on point C - 24517 N

$$R_A - 24517 - 24517 + R_D = 0$$

$$R_A + R_D = 49034 \quad \text{.....................................} \quad (1)$$

Bending moment at point A =0

$$\therefore \ (24517\ X\ 180) + (24517\ X\ 805) - (R_D\ X\ 1010) = 0$$

$$R_D = 24517 \text{ N}$$

By using equation (1) we get,

$$R_A = 24517 \text{ N}$$

Step 3 - Bending Moment calculation

Bending Moment at point A = 0 N.mm

Bending Moment at point B = 4413060 N.mm

Bending Moment at point C = 4413060 N.mm

Bending Moment at point D = 0 N.mm

Step 4- Torsional moment

$$T = \frac{P\ X\ 60}{2\pi N}$$

$$T = \frac{15X10^3X60}{2\pi\ X\ 285}$$

T = 502.590 N.mm

Step 5 -Shaft diameter on strength basis (TORQUE)

$$T_{eq} = \sqrt{(M_B)^2 + (M_T)^2}$$

$$T_{eq} = \sqrt{(4413060)^2 + (502.590)^2} = 441587.002 \text{ N.mm}$$

By using Maximum Shear Stress theory,

$$\tau_{max} = \frac{16}{\pi(68)^3}\ x\ T_{eq}$$

τ_{max} = 71.94 Mpa > 51.66 Mpa(permissible/allowable shear stress)

∴ Shaft is failed.

Analytical Calculation Of Existing Shaft

Model Formation -

Here, we processed the coil car shaft using the Ansys method. We use the solid work software to generate the model, import it into Ansys, apply the appropriate loading conditions, and then compute the analytical coil car shaft

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result. The shaft for the coil car is initially built in solid work with a 68 mm core diameter. Shaft steps are not included here because we do not account for them in the theoretical computation either. To develop the shaft design in Solid Work, we merely utilised the sketch and extrude tools.

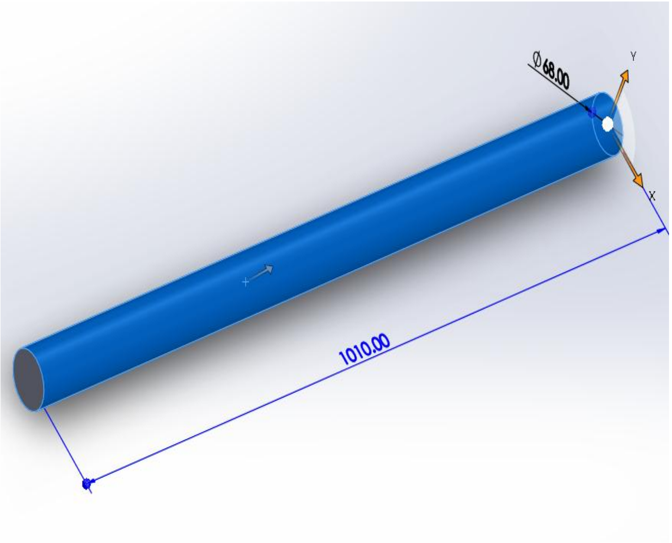
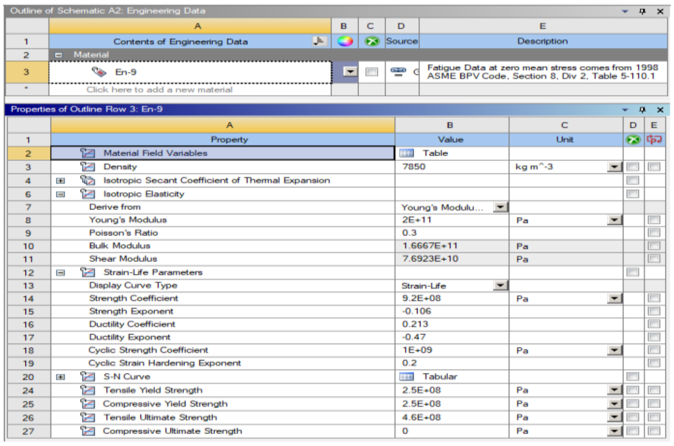


Fig 4.1.3 Shaft Solid work Model

As soon as the 3D model is complete, we simply save the shaft as a .sldprt file. Ansys imports this .sldprt file without issue. Based on the available circumstances, we designed a 68 mm diameter by 1010 mm long shaft in solid work programme.

