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Experimental Investigation and Failure Analysis of helical pinion shaft in WAG-9 Locomotive

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ABSTRACT

Railway transport is an important aspect in the transportation system of our country. For timely service in passenger as well as goods transport, the efficiency and long service life of the systems components are important factors. The component for the study has been obtained from the Central Railway, Electric Loco Shed Ajani Nagpur M. S. India. In the present study the premature failure of one of the component of traction motor assembly (Helical pinion shaft) is carefully investigated. Different analytical tools such as Non Destructive Test for identification of the crack and for measuring the depth of the crack are used for experimentation. The cause of the identified failure is systematically analyzed by performing chemical test, hardness measurement and metallographic examination of the failed component. The results of all the analysis is correlated in the present study.

Keywords: Failure Analysis, Hardness Measurement, Microstructure.

1. INTRODUCTION

WAG9 is an electric locomotive engine of Indian railways used to haul specially goods train. The locomotive has six axles in two sets of three frontal and rear wheels, shown in figure 1. The traction motor of WAG9 is a main power transmission part of locomotive. It runs at 850 kW at 100 rpm. The traction motor is an assembly used in Indian railway locomotive as the main power transmitting unit as shown in fig 2. The whole assembly consists of an arrangement transmitting the torque generated by the traction motor through helical pinion to main gear and through main gear to wheel assembly. The traction motor is mounted on the chesis of the bogie. The tractive effort required to run the locomotive is transmitted by traction motor through helical pinion and main gear. As this assembly is main power transmitting unit, numerous types of forces acts on the assembly which may be static or dynamic. A Helical pinion is a very common part in many machine assemblies. In helical gears, the contact between meshing teeth begins with a point on the leading edge of the tooth and gradually extends along the diagonal line across the tooth. [1] There is a gradual pick up of load by the tooth, resulting in smooth engagement and quiet operation even at high speed. Helical gears are used in automobiles, turbines and high speed application even up to 3000 m/min.

The material of the helical pinion shaft in the proposed study is forged steel.

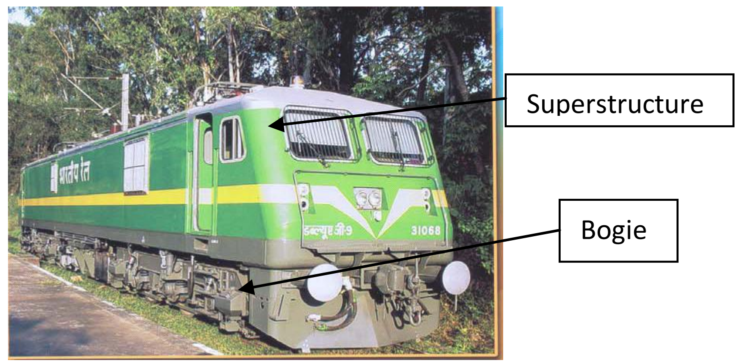

Figure: 1 WAG9- Locomotive

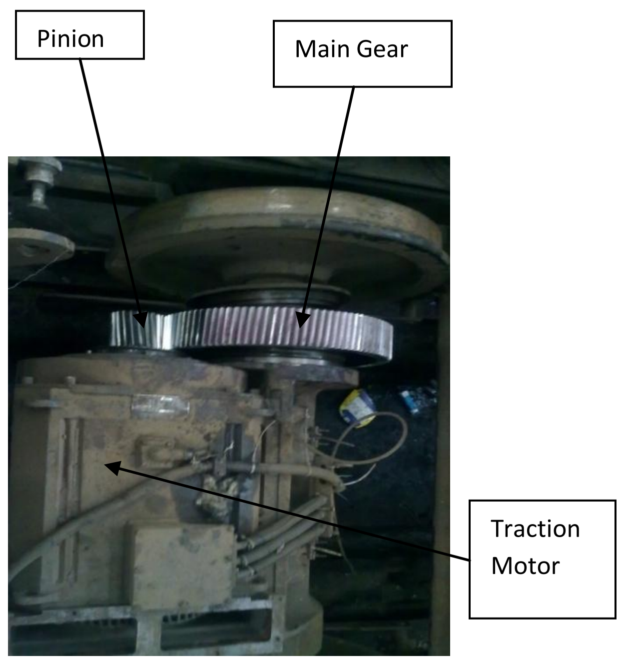

Figure 2 Traction motor asssembly

Figure3: Helical pinion of traction motor

Dimensional details of helical pinion are as follows which are mentioned in the input data [2].

Table 1 Dimensional details of helical pinion shaft.

Outside diameter (mm)	Inside diameter (mm)	Weight (kg)
110	25	41

The helical pinion shaft material is made up of forged steel (DIN 17182 -17CrNiMo4) [2].In this proposed study the failure investigation of the crack formed at notch region (figure4) and premature failure of the shaft of the helical pinion is discussed in details.

