RELIABILITY MEASURES FOR COMMUTATORS OF HS-15250 TRACTION MOTORS

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Abstract
The problems related with chipping, breakage, excessive & uneven wear of carbon brushes and flashover have been affecting the reliability of HS-15250 traction motors, adversely. Authors carried out a root cause analysis of these problems and pinpointed the higher ovality on commutators as the root cause. This was further investigated and deviation from the recommended manufacturing process has been attributed to the main reason of the problem. This paper gives the complete analysis of the problem and corrective measures for manufacturers as well as maintainers while emphasizing the fact that any temptation to ‘change’ the original process without giving proper technical reasons, in the name of improving ‘productivity’ or ‘production’ can prove counter-productive as demonstrated by the present experience.

1. Introduction

1.1. During 2008, Zonal Railways experienced flashing of commutators of HS-15250 traction Motors, used in WAP4 Locomotives. Besides flashover, other problems such as uneven brush wear, breakage of carbon brushes, etc were also reported. Analysis of the field data suggested an acute incidence of the problem in the traction motors, manufactured by Chittaranjan Locomotive Works (CLW) during 2006-07. These are the symptoms of high ovality in commutators, which had increased beyond the service limit within six months! As an immediate measure, all the existing SMI/MS/TCs for proper upkeep of commutator and brush holder revolving ring (BHRR) were reiterated. The good maintenance practices for commutators recommended by OEM as well as those evolved over the long years of experience in maintaining DC traction Motors were reemphasized.

This report deals with root-cause analysis of the problem and the corrective actions. Two pronged strategies were identified to tackle this problem. Better quality control during manufacturing of commutators is the key to eradicating the problem. Since a large population infected with the problem is already in service, condition monitoring of commutators to weed out ones with serious condition involving in-situ measurement was also planned. Possibility of in-situ machining of commutators is also being explored. Corrective measure such as replacement of defective disc springs was found to be an effective solution in the medium term. Finally, replacement of commutators, wherever inescapable, is being conceived as the last resort to utilize the traction motor for its full life.

2.0 Observations
The picture below shows a good profile and another bad profile. The good profile was measured at CGL Bhopal in a commutator at the time of manufacture while the other one was recorded after one year’s service in a WAG-7 locomotive.)
1.2. In traction motors received along with WAP4 locomotives manufactured during 2006-07 and later, the problem of excessive flash over of commutators was reported. Apart from flashover, uneven wear, chipping of carbon brushes and ridge formation on commutator surfaces were other observations. Data collected from Zonal Railways was analysed carefully.

1.3. Some of the Zonal Railways didn’t report any of these problems in WAP4 locomotives. Their fleet of WAP4 locomotives is of relatively old and mostly hauling trains with maximum speed of 110 Kmph.

1.4. The problem of flashing in commutators of WAP4 locomotives was so acute that it forced the maintenance sheds to resort to re-profiling of commutators in AOH. Normally a commutator of HS-15250 is re-profiled only after three years of service. Such hasty re-profiling would shrink the life of commutators.

2. Investigations

Having analysed the failure statistics, to gain deeper insight into the problem, in-situ measurements of profile of commutators were carried out in various loco sheds on traction motors of different vintages. It was observed that ovality as measured in TIR (TIR: Total indicated Run-out) and MBTB (MBTB: mean bar to bar height) was exceeding the service limit after a service of six months or even less. The service limits are 0.06 mm and 0.005 mm respectively. These limits had been defined in the era when such sophisticated tools of measurement were not available. There is a case for redefining the limits matching the method of measurement. That apart the actual observations were far higher- of the order of 0.2-0.4 mm (TIR) and 0.04 mm (MBTB).

Original Hitachi documents for transfer of technology for commutators were studied and the process recommended by Hitachi was compared with that in practice at CLW/ Chittaranjan, BHEL/Bhopal and CGL/Bhopal.
3.1 Audit of Commutator Manufacturing Process at CLW

RDSO carried out a technical audit of manufacturing process and facilities at CLW along with officers of CLW. During the audit, complete process of commutator manufacturing beginning with stacking of copper and micanite segments to final assembly on the armature was compared with CLW’s Work Instruction and OEM’s guidelines. Major deviations detected during the audit are listed below

2.1.1. **Dynamic Seasoning** of commutators was being done at 800-1200 rpm against the specified 3050 rpm. It was also gathered that this relaxation was introduced in late nineties. CLW in its comments on Technical Audit expressed its inability to carry out dynamic balancing at 3050 rpm due to the problem of breakage mica segments at higher rpm. This is indicative of poor quality of micanite segments being used by CLW. It is obvious that dynamic seasoning at low speed does not fulfill the objective of subjecting the commutator to stresses of actual service thus leaving the commutators not ‘seasoned’.