Material -

We used the static structure module in Ansys to analyse this coil car shaft issue. Before beginning the analysis, we must first think about the qualities of the materials. We added this material characteristic to Ansys because our shaft is made of En-9 material.



Outline of Schematic A2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	En-9			G	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

Properties of Outline Row 3: En-9

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modulu...			
8	Young's Modulus	2E+11	Pa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.6667E+11	Pa		
11	Shear Modulus	7.6923E+10	Pa		
12	Strain-Life Parameters				
13	Display Curve Type	Strain-Life			
14	Strength Coefficient	9.2E+08	Pa		
15	Strength Exponent	-0.106			
16	Ductility Coefficient	0.213			
17	Ductility Exponent	-0.47			
18	Cyclic Strength Coefficient	1E+09	Pa		
19	Cyclic Strain Hardening Exponent	0.2			
20	S-N Curve	Tabular			
24	Tensile Yield Strength	2.5E+08	Pa		
25	Compressive Yield Strength	2.5E+08	Pa		
26	Tensile Ultimate Strength	4.6E+08	Pa		
27	Compressive Ultimate Strength	0	Pa		

Fig 4.1.4 Shaft Material Specification (Ansys)

Meshing Condition -

Mesh creation is one of the most important steps in performing an accurate simulation with FEA. A mesh is made up of numerous parts with nodes whose coordinate coordinates in space can vary based on the kind of element used to represent the geometry's shape. Uneven forms are challenging for FEA solvers, while common shapes like cubes make it considerably simpler. Amorphous shapes are converted into "elements," which are more recognisable volumes, by the process of meshing. Determining which CAD model elements from your FEA simulation package, such as Mechanical, require meshes and which do not is critical.

CAD geometry is typically highly complex and detailed for production needs. To save time, you might defeature, or eliminate, some of your geometry if you don't need every detail for a simulation. There are two categories for meshing techniques. For these uses, we're referring to 3D models.

1.Tetrahedal element meshing or “tet”

2. Hexahedral element meshing or “hex”

Hex or "brick" elements are more accurate than tet elements at lower element counts. The most effective option for complex geometry may be tet elements. We decided to use hexahedral element meshing in our analysis because of the simplicity of our geometry and the requirement for an accurate result. Starting with a full-size mesh, we apply sizing commands and reduce the size to 0.01. By lowering the mesh size, this aids in producing better results..

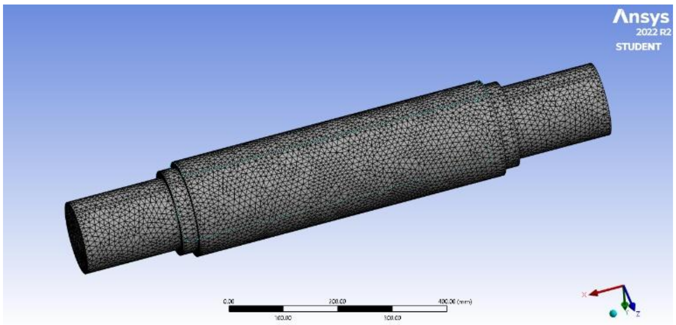


Fig 4.1.5 Shaft Meshing (Ansys)

Loading condition -

The weight on the hydraulic cylinder is actually transferred from the carriage to the shaft and finally to the wheel, depending on the situation. A two-coil car, for instance, can carry up to eight tonnes of coil on a mill machine, but for the purposes of this analysis and improvement, we're going to apply ten tonnes of force on the four wheels of the shaft. We apportioned these 10 tonnes of weight so that 2.5 tonnes of weight were applied to the shaft at each corner of the carriage. Thus, one shaft is capable of supporting a 5-ton load. We take the shaft without steps and point loads like the 5 tonnes of force operating on the shaft into account when analyzing the current shaft .In order to come as close as feasible to the actual loading condition, we fixed the right and left sides of the shaft under this loading scenario. We included rotational velocity in our coil car shaft study since, under this loading scenario, the gear linked to the front wheel shaft also generates momentum. We won't include the rear wheel shaft gear in our analysis because it was not installed. Other loading circumstances in rare wheels are the same, with the exception of gear condition..

