Analysis of Maintenance Strategies of Locomotive Diesel Engine Axle Gearbox

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Abstract— This Paper provide the different optimum processes of maintenance of axle gearbox in a Diesel Engine Locomotive, to observe situation of consistency, availability and inventive maintenance. This plan is considered in a way to identify the gear profile failure, gear pitting, backlash and tooth thickness. In this paper, mainly different types of Condition Based Maintenance are used to monitors the actual condition of the gear profile according to failure. In this way decision of the maintenance plan is easy. Then according to situation different plan may be chose. Therefore, each stage of replacement and repair is perfect.

Key words: Axle Gearbox, Gear Profile Failure, Gear Pitting, Backlash, Tooth Thickness and Condition Based Maintenance.

I. INTRODUCTION

The modern diesel locomotive is a self-contained version of the electric locomotive. Like the electric locomotive, it has electric drive, in the form of traction motors driving the axles and controlled with electronic controls. It also has many of the same auxiliary systems for cooling, lighting, heating and braking for the train. It can operate over the same routes (usually) and can be operated by the same drivers.

Kanpur Electric Loco Shed maintains locomotive for utilization in goods and passenger train. All the miner and major inspection are carried out in the shed on a regular schedule specified by RDSO (Research Design Standard Organization). Monthly schedule is done at an interval of 45 days and major schedule are carried out after 18 months.

Kanpur shed maintains two types of loco motives viz. WAP4 & WAG7.

1) WAP-4 W= Broad Gauge, A = AC Traction, P= Passenger
2) WAG-7 W= Broad Gauge, A = AC Traction, P= Passenger

Axle gear box is used to power transmission from traction motor to axle through spur gear. Locomotive gearboxes including axle mounted and nose suspended designs which offer strength, reliability and flexibility. We understand that need of maximum availability.

A. Axle Gearbox Arrangements:

Modern rail vehicles offer high travel comfort, generate little noise and are economical while achieving very high performance capacity. Rolling bearings from Schaeffler Group Industrial in gearboxes, traction motors and nose and axle-suspended motor bearing arrangements make an important contribution here. For locomotives, power cars and multiple units or for local trains: FAG bearing solutions for drive systems are specifically designed for the particular application. Rolling bearings in gearboxes stabilized the shaft and support the transmission of forces. In doing so, they must withstand extreme loads under complex environmental influences [12].

The bearing types principally used for gearboxes are tapered roller bearings; four points contact bearings and cylindrical roller bearings. Bearing types used less frequently include deep groove ball bearings, spherical roller bearings and angular contact ball bearings.

The main requirements for bearings in gearbox are given below [6].

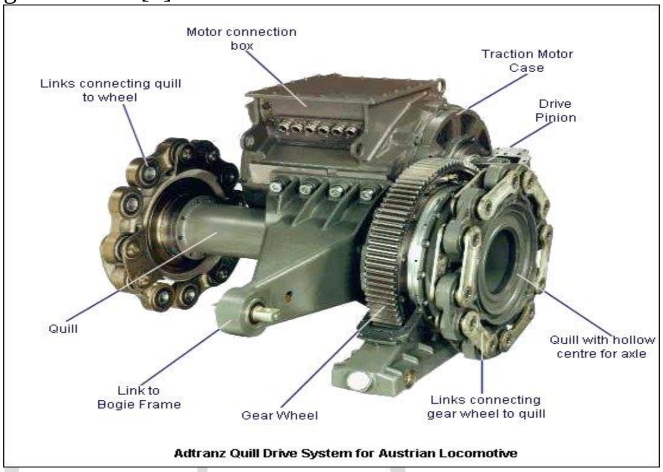

Fig. 1: Diagram of DC suspended traction motor and bearing arrangement [6]

- high speeds
- high loads
- vibrations and shocks
- high temperatures
- high guidance accuracy
- compact construction

Based on these characteristics, bearings are selected in consultation with the gearbox manufacturer. Characteristic features of FAG gearbox bearings:

- Strengthened internal construction
- Special cage design
- Restricted tolerances and adjusted internal clearance
- Retaining slots in the outer ring to prevent "co-rotation".

II. LITERATURE REVIEW

Daming Lina et.al (2003) studies condition vibration data from eleven gearboxes run to failure on the mechanical diagnostic test-bed at Penn State University Applied Research Laboratory was processed calculating the fault growth parameter (FGP) from the residual error signal. FGP, its revised version FGP1 and some other variables calculated from the residual error signal were analysed using the proportional-hazards modeling technique. Several statistical and replacement decision models were built based upon the observed condition data and ensuing failure events.