2.1.2. **Three Vs Four Cycles**: During 2006-07, CLW used to do three rounds of dynamic seasoning due to non-availability of sufficient number of dynamic seasoning machines against four cycles as recommended in Hitachi TOT documents. With addition of new machines now, fourth cycle has been restored.

2.1.3. **Commutator Nuts** were found loose in many of the commutators in service. The problem was investigated by CLW and it was found that the material used for disc spring is mild steel in place of spring steel material confirming to EN24/BS970 or JISG 4105 GrSCM440. The disc springs made of improper material could not provide the reaction force expected of them resulting in the loosening of associated ring nuts.

2.1.4. **Commutator Pole Pitch Measuring Machine** was found to be defective. The function of this machine is to ensure that while carrying out the assembly of copper and micanite segments, *these are distributed evenly across the periphery of commutator*. This is a necessary pre-condition for ensuring perfect roundness of commutator. Based on the measurement of eccentricity in the commutator, necessary adjustment is recommended in the TOT document of Hitachi so that eccentricity can be brought within permissible limits.

2.1.5. **Process of Assembly** of commutator from segments grouping to mounting on armature was demonstrated. Essentially the process has several steps which are time consuming. The cycles of static seasoning and dynamic seasoning involve heating the commutator in ovens for long periods of time interspersed by a procedure of tightening the nut under gradually increasing pressure. There is a temptation, without doubt, a temptation to by pass the steps for achieving speedier production with lesser effort.

2.1.6. **Poor Quality of Materials** Large scale rejections of materials as mica segments during the process reflect laxity in inspection at the time of procurement.
2.1.7. **Purchase of Commutators:** CLW is purchasing complete commutators without steel parts from approved sources. However, the standard laid down for manufacturing facilities and process to be followed by suppliers leave much to be desired.

By the time the problem came up for study in 2008-09, two more manufacturers BHEL, Bhopal and CGL, Bhopal had started manufacturing HS-15250 traction motors after a long spell of 10 years. Though not a part of investigation but to prevent any future extension of the problem their manufacturing process as also audited.

### 3.2 Audit of Commutator Manufacturing Process at BHEL Bhopal

3.2.1 They were generally carrying out dynamic seasoning at 3050 rpm. Still the issue was discussed with the management which responded positively by re-commissioning two seasoning plants with required modification to reduce vibration at high RPM. This resulted in extra capacity a guarantee against tendency to by-pass the process during the periods of high rate of production. They are also buying mica segments from approved sources only. There was no problem of breakage of mica as reported by CLW.

3.2.2 It was found that adequate care was not being taken to evenly spread the micanite segments of varying thickness while stacking. The Pole Pitch Measuring Machine is not available at BHEL also.

3.2.3 Further investigations revealed that the press used for pressing the commutators was not able to develop the require pressure stably in job after job. The press was recalibrated and deficiency brought to the notice of the management. They have initiated corrective action.

3.2.4 Following the experience at CLW, measurement of characteristics of Disc Springs before fitment was made a regular practice. Similarly the nuts were tested for hardness and pitch of the threads. This resulted in weeding out of bad Disc Springs and Commutator nuts right at the start.

3.2.5 Final turning of commutator profile should be done with a diamond tipped tool in order to achieve a very high standard of ovality and finish. BHEL were not using the same. They arranged the diamond tool. They were also advised to verify the accuracy of lathe periodically.

### 3.3 Audit of Commutator Manufacturing Process at CGL, Bhopal

3.3.1 The stacking and seasoning processes were found in order. Indeed CGL also do not have Pole Pitch Measuring Machine. However, an alternative method followed by them involving measurement of chord containing 48 bars appears to be the best substitute. Besides they are also following methods using V blocks for eliminating errors of perpendicularity and skew.

