सत्यमेव जयते

**GOVERNMENT OF INDIA**

**MINISTRY OF RAILWAYS**

# Technical Audit

# of

# Wheel Pressing Procedure

# for

# Electric Locomotives

**Report No.: RDSO/2016/EL/TAR/0007 Rev. '0'**

**Issue Date: 03.06.2016**

| | |
|---|---|
| Approved by | ओमप्रकाश |
| EDSE(Co-Ord) | Signature |

**Issued by**
**Electrical Directorate**
**Research, Designs and Standards Organisation**
**Manak Nagar, Lucknow-226011**

| Prepared By | Checked By | Issued By |
|---|---|---|
| | | |

# Technical Audit of Wheel Pressing Procedure for Electric Locomotives

## 1. Background

1.1. There have been cases of breakages of wheel discs reported in Loco no. 27555 and 27489 of Electric Loco Shed, ED. Further, increase in cases of Gauge Widening has also been reported by Southern Railway.

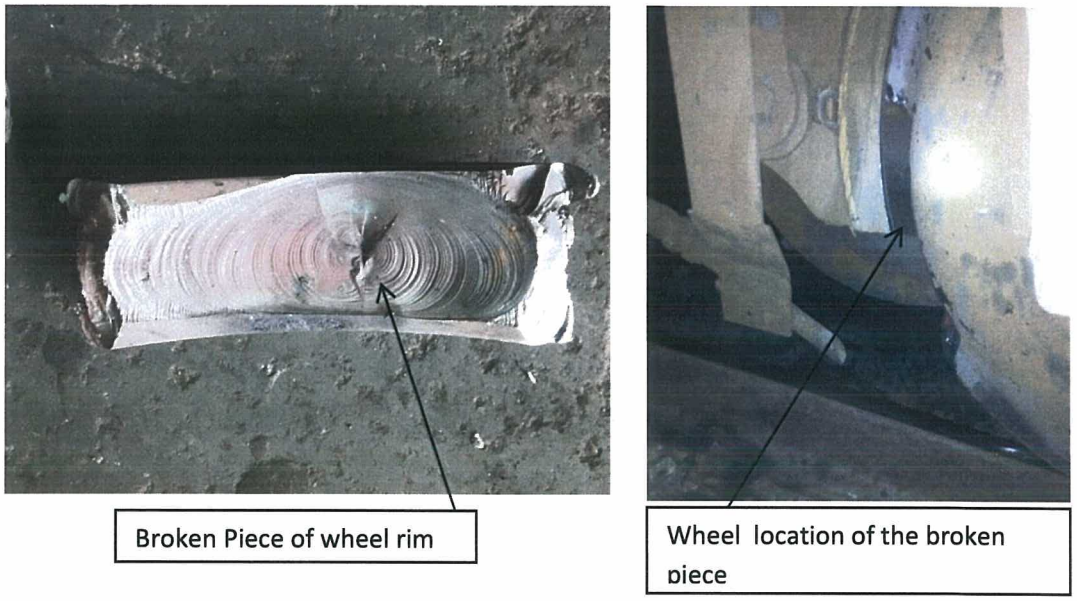



Fig 1 : Breakage of wheel disc at rim in Loco. No 27555

1.2. The investigation of Loco no 27555 was carried out by M&C directorate and it has reported that the wheel disc had failed due to shattered rim cracking which is caused by rolling contact load on tread surface resulting in tangential Hertzian stresses at subsurface level. This creates crack when stresses exceed yield strength which propagate in a fatigue manner. Further, no heat affected area was observed on macroscopic examination after etching.

1.3. During the course of investigation it was observed that the manufacturer's serial number was not available on the wheel disc. It was informed by Electric Loco Shed, Erode that Loco works, Perambur machined the hub face which carried the manufacturer's serial no after pressing-in the disc and punched their own serial number. Further, no record is being kept at the workshop for original

serial no. Therefore, the original serial number could be traced for follow-up action.

1.4. The breakage in wheel disc of Loco no 27489 was in the web portion circumferentially outside the hub and the wheel disc was sent to Perambur Loco Works for analysis. The circumferential crack suggests stresses developing in web portion of the disc. This could be due to manufacturing defect or may be due to improper wheel pressing resulting in high residual pressure in fillet portion. The metallurgical investigation of this wheel is awaited.

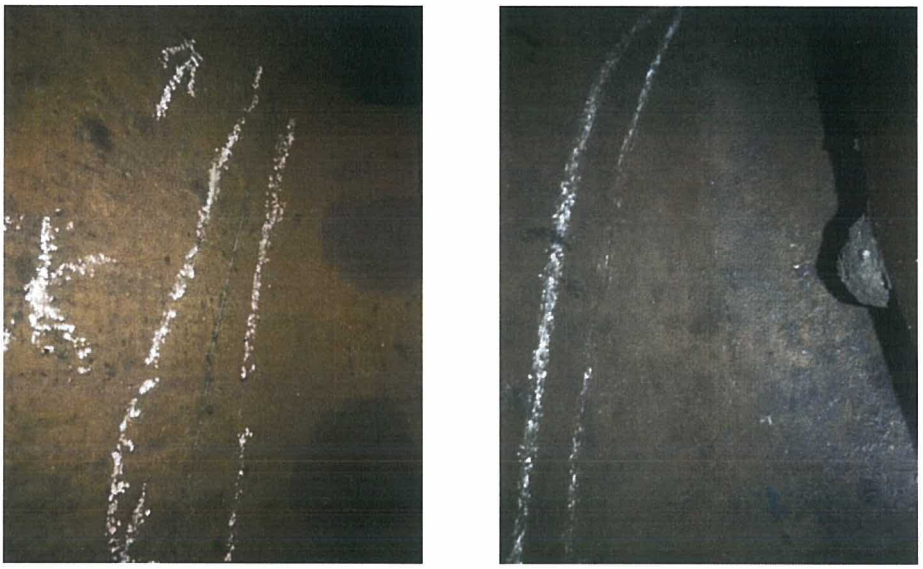


Fig 2 : Circumferential crack in the web portion of wheel disc close to hub in Loco no 27489