Nxiukun Wei et.al (2004) analyze that gearbox, an important component of urban rail vehicles working in the most severe conditions, plays a crucial role in the urban rail vehicle fault diagnosis. It is necessary to detect the fault of gearbox at an early stage to prevent human casualties and reduce maintenance costs. Most of the data-driven fault diagnosis methods are based on an experimental platform, which has many disadvantages such as costly maintenance, limited application, and limited degree of fault simulation. In this paper, a new method based on SIMPACK is proposed and conform efficient by testing, which can overcome the disadvantages of the experimental platform. Meanwhile, MATLAB was applied to time–frequency domain analysis and wavelet packet analysis. These analysis results demonstrated the feasibility and reliability of this method.

Lance J. Antolick et.al (2010) recommends the most effective gear condition indicators for fleet use based on both a theoretical foundation and field data. Gear diagnostics with better performance will be recommended based on both a theoretical foundation and results of in-fleet use. In order to evaluate the gear condition indicator performance on rotorcraft fleets, results of more than five years of health monitoring for gear faults in the entire HUMS equipped Army helicopter fleet will be presented. More than ten examples of gear faults indicated by the gear CI have been compiled and each reviewed for accuracy. False alarms indications will also be discussed. Performance data from test rigs and seeded fault tests will also be presented.

Aurel radula et.al (2010) studied about the effect of residual stresses on the fatigue propagation of cracks represents a major concern for important components subject to complex loading. The purpose of present research is to numerically predict the lifetime of axles used for railway tank wagons in various theoretical conditions. The developed procedure is based on both calculating residual thermal stresses by mean of finite element method, and the number of cycles to fracture, using the closed form solution of NASGRO equation for fatigue. Calculations of fatigue resistance are based on fatigue crack development starting from an initial crack detectable by means of non-destructive testing.

Prashant Bagde et.al (2011) analyses about the gearbox are an important element of any machine so it is very important to make study on that and finding out faults accoutering in the gearbox. It is possible every time to observe the gearbox for its faults so the vibration changes in the gearbox is used for the possible faults. In this thesis the faults accoutering in the gears are studied and how the vibrations are changes for a particular fault are studied. The modeling of the elements will be done on the CATIA.

Manoj a. Kumbhalkar et.al (2011) studied about the springs are subjected to cyclic load and failures are not uncommon. However, the high rate of failure of the specific spring in the composite assembly calls for the investigation. Wag-9 type electric locomotives, of Indian railways fleet, used for goods train hauling and maintained at Ajani electro loco shade, of central railway has the history of frequent failure of the middle axle primary inner suspension spring. the study of failures revealed that, this specific component fails at a much higher rate between first to third coil from the top end. Though the exact time and instance of failure cannot be ascertained as it does not halt the loco and it is noticed only when the loco comes for maintenance. This paper discusses the FE analysis of the same. This paper discusses the details of FE analysis of arrangement for the loading on straight and curved path.

Mark Lee Johnson et.al (2011) explores how oil selection can affect gearbox efficiency. According to the US Energy Information Administration, the United States generated 1,006 billion kwh of electricity in 2007. (EIA) It is generally accepted that electrical motors account for about seventy percent of industrial electrical power consumption. Assuming that electric motors are all driving gearboxes, and then every one percent increase in gearbox efficiency saves the equivalent yearly output of an 800 MW power plant. Small changes in efficiency can have a large aggregate impact. Unlike other efficiency-improving ideas, lubrication changes require no changes to existing equipment.

Jean-Luc Dion et.al (2012) develops an experimental and numerical study of dynamic phenomena involving gear impacts with one loose gear (non-engaged gear pair) inside an automotive gearbox. A dedicated test bench was designed for this study. Signal processing tools, based on the Order Tracking Method, were specially developed in order to clarify the underlying phenomena. A Particular attention was paid to the relationship between the drive shaft excitation and the energy and nature of impacts.

Dhameliya B.N. et.al (2013) describes the roll of spherical roller bearings in railway bogie wheels. Spherical roller bearings are critical components whose failure may have catastrophic consequences. The present study aims to analyses the mechanical stability of greases and temperature of bearings as indicators for condition-based bearing maintenance. The performed case study includes nine fully-formulated commercial greases examined in the wheel bearings of five ore cars operated in railway workshop.