3.3.2 The seasoning plant has an excellent display of temperature record. This can even be accessed from remote location. One of the three seasoning plants available with CGL was found to give vibrations as the speed exceeded 2800 RPM. They have now corrected the situation by rebuilding the foundation.

3.3.3 No other deviations were noticed.
3. Reasons of Flashover in Commutators

Possible reasons for high ovality leading to flashing of commutators of traction motors can be attributed to following reasons:

a) Use of mild steel disc spring in place of spring steel material confirming to EN24/BS970 or JISG 4105 GrSCM440.

b) Dynamic seasoning at 800-1200 rpm in place of 3050 rpm as recommended by Hitachi TOT documents resulting in incomplete consolidation of insulating materials in the commutators.

c) Three cycles of dynamic seasoning in place of five cycles of 10 hours each recommended by Hitachi.

d) Non-functioning of commutator pole pitch measuring machine and no suitable alternate procedure adopted by CLW.

e) Use of sub-standard materials such as mica segments and mica ‘V’ Cones.

f) Poor quality of commutator assembly supplied by approved vendors as these were supplying materials in quantity much more than their actual capacity.

4. Recommendations

Commutator is an assembly in which reliability and performance are literally built into it during the first manufacture. Therefore it must undergo long strenuous cycles of seasoning after a very careful assembly of basic components. A badly manufactured cannot be subsequently improved by any means. Already about one thousand five hundred traction motors with sub-standard commutators are in service. To replace all commutators at one go is practically impossible.

The authors are reminded of the Murphy’s Law which goes as under:

*When everything else fails, read the maintenance manual!*

Sarcastic as it may sound, but it is the finest way to sum up the solution to the problem at hand. Let it be borne in mind that Hitachi supplied about 800 traction motors at the time of transferring technology. CLW and BHEL manufactured thousands of traction motors with the same technology with minor modifications for addressing the problems observed in the beginning. This kind of problem has surfaced never before. Therefore the reason has to be in deviations from the laid down process. True, hence, that the audit revealed glaring deviations from the OEM’s approved process. Some of the deviations are entrenched deeply as these are related to the choice of machines which cannot be easily altered. The seasoning plant is a case in point. *RDSO should initiate development of a Pole Pitch Measuring Machine since this is a general shortcoming across all manufacturers.*

4.1. Action Plan for Manufacturers

4.1.1. With immediate effect, CLW shall switch over to disc spring of spring steel material conforming to EN24/BS970 or JISG4105 GrSCM440 and the firms supplying wrong material shall have to be taken up suitably. Random testing of disc springs for its material properties and characteristics by concerned shop shall be done at CLW in every lot.
4.1.2. CLW shall modify its Work Instruction no. W23.031, Ver 4, effective from 04.08.2007 for Dynamic Seasoning of Hitachi commutators according to original Hitachi Design and TOT Documents no.10V701-607. In addition to this, CLW shall review its other work instructions in light of original Hitachi Design and TOT Documents no.10V701-607.

4.1.3. CLW must modify its Specification No. 4TMS.095.034, dt.12.10.2007, Alt-1 to incorporate dynamic seasoning at a speed 3050 rpm in line with Hitachi Design and TOT Documents no.10V701-607 so that commutators procured from trade can be free from defects.

4.1.4. All insulating materials to be used shall have sufficient shelf life and CLW shall evolve suitable procurement mechanism to get material with reasonable left out shelf life, such as staggered supply, etc. Use of all the material shall be ensured before their expiry dates.

4.1.5. CLW shall plan dynamic seasoning at a speed 3050 rpm as recommended by Hitachi and the quality of micanite breaking at higher rpm indicates poor quality of micanite which needs to be further investigated.

4.1.6. CLW shall ensure working of Commutator pitch measuring machine or suitable alternate method may be evolved as followed in CGL/BPL.

4.1.7. Inspection of input materials should be toned up to prevent rejection at shop floor level. Approving authority must be informed about shop floor rejection for suitable action against the supplier firm.

4.1.8. CLW shall maintain four cycles of dynamic seasoning.

4.1.9. Staffs and supervisors must be counseled for ensuring the steps of work instruction of CLW. The complete process needs to be understood the way it is implemented on the ground within the frame work of working conditions in shops.

