GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
भारत सरकार - रेल मंत्रालय

TECHNICAL SPECIFICATION FOR TRACTION GEARS & PINIONS OF WAG9, WAP7& WAP5 ELECTRIC (ABB) LOCOMOTIVES

डब्ल्यूएजी9, डब्ल्यूएपी7 और डब्ल्यूएपी5 इलेक्ट्रिक(एबीबी) लोकोमोटिव के कर्षण गियर एवं पिनियन हेतु तकनीकी विशिष्टि

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FOREWORD

Traction gears & pinions constitute vital part of the power transmission system of locomotives and call for sophisticated techniques in manufacture, with special material, equipment and quality control requirements.

1. SCOPE

This specification is applicable for traction gears and pinions used in WAG9, WAP7 & WAP5 (ABB) Electric locomotives. It covers technical requirements of manufacturing and supply from raw material to finished stage. Traction gears and pinions drawings of these locos are listed at **ANNEXURE - "B**".

2. MATERIAL

2.1 Gears and pinions shall be manufactured from forging quality steel made according to DIN 3990 Part 5 or by open hearth, electric, duplex, basic oxygen or a combination of these processes. The steel shall be fully killed and homogeneous. The steel shall also be subjected to secondary refining including vacuum degassing. Sufficient discard shall be made from each ingot to ensure freedom from pipe, harmful segregation and other defects.

2.2 Chemical Composition & Mechanical Properties:

The gears and pinions shall be manufactured from steel grade 17CrNiMo6 to DIN 17210 (for Case Hardening Steel).

2.3 The inclusion rating of the steel shall not exceed A=2.5-1.5, B=2-1, C=0.5-0.5 & D=1-1 for both thin and thick series. The field of each type of inclusion shall be determined in accordance with DIN 3990 Part 5 (or IS: 4163 and shall be taken as the rating).

2.4 Chemical composition and Mechanical properties of the steel used shall conform to the relevant material specification or as per the given Table 1 and 2**.**

2.4.1 Chemical Composition: The chemical composition of the gear / pinion steel shall be as given in Table-1

TABLE -1

SN	Element	17CrNiMo6 to DIN 17210	
		Minimum	**Maximum**
1	**Carbon**	0.15%	0.20%
2	**Manganese**	0.40%	0.60%
3	**Phosphorus**	0.035 Maximum	
4	**Sulphur**	0.035 Maximum	
5	**Silicon**	0.40 Maximum	
6	**Nickel**	1.40%	1.70%
7	**Chromium**	1.50%	1.80%
8	**Molybdenum**	0.25%	0.35%

2.4.2 Mechanical properties: -

The mechanical properties of the gear/ pinion steel shall be as given in Table-2

TABLE-2

Material	**(With 30 mm Dia. test piece as per DIN17210)**			
	Tensile strength (Mpa)	Yield strength (Mpa) minimum	% Elongation (mm) minimum	Reduction area (mm^2) minimum
17CrNiMo6	1080 to 1320	785	8%	35%

2.5 In case of steel to any other composition, prior approval of RDSO shall be obtained.

3. MANUFACTURING OF FORGED BLANK

3.1 The gear and pinion shall be manufactured by rolling/forging ingots into blooms / billets / bars (made from adequately rolled / forged cropped ingots) to the blank stage, followed by closed die or upset forging, or peripheral forging**.** The ratio of reduction at different stages shall be as follows**:**

a) The minimum-reduction ratio from the minimum section of the ingot to maximum section of the round bloom / billet by forging shall be **4:1.**

b) The gear blanks shall be made by a process of closed die or upset forging, followed by peripheral forging under a power hammer or press**.** The reduction ratio in height by upset forging from round bloom/bar to the gears blank shall be at least **4:1.**

c) The forging and rolling processes shall be performed in such a manner, that the central axis coincides with the axis of the gear wheel.

d) The semi-product (bloom) intended for the manufacture of forged blanks of gears/pinions shall be obtained from cropped ingots, without any pipe.

e) In case only forged blanks are purchased, the manufacturer shall ensure free access of the inspecting authority at his works for the satisfaction of the latter that the material is being supplied in accordance with this specification.

