Action Plan to Arrest Breakage of Brake Lever Assembly in WAP7 Locomotives

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Abstract

Breakage of brake riggings in WAP7 locomotives has been a matter of concern since 2004 , almost after its commencement of manufacturing , which is having same bogie design as that in WAG9 locomotives. Both of these bogies are having TBU/PBU assembly for brakes , but breakage of brake hangers in WAG9 locomotives are unheard off. This paper deliberates on root cause analysis of the problems , issues related with higher levels of shocks and vibrations in WAP7 locomotives, operating at a speed of 130 kmph and on remedial measures most suitable for WAP7 locomotives without making any structural change in bogies. One WAP7 locomotive of GMO base, manufactured with modified bogies is in service over more than a year without any problem. In addition to the safety in train operations, other benefits include fractional cost (one tenth with respect to existing TBU/PBU arrangement),better maintainability, making train operation more safe, crew friendly as there is no hassles of brake binding/parking brake jamming ,increased speed potential to 140 kmph from 130 kmph, with CRS sanctions, etc.

1. INTRODUCTION

1.1. Indian Railways imported 22 WAG9 locomotives from M/s. ABB, Switzerland in 1997-98. Later on, CLW started manufacturing these locomotives and were subsequently indigenised through transfer of technology. WAP7 Electric locomotives for a max. speed of 130 kmph , were manufactured by CLW with the same brake rigging arrangement as was used for WAG9 locomotives and introduced in 2002-03. The braking system of WAP7 and WAG9 locos are identical in all respect of its working, the bogie and brake rigging. With the introduction of WAP7 locos during the year 2002-03, the breakage of brake hangers has started from 2004. But in WAG-9 locomotives for a maximum speed of 100 kmph has no breakages of brake hangers. Worldwide, PBU/TBU is not in use on high speed passenger locomotives. The disc brake are generally used which is not possible in WAP7 locomotive axle hung motor design.

1.2. The breakages of hanger are directly related with the higher speed of 130 km/h in WAP7, which are due to high level of vibrations and shocks at higher speed. The matter was so serious from the point of view of safe train operation, Railway Board vide their letter no. 2007/Elect (TRS)/440/21(3-Ph. Dt. 09.08.07 had constituted a committee comprising of CEE/RS/NR (Convener), CEE/(PL&I)/CLW and EDSE/RDSO for jointly investigating the failure of breakage of journal of loco no. 30209 WAP7, GZB , which has been followed by a series of meetings and deliberations with all concerned .

1.3. The paper is a root cause analysis of the problem and on remedial measures most suitable for WAP7 locomotives without making any structural change in bogies. One WAP7 locomotive of GMO base, manufactured with modified bogies are in service over more than a year without any problem.

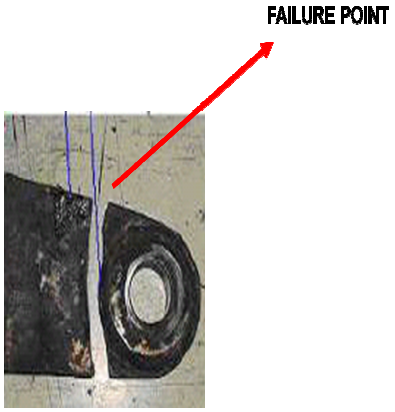
1.4. Other benefits include fractional cost (one tenth with respect to existing TBU/PBU arrangement),better maintainability, making train operation more safe, crew friendly as there is no hassles of brake binding/parking brake jamming ,etc.

1.5. With the modified brake riggings , the speed potential of WAP7 locomotive got upgraded to 140 kmph from 130 kmph . This has got the sanction of CRS.

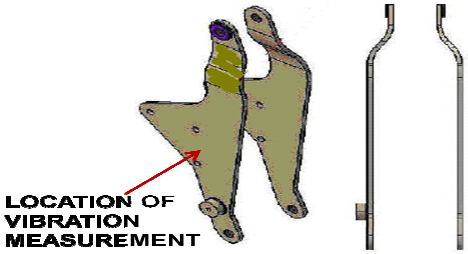
2. Observations:

The braking system of WAP7 and WAG9 locos are identical in all respect of its working, the bogie and brake rigging. Of late, Railways have reported the failures of brake hangers in WAP7 locos only from 2004. The system has been in use in WAG9 locos and there has been hardly any failure of brake hangers in these locos except one stray case reported by GMO/ECR. The failure pattern, data and other design details have been studied. The breakages of hanger are directly related with the higher speed of 130 km/h in WAP7, which are due to high level of vibrations and shocks at higher speed. The details of breakage of brake hangers and other failures in WAP7 locomotives at GZB & GMO are summarized as under :