4.1.10. The above apply equally well to other manufacturers of traction motors e.g. BHEL and CGL who are also manufacturing commutators themselves. There is a tendency to procure commutators from external sources. It is absolutely necessary to assess the capability (availability of facilities) and capacity (quantity of those facilities) of these vendors. Thereafter the ordering should take into account capacity not just capability.

4.2. Action Plan for Railways

Beside the measures which CLW are required to take in new manufacture, in order to mitigate the effect of a large number of troublesome commutators in service, railways are also recommended to follow good maintenance practices as recommended by Hitachi, relevant SMI/MS/TCs issued by RDSO

4.2.1. Railways can plan to send these armatures in phased manners to their nominated re-winding shop for re-tightening of commutator check nuts. TMW, NK has been asked to evolve a process of in-situ replacement of MS disc spring with one with spring steel. This measure has proved successful.

4.2.2. RDSO has been issuing SMI/TC/MS on maintenance of Hitachi Traction motors which railways must follow. SMI/MS relevant to overcome the problem of flashovers are listed below:
4.2.3. Good maintenance practices, evolved over the period of decades of experience and those recommended by Hitachi are also reiterated in Annexure I and tips for troubleshooting in case of flashover of an armature are enclosed as Annexure II. Sheds/workshops shall follow maintenance practices as recommended by Hitachi and troubleshooting tips.

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>MS/SMI Number &amp; RDSO’s ref</th>
<th>Title</th>
<th>Objective</th>
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<tbody>
<tr>
<td>1.</td>
<td>SMI No.RDSO/2007/EL/SMI/0243Rev. ('0') ; EL/3.2.100 Dated: 22.3.2007</td>
<td>Special Maintenance Instructions for Fixtures and Gauges for Brush holders and BHRR Assemblies of Traction Motors type TAO-659 and HS-15250A of Electric Locomotives</td>
<td>To minimize flashing of commutators and other quality related failures on account of improper dimensions of brush holders and BHRR components, Certain Jigs and fixtures need to be maintained with manufacturers, contractors doing rehabilitation on works contract, Railway Work shops and Electric Loco sheds. This SMI covers list of Jigs and fixtures for Quality Control. This will help achieve better neutral axis setting and hence better characteristics.</td>
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<tr>
<td>2.</td>
<td>MS ELRS/MS/0329 (Rev '0') ; No.EL/3.2.100 Dated: 18.08.2004</td>
<td>Replacement of Brush Holder spacers for HS15250A Traction Motor made of brass with PTFE.</td>
<td>Presently, brush holder spacers for Hitachi HS15250A Traction Motor are made of brass. When these spacers get worn out on inner dia leading to enlarged inner diameter, they become prone to cause flashover due to proximity to commutator. In order to avoid such cases of flashovers, it is proposed to replace the brass spacers with those made of PTFE.</td>
</tr>
<tr>
<td>3.</td>
<td>MS No. RDSO/WAG5/25; EL/3.2.172 , 25.01.98</td>
<td>Provision of grease outlet, i.e., drain hole in ‘CE’ outer bearing cap of traction motor type HS 15250A and procedure for re-greasing of armature roller bearings (PE &amp; CE)</td>
<td>To avoid heavy flash over in traction motor type HS 15250A due to accumulation of excess quantity of grease of C.E and to avoid CE end bearing failure. Bearings in side the commutator chamber which results in the deposition of carbon dust etc. in the commutator chamber during service and causes flash-over.</td>
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</table>
4.2.4. To maintain higher reliability of the passenger locomotives, Railways can resort to swapping of old armatures having no history of flashing in WAG7 locomotives with those in WAP4 locomotives as an immediate measure.

5.0 Conclusion

It can be concluded that the present problem has arisen because CLW deviated from the manufacturing process laid down by the original collaborator Hitachi, Japan. There is an urgent need to restore the process to its original form without delay. At the same time new manufacturers who are joining the fray need to stick to the original process. Any temptation to ‘change’ the original process in the name of improving ‘productivity’ or ‘production’ can prove counter-productive as demonstrated by the present experience.

6.0 Acknowledgement

The authors would like to express their gratitude to management of CLW, BHEL and CGL as well as ELS Jhansi for their cooperation. Shri MM Agrawal of Carbon Lorraine helped us with measurements of commutator profiles.