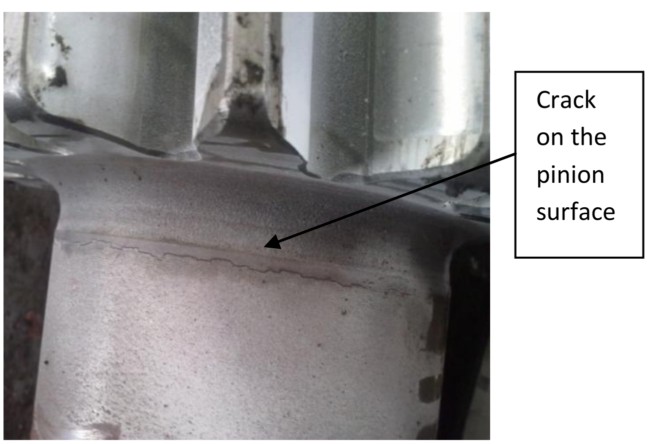

Figure 4 Failure Component Helical pinion with crack on the surface

2. Experimentation and Methodology

Experimental testing that has been carried out to investigate the failure of the helical pinion shaft.

- Non-destructive test for crack detection:

  a) Magnetic particle test : as per ASTM SE-709 ARTICLE-7
  Fluorescent powder with ultraviolet Light.
  MODEL:MG-410 Make MAGNAFLUX
  b) Ultrasonic flaw detection as per ASTM-A-388 Back wall Reflection.
- Chemical Test: Wet quantitative analysis of the helical pinion as per the standard procedure.
- Mechanical Test: hardness testing using standard Rockwell hardness tester (B scale).
- Microstructure: Metallographic examination using standard procedural steps for sample preparation. This is followed by optical microscopic examination using inverted binocular (Censico make) microscope installed with image analysis software.

3. RESULT AND DISCUSSION

A] Non Destructive Testing

Non-destructive testing is the use of physical methods which will test materials, components and assemblies for flaws in their structure without damaging their future usefulness. NDT is concerned with revealing flaws in the structure of a product.

a] MAGNETIC PARTICAL TEST:-

The magnetic particle (magna flux) inspection method is used to detect cracks, laps, seams, inclusions and other types surface of near surface discontinues in ferromagnetic materials. Typically, we used magnetic particle inspections to find fatigue induced surface and near surface cracks in helical pinion parts. For carrying out the test the fluorescent powder mixed in liquid is spread on the pinion surface. At the same time pinion is magnetized with instrument and ultraviolet light is focused on it. The image below shows the typical crack lining along circumference of pinion shaft.

www.ijmer.com Vol.2, Issue.3, May-June 2012 pp-1263-1266 ISSN: 2249-6645

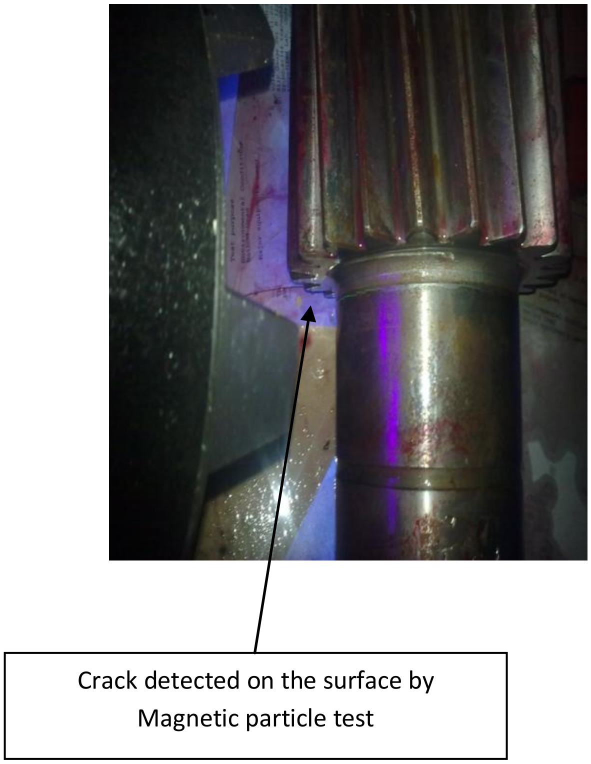

Fig 5 Helical pinion

b] Ultrasonic Test

It uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more. Ultrasonic sound waves are much higher than the audible range are produced and made to pass through the pinion. The time interval between the transmitted ray and reflected ray is recorded by a cathode ray oscilloscope. The depth of the crack from the surface of the helical pinion can be easily calculated by ultrasonic testing.[3] In this inspection the ultrasonic graph or signals shows discontinuities near notch region as well as at the end of shaft.