4. FORGED BLANKS FREE FROM DEFECTS:

4.1 Billets, blooms, slabs and bars shall be free from cracks, surface flaws, laps, rough, jagged and imperfect edges and all other surface defects which may result in defects in the forging made therefrom**.**

4.2 Forging or forged blanks of gears and pinions shall be free from cracks, lap or any other harmful surface or internal defects.

4.3 No welding shall be permitted on the forged blank. The outside surfaces of the forged blanks shall not show any flaw, cracks, fold or other injurious defects. The forged blanks shall be provided with adequate allowance for machining all over and shall suitably be annealed to facilitate subsequent machining.

4.4 Forging supplier shall furnish test report showing the Mill source, Chemical composition, inclusion rating of material, forging ratio and grain flow pattern of gear and pinion blanks supplied to the gears manufacturer.

4.5 A photograph of grain flow pattern of forging blank of pinion and gear and material as per clause 2 should be submitted prior to prototype inspection by RDSO.

5. TESTS ON ROUGH FORGED GEARS BLANKS:

5.1 **Macro etch test:** The macro-etch examination shall be done in accordance with DIN 3990 Part 5 (or as per ASTM-E381 method of Macro-etched testing & inspection of steel forging). The macro-etched section shall reveal satisfactory flow line pattern right upto the centre of the forged blank. This shall be done at the works of the forging supplier by the manufacturer.

5.1.1 **Microscopic test:** The microscopic examination shall be done in accordance with DIN 3990 Part 5 for determining the microstructure of gear wheel blanks. The microstructure shall be normalized after heat treatment as per clause 6.1.

5.2 **Grain size:** The grain size of forging shall be in the range of 6 or finer-grain structure. Test shall be done in accordance with IS:4748 or ISO:643 (Latest Version) for determination of grain size.

5.3 **Ultrasonic Test:** All forged blanks, after rough and final machining is performed on them shall be tested ultrasonically for ensuring freedom from casting and forging defects in accordance with given in **ANNEXURE- "A"**

5.4 **Hardness Test:** The forging when tested in accordance with IS: 1500 shall show a hardness value of 179 – 229 HB.

6. PRE-MACHINING HEAT TREATMENT OF FORGED BLANKS:

6.1 To relieve the residual, forging stresses, the forging shall be normalised at 900°C - 1000°C. The soaking time shall be given according to ruling thickness forged blank as per DIN 17210**.**

7. *HEAT TREATMENT OF GEAR/PINOIN*:

7.1 Case Hardening:

The active tooth surface of the gear/pinion shall be suitably case carburised, hardened and tempered to obtain the specified case depth, case hardness and physical properties of core.

7.2 Effective Case Depth:

7.2.1 Definition and Measurement:

The effective case depth is defined as that at which a hardness of 500 HV 5 (50 RC) is obtained. The depth is measured perpendicularly inwards from the surface. The available case depth after finish grinding shall be 1.8 mm minimum or as mentioned in relevant drawing.

7.2.1.1 Case Depth of Carburised and Hardened Gears:

For checking the case depth, one spy-piece shall be provided per container when box carburising and at least one, but preferably two (towards top and bottom of furnace) when gas carburising. The spy-piece shall be of a section, which adequately simulates that of the teeth which it represents and shall be placed near to but not on the gear teeth. The spy-piece shall be of the same material from which the gears are made.

After carburising, the spy-piece shall be hardened and tempered alongwith the gears it represents, and then broken. Hardness survey of the case shall be carried out after grinding and polishing as per DIN 3990 Part 5(or IS: 6416-1988 (Latest version) Method of measuring case depth of steel. The results shall be as specified in (Cl.7.2.1)

Alternatively, the end of the teeth remote from the traction motor side may be ground back at an angle to reveal the case for visual examination or hardness testing.

7.2.2 Hardness of Case-hardened Layer:

Surface hardness of the gear after grinding measured at tip, flank or root shall not be less than 650 HV 30 or 58 RC (620 HB).

7.2.3 Micro Examination:

At least one spy-piece per carburising batch shall be microscopically examined for establishing absence of cementite network and free cementite. Retained austenite content of 30% maximum may be permitted in the carburised zone. This is as per DIN 3990 Part 5.

