

6.2.2.2 The diameter of straight rods must be within the following limits:

| Diameter of Rods in mm | Tolerance in mm |
|------------------------|-----------------|
| 06 - 10 | ± 0.075 |
| 10 - 18 | ± 0.090 |
| 18 - 30 | ± 0.105 |
| 30 - 50 | ± 0.125 |
| 50 - 80 | ± 0.150 |

- 6.2.2.3 A thin corrosion protection layer shall be provided on the bar/rod before dispatch. Corrosion protection of the bars/rods shall be as per Clause 3.0 of ICF/MD/Spec-155 issue 01, Rev.01 (or latest). The bars shall be coated with Lacquer, cellulose, pigmented, finishing, glossy to IS:5691-1970 (or latest) to a Dry Film Thickness of 3-5 microns. After the application, coating is dried up, bio-degradable material shall be used for packing. If any plastic material is used for packing, necessary government guidelines should be followed.
- 6.2.2.4 Corrosion protection shall be adequate to last for period of two months under storage in covered place. This shall not be in the form of oil/grease to prevent bar slippage during end tapering operation. The chemical used be such as to burn off or vaporize during heating at a temperature of 150 °C & above leaving no residue.
- 6.2.2.5 Sample check of bars should be carried out for checking of rusting and straightness of bars before manufacturing process. Raw material stacking may be done according to the production schedule. The long storage of bars should be avoided as it leads to loss of straightness and initiation of rusting.

7.0 SPRINGS:

7.1 General:

7.1.1 Manufacturing sequence shall include the following operations, in order given below:

| S. No. | Process |
|--------|---|
| 1. | *Formation of ends & Stamping |
| 2. | Hot coiling |
| 3. | Quenching |
| 4. | Tempering |
| 5. | Scragging |
| 6. | End grinding |
| 7. | Shot Peening |
| 8. | Crack Testing (Magnetic Particle Testing) |
| 9. | Load-Deflection Testing |
| 10. | Phosphating |
| 11. | Painting |
| 12. | Load-Deflection Testing (if required) & Marking |

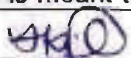
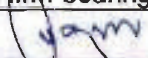

* Formation of ends & Stamping:

Alternate method apart from mentioned in the specification for end formation & marking/stamping may also be accepted subject to prior approval of Carriage Directorate, RDSO.

7.1.2 The surface of the springs shall not have any defects (lamination, grooves, machining marks, cracks, crevices etc.) which may be detrimental to spring performance or life. Any surface and sub-surface defects identified during the electromagnetic crack detection test shall not be permitted.

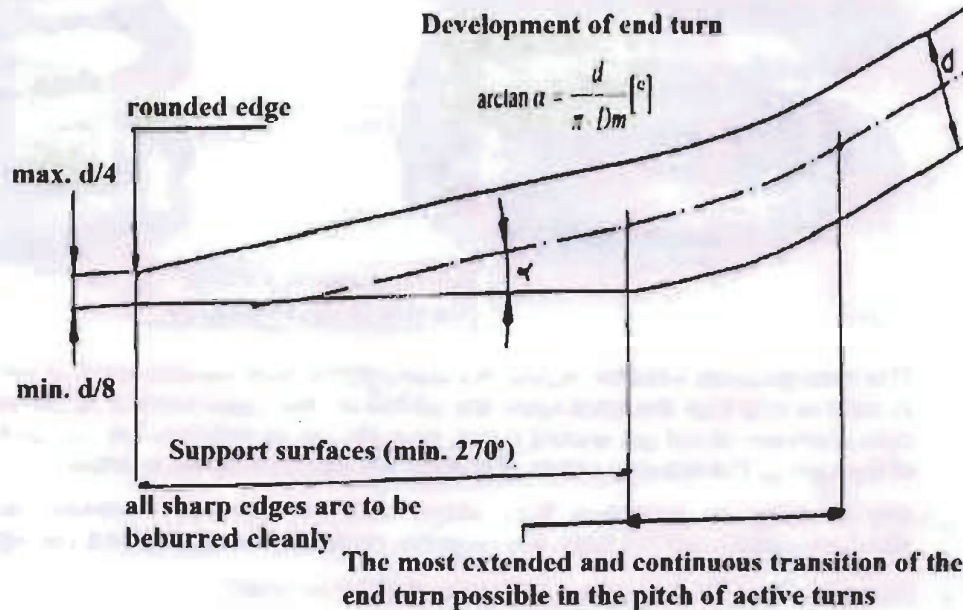
7.2 Formation of Ends:

