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Research paper

Rejection Rate Analysis on Rail Wheels

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Abstract

These analysis ambitions to ascertain the major core cause of failures of rail wheels and to prevent the occurrence of same in future. One working model of train is developed to estimate the heat generated at brake pad-wheel and rail-wheel interfaces for locomotive and wagon wheels using the performance characteristics of brake blocks, the slip characteristics of wheel-rail traction and the resistance characteristics of a running train for given operating and braking conditions. The heat dissipation characteristics of rail-wheel and brake pad units interfaces in locomotive and wagon wheels and wheel running temperatures for different wheel profiles for different train running conditions are estimated. This work is carried out to identify the under-lying machinery of locomotive wheel failure due to widening and condemning of gauge. It has also accomplished the investigation on the impact of the type of brake block, wheel profile and braking conditions on locomotive wheel fiasco from gauge widening and condemning are also been carried out. It is suggested to use a high friction coefficient composite brake block results in higher wheel temperatures and cause large gauge changes, particularly for independent braking. Further, S-shaped wheels are found to be best suitable for avoiding undue gauge reduction or increase.

Keywords: *brake system; locomotive; rail wheel*; *rejection rate; root cause analysis.*

1. Introduction

Wheel tread/tyre profile used earlier was standard 1 in 20 taper after the root radius. Currently a worn wheel profile or worn adapted profile was prescribed to reduce the wheel wear and to increase the wheel life. As per requirement, during POH/ROH/Maintenance of wheel set/wheel re-profiling, wheels tread are be turned as per intermediate profile with varying wheel flange thickness choosing the appropriate flange thickness out of nine flange thicknesses so as to minimize material removal at the time of turning. These intermediate profiles have been included to optimise the life of wheel.

Wheel diameter for new wheel is 1002 mm. Condemning wheel diameter is 906 mm for all versions except CASNUB 22NLC Bogie. Minimum wheel diameter for CASNUB 22NLC bogie is 955 mm.

Wheel parts are;

- Disc
- Axle
- Catridge tapered roller bearing
- Spherical roller bearing

1. Disc:

The wheels of a train normally rest on the rails on which they move. They sit on the rails without any guidance system mostly. The guidance may be needed for the shape of the tyre in relation to the rail head. In contrast to prevalent acceptance, the flanges should not be in contact with the rails. The derailments of trains are prevented only by the Flanges that are used as a safety feature. The conical shape is preferred for wheel tyre whereas slight curvature is preferred for the rail heads. The degree of coning which varies will be set by Railway Company. The standard angle preferred in UK is 1 in 20 (1/20 or 0.05) whereas in France it is maintained as 1/40. The angle of wear would be as little as 1 in 1.25 before the wheel is re profiled.

2. Axle:

The wheel set is made of a pair of wheels rigidly fixed to an axle. A bogie or truck will be provided with two wheel sets. Most bogies comprise of inelastic frames. The bogie frames are being turned into curved shapes by leading wheel set as the wheel set has to be directed by the rails. Degree of slip and several forces required to allow the alteration of directions are to be considered. The bogie in general carries about half of the weight of the vehicle that it supports. During high running speed, it may direct the vehicle into a curve path rather than in a straight line path. Some of these mechanical problems of rigid wheel mounted in a rigid bogie frameset can be minimised with the help of some recent designs that have been incorporated in the form of radial movement of wheel set.

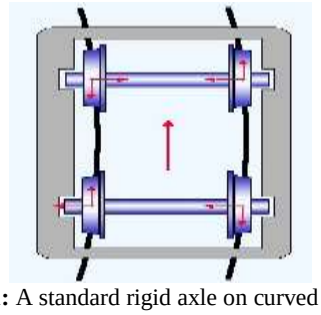


Fig. 1: A standard rigid axle on curved track

3. Catridge tapered roller bearing:

Cartridge Tapered roller bearings with technology from Brenco, USA, have the outstanding property of requiring no field lubrication. They are mainly used in various wagons like BOXN, BCN, BTPN, etc. Segments of cones are used to produce the inner and