**********
Good Maintenance Practices for Commutators and BHRR of Traction
Motors type HS 15250 A

1. Brush holders and carbon brushes

1.1. Check of brush holder, blow out the holder case pocket with clean air and wipe with a dry cloth carefully, if carbon dust is found.

1.2. Ensure spring pressure (at assembly) shall be near to 3.44 kgf. for brush length of 64 mm and not less than 2.88 kgf. for the brush length of 25 mm. To adjust the spring pressure, shed can use digital weighing balance. Minimum weighing capacity 10 kg.

1.3. Shed may keep brush holders of one loco set (36 nos.) in spares. These holders should be kept ready after adjusting the pressure as mentioned above.

1.4. Whenever an overhauled/new BHRR is to be provided, it must have holders of above known/measured pressure.

1.5. Clean the surface of insulating rod to remove contamination which may cause a creeping short-circuit. In case, surface of insulating rod has been roughened by flash-over, etc., correct with zero grade sandpaper and clean. If the surface is heavily damaged and cannot be corrected with zero grade sandpaper, replace it with a new one.

1.6. Please check to see that the pocket dimension of brush holder case and carbon brush dimension are as specified in Table I with gauges as per RDSO’s SMI No.0243. If the holder pocket is found worn out beyond the maximum wear limit, replace it with a new holder.

<table>
<thead>
<tr>
<th>Table - 1</th>
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<tbody>
<tr>
<td>Symbols</td>
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<tr>
<td>-----------</td>
</tr>
<tr>
<td>B</td>
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<tr>
<td>W1</td>
</tr>
<tr>
<td>W2</td>
</tr>
</tbody>
</table>

1.7. Ensure if the length of carbon brush is sufficient till the next inspection run.

1.8. Check the condition of carbon brushes, no crack, chipping, breakage in the carbon brush, no looseness or drop-off of pigtail from the tamped part (breaking of pigtail strands shall not be more than 10%). Follow troubleshooting tips as per Annexure II.

1.9. Please ensure that contact of the carbon brush and commutator is in proper condition. Check the gap between brush holder and commutator. It should not be more than prescribed limit. Gap between commutator & brush holders should be between 2-4 mm. For this a packing of known thickness can be put on commutator for adjusting the gap.

1.10. While replacing the carbon brushes, observe the following strictly:

1.10.1. After inserting the carbon brush into the pocket of brush holder, try to move the carbon brush up and down, and make sure that it moves smoothly.

1.10.2. While fitting the brushes on commutator in shed, their bedding should be ensured.
1.10.3. It is advisable to remove the patina from commutator surface in case different grade is to be provided.

1.10.4. Brush bedding stone of medium grade is recommended.

1.10.5. Care shall be taken that the lead wire (Pig tail) of carbon brush is not caught by the spring, when setting the brush spring after inserting the carbon brush into the brush holder.

1.10.6. Ensure slide-fitting so that the carbon brush contacts the commutator surface correctly. After completion of the slide-fitting, blow away brush powder with compressed air.

1.10.7. Tighten the terminal bolts of carbon brush lead wires securely.

1.11. Don’t release the brush spring of brush holder from hand suddenly or do not drop the spring off the spring support, otherwise the carbon brush may break or the brush spring may be damaged. So, place the brush spring on the carbon brush gently.

2. Maintenance of Commutator Surface

2.1. Use brush bedding stone to remove the rough film on the commutator surface, whenever turning is done either for correcting the surface unevenness such at stepped wear and eccentricity.

2.2. In any case emery paper should not be used on commutator surface. Use only sand paper (yellow color paper)

2.3. Use Commutator Profiler to measure commutator profile, if there is a repeated problem of flash over. If the measurement is out of prescribed limit (Table 2), turn the commutator.

2.4. Turning the commutator surface

2.4.1. Apply turning to the commutator surface:

- if eccentricity, inequality in diameter, high-bar low-bar etc. are generated in the commutator beyond the specified value

<table>
<thead>
<tr>
<th>Item</th>
<th>Corrective (Service) Limits</th>
<th>After turning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eccentricity</td>
<td>Not more than 0.1 mm</td>
<td>0.03 mm</td>
</tr>
<tr>
<td>Inequality in Diameter</td>
<td>Not more than 0.05 mm</td>
<td>0.005 mm</td>
</tr>
<tr>
<td>High-bar ,Low-bar</td>
<td>Not more than 0.005 mm</td>
<td>0</td>
</tr>
</tbody>
</table>

- If there is a stepped wear is caused in commutator surface.
- After turning, ovality of commutator should be measured on lathe itself, so that in case of any correction, it can be done there.