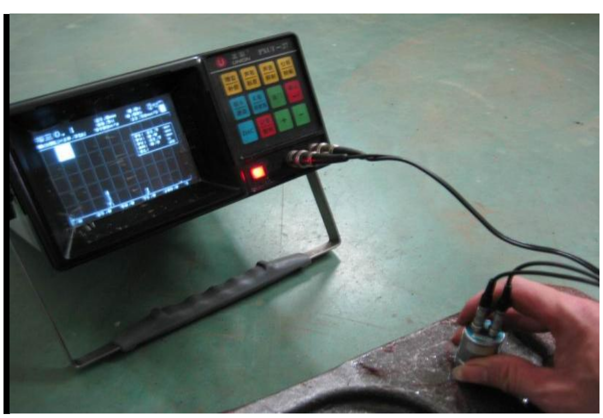

Fig 6 Ultrasonic test

With the ultrasonic test a crack is detected on the surface of the pinion shaft at a depth of 25-30mm

B] Chemical Analysis Test

Quantitative chemical analysis of the helical pinion shaft is carried out as per the standard procedure to validate the input data. The results are shown in table no.2.

Table2: Chemical analysis of helical pinion shaft.

Sample	**%C**	**%Si**	**%Mn**	**%S**	**%P**	**%Cr**	**%Ni**	**%Mo**
As per drawing	0.15 to 0.20	0.4 Max	0.4 to 0.6	0.035 max	0.035 max	1.5 to 1.8	1.4 to 1.7	0.25 to 0.35
As per experimentation	0.24	0.13	0.78	0.025	0.031	0.98	1.64	0.31

It is observed that carbon content of the helical pinion is quite higher (0.04%) than the specified value. Similarly lower Chromium content (0.82%) is observed after investigation in the report as against specified value of 1.8%. In order to cross check this observed value, further investigations such as hardness measurement and metallographic examination were carried out.

C] Mechanical testing: (Hardness measurement)

Standard Rockwell Hardness Tester is used to measure the hardness value at the failure section.Table3.shows the results of hardness measurement. Wide variation in the hardness value is observed.

The observed range of hardness is 34 -28 BHN, where as the required hardness value as per the drawing is 52 BHN. Absence of alloyed carbide (chromium carbide) might be responsible for lowering of the hardness. (52 BHN specified in the drawing). Possibility of non homogeneity in the chemical composition is also evident from this wide variation of hardness value.

Table3: Hardness Measurement at various locations of the failure surface.

Sr No	Rockwell Hardness B SCALE (100kg load)	Corresponding BHN Using standard conversion chart. (3000kg load)
1	34HRB	49

www.ijmer.com Vol.2, Issue.3, May-June 2012 pp-1263-1266 ISSN: 2249-6645

2	30HRB	47
3	28 HRB	42
4	27HRB	41
5	29 HRB	44
6	33 HRB	48

D] Metallographic analysis (Micro structural examination)

Variation in the chemistry of the helical pinion shaft and measured hardness value of the helical pinion shaft is correlated with the metallographic examination of the failed component. Standard procedure of polishing the samples using Emery papers Grade 0/1, 0/2, 0/3, 0/4 was followed before micro examination.

Before etching the sample, velvet cloth polishing was done using alumina abrasive paste [4, 5].The observed microstructure is shown in figure7.

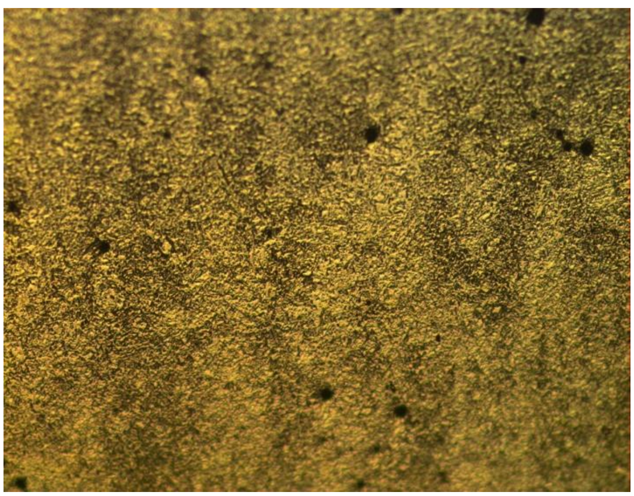

Figure:7 Metallograph of the failure component of the Helical pinion shaft. X100.

From the figure7, following observations are made:

1. Almost 30 % region in the microstructure shows Carbide phase (Fe_3C) with ferrite background.

2. The metallographic analysis can be very well correlated with the chemistry of the component. The observation as per the microscopic examination gives clear-cut indication of higher carbon content in the material, although specified value of the carbon is 0.20%.

4. Conclusion and further suggestions

Based on experimental investigation of helical pinion shaft in WAG-9 Locomotive following conclusions are drawn:

1. Validation of entire input data has shown some discrepancy as in the quantitative chemical analysis and hardness measurement.

2. This variation is reconfirmed by micro examination of the helical pinion shaft.

Also for further analysis to confirm failure causes it is recommended,

1) To conduct stress analysis of the helical pinion

2) The design aspects such as sudden change in design (notch region in this case) also should be taken in to consideration for analysis.

5. ACKNOWLEDGEMENT

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