1.5. Further to this Southern Railway has reported increase in cases of wheel gauge widening tabulated as under:-

| Year | Brake Block | No. of cases | | |
|---|---|---|---|---|
| | | Coaching | Goods | Total |
| 2013-14 | Cast Iron | 2 | 1 | 3 |
| 2014-15 | Cast Iron | 4 | 4 | 8 |
| 2015-16 (upto Jan'16) | Cast Iron | 0 | 3 | 3 |
| | Composite | 8 | 3 | 11 |

1.6. In view of the above, it was decided to audit the wheel pressing procedure being followed in various loco workshops. Accordingly, Loco Works, Perambur

was visited on 23-24.2.2016 and 31.3.16, Wheel Shop at ELS/CNB was visited on 22.3.2016 and KPA workshop was visited on 11-12.5.16.

## 2. Procedure for Wheel Pressing :

RDSO has issued technical circular no. RDSO/2015/TC/0132 on 5.10.2015 to lay down the interference and guidelines for pressing-in of wheels on axles of electric locomotives. The main instructions are as under :-

2.1. The wheel disc should be at the same ambient temp as the axle at the time of pressing-in.

2.2. The axle shall be fully machined as per relevant drawing. The smaller dia must be at outside end if there is any taper (within limit as indicated in drawings for axle).

2.3. Surface finish of the wheel bore and wheel seat should be kept as per relevant drawings and a record of the same to be kept.

2.4. Interference between wheel seat and bore should be kept between 0.0009d to 0.0015d+0.06mm where'd' is nominal diameter of wheel seat in mm.

2.5. Both the wheel bore and wheel seat must be coated with prescribed lubricants i.e. ARCA mounting paste or NALCO-3295 or mixture of 5.5kg white lead with 4.5l boiled linseed oil. Use of Molykote GN Plus, raw linseed oil, other lubricating oils either alone or for thinning should not be used for this purpose.

2.6. The assembly of wheel with the axle must be carried out with hydraulic press taking precautions to prevent deformation of the components and damage to the machined parts.

2.7. In case of out-of-balance wheels, the wheels shall be fitted such that the residual out-of-balance of each of the two wheels of the same set lies in the same diametrical plane and on the same side of the center line of axle. The residual out-of-balance of the brake disc must lie in the same diametrical plane and shall be on the opposite side of the center line of axle.