Dietmar Klingbeil et.al (2013) explains that at a low speed an axle was broken. Fortunately, the derailment happened at a low speed so that nobody was injured. The reason for the broken axle was investigated and it turned out that most likely large inclusions located shortly underneath the surface in a T-transition were the origin of the final crack. Basing on that result, a systematic investigation on existing safety assessments of railway axles was performed. This results in an analysis of the production process of axles and in a critical review of existing of existing assessments. Improvements and future developments are outlined.

Meral Bayrakta et.al (2014) explain that axle is one of the most important components of a rail vehicle which transmits the weight of the vehicle to the wheels, meets the vertical and horizontal loads formed during static and dynamic moving, and carries the driving moment and braking moment. The prediction of fatigue failure of axles plays an important role in preventing fatigue fractures. Varying loads on components lead to cumulative failure in the mechanism. In this study, failures in axles of rail vehicles serving the Istanbul Transportation Co. have been investigated.

Dechen Yao et.al (2014) proposed a new technique for detecting faults in the railway gearbox by applying the time frequency parameters and genetic algorithm neural network to deal with railway gearbox fault signals. In this method, wavelet analysis and empirical mode decomposition (EMD) are carried out on gearbox vibration signals for extracting the time-frequency feature parameters. Then genetic algorithm neural network (GNN) is used for the classifications of the time-frequency feature parameters. The analysis results show that the effectiveness and the high recognition rate in classifying different faults of railway gearboxes.

Cai Yi et.al (2015) presents a novel and adaptive procedure based on ensemble empirical mode decomposition (EEMD) and Hilbert marginal spectrum for multi-fault diagnostics of axle bearings. EEMD overcomes the limitations that often hypothesize about data and computational efforts that restrict the application of signal processing techniques. The outputs of this adaptive approach are the intrinsic mode functions that are treated with the Hilbert transform in order to obtain the Hilbert instantaneous frequency spectrum and marginal spectrum. Anyhow, not all the IMFS obtained by the decomposition should be considered into Hilbert marginal spectrum.

A. Findings from Literature Survey:

1) Provide an effective maintenance plan for axle gearbox to decrease failure.
2) Recommend the most effective gear condition indicators for use based on both a theoretical foundation and field data.
3) Condition Based Maintenance (CBM) or predictive maintenance is a technology that strives to identify initial faults before they become critical which enables more accurate planning of the preventive maintenance.
4) Temperature measurement (Temperature-indicating paint, thermographs) helps detect potential failures related to a temperature change in equipment.
5) Effective lubrication is extremely critical to all axle gearboxes and proper lubrication will help prevent gear and bearing failures.

III. Maintenance Strategies of Locomotive Engine Axle Gearbox

Maintenance schedule planned to perform an audit on the axle gear box to determine the cause of failing. During these schedules, Temperature measurements, visual inspections foundation are performed. Besides this, the maintenance planning, technical data use of wearable parts is reviewed. These comprehensive compressors schedule allow us to draw up the condition of axle gear box and propose potential solutions. The schedule showed that a measurement of cracks of axle gear box was necessary to prevent wear of moving parts and auxiliaries would lead to an unplanned shutdown. Additionally, it was advised to renew the axle gear box foundation. To ensure its continuous operation, scheduling the overhaul becomes necessity.

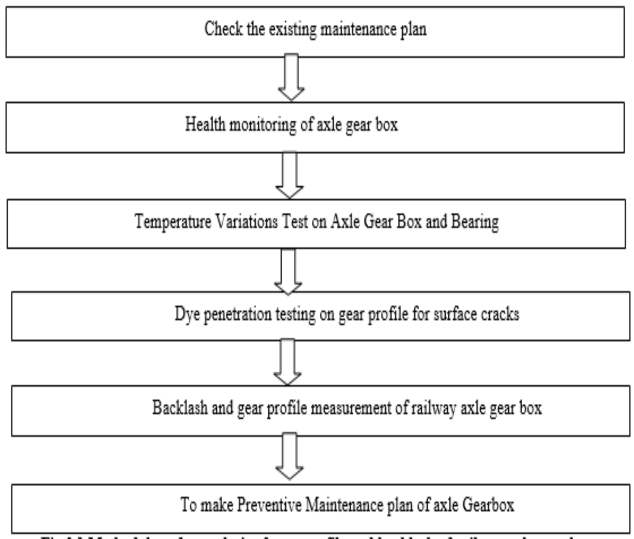

Fig. 2: Methodology for analysis of gear profile and backlash of railway axle gear box

A. Existing Maintenance Plan:

1) Monthly Schedule:

- Visually examine the axle box for any unusual condition.
- Investigate lubrication leakage at housing joints.
- Check for missing or improper locking of cover studs.
- Observe any sign for overheating on the outside portion of the axle gear box.
- Running temperature should not be more than above ambient temperature +120C.
- Examine the shunt connection between traction motor and under frame for looseness and tighten whenever necessary.

