Defects in Wheels and Axles and Detection by Ust

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ABSTRACT

In this paper we discussed about various defects in the wheel and axle of the locomotive and the techniques which are currently employing in the Indian railway's workshops all over India. The techniques used are homogeneous throughout the country which is designed and developed by the RDSO, Lucknow.

I. WHEEL

Wheels are made up of carbon steel forgings which are subsequently heat treated and machined to subsequent dimensions. Wheels are also manufactured by casting process. The defects in wheel may be classified in two groups,

1. Inherent defects
2. Service defects

1. INHERENT DEFECTS

The defects encountered during steel-making, shaping and machining operations may be summarized as unsatisfactory chemical composition, micro structure, harmful inclusion, segregation, pipe, flake, etc. which are associated with faults in the making of steel and manufacturing into wheels.

As wheels are also manufactured by casting process, defects related to casting may appear as porosity, blowholes, and slag inclusions etc. Improper heat treatment may lead to coarse grain structure, Processing defect arise during machining, fabrication, handling etc. They can be summarized as deep tool mark, dent mark arising during machining, fabrication, handling etc.

2. SERVICE DEFECTS

Defects developing in wheels during their service life due to service condition leading to failure. The examples are written below.

2.1 Wheel shelling defect: Wheel shelling, separation of metal from wheel, is a rolling contact fatigue phenomenon that leads to damage on the wheel tread and eventually small pieces of the wheel tread break off.

2.2 Thermal cracking defect: Thermal cracking is a process that requires elevated temperatures which is generated during severe braking. Often, these cracks are found on wheels with heat checks and the cracks appear to be closely related.

2.3 Sliding defect: It occurs when wheel will slide on a rail as a result of the retarding force between wheel and brake shoe is greater than the adhesive force between wheel and rail.

2.4 Wheel Spalling defect: It occurs in service after the wheel slides on the rail and patches of martensite are formed on the tread. In spalling, the crack network is either perpendicular or parallel to the surface.

2.5 Shattered Rim defect: This type of defect originate at the sub-surface of tread resulting in fatigue initiation which further progresses circumferentially and when the fatigue crack gets connected with tread surface, a chunk of metal is dislodged from tread.

Other defects in wheel can be written as sharp corner at rim edge, wheel flat, spread rim, thinning of flange, punch mark at wheel rim etc.

WHEEL DEFECT PHOTOGRAPHS

FIG 1: CRACK WITHOUT FRACTURE

FIG 2: SHELLING ORIGIN
(I) SURFACE MARTENSITE SPOTS, NORMALLY BY SLIP

(II) SUBSURFACE FATIGUE DUE TO ROLLING CONTACT CAUSED BY TANGENTIAL STRESS

FIG 3: VERTICAL SPLIT
ORIGIN- INHERENT DEFECT IN INGOT
REMEDY- PROPER CROPPING OF INGOT

FIG 4: SHARP CORNER AT RIM EDGE
ORIGIN-SHARP CORNER AT RIM EDGE
REMEDY-AVOIDANCE OF SHARP EDGES

FIG 5: SHATTERED RIM
ORIGIN- INHERENT DEFECT LIKE CLUSTER OF INCLUSIONS, FORGING BURST, LOWER STRENGTH.
REMEDY- CLEAN STEEL, USFD - TREAD PROBING

FIG 6: THERMAL CRACKS
ORIGIN-THERMAL CRACKS
REMEDY-LOWE C%, DESIGN, DISC BRAKE, MAINTENANCE OF BRAKE SYSTEM

THERMAL DAMAGE TO WHEEL
FIG 7: OBSERVATION ON HEATED WHEEL
Chemistry & Mechanical properties satisfactory
Macro showed heat affected area
Micro showed spheroidal pearlite

FIG 8: THERMAL DAMAGE TO WHEEL

FIG 9: ORIGIN - PUNCH MARK
REMEDY- SUGGESTED AT WHEEL BOSS

II. AXLE

Railway axles are one of the most highly stressed components of the various rolling stocks in use. The safety and reliability of these axles are therefore of paramount importance. The following discussion is about defects, which are observed on them.