8. FINAL MACHINING OF GEARS & PINIONS:

8.1 Bore of the gears is referred to as the fitting surface.

8.2 Fitting surfaces of the gear and pinion shall be ground finished before finish grinding the teeth.

8.3 The surface texture of the fitting surfaces of gear and pinion shall not be coarser than the values specified in the relevant drawings.

8.4 The gear teeth shall be of involute profile, cut and ground on gear generating machines. Protuberance cutter shall be used for generating the teeth for automatically producing the most

suitable stock allowance for grinding and generating simultaneously the largest possible tooth fillet of semi-circular shape with absolute uniform transition for the involute tooth flank to the tooth root after grinding. No discontinuity/ Step formation from the ground tooth flank and the machined root fillet shall be permitted.

8.5 The tooth profile shall be given the 'tip' and `root` relief in accordance with the specification mentioned in the relevant drawings. The longitudinal crowning shall be provided as specified in the relevant drawings.

8.6 The dimensions, tolerances and surface finish and hardness specified in the relevant drawings shall be strictly adhered to. The following errors/ deviations shall be measured as per gear/pinion relevant drawings.

a) Overall dimensions.
b) Individual error of pitch.
c) Consecutive error of pitch.
d) Cumulative error of pitch.
e) Profile error.
f) Alignment error.
g) Radial run out.

8.7 The gear / pinion should be free from sharp edges.

8.8 The working face of the teeth shall be free from defects such as heterogeneity in metal and forging / cutting / grinding imperfections. Any repair of these surface defects shall be prohibited.

8.9 The end faces of the teeth shall also not show defects similar to Clause 8.8 particularly near the root circle.

9. SHOT PEENING:

Shot peening should be done on fillet radius and root of gears before grinding, to impart compressive stress. All tooth surfaces should be protected against peening or should be as per relevant drawings requirement. Use S330 hard shot to obtain 200% minimum coverage in root area. Peening intensity should be between 0.007-0.010C (0.178mm- 0.254mm), or shall conform to the relevant drawings. The method of test & measurement for shot peening shall be carried out as per IS: 7001-1989 (latest version).

10. TESTS ON SAMPLE & FINISHED GEARS / PINIONS

10.1 TEST SAMPLE

The test sample shall be made in the form of a bar from a bloom of relevant cast selected at random, shall be first forged down to 1/4 of the original section and then a test bar of diameter as per relevant material specification shall be turned from the forging.

This test bar shall then be heat treated (blank carburising, hardening and tempering) alongwith the gears / pinions of the same cast as indicated in Clause 10.1.1 and then the test piece machined. It shall carry the following markings for identifications:

(a) Steel used
(b) The Cast number / Heat no.

NOTE: (i) Blank carburising means the thermal treatment associated with carburising as applied to a test piece without using any carburising medium.

(ii) Tests on bar stock: - one bar stock shall be cut in the presence of the inspecting authority and macro test shall be carried out to determined if sufficient working as defined in this specification has been done as the ingot to obtain the bar stock.

(iii) Test sample shall be repeated at an interval of **every five years** and also whenever the failures of gear and pinion take place.

10.1.1 PHYSICAL TESTING ON MATERIAL:

The following tests shall be conducted at the Works of the gear manufacturer or in an approved test house at the cost of manufacturer on the test samples selected as per Clause 10.1. At least, one sample per cast shall be subjected to the following tests:

i) Ultimate tensile strength
ii) Yield stress.
iii) Elongation percentage.
iv) Reduction in area.

10.1.2 Chemical Composition & Physical properties:

One test sample per cast shall be chosen for chemical composition. The analysis of steel shall be carried out either by method specified in IS: 228 “Method of chemical analysis of steel and it’s relevant parts of any other established instrumental method (Spectrometer)”. The chemical composition and physical test results shall confirm to the relevant material specification.

The chemical composition and physical test result shall conform to the relevant material specification. If any one of the test sample fail to meet the requirement as mentioned in relevant material specification, the entire lot shall be rejected. In the events of rejection of entire lot, the lot offered shall be made unusable in presence of purchasing / inspecting authority. However, approving / purchasing authority reserves the right to repeat the tests at their discretion at certain time interval.