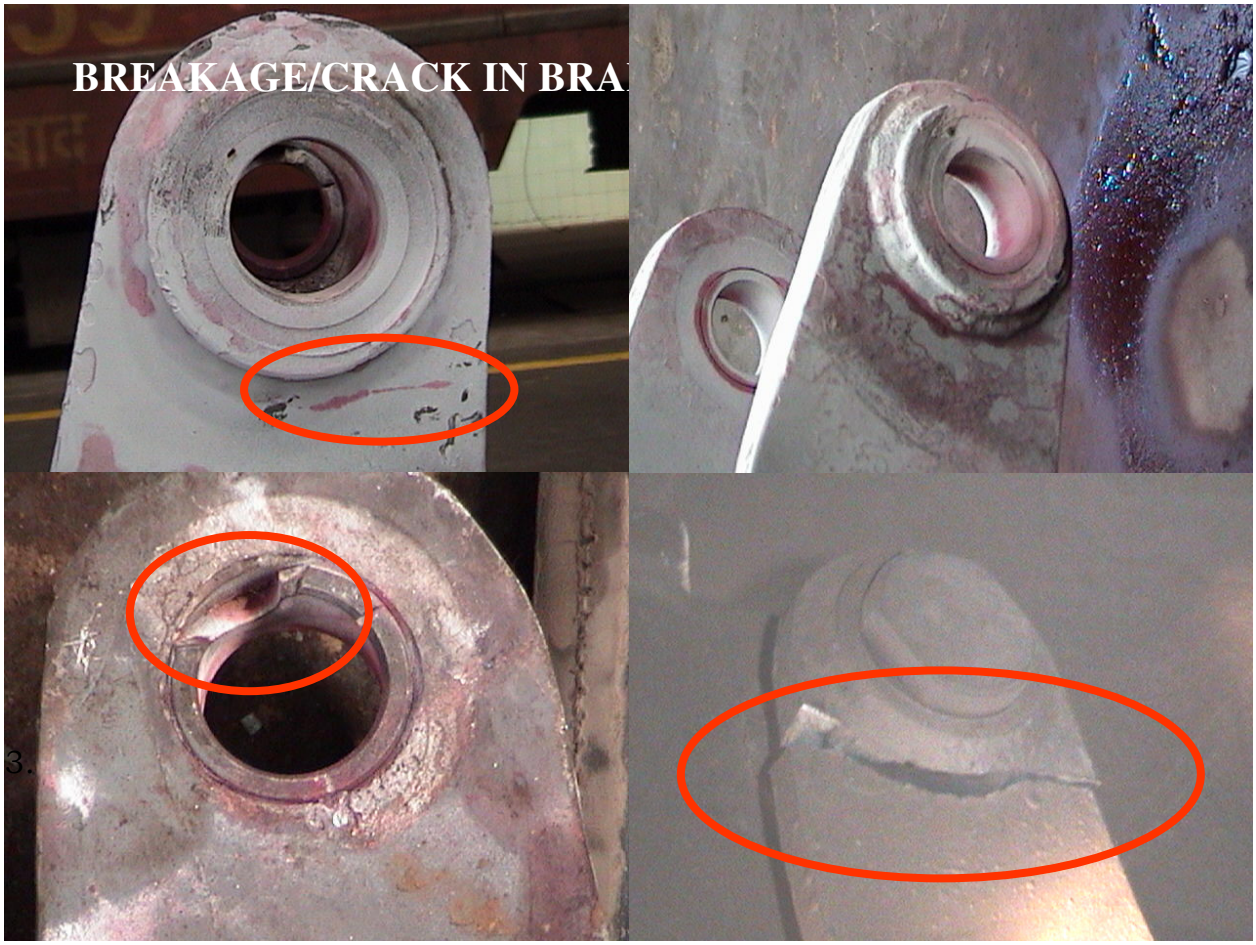
2.1. 100% of the breakage took place at the top of the hanger plate and just below the welding done for fixing of additional ring to enable fixation of bush of 20 mm width.



Failed Bracket



2.2. Both the inner as well as outer hangers are breaking. However, the cases of breakage of inner hangers towards bogie frame are much more which 80% of the total failures.



3.