A) STEEL MAKING

The steels are required for manufacture of axles can be made in open hearth furnace, basic oxygen process or a combination of these processes. The steel so manufactured is required to be of killed quality in order to have maximum fatigue strength under condition of dynamic loading. The steel required to have a maximum of 0.007% of nitrogen and 2ppm of hydrogen if produced by basic oxygen processes. These two elements have the
tendency to develop crack/brittleness during subsequent manufacturing operations or service.

In order to obtain the desired mechanical properties and freedom from hot shortness and cold shortness, sulphur and phosphorous contents should not exceed 0.05%. The steel so produced are in the form of ingots which is further worked down to obtain the final product. In order to ensure freedom from undesirable piping and harmful segregation, sufficient discard is necessary from the ingot.

**B) AXLE FORGING**

The ingots so produced are converted in the form of blooms in a blooming mill and the finished shape of the forged axle is obtained by forging the bloom in a press or a forging hammer. The reduction ratio from ingot to axle should not be generally less than 4:1. The forged axles are allowed to cool slowly after forging. The forged blanks are thereafter suitably heat treated (normalized or quenched and tempered) to obtain the desirable microstructure and mechanical properties.

During the process of manufacture of steel and also during subsequent mechanical working operations for producing the final shape of axle, it is essential to ensure freedom from defects e.g. pipe, segregation, cracks, flakes, laps, seam, etc. These defects are undesirable as their presence leads to failure of axles in service.

Sufficient control of heat treatment process is essential to obtain the desired mechanical property and avoid undesirable microstructure (e.g. overheated or burnt structures).

**C) MACHINING**

The forged and heat treated blocks are thereafter machined to drawing dimensions providing generally 60 included angle for lathe centers. Utmost care is essential in maintaining the specified surface finish especially on the journals and wheel seat areas. The fillet radii at each change of section has to be a gradual transition and of correct dimension. Sharp changes in section, tool marks, dent marks, machining marks etc. on the surface of the axle are undesirable. The fatigue properties on the axles are highly sensitive to the surface imperfections. It is only logical, therefore, that the handling of the machined axles also warrants due care to prevent surface damage.

**D) DEFECT OBSERVED ON THE AXLES AND THEIR ORIGIN**

The defects arising on the axle are therefore primarily due to shortcomings during manufacture and also during manufacture and also due to a variety of service conditions to which they are subjected.

The sources of various defects are – a) steel-making and shaping operation b) machining operation c) heat-treatment operation d) assembly operation e) repair practice f) maintenance practice and g) corrosion.

The defects encountered during steel-making and subsequent shaping operations are piping, segregation, slag inclusions, cracks, laps, seams, rokes etc. The defects in the heat treatment operation could be non-uniform micro structure, overheated or burnt structure, decarburization, surface defects etc. Machining if not carried out properly can lead to rough turning marks, tool marks, insufficient fillet radii etc. Unorthodox methods of assembly, use of oxy-acetylene flame/incorrect treatment and interferences, insufficient pressing-in pressure, all have detrimental effects on the life of the axle. The axle boxes are required to be properly maintained in respect of lubrication, tightening torque and ingress of foreign matter. The areas exposed to the atmosphere are prone to corrosion and the corrosion pits formed work as stress concentration areas.

The most vulnerable locations of fracture in axles have been found to be inner wheel seat, journal and transition zones or fillets.

Causes of inner wheel seat failure have been attributed to sharp edged hubs, hubs shorter than wheel seats, fretting corrosion and machining marks giving rise to crack initiation and finally fracture. Failures in fillet area are attributable to insufficient fillet radii, tool marks etc.

Journal breakages have been found to be caused by notches, produced by inner race edges, local heating and pressing in discrepancies.
III. DEFECT DETECTION OF NEW COMPONENTS BY ULTRASONIC TESTING

1) WHEEL

For detecting internal discontinuities in the rim and the hub of the wheel, ultrasonic inspection is carried out. It shall be performed after final thermal and machining operations. The wheels are passed through Go/no Go evaluation system of ultrasonic testing method, based on Indian Railway Specification. Recent system of evaluation can also provide the position and severity of defects.