10.2 TESTS ON FINISHED GEARS & PINIONS: -

10.2.1 Type Tests**:** These will be conducted by RDSO on prototype gears/ pinions whenever a new source is to be approved to acceptance tests mentioned at Clause 10.2.2 and other tests laid down in relevant specifications. The lot offered for prototype tests should not have less than 6 gears. One gear / pinion forged blank of the same lot shall be kept and cut and both macro, micro tests shall be done as per Clause 5.1 & 5.1.1. The prototype testing of gears & pinions may be repeated five (5) years after prototype approval at the time of Quality Audit by RDSO or earlier, if several failure cases are observed.

(a) Material test**:** Confirmation of the properties of material as mentioned in material relevant specification are mandatory for product approval or approval of manufacturer. It will be carried out in presence of RDSO representative.

(b) Hardness Check**:** The hardened teeth of all gears, after appropriate heat treatment, shall be tested for surface hardness. The hardness shall be measured at four equidistant points in the proximity of the root circle of the teeth. The average value of four readings shall conform to the values specified in Clause 7.2.2. The variation between the maximum and minimum values shall not exceed 40 points HV (as per DIN 3990 Part-5).

(c) Crack Detection check**:** All the finished gears/pinions should be subjected to crack detection by suitable method such as magnetic particle test (MPI) or fluorescent test as per IS: 7743 in conjunction with IS:3703 (Latest version) and die-penetration test (DPT) as per IS: 3658), on the discretion of inspection authority. Ultrasonic testing on rim & hub portion can also be employed to check any internal cracks in the forged & finished gears / pinions.

(d) Dimensional & Tolerance checks**:** The finished gears shall be checked for dimensional accuracies, tolerance, surface finish and tooth errors / deviations as per Clause 8.6.

If any one of the gears fails to meet the requirement as mentioned in relevant material specification and dimension of drawing, the entire lot shall be rejected.

10.2.2 Acceptance Tests (During Routine inspection): These are the tests to be conducted, during routine inspection by purchaser / RITES against individual orders:

a) Overall dimensions check.
b) Hardness check.
c) Crack detection test.
d) Tooth error/ deviations as per gear/ pinion relevant drgs.

During routine inspection, inspection authorities shall check 30% of gears & pinions from the lot offered.

11. MARKING

Following information shall be engraved or punched on the free side of the gears, which shall be indelible and clearly legible.

i) Name or vendor code of the supplier.
ii) Job sr. no., date of manufacture e.g. 05/19.
iii) No. of teeth & Gear Ratio.
iv) Heat treatment batch no. & lot no.
v) Drawing no. and Material specification no.
vi) Vendor code of forging supplier
vii) Applicable for Loco type i.e. WAP5 or WAP7 or WAG9 Loco

12. Quality Assurance Plan:

12.1 QAP shall be submitted by manufacturer before undertaking manufacture of prototype and got approved by RDSO. The QAP should be framed in such a manner so as to ensure inherent protection against the use of incorrect machine parameters for case hardened gears. QAP shall also have the following information**:**

(a) The Quality Assurance Plan should incorporate quality assurance activities planned for manufacturing & supply of bull gear and pinion in order to fulfil specification quality, requirements given in relevant gear/pinion drawings, specification, standards & other applicable documents for it. It shall include detailed stage inspection plan, agency carrying out the check, sampling lot and acceptance limits. Frequency of various checks, details of nature of work involved in the checks and records maintained regarding these checks shall be indicated.

Manufacturer shall on demand by the purchaser, make the records of checks carried out during internal quality assurance available for scrutiny.

13. ACCEPTANCE OF FINISHED GEARS AND PINIONS GUARANTEE

13.1 Unless otherwise agreed between the supplier and the purchaser, a minimum 72 months (**six years**) guarantee for reliable service, shall be ensured by the supplier. The supplier shall undertake to replace, as quickly as possible, the defective gear/pinion on account of faulty material or workmanship. If failure of a particular gear involves the failure of the other mating gear/gears, the supplier shall also be responsible for the replacement of the damaged gear/gears.

13.2 "The Inspecting Officer shall verify the internal test reports of various stages of manufacturing of gears / pinions during the routine inspection (i.e. acceptance tests) for conformity with specifications as well as the finished condition before authorizing for delivery."