2.8. The pressing-in force as a function of displacement should be recorded using automatic recorder:-


Fig 3 : Automatic recorder for pressing-in force vs displacement

The resultant graph should be similar to ideal/good graph as shown below:-

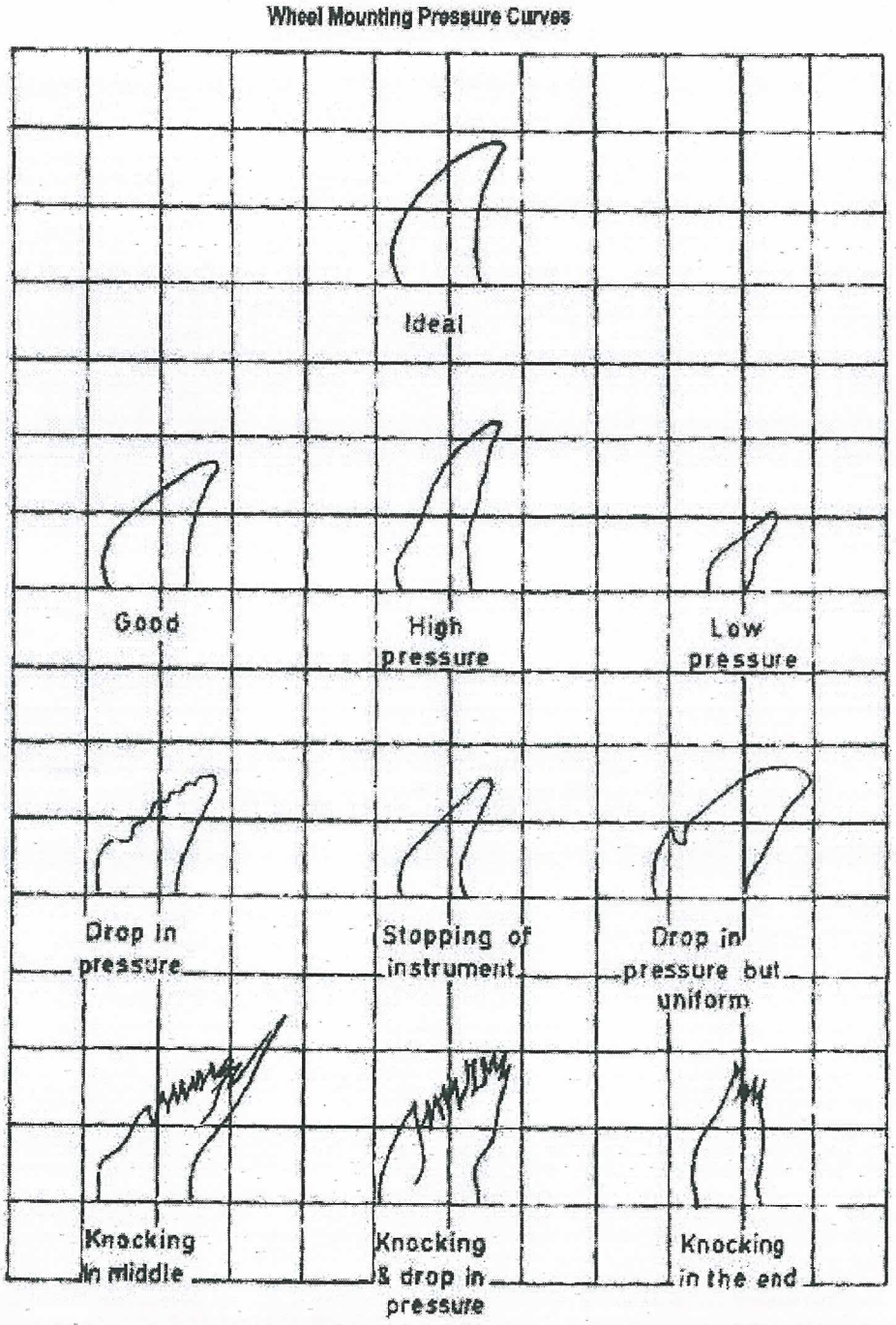



Fig 4. Sample Pressure vs Displacement Graphs

## 3. Observations

3.1. The observations during these visits and recommendations regarding improvements are given in the following paras:-

3.2. When the disc gets pressed out the surface of the wheel seat on axle gets scored. The workshops normally do not perform any machining/finishing operation on the wheel seat to prolong the life of axle since every machining would reduce the diameter of the wheel seat and axle would have to be replaced once the diameter of wheel seat gets below 242mm (the diameter of bore of rough machined wheel disc).

3.3. None of the workshops were measuring surface finish. Loco Works, Perambur started measuring the surface finish since end-March when the workshop was visited. However, the records available, since the measurement started, show that the surface finish is often out of prescribed range both for wheel seat and wheel bore. This measurement is recorded in the rough register and still not recorded in the wheel record. The workshops informed that they do not have the facility for honing of the axle with mounted bull gear and so surface finish cannot be controlled at the time of rediscing.

Fig. 5 : Measurement of surface finish of axle at wheel seat

3.4. Some of the workshops were yet to switch over to lubricants prescribed vide the technical circular and were using lubricants such as castor oil, molykote etc. Perambur workshop informed that they were using castor oil based on RDSO letter no. MW/WA/WAP dated 8.2.1993 issued to WAP/SBC (now RWF/SBC). However, the letter refers to BOXN wheels and does not relate to Electric Locomotives.

3.5. Wheel bore & wheel seat on axle is cleaned by cotton, however lubricant is being applied by hand on the wheel bore only and it was informed that it we apply the lubricant on both the wheel seat and bore, the pressing-in pressure is not reached even after keeping interference at the maximum.

3.6. All the workshops are measuring wheel seat diameter of axle and wheel bore diameter and are maintaining prescribed interference. However, the pressing-in pressure varied from 95-151T as opposed to 95T to 132T. This has now been adjusted to 95T to 132T after being pointed out at the time of technical audit.

Fig 6 : Wheel disc pressing (Non-Gear Side)

3.7. The mounting of wheel discs was observed for a few wheel sets and graphs thus recorded analyzed. There were some deficiencies noted during the course of pressing-in. Some of these cases are discussed below:-

3.7.1. The wheel disc is pressed by the operator while another observer notes the distance of Motor Suspension Unit (MSU) from the wheel disc and given instruction to the operator to terminate pressing-in once the wheel disc touches MSU. However, this results in delay and the wheel disc gets pressed against the MSU shown by the sudden rise in the pressure at the time of contact before the pressure is removed. It can be seen from the graph below (Fig. 7) that the pressure suddenly jumps from 114T to 124.9T at a displacement of 150mm without any change in displacement. This is a result of pressure being exerted by the wheel disc on the MSU and is not related to the pressure being due to interference. This results in the pressure recorded by the automatic recorder at a higher value than the actual press-in pressure (124.9T instead of 114T as shown in Fig 7). Additionally, this would also introduce compressive stress in MSU and its bearings, which would result in net outward force on wheel disc.