outer ring raceways. The tapered profile is used for rollers only then it would be possible to conical surfaces of the raceways and the roller axes would meet at a common point on the main axis of the bearing once the rollers are projected. This conical geometry profile is preferred as it would provide a larger contact patch so that greater loads could be carried in comparison to spherical (ball) bearings, whereas the geometry refers to the tangential speeds of surfaces of each rollers are the same as that of raceways along the entire contact patch and no differential scrubbing will be produced. When a roller slides rather than rolls, it is capable of producing wear at the roller-to-race interfaces, it is due to the variation of surface speeds that creates a scouring action. Wear may lead to degeneration of close tolerances which would normally prevail in the bearing and it may escalate other problems also. It is possible to get clean rolling in the case of a tapered roller bearing which may minimize rapid wear. The Flanges of inner ring are utilized to guide rollers. By means of these flanges it is indeed possible to prevent the rollers from sliding out during high speed operations. The bearings can withstand larger axial forces if it is provided with larger half angles on the conical surfaces.

4. Spherical roller bearing:

Spherical roller bearings will normally have two rows of rollers. One row will have a common sphered outer ring raceway and the other will have inner ring raceways that is inclined at an angle to the bearing axis. In the outer ring race way, the centre point of the sphere would fall on the bearing axis. Hence it is possible to ensure, the bearings can self-align themselves and are not affected by any misalignment of the shaft in relation to its housing. This misalignment of shafts is produced by the deflection of shafts. In the case of heavy radial load applications; the self-aligning type Spherical roller bearings are used. These bearings are designed with barrel shaped rollers to automatically compensate larger angular errors known as shaft misalignments. In this type of bearing designs, it is preferred to have double row rollers provided with common spherical raceways along the outer ring. This modification has a significant advantage in the cases where the possibility of maintaining exact parallelism between axes of shafts and housing is cumbersome.

2. Proposed Methodology

This paper aims to find the Rejection rate of Wheel and to reduce it by changing the diameter, burnishing the wheel, increasing the lubrication, Profile turning, Axle turning.

2.1. Wheel Defects:

The railway system mandates highest standard of safety and reliability of service of its vehicles. It is possible to maintain such a safety standard only if appropriate technical systems and operating methods are adapted. Such systems would meet the requirements on safety and good order of traffic can also be maintained. The early and timely detection of defects is feasible with non-destructive testing methods that are quick, reliable and cost-effective. Since failure in railway wheel set can lead to disaster, the periodical inspection of the systems and their components to locate or identify the defects of wheels and axles are obligatory. The NDT techniques such as Eddy Current testing, Acoustic Emission and Ultrasonic testing are used frequently on railway Wheel set in service to ascertain their serviceability. But, it is not possible to identify the crack initiation as and when it occurs with the help of Ultrasonic Testing as this technique induces noise echoes.

2.1.1 Burnt Rim:

If a portion off Lange or rim breaks off, the wheel must be removed from service. Illustrate sunburnt rim. The break shows rough Granular fracture, this would indicate, in a wrought steel wheel, that it has been over heated in the process so manufacture.

2.1.2 Broken Flange:

If cracked or broken rim develops more than the extent permissible the wheel should be condemned. Such defects are also rare on steel wheels.

2.1.3Tread Shelled:

The wheel has a shelled tread when pieces of metal break out as shown in figure 3.3. DL–1522–C&D and must be removed from service. Unless this defect has progressed too far, it can generally be turned out taking care that all evidence of the defect is eliminated before putting such wheels in service.

2.1.4 Thermal Crack:

Intense brake heating cause thermal cracks that are formed in criscross directions on the tread. These cracks are normally confined within the tread or flange. The cracks may extend and get through the whole tread on to the plate on rare occasions.

2.1.5. Shattered Rim:

The wheel that shows a circumferential crack on the front or back face of the rim must be removed from service.

