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Failure Analysis For Initiation Of Crack On Helical Pinion Shaft-A Review

Gadekar Rahul[1], M. A. Kumbhalkar[2], Gayakawad Akash[3], Jadhav Dhananjay[4], Phalake Ashitosh[5]
[1,2,3,4](Students, Department of Mechanical Engineering/JSPM NTC, Pune/India)
[5](Assistant Professor, Department of Mechanical Engineering, JSPM Narhe Technical Campus, Pune, Maharashtra, India)

Abstract: *WAG means Wide gauge AC traction Goods duty.WAG-9 is the most powerful engines in the country yet. For time to time service consideration in passenger as well as goods transport, the efficiency as well as longer service life of system components are important factors. The component which has been study is obtained from the "Central Railway Electric Locomotive Workshop, Bhusawal, India."In the recent study, the premature failure of traction motor assembly in WAG-9 is carefully investigated. The various literatures has been carefully compared and reviewed to get a proper helical pinion shaft failure analysis. From these literature reviews, the main objective of this paper is to study various Shaft Failure Analysis and Methodologies to select the best method to find out and analysis the Initiation of crack on Pinion Shaft.*
Keywords*: Failure analysis, crack detection, methodologies, traction assembly.*

I. Introduction

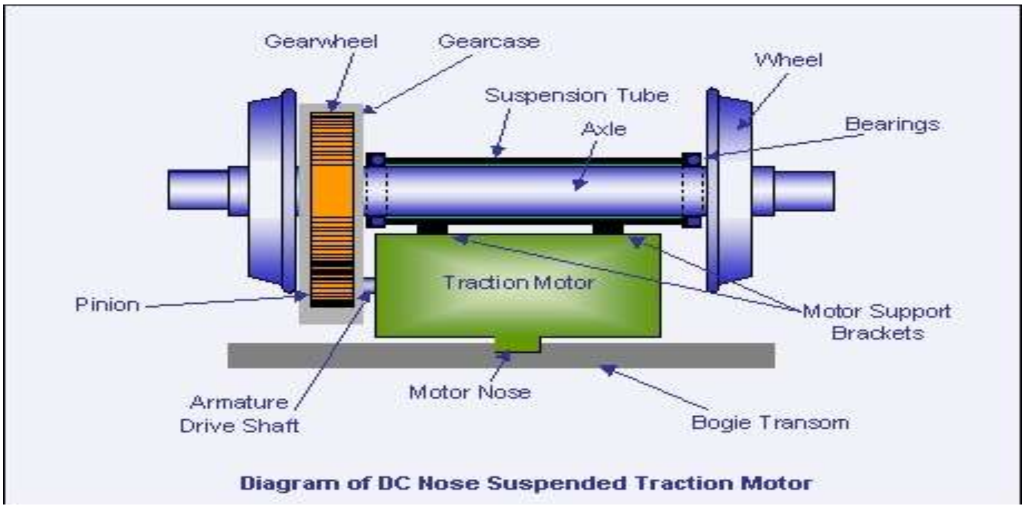

Figure 1-Traction Motor Assembly

WAG-9 is a type of electric locomotive used in India. Till now, it is the most powerful locomotive in Indian Railways' fleet. Each Locomotive, Traction motor of WAG-9 is main power transmission part of locomotive. It runs at 850 kw at 100 rpm.Its weight is 2100 kg. The complete assembly consists of an arrangement, that transmitting the torque generated by the traction motor through helical pinion to main gear and through main gear to wheel assembly(fig.1). The tractive effort required to run the lovomotive is transmitted by traction motor through a helical pinion and main pinion. Here we use the helical type pinion because it has smooth engagement and quiet in operation even at very high speed. In this assembly(fig.1), the various types of forces and stresses on the assembly which is either static or dynamic. The material used for the helical pinion shaft is forged steel (17CrNiMo4). It is also required to consider and find out the Tractive Effort. Tractive effort is the effective force that necessary to propel the vehicle at the wheels of locomotive. So this paper summarises the discussion about the failure and analysis of various mechanical systems.

II. Static Analysis

It is necessary to find out the detection of defects earlier in the process so that we conduct the static analysis. This is achieved by various methods & techniques.

a.Analytical Approach:

From the analytical result it is conclude that the bending stresses are sensitive to center distance variation. Also larger pressure angles are suggested for the pinion tooth due to lower bending stresses occurring at its fillet [7]. The calculation model includes the impact of service conditions and fatigue damage accumulation. The effect of material degradation in the surface layer is included in the analysis [9].

b.Experimental Approach:

The experimental testing which are also carried out to analysis and find out the failure of the pinion shaft.