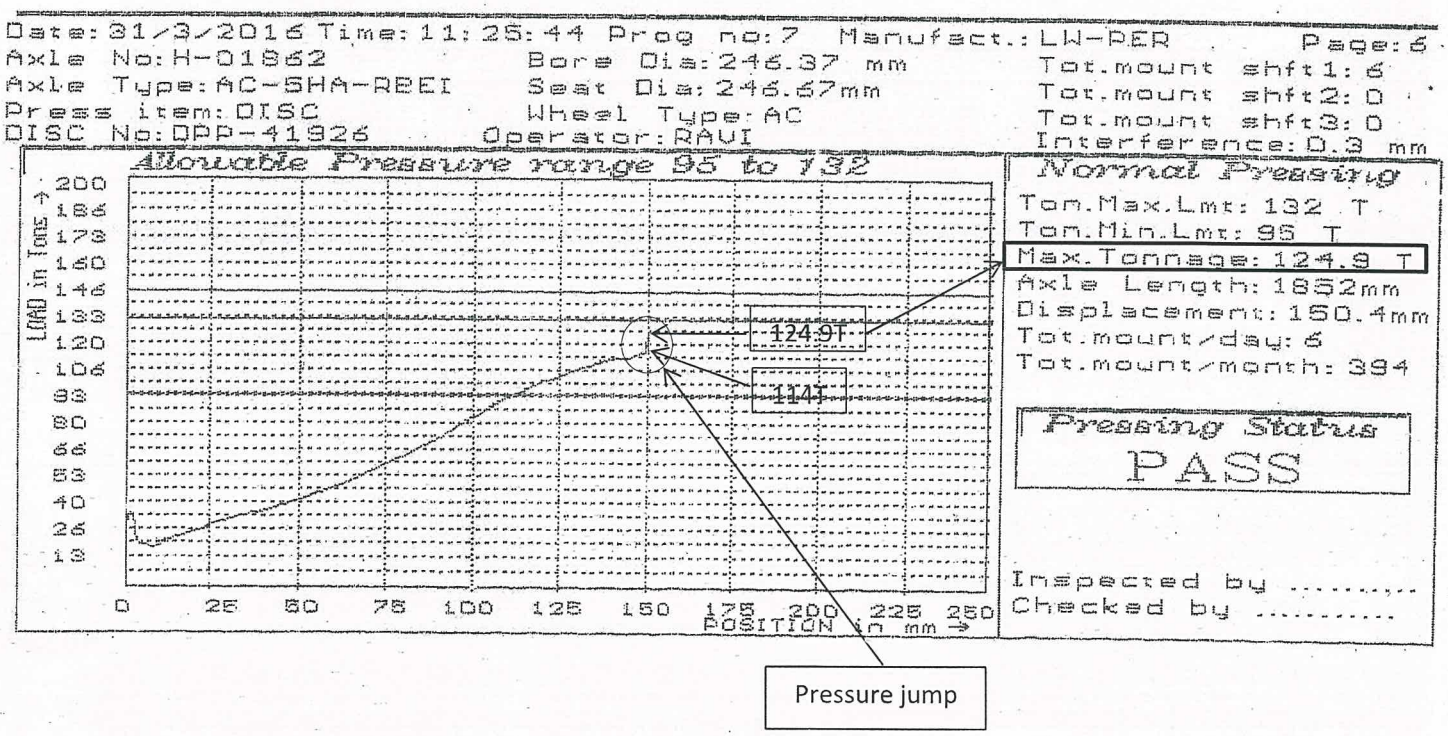



Fig. 7 : Sudden rise in pressure due to contact of wheel disc with MSU

3.7.2. In the wheel pressing graph shown below as Fig 8, it can be seen that the pressing-in pressure is below 95T for most of the displacement and there are sudden erratic fluctuations in pressure towards the end and the final pressure is recorded as 95T. The graph represents 'knocking in the end' in the wheel mounting pressure curves as per the Technical Circular. However, the status is reported as "PASS" as the maximum tonnage is recorded as 103.8T.

In this case the interference is kept as high as 0.4mm which is within limits (0.23mm to 0.43mm for wheel seat dia of 251.95mm) but the pressure recorded is on the lower side which The scale of the graph is from 0 to 450T which should be reduced to 0-200T so that the graph can be manually inspected and such fluctuations of around 20T can be noticed.

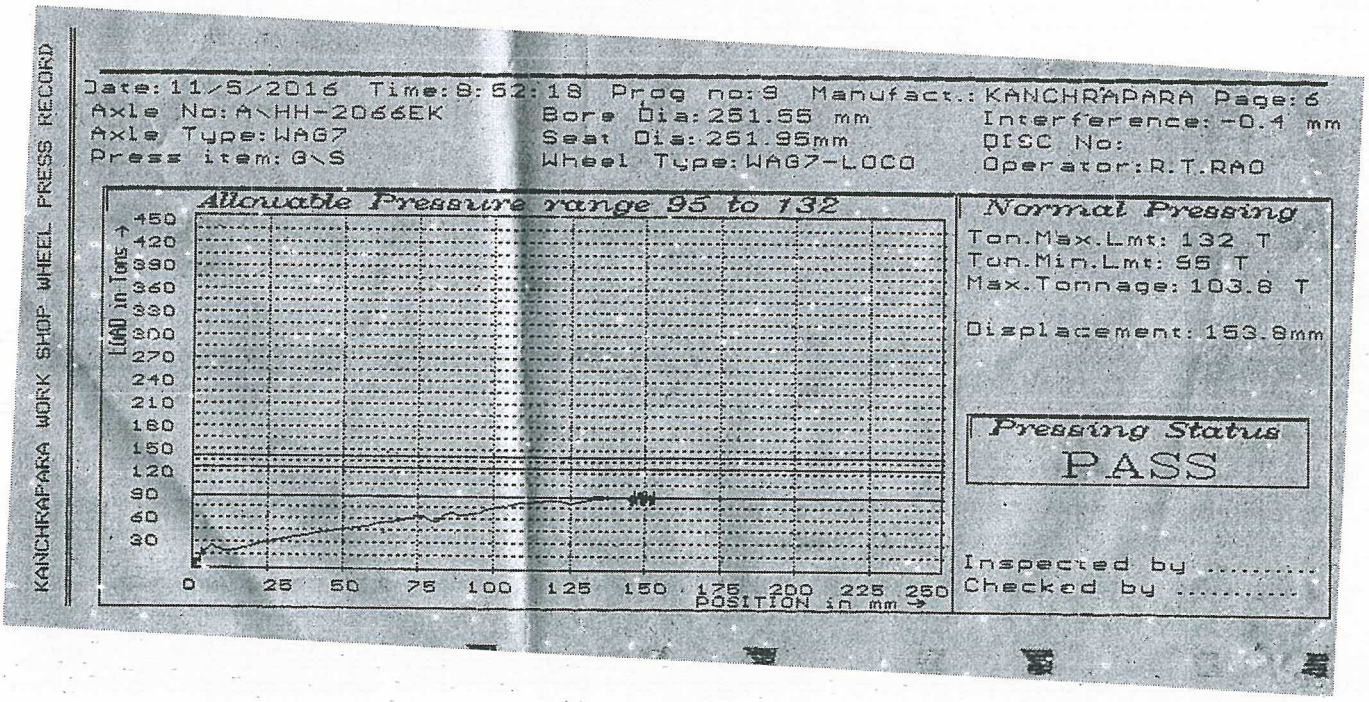



Fig 8 : Low pressure and knocking at the end (Not recommended)