3. Load on Wheels

3.1 Wheel Flat Loading:

The severity and shape of the damage on the wheel varies the loading pattern mainly because of out-of-roundness of the wheel. The out-of-roundness of wheel can be romanticized by a flat on the surface that would be visible as a chord on the profile of the wheel that is on circular profile. This change may result in loss of contact between the rail and wheel for a short duration of time and then contact between them will be regained. This phenomenon is an ideal one which would result in lifting and hitting of wheels on rails as the wheel gets risen above rail. Once the contact is about to be recovered, there would be large impact force in the wheel-rail pair. However, the loss of contact between this pair, as the wheel and rail move in opposite directions, would not be total mainly because of the presence of bogie suspension system. During the initial phases, the overall effect may produce decrease in contact force followed by increase in contact force as the wheel continuously moves in downward direction due to inertia.

3.2 Wheel Rail Contact:

Finite Element Analysis was used by Kleiner and Schindler to estimate the pressure distribution between two contacting bodies. That analysis used as many as 17 contact pointsfromS1002 wheel profile to60E2 rail profile. In addition, an experimental equation was also established that would enable it to determine the maximum surface pressure depending upon wheel load and also due to the lateral displacement of wheel with respect to rail. On tread surface, the normal pressure distribution is found in similar manner to that of contact stress distribution and which is found to be similar at different lateral contact positions. It is decided to examine the equivalent stress distribution on either side of the wheel tread and also the rail surfaces were also examined. Besides, the stress distributions were also examined for driving-wheel.

3.3 Thermal Stresses on and Under the Wheel Tread:

Wu et al. formed 2D coupled thermal-elastic-plastic models in finite element analysis with material properties that are temperature dependent to analyse the distributions of residual stress and strains on either sides of rail head, while more than one wheel go by different loading conditions with/without thermal load. During this analysis, the contact pressure was found to have got idealized as visible in the case of Hertzian distribution. It was concluded that besides equivalent plastic strain on rail head surface, the residual von Misses stress and displacement was highest when considering thermal effect on every wheel overtake. The evaluated model may assist to understand the growth and promulgating mechanism of friction induced thermal fatigue on rail head.

3.4 Rail Data:

Analysis was performed with the typical data collected from Indian Railways, by considering a railway train comprises of one wagon fitted with an engine. The engine was provided with 12 wheels (six wheels on either side). The wagon was fitted with eight wheels, four on each side, but only one side of the railway track was considered for analysis.

3.5 Determining the Contact Parameter:

It is possible to employ many analytical and experimental methods for computing the contact parameters of rail and wheel combination. The most familiar one that is conventionally used in the case of normally loaded contacts is Hertz theory. Apart from this theory, there are several numerical and experimental methods existing for both types of tractions that is normal and tangential tractions.

4. Root Cause Analysis

4.1 Damage Characteristics:

It was observed from literatures that wheel damage data and data obtained from wagon wheels on similar line has typically shown a peak from mid to late winter. The distribution of wheel repro61ings owing to ReF or thermal cracks in year 2011 is presented together with a hint of differences in ambient line temperature and accumulated from over the seasons.

4.2 Wheel Damage Pattern:

Though wheels are generally showed a broad range of damage types, the utmost type of damage observed was a gang of cracks of 3.5 to 4 cm from the field side of wheel. The alike type of surface damage was noted in 2009. This type of damages were compared and observed that the location of damage band is nearly the same. However the damage occurred in 2009 was slimmer band prominent to peeling type fracture of surface material. Additionally, discoloration and flange wear was very frequent in 2009 than 2011.

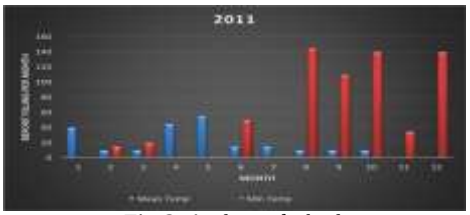


Fig. 2: Analysis of wheel

4.3 Wheel & Rail Profiles:

The RCF band on the field side is associated to low rail contact during curve negotiation, possibly with some added load owing to either braking or traction. The impartially localised impairment band is the sign of a rather small width of contact patch that would relate to a deprived wheel/rail profile match on fairly high proportion of the curves. Further, the strident divisor between Ref zones 1 and 3 should be connected to disjointedness in the rail profile curvature of the low rail (no pertinent discontinuity was found on the wheel). It was distinguished that diverse rail profiles on low rail were employed on Norwegian and Swedish parts of the line.