7.2.1 Both the ends of the rod shall be tapered by Taper rolling to a length which shall be equivalent to an arc angle of 270° (minimum) formed by end coils of the spring. This is meant to ensure a firm bearing of about 75% of the mean coil circumference

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at support surfaces of the finished springs. Formation of ends by hammering is totally unacceptable. The tapered faces should not have steps, pits or crack. The rod should be heated up to 910 to 920 °C during end tapering operation and the stamping operation must be completed before 850 °C. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.

- 7.2.2 End taper the rod in such way that tip thickness is $d/3 \pm 1$ mm and then making coil spring perfectly in parallelism and squareness and after grinding, its tip thickness should be in the range of minimum $d/8$ to maximum $d/4$ as shown in figure below subject to the condition that it shall not be less than 3 mm in any case.



7.3 Stamping:

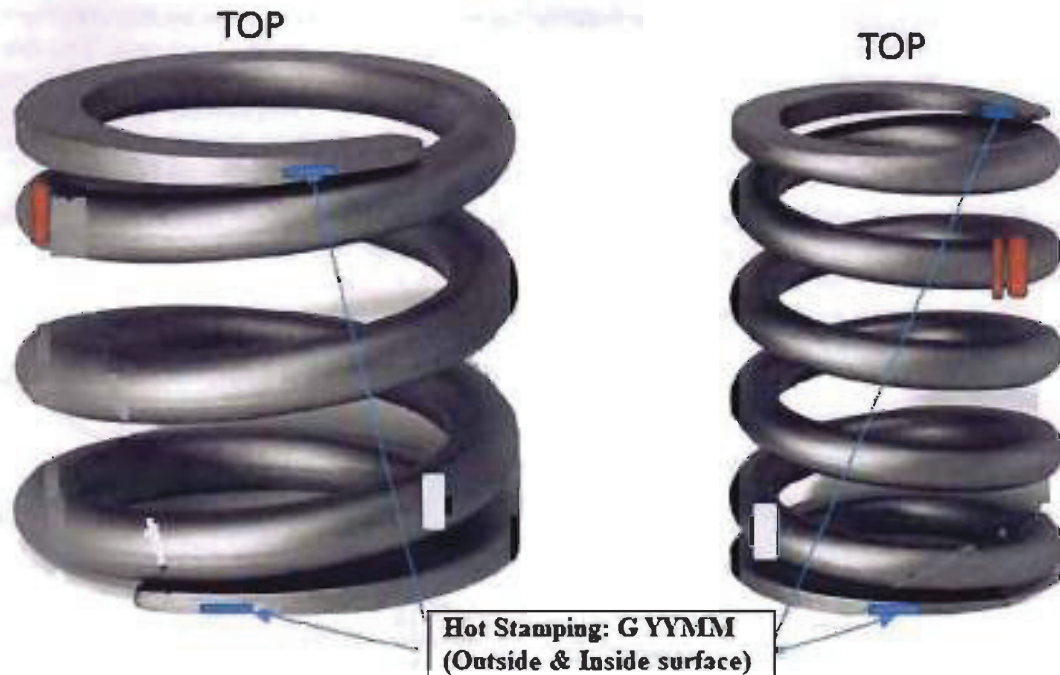
- 7.3.1 The ends of rods (Para 7.2) shall be heated in an electric, oiled or LPG fired indirect heating furnace which are equipped with temperature controller and recorders. Temperature to which these ends shall be heated should be predetermined according to composition of the material. The stamping operation must be completed before 850 °C. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.