3.8. The face of the wheel disc is machined to achieve the required clearances for axle box mounting. As this surface contains the identification mark of the supplier of wheel disc, the information is lost while machining. However, the workshop was noting part of the Serial number and punching it back after machining. It can be observed from Fig. 9 below that a substantial part of information is lost and only middle part of original punch mark is re-punched. This doesn't serve the purpose and workshop agreed to re-punch the entire number to ensure traceability.

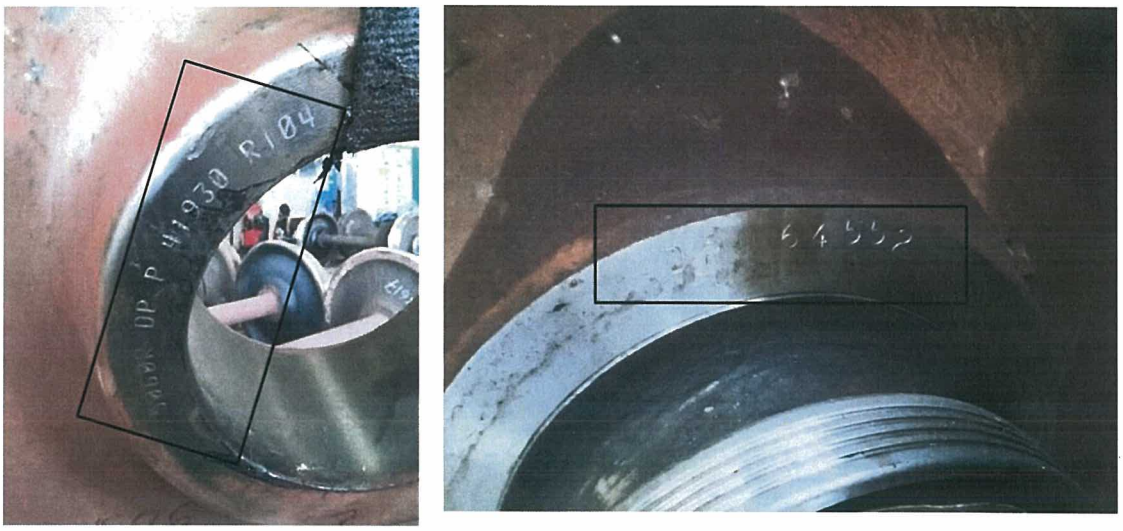



Fig 9 : Punched Identification Marks on Wheel Hub

# 4. Recommendations:-

4.1. It should be ensured that RDSO Technical Circular No. RDSO/2015/EL/TC/0132 (Rev-0) dated- 01.10.2015 issued vide RDSO letter no. EL/3.2.108 dated 5.10.15 regarding procedure for pressing-in wheels on axles in electric locomotives is followed by all wheel shops.

4.2. 100% Ultrasound testing must be carried out by a fully trained person on wheels and axles before wheel pressing. The results should be recorded and preserved for future reference.

4.3. The axle shall be fully machined and finished as per the relevant drawing. If any taper exists (within limit), the small diameter must be at outside end (reversed taper not allowed).

4.4. Interference between wheel seat and bore should be kept in the range between 0.0009d to 0.0015d+0.06 mm where'd' is nominal diameter of wheel seat in mm. However, the stipulated pressing-in pressure as per the relevant drawing shall be the final criteria for assembling wheels on axles. This is in view of fact that besides the interference, the pressing-in pressure also depends on various other factors like the surface finish, ovality & taper (though within the stipulated limits) etc.

4.5. Surface finish of the wheel bore and wheel seat area of the axle should be measured and maintained as given in the relevant drawings. Suitable arrangement should be made so that the axle mounted with bull gear can be honed in order to achieve the required surface finish on the wheel seat. A record of actual measurements of the same shall be maintained.

4.6. The wheel bore and the wheel seat area of the axle must be cleaned carefully to remove rust, grit, burr, chips and grease before assembly.

4.7. During mounting the wheel on axle, it is recommended that a mixture of 5.5 Kg of white lead with 4.5 liters of boiled linseed oil be used as lubricant. Alternatively, NALCO-3295 or ARCA mounting paste can be used. No other lubricant should be used for pressing of wheels of electric locomotives.

4.8. At the time of pressing-in, it should be ensured that the solid wheel disc is at the same ambient temperature as the axle.

4.9. The wheel pressing machine shall be equipped with a correctly calibrated pressure indicating gauge and automatic recorder producing a plot of pressing-in force as a function of wheel displacement relative to the axle wheel seat

throughout the pressing operation. This plot shall be large enough to permit a precise determination of pressing-in force at any position on the curve.

The pressing-in speed should be slow enough to ensure the following :-

4.9.1. The pressing-in pressure should start rising before the displacement of wheel on the wheel seat reaches 20 mm.

4.9.2. The pressing-in pressure shall gradually and smoothly increase with the displacement of the wheel, until a maximum value is reached which shall not exceed the maximum specified value as per the relevant drawing.

