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Experimental Investigation and Failure Analysis of Pivot Head in WAG-9 Locomotive

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ABSTRACT

Railway system in India plays a vital role in transportation. The demand of prolong service life and reliability of the various component are always considered as critical issue [1].The component of 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 components of traction link (Pivot Head) is carefully investigated. Different analytical tools such as Non Destructive Testing 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, NDT, Pivot Head, WAG-9 Locomotive.**

I. INTRODUCTION

WAG-9 is the name of a type of electric locomotive used in India shown in figure 1.This six axle loco is designed to give a starting tractive effort of 460 KN and maximum braking effort of 260 KN. Rated 6000 HP. Pivot Housing is an assembly used in Indian Railway's loco WAG-9/WAP-7as a main power transmitting unit as shown in fig.2 This assembly connects the superstructure (under frame) and bogies. The centre-pivot of the bogie is used to transmit the tractive and braking forces. It has also to bear the body weight. As this assembly is main power transmitting unit, numerous types of forces acts on the assembly which may be static or dynamic. Pivot assembly comprises of various components such as traction link, safety cables, chain, link rod, pivot head, ring, retaining plates, and locking tab [2].

Figure1: WAG-9 Locomotive

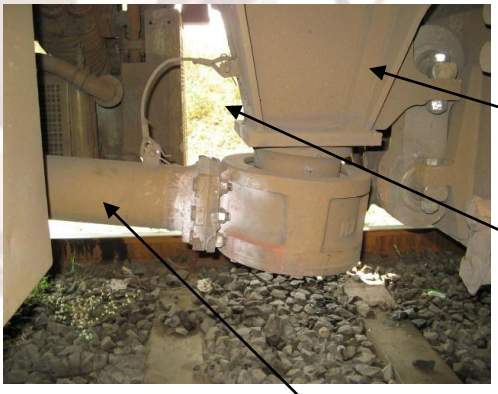

Figure2: Pivot Head Assembly

In this assembly the pivot head is situated at each end of the link rod.

Figure3: Pivot Head

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

Table1: Dimensional details of pivot head

Outside dia.(mm)	Inside dia.(mm)	Weight(kg)
320	250	31

This Pivot Head material is made up of cast steel (DIN 17182 GS 20Mn 5) [2]. In this proposed study the failure investigation of the crack formed at curvature of the flange region ("Fig.4") and premature failure of the Pivot Head is discussed in details.

Crack

Figure4: Failure Component

II. EXPERIMENTATION AND METHODOLOGY

Following experimental testing has been carried out to investigate the failure of the Pivot Head.

- Non-destructive testing for crack detection:
  a) Magnetic particle testing:

  As per ASTM, SE-709ARTICLE-7 Fluorescent powder with ultraviolet Light.

  MODEL: MG-410 MAGNAFLUX.

  b) Ultrasonic flaw detection as per ASTM-A-609 Backwall Reflection procedure B.

- Chemical testing: Wet quantitative analysis of the pivot head as per the standard procedure.
- Mechanical testing: 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.

III. RESULT AND DISCUSSION

A] Non-Destructive Testing:

Non-destructive testing methods are most commonly used for failure analysis.The presence or absence of the surface and sub-surface failures,and haircrack

which are responsible for premature failure of the component can be detected using this technique.

a) **Magnetic Particle Testing:**

This test is used for detecting cracks in metal like cast iron and steel which can be magnetized. For carrying out the test casting is magnetized and then fine particles of iron powder are spread on its surface. Presence of cracks in the casting results in interruption of the magnetic field and leakage of magnetic flux at the place of the crack. Vary small cracks near the surface which may not even be detected by radiography are easily revealed by this method.

Figure5: Magnetic Particle Testing

It is reported that cracks were found at the curvature of flange in Pivot Head. For detail investigation of this crack, Ultrasonic test was carried out.

b) **Ultrasonic Test**:

Ultrasonic testing is used to detect defects like crack, voids within the interior of the casting. The method uses reflection and transmission of high frequency sound waves. Ultrasonic sound waves are much higher than the audible range are produced and made to pass through the casting. 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 casting can be easily calculated by ultrasonic testing [3].

Figure 6: Ultrasonic Flaw Detector

It is reported that cracks were found in pivot head at a distance of 70 &72 mm from scanning surface (entire surface representing curvature of the flange).

B] Chemical Testing:

Quantitative chemical analysis of pivot head is carried out as per the standard procedure to validate the input data. The allied observations are shown in "Table no.2".

Table2: Chemical analysis of pivot head.

	C %	Si %	Mn %	S %	P %	Cr %	Ni %	Mo %
As per reports	0.32	0.39	0.89	0.013	0.021	0.15	0.066	0.053
As per drawing	0.23	>0.06	0.9-1	0.015	0.021	0.3	0.07	0.06

It is observed that carbon content of the pivot head is quite higher (0.32%) than the specified value. Similarly lower Chromium content (0.15%) is

observed after investigation in the report as against specified value of 0.3%. 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 106-131BHN, where as the required hardness value as per the drawing is 150 BHN. Absence of alloyed carbide (chromium carbide) might be responsible for lowering of the hardness. (150BHN 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	74 HRB	131
2	67 HRB	111
3	68 HRB	116
4	64 HRB	106
5	72 HRB	126
6	74 HRB	131

D] Metallographic Analysis (Microstructural examination):

Variation in the chemistry of the Pivot Head and measured Hardness value of the Pivot Head is correlated with the metallographic examination of the failed component of Pivot Head. 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 "Fig.7".

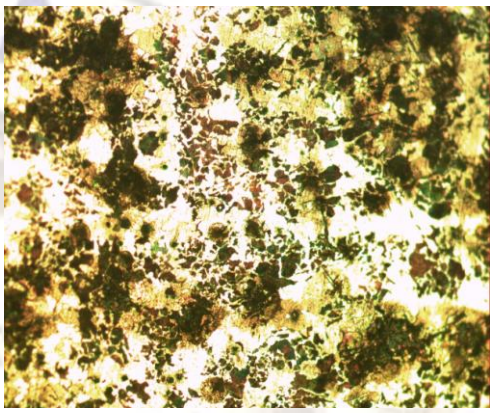

Figure:7 Metallograph of the failure component of the Pivot Head. X100.

From the "Fig.7", following observations are made:

1. Almost 50 % region in the microstructure shows Carbide phase (Fe_3C) Iron Carbide and Alloy Carbide.
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 0.23%.
3. Coarse grain structure is observed.
4. Non-uniformity in overall grain size is observed.

IV. CONCLUSION AND FURTHER SUGGESTIONS

Based on investigation of Pivot Head 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 Pivot Head.

It is therefore suggested that some suitable heat treatment will enhance the life of the Pivot Head. For the existing lot of the Pivot Head, homogenization anneal followed by the suitable cooling cycle will help in refinement of the grain size. This homogenized and refined grain structure will further increase the hardness value. The life of the Pivot Head thus will get increased to certain extent and the failure rate will get declined.

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