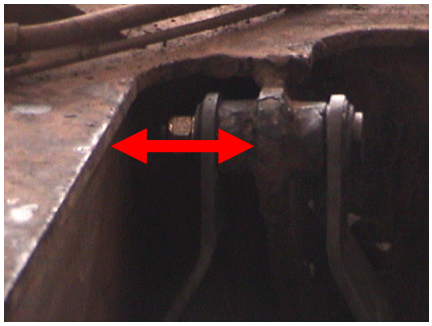
2.3. The outer brake hanger has been rubbing with the bogie frame in WAG9 as well as WAP7 locos. The rubbing marks are varying from 0 to 4 mm depth in the 12 mm thick plate of brake hanger. Almost in 90% of the WAP7 locomotives the brake hangers are rubbing with the bogie frame. But, the breakages also took place where there has been no rubbing in the outer brake hanger plate with the bogie frame. The rubbing of brake hangers in WAG9 locomotives is observed in 10% of the locomotives only.

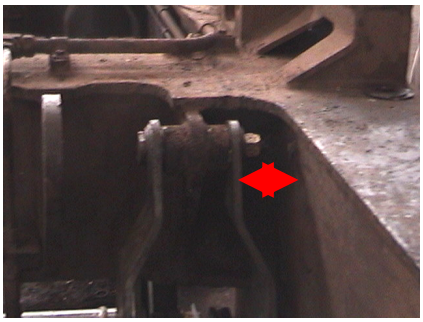
2.4. The failures are also more at the wheel location where PBU along with TBU are mounted. Nearly 80% of the failures are in PBU locations. The weight of the PBU along with TBU is more than the TBU.

2.5. The gap between outer hanger and bogie frame is found to be as low as 4 mm in place of designed value of 13 mm. Such cases of low clearance are found only in CLW built bogies. The flaws in the jigs & fixtures of bogie frame at CLW during manufacturing process has already been identified by CLW itself and corrective action has been taken for WAG9 & WAP7 locomotives.

VARIABLE CLEARANCE BETWEEN BOGIE FRAME AND BRAKE HANGER

- **THE DISTANCE BETWEEN TUBE (WHERE THE BRAKE HANGER PIN IS PROVIDED) AND BOGIE FRAME IS VARYING FROM (136mm TO 152.0mm).**





In the CLW built bogie, there is excessive play between pin and the bush of the tube (bracket) from which complete brake unit (TBU & PBU) is suspended. To solve this problem of fast wearing of bush and parent material of tube itself , corrective action has been identified and taken at CLW. The material specn. of the tube in vogue was as per IS:2062 in place of requirement as per IS:8500 Grade Fe540B.The material selected for brake hanger, as per IS:8500Fe540B is in line with the original specn. of AS:3678 in terms of its chemical composition and mechanical properties and the same has been verified too.

2.6. Some of the breakages of hangers are taking place irrespective of their locations on wheels as well as the type of brake unit i.e. whether it is TBU or PBU. However the failures in PBU are more due to its weight of 150 kg compared to TBU complete weight of 130 kg.

2.7. The breakage of studs of slack adjustor unit at the bottom of the brake hanger is causing complete falling of slack adjustor unit which in turn may lead to more vibrations in the brake hanger.

2.8. Railways have been procuring the complete brake unit and their spares including the brake hangers only from OEMs i.e. M/s FTIL and Knorr Bremse. The cases of hanger failures are almost equal in the brake system of both M/s FTIL & Knorr with respect to their population. The size and shape of the hangers and their nature of failures are also similar for both the OEMs.

3. **Failure Investigation:**

The initiation of crack begins from the welded portion near the bush. This gradually develops and results in failure from that point over a period of time due to fatigue.

Five (5) nos. of failed samples of brake hanger of WAP7 were sent to Metallurgical & Chemical Directorate of RDSO for investigation and confirmation of microstructure , chemical composition etc. to IS: 8500 Grade Fe540B. During micro and macro structural examination, it is found that there is a formation of bainite in the alloy steel

which is more brittle in the heat affected zone. The breakage of lever arm is attributed to presence of bainite and martensite at heat affected area due to improper welding execution. It is observed that the breakage have been taking place from the heat affected zone due to excessive heat generated during the process of welding. This excessive heat generation may be due to wrong selection of electrodes, high current and non-standard procedure of welding techniques for welding structural steel as per IS: 8500. Therefore, the causes of failures in all the brake hangers are same.

As the reported failures of brake hangers plates were more in WAP7 locos which runs mostly above 110 km/h, therefore it was considered essential to record the vibration and stress level at the top of brake hanger at different speeds.

3.1. Instrumented Trial for Measurement of Vibration and shock

Vibration and shock levels were recorded on 2 Nos. of new brake hangers on 15/09/07 by Electrical Directorate of RDSO in association with Testing Directorate of RDSO after getting them fitted in loco no. 30229 on Shatabdi express between New Delhi to Lucknow. Highlights of the report is listed below :

3.1.1. The reports indicate that upto the speed of 90 km/h there is hardly any vibration. But as the speed of locomotive increases above 90 km/h the complete PBU/TBU unit starts vibrating in lateral direction and at the speed of 130 km/h, the vibrations become more severe in the PBU/TBU as it starts oscillating upto 10-15 mm in the lateral direction at a frequency of 3-4 cycles/second.