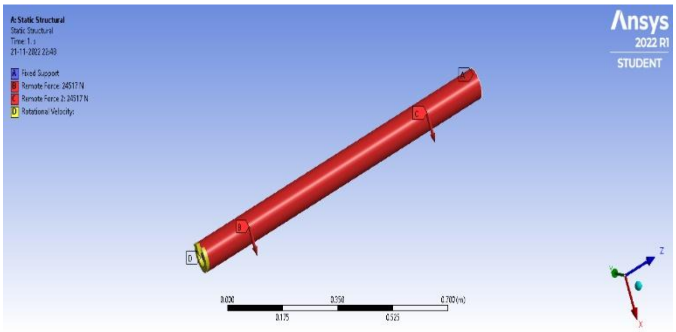


Fig 4.1.6 Shaft Loading Condition (Ansys)

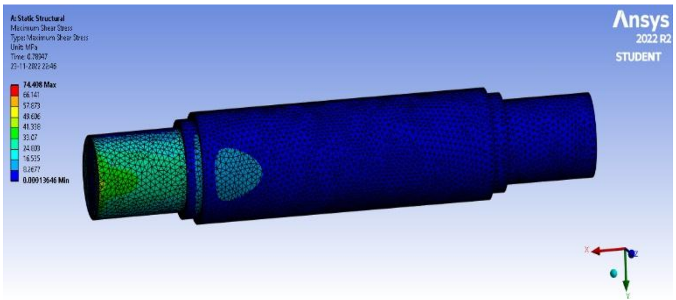


Fig 4.1.7 Stress Concentration

Using the proper material, meshing, and loading conditions, we move on to obtain results. As a result, we originally focused on the maximum shear stress value. since during the theoretical computations, we focused on the maximum shear stress value.

5. CONCLUSIONS

The idea conveyed by the shaft's design is that the shaft failed at the specified diameter. The stress decreases dramatically as the diameter of the shaft increases. After determining the final diameter of the shaft (80 mm), we increase the step by 10 mm (i.e 90 mm & 100 mm). In comparison to existing shaft diameters, the new shaft design provides a longer fatigue life.

Visual inspection, stereoscope inspection, and material testing. Aside from that, hardness testing and available data show that our shaft failed due to bending moment, stress concentration, and misalignment.

We can clearly see from the analytical study that stress concentration is higher in the shaft step where area changes occur. This stress is reduced by using a proper radius fillet or chamfer. Because there are no radius fillets in the existing shaft, the stress in that area is greater. This stress is reduced.

We also provide three material options as part of the study's requirements. En-9 was the best material for the shaft. For this shaft, we also use En-24 and C55 Mn75 materials. Based on the weight method, we can conclude that En-9 material is the best for manufacturing shafts.

REFERENCES

[1] Deepan Marudachalam, M.G., Kanthavel, K. and Krishnaraj, R., 2011. Optimization of shaft design under fatigue loading using Goodman method. International Journal of Scientific & Engineering Research, 2(8), p.1.

[2] 2Asi, O., 2006. Fatigue failure of a rear axle shaft of an automobile. Engineering failure analysis, 13(8), pp.1293-1302.

[3] Prajapati, H.R., Patel, B.P. and Patel, N.V., Investigation of Stress Concentration Factor for Keyway on Shaft under Different Loading Conditions: A Case Study.

[4] Xiaolei, X. and Zhiwei, Y., 2009. Failure analysis of a locomotive turbocharger main-shaft. Engineering Failure Analysis, 16(1), pp.495-502.

[5] Göksenli, A. and Eryürek, I.B., 2009. Failure analysis of an elevator drive shaft. Engineering failure analysis, 16(4), pp.1011-1019.

[6] Hariom, V.K. and Chandrababu, D., 2016. A review of fundamental shaft failure analysis. International Research Journal of Engineering and Technology, 3(10), pp.389-395.

[7] V.B.Bhandari ,"Design of Machine Element" 1994 Tata McGraw Hill Publication Company Ltd