4.9.3. This maximum recorded value should not fall during the pressing-in operation by more than 5 ton and any such fall should not result in a value less than the minimum pressure specified in relevant drawing, nor the pressure drop should occur prior to the final 25 mm of displacement.

4.9.4. The final pressing–in pressure should lie between the stipulated pressing-in pressure as per the relevant drawing.

4.9.5. This plot should be inspected and compared with the reference plots given in technical circular to arrive at a decision regarding correctness of wheel pressing instead of merely looking at the "PASS" or "FAIL" reported by the machine.

4.10. It should be ensured that the wheel disc doesn't press Motor Suspension Unit at the time of processing. Suitable arrangement for automatically switching off pressure, once disc touches MSU or completes its movement is desirable to reduce dependency on manual skill and reflexes.

4.11. The manufacturers' serial number should be properly noted down before machining of hub face. After machining the same serial no should be punched again on the hub to ensure traceability of the wheel discs. This will permit proper investigation in wheel disc failures particularly those in which problems are noticed in a particular source/batch/heat.

## References

1. RDSO Instruction Bulletin No. MP.IB.VL-01.02.09 (Rev 01)
2. RDSO Technical Circular no. RDSO/2015/EL/TC/0132
3. M&C Investigation Report no. 17/16 issued vide letter no M&C/MIT/I&T/6 dated 2.6.16
4. MP Investigation Report no. MP.INV.51 (Rev.00)

# M&C DIRECTORATE

**No. M&C/MIT/I&T/6** **Date: 02.06.2016**

## Investigation Report No. 17/16

**Sub: Metallurgical Investigation of wheel disc of WAG7 Loco no. 27555.**

**Ref: DSE/C&S/ Electrical Directorate's note no. EL/3.2.108, Date 12.02.2016**

In reference to above, a fractured piece broken out from rim portion of wheel containing the tread part was received for metallurgical investigation. The counter part of the failed wheel disc was not received. Details of investigation are as under:

**1. M&C Lab. Identification No. - 17/16**

**2. Sample particular (as furnished)**

| | | |
|---|---|---|
| 1. | Component/System Identity (coach/Loco/Wagon etc.) | Wheel disc specimen wheel no. 6-27555 |
| 2. | Date of failure | 30.01.2016 |
| 3. | Place/Railway | CEU(Chiheru) |
| 4. | Location in System if part of assembly | Wheel set |
| 5. | Drawing No./Specification No. | 4948R, SPEC-IRS-R-34-2003 |
| 6. | Sketch of failed component after joining fracture pieces, Please attach | Not received |
| 7. | Function of component in brief. | Wheel |
| 8. | Manufacturer | DP |
| 9. | Identification mark on the component. | 31649-17 |
| 10. | Date of Manufacture | Not Known |
| 11. | Date of fitment | 31.03.2006 at PER |
| 12. | Failed in service/assembly/maintenance | Failed in service |
| 13. | Caused derailment/accident | No |
| 14. | Train No. in case of Accident | Not applicable |
| 15. | Nature of stresses/loading | Light engine movement |
| 16. | Working environment (Temp/humidity etc.) | Varying |
| 17. | History of repair/maintenance | IOH on 28.08.2014 & IB on 12.12.2015 |
| 18. | Document allowing welding repair if any | Nil |
| 19. | Last NDT Testing/result if applicable | Not applicable |
| 20. | Attach Report of prelim investigation | Not received |
| 21. | Expected service life | 9 years |
| 22. | Condemning criterion | Diameter |

## 3. Visual Examination

A fractured piece broken out from rim portion containing the tread part having 400 mm circumferential length & thickness about 38 mm is received **(fig.1)**.

The broken piece has fractured faces on either ends and opposite end to tread surface. Visual examination revealed that the piece had broken due to shattered rim phenomenon. The fractured had initiated at a depth of about 35 mm from existing tread surface. The fracture had progressed horizontally on either side parallel to tread surface with the formation of beach marks. On one side the horizontal fatigue had progressed 131 mm from origin & other side 200 mm **(fig.1)**. After wards the fractured had changed the orientation towards either ends & progressed in a transverse manner (Radial) causing breakage of the piece from rim portion.

At initiation zone crack extending towards the front rim side is about 46 mm & back rim side is about 34 mm width **(fig.2)**.

At corresponding location of fracture initiation zone which is having a crack in subsurface, a crack having width 55 mm is noticed on the tread surface **(fig.3)**.

The counter fracture piece was not received. From the geometry of received piece, it appears that initiation point was almost located to near tread web transition (fig.4).

The wheel appears to be considerably wear out. The existing wheel diameter is 1023 mm as furnished and new wheel diameter is 1092 mm. Thus the limit of wear is about 34.5 mm.