3.1.2. There was no hitting of hanger with bogie frame during the field trial. The clearance of brake hangers with bogie frame was 12 mm(approx.)

3.1.3. The oscillations of 3-4 cycles/second and maximum amplitude of 15 mm(i.e. 30 mm swing) will reduce the life of the hangers which breaks at the weakest point i.e. just below the welding as shown in the figure.

3.1.4. The hitting of hanger with bogie frame due to less clearance and play between tubes & pin are further aggravating the failures by introducing fatigue in the plate.

4. ACTION PLAN

Besides recommending some immediate and short term measures , which can be carried out by Loco Sheds , RDSO concentrated on long term measures. Constraints as explained above were , limited space because of axle hung nose suspended mounted TM arrangement , no experience worldwide to use PBU/TBU above 120 kmph speed , arduous operating conditions such as higher levels of shocks and vibrations ,possibility of use in existing bogies of WAP7 without carrying out any structural changes, etc .

Arrangement of PBU/TBU in WDP1 diesel locomotive (50 Nos.) was also studied where problems of malfunctioning of Parking brake system is common.

After a series of brain storming sessions with manufacturers & designers of brake system , user Railways , in depth study of literatures , available ,it was decided to use proven brake arrangement at 140 kmph speed in Indian Railways operating conditions.

4.1. Accordingly, a feasibility study was done by RDSO for adopting conventional WAG7 brake rigging arrangement in place of existing WAP7 brake rigging arrangement and it was observed and found that

4.1.1. There was adequate space and clearances available between wheel and traction motor, bogie and body, wheel and axle box.

4.1.2. The existing heavy mass hanging (135 kg of TBU/PBU) arrangement of WAP7 can be avoided by mounting of brake cylinders, levers and slack adjusting unit on the top of bogie frame in WAP7 locomotive similar to WAG7 and WDP2. Hanging mass of brake levers in WAG7 can be reduced to 40 kg which was even lesser than the WAP4 where there is no problem of breakages of brake levers/assembly. Therefore, the breakages of brake levers at higher speed will not take place.

4.1.3. The mounting of brackets and guides can be done in the cross transom of bogie frame.

4.1.4. The E-70 Pneumatic brake system, will be used without any changes and is found compatible with the conventional brake rigging too.

4.2. The WAG7 brake rigging consists of 4 brake cylinders per bogie i.e. 1.5 wheel per brake cylinder and levers, pull rod, brackets etc. is almost identical. However, it required the minor dimensional adjustment in the existing brake rigging at individual component level on account of the following reasons-

4.2.1. The overall length of the bogie is 5930 mm for WAP7 as against 5775 mm in WAG7.

4.2.2. There is a difference of 50 mm in wheel base (1850 mm in WAP7 and 1900 mm in WAG7)

4.2.3. The brackets , bottom mounting plates of brake cylinder , will be of different dimensions and shape due to difference in the sizes of longitudinal & lateral beams of bogie. Out of total 57 items of brake rigging type WAG7, only 5 items will need some modification. Rest other items are common and identical.

4.2.4. The infringement of brake levers with dampers, footsteps and pneumatic pipelines will be taken care of by suitably re-locating these items.

4.3. Accordingly, the modification required to be carried out in the bogie frame of WAP7 was finalised as under:

4.3.1. Removal of existing tubes and brackets from the bogies by oxy-cutting

4.3.2. Grinding/finishing of the bogie surface.

4.3.3. MIG welding of brackets , studs for mounting brake cylinder and brake levers and slack adjuster unit.

4.3.4. Removal of existing pneumatic pipelines and re-laying of pipelines suitable for WAG7 brake rigging.

4.3.5. Stress relieving(normalising) of bogie frame after welding at a maximum soaking temperature of 600 deg.C

RDSO then prepared a detailed instruction and drawings for the above modifications wherein it was found that out of the total list of 57 items, 5 items were uncommon and two new items were required. Rest of the items was common.

The above work needed precise welding, heat treatment of bogie and alignment of brake rigging. Therefore one loco set (2 bogie frames)was modified with the help of a bogie manufacturer. The photos of unmodified and modified bogie frames are shown below:

Unmodified bogie frame

Modified bogie frame

4.4. **Computer Simulations and Trials :**

4.4.1. After the above modification work trials were carried out on the WAP7 loco with modified brake rigging arrangement. Initially the loco was put on trial in passenger train for a period of 10 days and after its successful run the loco was put on trial in mail/express train and its performance was observed for a period of 20 days. The trial run proved very successful.