2) Bi-Monthly Schedule:

- Check and ensure proper fixation of front covers of the axle gear boxes.
- Axle gear boxes front covers to be removed and condition of grease to be checked. Renew the grease, if necessary.

3) Check Condition of Earthling Assembly:

- Four monthly schedule
  Check and ensure proper fixation of the axle box front cover and collar plates. Axle gear box front covers and collar plate is to be removed for ultrasonic testing and renew the grease.
- Send a sample of grease to laboratory for testing.

4) Overhauling After 18 Month

- Cleaning and refurbishing of parts.

B. Health Monitoring of Axle Gear Box:

Health monitoring of axle gear box is based on Condition Based Maintenance. Today, most maintenance actions are carried out by either the predetermined preventive- or the corrective approach. The predetermined preventive approach has fixed maintenance intervals in order to prevent components, sub-systems or systems to degrade. Corrective maintenance is performed after an obvious fault or breakdown has occurred. Both approaches have shown to be costly in many applications due to lost production, cost of keeping spare parts, quality deficiencies etc. Basically, predictive maintenance or Condition Based Maintenance (CBM) differs from preventive maintenance by basing maintenance need on the actual condition of the machine rather than on some preset schedule. CBM plan take following steps-

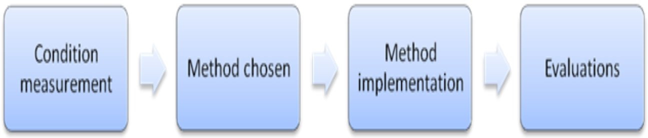

Fig. 3: Steps of CBM [6]

1) Condition Measurement:

Condition of gear profile is analysed by Temperature Variations Test on Axle Gear Box and Bearing.

Temperature Variations Test on Axle Gear Box and Bearing

Temperature measurement helps detect potential failures related to a temperature change in equipment. Measured temperature changes can indicate problems such as excessive mechanical friction degraded heat transfer (Fouling in a heat exchanger) and poor electrical connections (For example, loose, corroded or oxidized connections). The following table outlines the more common types of measurement with comments on applications and a brief technical description of the method.

Health of axle gear box is monitor on the basis of temperature variation test. Axle box temperature is to be measured at the front cover rather than at the crown of axle box. The maximum temperature limit of bearing case is

T max. = 2*T atmosphere

But for safe condition T max. = T atmosphere +120C

Temperature is measured by non-contact type infrared temperature gun. If temperature of Axle Box is increase above T atmosphere +120C during test. Then vibration generated in Axle Gear Box, which meeting with traction motor by gear, generate heat due to failure and cracks on tooth profile. This variation of temperature decides the failure in meeting gear.

2) Method Of Condition Based Maintenance:

- A variety of technologies can and should be used as part of a condition based maintenance programme.
- This technique is limited to monitoring the mechanical condition not other critical parameters required for maintaining reliability and efficiency of machinery. Therefore, a comprehensive condition based maintenance programme must include other monitoring and diagnostic techniques.

Technique use-

- Dye Penetration Testing on Gear Profile.
- Dimensional Analysis of Gear Profile and Backlash of railway Axle Gear Box.

C. Dye Penetration Testing On Gear Profile For Surface Cracks:

On the basis of visual inspection of gear profile after DPT different type of defect identified. They are shown in the fig 3.3

- Continuous line -Continuous line indications are caused by cracks, lack of fusion, incomplete penetration, scratches. Cracks usually appear as jagged lines and wavy lines. Scratches and die marks appear in a variety of linear patterns but are readily recognizable when all penetrant traces are removed.