4.4 Causes for Seasonal Variations in Damage Rate:

A proposition which matches the perceived periodic pattern is represented as follows: In mid-winter, basically all wheels do get re- profiled rather lately. The increased loading due to winter conditions will impose additional wheel tread damage; however cracks will take a while to develop. In late spring the track based lubrication is activated on that will cause initiated cracks to propagate faster corresponding mainly to a first peak in late summer. Further, during June August rails are ground. The induced profile disparity increases contact stress magnitudes. Further, grinding removes residual lubrication on the rail surface, which may have an effect in increasing friction. This will increase RCF formation, which causes needs for repro fillings in the autumn. As autumn and early winter steps forward, the profile disparity is progressively worn down, wheels reprofiled, etc.

4.5 Mitigating Actions:

To reduce these damages, the loco-based lubrication was overhauled. In this method, the interval of lubrication was reduced from 300 m to 200 m. In addition, the track based lubrication was progressively turned on as weather permitted. The consequence has been a decrease in wheel repro filings during the spring of 2012. A similar decrease occurred also previous years, so one should not draw major conclusions from this. However an inspection in June revealed a somewhat different damage pattern. A comparison to a damaged wheel in December 2011 reveals that the band of RCF 3 damage remains, but the RCF cracks in zone 1 are absent. It should be noted that this damage was only found on two wheels (of 13 investigated; 11 with no significant damage and one also with skid marks). Consequently it is too early to say if this is a sign of an altered trend. With this being said, it may be a sign that curving friction has decreased and that the dominating cause of surface initiated RCF has shifted to braking. It may also be connected to a wear-in of the inner rail profile. It should be noted that owing to the head hardened rails used on the line wear-in is generally a rather slow process.

Table 1: Survey of N wheel 2016-17

SURVEY OF "N WHEEL" SETS RECEIVED FROM SHOP 7DURING 2016-2017													
		Incoming			Ra			Rd			Cond.		
Month	**Shop**	**Div**	**Total**	**Shop**	**Div**	**Total**	**Shop**	**Div**	**Total**	**Shop**	**Div**	**Total**	**Avg**
APR 16	823	546	1369	25	12	37	41	9	50	0	0	0	0.0
MAY 16	916	104	1010	39	13	52	33	2	35	5	0	5	0.5
JUN 16	822	318	1140	25	2	27	70	0	70	5	0	5	0.4
JUL 16	889	161	1050	37	6	43	40	3	43	2	0	2	0.2

AUG 16	969	201	1170	35	13	48	35	7	42	4	1	5	0.4
SEP 16	894	117	1011	48	16	64	59	6	65	3	1	4	0.4
OCT 16	987	131	1118	51	14	65	49	5	54	5	2	7	0.6
NOV 16	1134	136	1270	71	10	81	82	9	91	8	1	9	0.7
DEC 16	553	147	700	32	8	40	31	12	43	4	3	7	1.0
JAN 17	808	482	1290	39	23	62	47	24	71	4	2	6	0.5
FEB 17	938	212	1150	59	25	84	33	15	48	5	3	8	0.7
MAR 17	1206	250	1456	75	13	88	46	7	53	7	5	12	0.8
TOTAL	10929	2805	13734	536	155	691	566	99	685	52	18	70	0.5