14. PROTECTION AND PACKING:

The gears/pinions shall be suitably protected against oxidation and corrosion by three coats of ready mixed paint, brushing Bituminous black to IS: 158 (Specification for ready mixed paint, brushing, bituminous black, lead free, acid, alkali, water and heat resisting for general purpose) or as mentioned in Purchase Order / item's drawings or other approved anti-rust compound capable of being removed easily by white spirit or kerosene oil, allowing sufficient drying time between each coat. After the last coat has dried, the gear shall be covered with waterproof paper. The gears / pinions shall then suitably be placed to prevent any damage during transport and handling.

15. APPLICABLE DOCUMENTS:

The specification refers to the following standards

Sl. No.	Reference Document	Description
1	DIN 17210	Case hardening steel
2	IS: 4163	Steel- determination of content of Non-metallic inclusion-micrographic method using standard diagrams
3	DIN 3990 Part-5	Calculation of load capacity of cylindrical gears, endurance limit & material qualities.
4	ASTM-E381	Method for Macro-etched testing & inspection of steel forging
5	IS: 4748	determination of the apparent grain size
6	ISO: 643	Steel Micrographic determination of the apparent grain size
7	IS: 1500	Method for brinell hardness test for metallic material
8	IS: 6416-1988	Method for measuring case depth of steel
9	IS: 7001- 1989	Shot peening of steel parts
10	IS: 228	Method for chemical analysis of steel
11	IS: 7743	Recommended practice for magnetic particle testing & inspection of steel forgings
12	IS: 3703	Recommended practice for magnetic particle flaw detection
13	IS: 3658	Code for practice liquid penetrant flaw detection
14	IS: 158	Specification for Ready mixed paint , brushing , bituminous, black, lead free, acid, alkali & heat resting.
15	IS: 12666	Method for performance assessment of ultrasonic flaw detection equipment.

ANNEXURE – "A"

STANDARD FOR ULTRASONIC TESTING AND ACCEPTANCE OF TRACTION GEARS AND PINIONS

1. Gears/pinions forgings shall be tested ultrasonically for soundness from one of the two side (flat) faces. In case of gears, the scanning could be restricted to the rim portion. The scanning shall be done with a 2/2.5 MHz, 25 mm dia probe. A suitable flaw detector or UT equipment may be used. However equipments characteristic shall meet the requirement of IS: 12666 (Latest version).

2. The range shall be so adjusted that the back echo from the opposite face for a particular size of gear/pinion under test shall occur at the extreme end of the screen and it's amplitude shall be approximately 75% of the full screen height. With this setting, the scanning shall be done by moving the probe circumferentially. In case the radial thickness of the rim of the gear and that of the pinion is considerable, the scanning may be done following multiple concentric paths separated by one probe position.

3. **Criteria for Acceptance / Rejection**:

3.1 Any flaw indication, the amplitude of which is greater than 25% of that of back echo obtained from an adjacent location, shall be rejected.

3.2 Flaw indications, the amplitude of which are less than 25% of back echo obtained from adjacent location may be accepted provided the back echo at that location is not less than 80% of the original and the total number of such flaw indications obtained on that gear/pinion are less than 5 and each flaw is separated from the other by more than 25mm distance. When there is a continuous flaw indication, the spread of the flaw shall not cover more than one probe position in any direction. Where such indications are obtained, scanning should be done in all radial directions at that location to verify the spread of flaw.

3.3 Where there is a flaw indication in the first quarter of the usable length of the trace, the same shall be confirmed by a scan from the opposite face.

3.4 Where the back echo is reduced to less than 80% of the original, the gear shall be rejected.

ANNEXURE – "B"

DRAWINGS LIST OF TRACTION GEARS / PINIONS USED IN WAG9, WAP7 & WAP5 LOCOS

SR. NO.	DESCRIPTION	NO. OF TEETH	DRAWING NO.	CLASS OF LOCOS
1	BULL GEAR	77	SKDP-3435	WAG9
2	SHAFT PINION	15	SKDP-3436	
3	SHAFT PINION	21	SKDP-3847	
4	BULL GEAR	107	SKDP-3848	
5	SHAFT PINION	20	SKDP-3473	WAP7
6	BULL GEAR	72	SKDP-3474	
7	PINION	17	SKDP-4148	WAP5
8	BULL GEAR	67	SKDP-4149	
9	INTERMEDIATE GEAR	35	SKDP- 4150	

NOTE: The drawings with latest alterations available with RDSO shall only be referred to.