2.4.2. Turning procedures of commutator surface:

- The degree of turning of commutator surface should be judged according to the conditions of commutator surface, and it must be cut at minimum required limit.
- After turning, under-cutting and chamfering should be performed.

2.4.3. Degreasing Work Always wear rubber gloves when degreasing with an acetone-soaked cloth to avoid insufficient de-greasing through handling by bare hands.

3. Ventilation of TM

Ventilation of traction motors should be checked properly with the help of manometer. No choking of incoming or out going air.

4. Inspection Schedules:

Follow the inspection schedules as recommended by OEM
### Annexure II

**Tips for Troubleshooting in case of Flashover of Armatures Hitachi TM**

<table>
<thead>
<tr>
<th>Troubled part</th>
<th>Possible cause</th>
<th>Inspection and remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Carbon brushes</td>
<td>Grade or form</td>
<td>Put the correct grade after carefully using zero grade sand paper on commutator.</td>
</tr>
<tr>
<td></td>
<td>Wear damage</td>
<td>Excess side wear of carbon brush makes gap to brush holder bigger and so replace with new one.</td>
</tr>
<tr>
<td></td>
<td>Chattering vibration</td>
<td>Remove oxygenated film of commutator surface.</td>
</tr>
<tr>
<td></td>
<td>Sticking of brushes</td>
<td>Remove dust and check gap to brush holder with filler gauge.</td>
</tr>
<tr>
<td></td>
<td>Sticking of oil or water</td>
<td>Unequal oxygenated film causes excessive wear. Replace with a new one.</td>
</tr>
<tr>
<td></td>
<td>Unbalance of brush current</td>
<td>Colour changes in pig tail of brush, streaks on commutator surface and contact of brush shall be checked.</td>
</tr>
<tr>
<td></td>
<td>Wearing out of brushes</td>
<td>Lift-up of carbon brushes causes spark and damage. Replace with new one.</td>
</tr>
<tr>
<td>2. Brush holder</td>
<td>Improper spring pressure</td>
<td>Check pressure and adjust pressure both for new as well as worn out brush and check if it is in between 3.44 Kgf to 2.88 Kgf</td>
</tr>
<tr>
<td></td>
<td>Improper attaching</td>
<td>Crookedness, pitch, gap should be examined and adjusted.</td>
</tr>
<tr>
<td></td>
<td>Wear of inside of carbon way</td>
<td>Excess gap to brush worsens sliding performance. Measure dimension. Replace with a new one.</td>
</tr>
<tr>
<td>3. Commutator</td>
<td>High-bar, low-bar deformation ovality.</td>
<td>Results in colour change, unequal oxygenated film, and abnormal wear of brush leads to flash over. Turn the commutator surface on lathe.</td>
</tr>
<tr>
<td></td>
<td>Joggle wear and roughening of surface</td>
<td>Results in excessive wear of brush. Polish commutator surface with lathe.</td>
</tr>
<tr>
<td></td>
<td>Shouting the bars be dust and foreigner between bars.</td>
<td>Inspect and cleaned.</td>
</tr>
<tr>
<td></td>
<td>Abnormal temperature rise</td>
<td>Colour would be change at abnormally high temperature. Examine ventilation and load and adjust.</td>
</tr>
<tr>
<td></td>
<td>Black bar</td>
<td>Adjust commutation.</td>
</tr>
<tr>
<td></td>
<td>Vibration</td>
<td>Examine radial clearance and lateral clearance of bearing, vibration from bogie, and unbalance of armature. Abnormality shall be adjusted according to the maintenance data.</td>
</tr>
<tr>
<td>4. Other parts</td>
<td>Inadequate condition of riser, layer short of armature coil.</td>
<td>Colour of commutator surface may be changed (ex. black). Adjust.</td>
</tr>
<tr>
<td></td>
<td>Ingress of dust, rain</td>
<td>Roughening of commutator surface, Machining commutator. Check the condition of bellows and clean loco side body mio filters</td>
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