Table 2: Survey of BLC wheel 2016-17

SURVEY OF "BLC WHEEL" SETS RECEIVED FROM SHOP11DURING 2016-2017													
		Incoming			**Ra**			**Rd**			**Cond.**		
Month	**Shop**	**Div**	**Total**	**Shop**	**Div**	**Total**	**Shop**	**Div**	**Total**	**Shop**	**Div**	**Total**	**Avg**
APR 16	12	0	12	0	0	0	0	0	0	0	0	0	0.0
MAY 16	20	14	34	0	1	1	0	1	1	0	0	0	0.0
JUN 16	20	2	22	0	0	0	0	0	0	0	0	0	0.0
JUL 16	58	0	58	0	0	0	0	0	0	0	0	0	0.0
AUG 16	20	3	23	0	0	0	0	2	2	0	0	0	0.0
SEP 16	59	1	60	1	0	1	5	1	6	0	0	0	0.0
OCT 16	43	6	49	0	0	0	0	1	1	0	0	0	0.0
NOV 16	17	13	30	0	0	0	0	0	0	0	0	0	0.0
DEC 16	221	0	221	1	0	1	0	0	0	2	0	2	0.9
JAN 17	60	23	83	2	2	4	0	0	0	0	0	0	0.0
FEB 17	154	10	164	4	2	6	0	0	0	0	0	0	0.0
MAR 17	124	7	131	2	0	2	4	0	4	0	0	0	0.0
TOTAL	808	79	887	10	5	15	9	5	14	2	0	2	0.2

5. Results and Conclusion

Table 3: Survey of N wheel 2017-18

SURVEY OF N WHEEL SETS RECEIVED FROM SHOP 7 DURING 2017-2018													
		INCOMING			**RA**			**RD**			**COND.**		
MONTH	**SHOP**	**DIV**	**TOTAL**	**SHOP**	**DIV**	**TOTAL**	**SHOP**	**DIV**	**TOTAL**	**SHOP**	**DIV**	**TOTAL**	**AVG**
APR	1001	427	1428	57	14	71	38	18	56	4	1	5	0.4
MAY	1155	105	1260	54	13	67	27	2	29	3	0	3	0.2
JUN	1054	163	1217	60	19	79	50	2	52	3	1	1	0.3
JUL	1023	257	1280	22	7	29	13	3	16	1	0	4	0.1
AUG	1151	129	1280	73	27	100	29	0	9	15	4	19	1.5
SEP	889	161	1050	49	10	58	8	4	2	1	1	2	0.2
OCT	983	107	1090	50	9	59	53	1	54	1	2	3	0.3
NOV	1165	96	1261	65	11	76	35	8	43	7	2	9	0.7
DEC	366	3	396	12	1	17	7	2	0	0	0	0	0
TOTAL	8787	14751	10262	442	115	557	280	40	320	320	35	11	0.4

Table 4: Survey of N wheel 2017-18

SURVEY OF N WHEEL SETS RECEIVED FROM SHOP 7 DURING 2017-2018													
		INCOMING			**RA**			**RD**			**COND.**		
MONTH	**SHOP**	**DIV**	**TOTAL**	**SHOP**	**DIV**	**TOTAL**	**SHOP**	**DIV**	**TOTAL**	**SHOP**	**DIV**	**TOTAL**	**AVG**
APR	1001	427	1428	57	14	71	38	18	56	4	1	5	0.4
MAY	1155	105	1260	54	13	67	27	2	29	3	0	3	0.2
JUN	1054	163	1217	60	19	79	50	2	52	3	1	1	0.3
JUL	1023	257	1280	22	7	29	13	3	16	1	0	4	0.1
AUG	1151	129	1280	73	27	100	29	0	9	15	4	19	1.5
SEP	889	161	1050	49	10	58	8	4	2	1	1	2	0.2
OCT	983	107	1090	50	9	59	53	1	54	1	2	3	0.3
NOV	1165	96	1261	65	11	76	35	8	43	7	2	9	0.7
DEC	366	3	396	12	1	17	7	2	0	0	0	0	0
TOTAL	8787	14751	10262	442	115	557	280	40	320	320	35	11	0.4

The root cause analysis for rain wheels was conducted in this project work. The major defects have been identified and corrective actions are suggested to eliminate the rejection rate. The rejection rate after implementation has been presented here with reduced rejection rate

- It is clearly observed that the average rejection rate of N wheel sets going to be condemned is reduced from 0.5% to 0.4%.
- It is clearly observed that the average rejection rate of BLCwheel sets going to be condemned is reduced from 0.2% to 0%.

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