- **Non-destructive test for crack detection:**
  1) Magnetic particle test: for performing the test, fluorescent powder mixed in liquid is spread over the pinion surface. Also at the same time pinion has been magnetized with proper instrument and high intensity ultraviolet light is focused on it. Then image obtained which is below shows some crack lining along the circumference of helical pinion shaft [1].
  2) Ultrasonic test: It uses sound energy which has very high frequency to conduct test and make readable measurements. The time intervals between the transmitted ray and reflected ray is recorded by a cathode ray oscilloscope. Finally depth of crack observed from the surface of helical pinion can be easily calculated by ultrasonic testing [1,6,8].
  3) Chemical testing: From this testing, we observed & conclude that amount of carbon content of the helical pinion is quit higher (0.04%) than that of the specified value [1,6,2].
  4) Mechanical testing: For this purpose, Standard Rockwell Hardness Tester is used to measure the hardness value of the failure section of helical pinion. The obtained value of hardness is in between 28-34 BHN. Where as the required hardness value as per the drawing is 52 BHN. The absence of chromium carbide might be responsible for lowering of the hardness [1,2,6].

Figure 2-Crack Detection

c.Finite Element Analysis:

FEA defines either a product will crack, failed, wear out or work with as per designes. It is completely computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow and other physical effects [10]. The whole analysis was carried out in 2 steps:

1) Analysis of failed shaft performance and fracture.
2) Analysis of stress, torsional resonance and shaft design.

Hence the material quality was good and failure was not due to material properties in shaft. FEA shows the considerable stress concentration at the shoulder chamfer region [4].

[10]The procedure followed for Finite Element Analysis:-

1) Modelling of shaft.
2) Forces applied on the shaft.
3) Shear stresses on the shaft.
4) Equivalent (von-mises) stresses.

5) Redesign of shaft by using various materials.

Helical pinion shaft analysis is carried out by performing the analytical method and using ANSYS-11 software. According to this method, maximum stresses are generated near the portion of gear(fillet). Also it can be observe that shaft is failed because of less diameter [10].

III. Fatigue Analysis:

The majority of component designs involves part subjected to fluctuating or cyclic loads. Such loading includes fluctuating or cyclic stresses that often result in failure by fatigue. The unexpected appearance of fatigue fracture surface may simply be the characteristics of material. Comparing the fracture with fatigue test sample concluded the failure mechanism was fatigue [4]. As studied, an analysis of failure of main shaft of locomotive turbocharger. The fracture position is located at groove between journals with different diameters. The rotating bending fatigue is the dominant failure mechanism of the shaft. The stress concentration at fillet area initializes the fatigue [4].

The railway components are usually designed for infinite life based on the endurance limit or fatigue limit of the material. While this is general sufficient a comparatively small number of failures occurs in practice, a fact that is due to limitations and uncertainties of the concept such as the number of loading cycles railway components such as axles and wheels experience over their service time, which is usually a multiple of the 106 to 107 cycles realized in a common S- N test [14].

[10]The shaft failed due to fatigue, which arises due to following reasons:

a) Presence of cyclic overloads.
b) Stress concentration: they may be due to production or operation causes e.g. undercuts.
c) Wrong adjustment of bearing, insufficient clearances.

The most shafts are subjected to fluctuating loads of combined bending and torsion with various degrees of stress concentration. For such shaft the problem is fundamentally fatigue loading [10]. The crack closure effect was experimentally investigated for an edge cracked beam with a fatigue crack. The fatigue cracks encompass an initial notch which was used for crack growth, it is hard to say whether this peak is related to the cracks or to the presence of the notch [11].

IV. Material Composition & Stresses:

The pinion analyzed in the study was manufactured with DIN 17CrNiMo6 steel cemented/carburized in a carbon rich atmosphere to reach the required 2.6 mm deep carbon rich surface layer, according to the DIN 50190 standard, and subsequently quenched (hardened) and tempered to obtain a structural piece exhibiting a hard and wear resistant surface layer allied to a very tough core to withstand a repeated impact loads [2].

[10]Redesign of shaft by using various materials:

a) SAE 6145 (Chromium Vanadium Steel)
b) SAE 4140 (Chromium Molybdenum Steel)
c) SAE 6150 (Chromium Vanadium Steel)

It is observed that the Material SAE 6150 (Chromium Vanadium Steel) is the best because its shear stress is very less than allowable shear stress.

Stresses Acting on pinion shaft are: Shear & bending stress , Equivalent stresses (von-mises), torsional stress [8,10].

V. Conclusion:

As per earlier stated that to know why system fails we need to perform different types of analysis. All the authors from different background they have taken particular cases for the study and evaluated. While investigating the failure of mechanical system they have gone through analytical as well as experimental approach to conclude the same.

1. SAE6150 (Chromium Vanadium Steel) is the best material suggests for manufacturing of shaft because its shear stress value is very less than allowable shear stress.
2. It concludes the design standards of the shaft considering maximum bending and torsional theory.
3. By studying the finite element analysis of helical pinion shaft using ANSYS software.

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