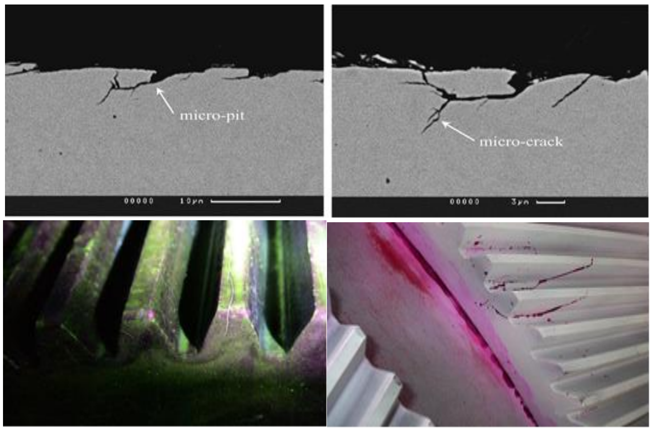

Fig. 4: Cracks on gear profile

- Intermittent line-The same discontinuities that cause continuous line indications may, under different circumstances, cause intermittent line indications. when this occurs, the discontinuities will appear as intermittent lines. Very light cracks yield similar signs.
- Round-Round indications usually are caused by porosity. Deep cracks appear as round indications since they trap a large amount of penetrant that spreads when the developer is applied.
- Small Dots-Small dot indications result from fine openings such as pin holes on the surface of gear profile

D. Dimensional Analysis of Gear Profile and Backlash of Railway Axle Gear Box:

- Set of profile deviation measuring gauge p-value and k-value with feeler gauges for bull gear 65 teeth mating pinion 16 teeth is used for measurement.
- The gauges are used by railroad and railroad repair shops to determine the amount of deviation from the original tooth profile.
- The main purpose of the gauge is to measure involute wear.
- The variance from the actual tooth profile and the worn tooth profile is uncovered through gaps.
- The feeler gauge indicates the involute wear or gaps typically from 0.24mm and greater.
- The gears are typically re-profiled if they are not beyond the tooth thickness condemning specification. The pinions are usually replaced.

1) Measurement of P-Value:

P-Value is measured by profile deviation measuring gauge and feeler gauge.

P-value= feeler gauge reading.

Limit of P-Value is up to 0.24mm

2) Measurement of K-Value:

K-value is measured by checking gauge. Limit of K-Value is 276.568 to 276.429 mm.

K-value is the radial distance along pitch circle of 8 teeth's.

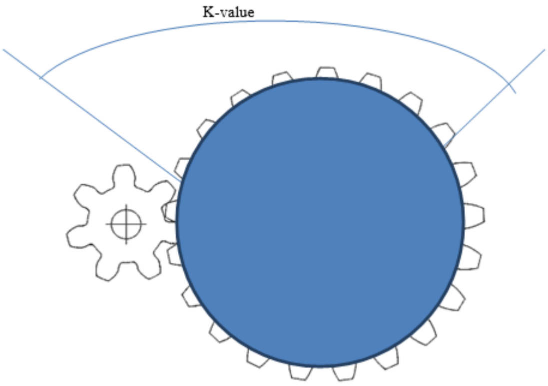

Fig. 5: Diagram of K-value

3) Measurement of Backlash:

Backlash

Backlash is the amount by which the width of a tooth space exceeds the thickness of the engaging tooth on the pitch circles. As actually indicated by measuring devices, backlash may be determined variously in the transverse, normal, or axial-planes, and either in the direction of the pitch circles or on the line of action. Such measurements should be corrected to corresponding values on transverse pitch circles for general comparisons.

IV. Conclusions

Based on the study, the following conclusions are obtained: -

1) Condition based maintenance plan predictive maintenance uses direct monitoring of the mechanical condition, system efficiency and other indicators to determine the actual mean-time-to-failure or loss of efficiency for each machine-train and system in this system.
2) The accurate measurement of gear profile and testing of axle gear box provide accurate repair and replacement of gear assembly.
3) Temperature distribution test offer the exact location of damaged section of gear, bearing and axle. The safe working limit of temperature of whole assembly is based on bearing temperature which not exceed from T max. = T atmosphere +120C.
4) The most serious factor that affects the systematic backlash is the inherent error of gear, Transmission ratio has great influence on the backlash for power transmission.
5) Backlash of gear train has a large relationship with gear meeting. Therefore, the pitch circle diameter of ring gear should be accurate according to design. If the requirements for design are not satisfied, then jamming of teeth generates the heat during running and damage profile of gear.
   Jamming occur if backlash exceed from 0.7 mm
   Gear profile will be damage if K-value is below 276.429 mm
   Gear tooth will be damage if P-value is exceeding from 0.24mm.
6) This data provides Maintenance management of factual data needed for effective planning and scheduling maintenance activities.

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