The rims of the wheels are checked through ultrasonic inspection to detect defects at two orientations.

a) Defect Parallel to the Rim Face (Axial Testing)
All wheels will be subjected to ultrasonic testing of rim through probing axially along the rim face to detect any flaw having orientation parallel to the rim face.

b) Defect Parallel to the Running Tread (Radial Testing)
All wheels will be subjected to ultrasonic testing of rim through probing circumferentially along the tread surface to detect any flaw having orientation parallel to the tread surface.

c) Penetration Test for Cast Wheel
An additional test for cast steel wheel is done for penetration checking to check suitability of material towards grain size. Only such wheels, which pass ultrasonic test for the rim, shall be subjected to ultrasonic testing of hub.

IRS-R-34-03. Method of ultrasonic testing & acceptance standard for locomotive wheels
IRS-R-19-93 part-ii (rev.3). Method of ultrasonic testing and acceptance standard for wrought steel wheels
IRS R19 part iii. Method of ultrasonic testing and acceptance standard for cast steel wheels.

2) AXLE

For detecting internal discontinuities in new axles the following three tests are done
A. Penetration Test
B. Discontinuity Detection Test
C. Longitudinal Discontinuity Detection Test

A) Penetration Test
For ascertaining the suitability or otherwise in respect of grain size of the axles this test is done. Axles with coarse grained structure exhibits poor fracture toughness, reduced impact resistance and propensity towards higher rate of crack growth Acceptance criteria will be as per IRS specification.

B) Discontinuity Detection Test
In discontinuity detection test, discontinuities present in the axle are detected. The axle is divided in three zones, zone I, II and III as specified in IRS specification. Axles should not have flaw size more than 3.2 mm in zone I, 6.4 in zone II and 9.5 in zone III.

C) Longitudinal Discontinuity Detection Test
In longitudinal discontinuity detection test, discontinuities present in parallel manner to the axis of axle like pipe are detected which remains undetectable in discontinuity detection test. This is being conducted on axles to check forging defects, which are parallel to the axle length. If these defects are not detected before putting the axles in service may develop fatigue cracks & lead to premature failure of axles in service and also these parallel defects may interfere during near end and high angle scanning conducted during periodical examination of axles.

IRS R 43 Ultrasonic testing of new rough turned axles for railway rolling stock-diesel and electric Locomotives, EMU motor coaches and powered axle of rail cars (applicable to all gauges)
IRS R 16-95 Ultrasonic inspection of new rough turned axles (applicable to all gauges) for steel axles for carriages and wagons.

IV. ULTRASONIC TESTING OF AXLES IN SERVICE

Ultrasonic testing of axles has been introduced in Indian Railways as a tool for preventive maintenance as also to ensure safety and reliability in passenger and freight service. Axles are critically stressed item of rolling stock.

FATIGUE CRACK develops in service which is TRANSVERSE in nature at vulnerable locations as wheel seat, gear seat, bearing seat, inner / outer fillets, and journal.

Fatigue cracks are caused by a combination of fretting due to relative movement between two parts, for example, wheel hub and axle, and the stress concentration introduced as a result of the sudden change of flexural stiffness produced by the pressed on wheel.

Failure of axles causing derailment in service is not uncommon and Railway systems throughout the world have introduced ultrasonic method for detection of such cracks in time so that failure of axles in service leading to catastrophic consequences is minimized, if not altogether avoided.

Ultrasonic method is employed for testing of axles. Generally this method is employed for detection of internal flaws in the component though with the type of stress augmentation encountered by axles in service the progressive cracking starts from the surface, there is no other suitable means of non-destructive testing including visual inspection for inspection of portions of axles under the wheel seat, gear seat or bearings. In other words axles are to be tested in fitted condition and surface cracks are like internal cracks in the assembly.

For successful Ultrasonic testing three points are to be satisfied
A) TRAINED OPERATOR
B) HEALTHY MACHINES WITH PROBE AND ACCESSORIES.
C) ADEQUATE TESTING PROCEDURE.

RDSO is also preparing necessary codes of procedure for ultrasonic testing of axles of different designs and issuing to the Railways for implementation.

Various types of axles are used in railways. These are Loco, Carriage, Wagon, EMU, Tower wagon, and Crane. As per Railway Boards instruction 100% ultrasonic testing on all axles in service at regular pre determined interval is to be implemented.

REFERENCES