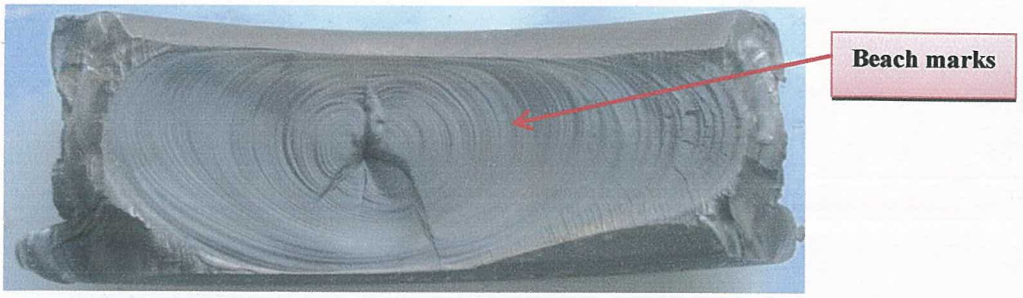



**Fig.1 Photograph of broken piece from wheel tread portion in as received condition.**

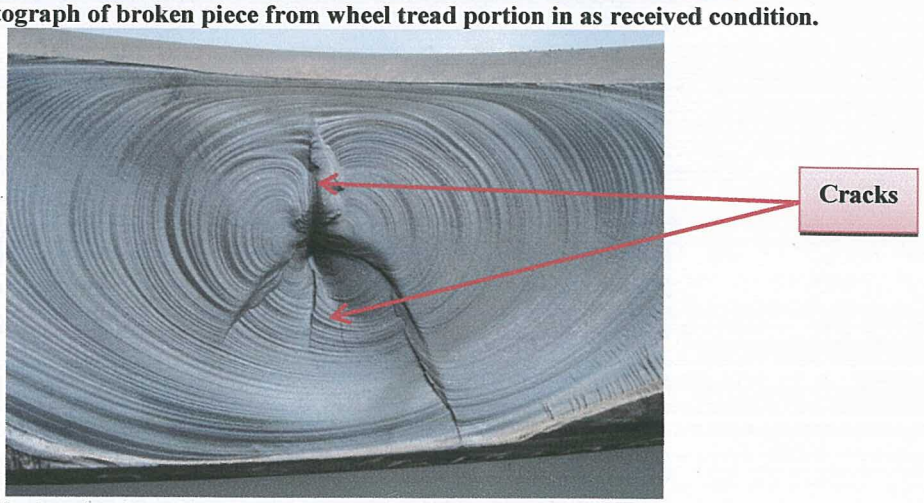



**Fig.2 Photograph showing location of crack towards front rim side & back rim side of tread.**


**Fig.3 Photograph showing location of crack on wheel tread at corresponding location of fracture initiation zone.**

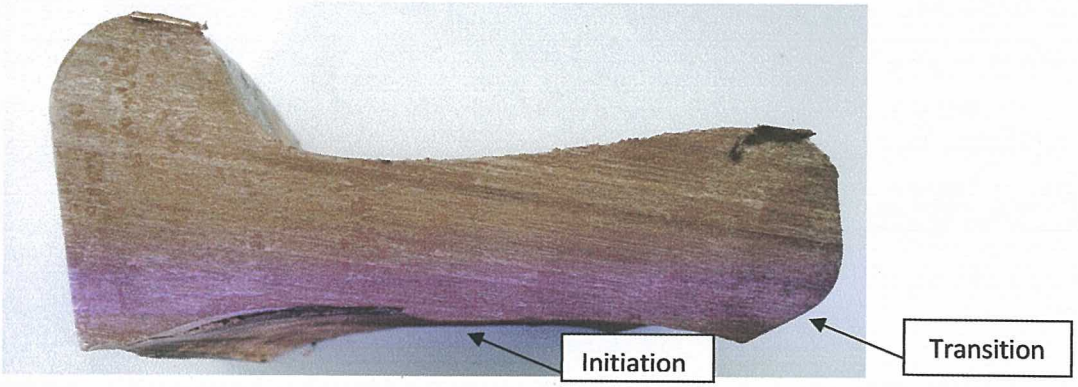



**Fig.4: Photograph showing location of crack initiation and transition area**

## 4. Chemical Composition

Piece taken from failed sample was analysed for chemistry of the material. The results are given as under:

| Elements | Sample No. 17/16 | Specified as per IRS: R-34-2003 | | Permissible variation from the limit specified in product analysis |
|---|---|---|---|---|
| %C | 0.58 | 0.57-0.67 | | +0.03, -0.02 |
| %Mn | 0.73 | 0.60-0.85 | | ± 0.03 |
| %Si | 0.37 | 0.15 min. | | - 0.03 |
| %P | 0.016 | 0.030 max. | | +0.005 |
| %S | 0.013 | 0.030 max. | | +0.005 |
| %Cr | 0.22 | 0.25 max. | Combined 0.50 max. | +0.05 |
| %Ni | 0.04 | 0.25 max. | | +0.05 |
| %Cu | 0.05 | 0.28 max. | | +0.05 |
| %Mo | 0.02 | 0.06 max. | | +0.02 |
| %V | 0.08 | 0.10 max. | | +0.02 |
| %Al | 0.014 | 0.02 max | | +0.002 |

## 5. Tensile Test

Tensile test piece could not be conducted due to insufficient size of received wheel disc.

## 6. Hardness Test

Hardness test was conducted on a transverse slice at the depth of about 5mm below the existing tread surface. The results are given as under:

| Depth of wear | Location | Hardness (BHN) (3000kg/10mm /15secs) | Specified as per IRS: R-34-2003 |
|---|---|---|---|
| 34.5 mm [(1092-1023)/2] | At 5mm depth from Existing tread surface (for new wheel 34.5 +5=39.5 mm) | 313, 305, 304 | 300-341 BHN (up to 30 mm for new wheel, minimum 300 at 30 mm depth) |

## 7. Macro Examination

Transverse slice taken adjacent to the fracture face was etched with nital. No heat affected area & no abnormality were noticed.