4.4.2. Meanwhile a computer simulation of EBD(Emergency braking distance) trial at different speeds commencing from 100 km/h to 160 km/h was carried out of existing WAP7 brake rigging and modified brake rigging and it was found that the modified arrangement was almost at par with the existing arrangement .

4.4.3. EBD trials of the locomotive was carried out on 02/07/09 between Mathura-palwal and oscillation trials are also been carried out. The EBD trials carried out were quite successful and confirmed the modified brake rigging arrangement functioning was exactly similar to the existing brake rigging arrangement and appears to be more reliable.

5. Conclusions

The adoption of conventional brake rigging would give following benefits over the existing PBU/TBU system -

5.1. The conventional brake rigging have been tested and tried over a period of time even at higher speed upto 180 kmph.

5.2. The maintenance will not only be easier but its cost will be far less since there are no rubber parts.

5.3. The adjustment and attention of the brake system is easier.

5.4. The initial cost of the brake system will be 10-15% of the present cost of TBU/PBU.

Results of Shock and Vibration Trials

TEST SECTION : NDLS-CNB
Date Of Run : 15-09-2007
Test Vehicle : WAP7-30229
Sampling Rate: 1000 Sample/Sec/Channel

Table No-1				
Maximum Value of Accelerations and Displacements Measured				
Av	Bogie Frame Accelerations			Brake Hanger
Speed	Longitudinal	Lateral	Vertical	Lateral Displacement
Kmph	Acc'n - g	Acc'n - g	Acc'n - g	mm
80-90	1.308	5.347	2.433	3.374
80-90	1.300	5.306	2.303	3.269
80-90	1.218	5.276	2.077	3.165
80-90	1.178	5.244	1.834	3.060
80-90	1.096	3.858	1.639	2.747
80-90	1.055	3.838	1.932	2.642
80-90	1.015	3.827	1.920	2.538
80-90	1.186	3.744	1.736	2.433
80-90	0.892	2.717	1.686	2.329
90-100	1.308	5.347	2.433	3.374
90-100	1.300	5.306	2.303	3.269
90-100	1.218	5.276	2.077	3.165
90-100	1.178	5.244	1.834	3.060
90-100	1.096	3.858	1.639	2.747
90-100	1.055	3.838	1.932	2.642
90-100	1.015	3.827	1.920	2.538
90-100	1.186	3.744	1.736	2.433
90-100	0.892	2.717	1.686	2.329
105-110	3.174	7.598	2.448	7.241
105-110	3.141	7.114	2.362	6.658
105-110	2.938	7.073	2.272	6.195
105-110	2.693	7.064	2.010	5.986
105-110	2.685	6.744	1.306	5.255
105-110	2.652	6.879	1.275	5.150
105-110	2.604	6.868	1.021	4.628
105-110	2.571	3.642	2.968	4.523

TEST SECTION : NDLS-CNB
Date Of Run : 15-09-2007
Test Vehicle : WAP7-30229
Sampling Rate: 1000 Sample/Sec/Channel

Table No - 2				
Maximum Value of Accelerations and Displacements Measured				
Av	Bogie Frame Accelerations			Brake Hanger
Speed	Longitudinal	Lateral	Vertical	Lateral Displacement
Kmph	Acc'n - g	Acc'n - g	Acc'n - g	mm
120-125	2.489	6.509	2.233	10.368
120-125	2.441	6.139	2.194	9.845
120-125	2.245	5.708	2.116	9.741
120-125	2.204	5.429	2.108	8.8
120-125	2.196	5.441	2.038	8.486
120-125	2.156	5.347	2.088	8.173
120-125	2.115	5.286	2.049	8.277
120-125	2.196	5.244	1.990	7.859
120-125	2.082	5.194	1.998	8.068
120-125	2.033	5.132	1.920	7.964
130	3.419	8.995	3.711	14.787
130	3.141	8.893	3.700	12.58
130	2.889	8.441	3.692	13.338
130	2.693	8.420	3.613	12.711
130	2.767	8.338	3.535	12.562
130	2.652	8.050	3.426	12.249
130	2.652	8.009	3.496	11.622
130	2.604	7.906	3.359	11.98
130	2.489	7.854	3.340	11.98
130	2.482	7.649	3.046	11.726
130	2.367	7.628	3.027	10.935
130	2.319	7.475	3.007	11.039
130	2.204	7.393	3.105	10.517