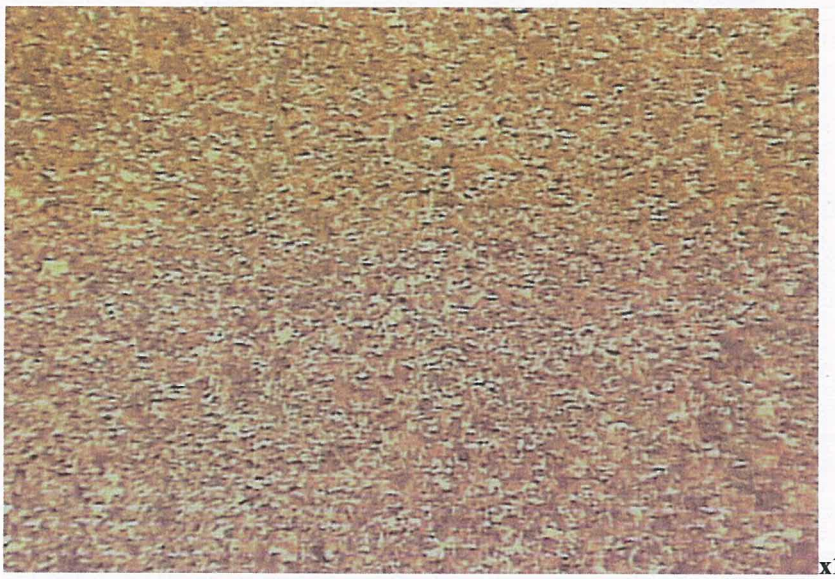
## 8. Micro examination

**Inclusions rating:**

| Sample No. | Sulphide | | Oxide | |
|---|---|---|---|---|
| | Thin | Thick | Thin | Thick |
| **17/16** | 1.0 | - | 1.0 | - |
| **Specified as per IRS: R-34-2003** | 2.0 max. | 1.5 max. | 2.0 max. | 1.5 max. |

**Microstructure:**

a) Microstructure was conducted on a sample taken from the existing tread portion. Micro examination revealed fine pearlite within thin & broken network of ferrite having ASTM grain size varying from 6 to 7 (fig.5).



**x100**

**Fig.5 Photomicrograph showing grains of fine pearlite within Thin & broken network of ferrite.**

b) Micro examination was also conducted on sample cut across the nucleus of initiation of fatigue. Microstructure did not reveal any slag entrapment or any inherent defect. On etching, it revealed fine pearlite within thin & broken network of ferrite having ASTM grain size varying from 6 to 7.

## 9. Discussion

Visual examination revealed that the wheel disc piece had broken due to shattered rim phenomenon. The fractured had initiated at a depth of about 35 mm from existing tread surface. The fracture had progressed horizontally on either side parallel to tread surface with the formation of beach marks. On one side the horizontal fatigue had progressed 131 mm from origin & other side 200 mm. After wards the fractured had change the orientation towards either ends & progressed in a transverse manner (Radial) causing breakage of the piece from rim portion.

The counter fracture piece was not received. From the geometry of received piece, it appears that initiation point was almost located to near tread web transition. The wheel appears to be considerably wear out. The existing wheel diameter is 1023 mm as furnished and new wheel diameter is 1092 mm. Thus the limit of wear is about 34.5 mm

**Chemical composition** of the wheel conforms to specification no. IRS:R-34:2003.

**Tensile** test could not be conducted due to insufficient size of received wheel disc.

**Hardness** values of the wheel conform to specification at 5mm depth of existing tread surface which is satisfactory. Hardness is still satisfying the norms of specification despite the considerable wear of wheel about 34.5 mm when compared with new wheel. The hardness location is about 39.5 mm away as against 30 mm specified location for hardness measurement.

**Inclusion rating** conducted on the received wheel disc sample is found satisfactory.

**Microstructure** revealed fine grains of pearlite within thin & broken network of ferrite having ASTM grain size varying from 6 to 7. At the initiation zone, any inherent defects like slag entrapment or shrinkage was not noticed.

It is evident from above that the wheel disc had failed due to shattered rim cracking i.e. propagation of a sub-surface crack parallel to the tread surface. In the shattered rim, crack initiation and propagation depends on several factors, such as rim thickness, wheel load and material of the wheel. Lower is the rim thickness higher is stress on wheel and higher is the tendency of shattered rim cracking.

Shattered rim cracking is caused by rolling contact load on tread surface which results in tangential hertzian stresses at sub-surface acting parallel to tread surface. When the stresses exceed the yield strength of the material, crack may initiate and progress parallel to tread in sub surface. This resulted in initiation of crack which further progressed in fatigue manner with the formation of beach marks and lead to separation of chunk of metal from sub-surface causing failure of wheel.

The failed wheel disc is having dia about 1023 mm. As per RDSO drawing no. D/WL 4948, the condemning dia is 1016 mm. Thus only about 3.5 mm wear limit is left and approaching almost the condemning limit. Due to reduced rim thickness approaching almost to the condemning limit, the rolling contact load has led to initiation of fatigue crack near to the rim web transition and resulted in dislodging of metal piece from the tread surface in shattered rim phenomenon manner.

## 10. Conclusion

Wheel metallurgy conforms to the specification for the tests conducted despite having lost the hardening area and a considerable wear of wheel about 34.5 mm.

Failure of wheel is due to shattered rim cracking. Failure has resulted in dislodging of a piece from tread surface due to formation sub-surface crack in fatigue manner. Due to considerable wear of wheel about 34.5 mm, in service rolling contact load has led to the initiation of sub-surface fatigue crack at about 35 mm below the existing tread surface near to the rim-web transition. The initiation of sub-surface fatigue crack had caused subsequently dislodging of a piece due to shattered rim phenomena.

Above conclusions have been made based upon metallurgical investigation of available sample and data only.

02/6/16

**(C. Sengupta)**
**Addl. Exe. Director/M&C**

**Distribution:**

1. **Sr. Divl. Electrical. Eng.(TRS), Electric loco Shed, N.Rly., Ludhiana-141001** **(By Regd. Post)**
2. **ED/Electrical/RDSO**