- 7.3.2 After the ends have attained desired temperature, following particulars shall be legibly hot stamped on both tapered ends (outer side) in serial order.

| | ** | *** | **** | **** | ***** |
|------|---------------|---------------------|----------------------------|--------------|-------------------------------------|
| | Material Code | Manufacturer's Code | Month & Year of Production | Drawing Code | Heat Code (in three letters/digits) |
| e.g. | CV | ABC | 1216 | F01 | --- |

The location of stamping particulars on springs must be in the middle of the dead-end coils as shown in figure below, so that the chances of initiation of fatigue do not occur.

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The material code shall be legibly hot stamped on both tapered ends of each spring in such a way that the particulars are visible on the outer surface of the ineffective coils and they do not get erased during end grinding or interfere with the performance of the spring. For drawing codes of springs Annexure-I may be referred.

Any deviation or exception from above may be accepted if vendor establishes alternate method will not have any negative implication on quality and traceability.

7.3.3 Materials Code for the various materials shall be as under.

| | |
|--------------|------|
| 51 Cr V4 | - CV |
| 52 Cr Mo V4 | - CM |
| 52 Si Cr Ni5 | - SN |

7.3.4 Stamping shall be done on the outer surface of the ends in the tapered end area.

7.3.5 The stamping depth must be adequate to ensure that the stamping particulars remain legible even after grinding and finish coating/painting of the springs.

7.3.6 Tool used for stamping must be rounded.

7.3.7 Size of letters of stamping shall be 5 mm on rods having diameter above 20 mm and 3 mm for bars having diameter 20 mm or less. No marking shall be done on springs made from rods of diameter of 9.5 mm and below.

7.4 Hot Coiling:

7.4.1 Rods with tapered ends shall be heated in electric, oil or LPG fired indirect heating furnace of minimum 10 metres, equipped with automatic temperature indicators, controllers and recorders and soaked sufficiently at that temperature in a controlled atmosphere (Soaking/Heating time = approximately 0.83 x Bar Dia. minute).

After clamping of rod for coiling, the formation of adjacent active coil should be formed very smoothly by controlling at least 10 different points on coiling machine by experimenting and putting different values. After getting perfection, these values should be stored for future usage and references.

7.4.2 With minimum time lag, rod shall be removed from the heating furnace and coiling end pitching done in a high speed automatic coiling and pitching machine. Bar

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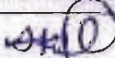
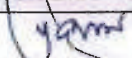

temperature before coiling operation should be 890-920°C. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.

- 7.4.3 Pre heated mandrel to minimum temperature of 80 °C shall be used for coiling and water shall not be allowed to come in contact with heated rod. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.
- 7.4.4 Coiling machine used for the purpose shall have in-built features to maintain uniformity of pitch and gap between end coil and adjacent coil without the need for any manual adjustment. The coiling machine shall be CNC/Computer/ PLC or PIV controlled.
- 7.4.5 Development of end turn of spring shall be as per Para 7.2.2 figure. Transition from the end turn to the active turn shall be in a most extended and continuous manner possible i.e. the gap between inactive coil and first active coil should gradually increase.
- 7.4.6 It shall be ensured at the time of end closing of the spring that the end gap between the tip and the adjacent effective coil is such that the tip does not bite the effective coil under load as well as under no load conditions. Closing of the end coil should be in built feature of coiling machine and no manual adjustment should be required.

7.5 Heat Treatment:

- 7.5.1 Temperature of the coiled spring just after coiling and before quenching should be 830 °C - 860 °C. With minimum time lag, coiled rods (called springs) as per Para 7.4 shall be oil quenched in a suitable quenching medium. The temperature of which is maintained within 40 °C - 70 °C in order to ensure optimum quenching conditions. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.
- 7.5.2 The quenching oil shall be kept at constant temperature range of 40 °C - 70 °C. The content of the quenching pool shall be adequately dimensioned with more than 10,000 liters of quenching oil and should be checked regularly for water and dirt content and filter it by centrifuge etc. and top up by fresh oil, if required. Record for the same checking shall be kept ready.
- 7.5.3 After quenching operation, tempering of springs shall be done in a continuous conveyor type tempering furnace. For producing required level of temper and hardness, springs shall be heated to pre-determined temperature range for sufficient length of time. The temperature of the spring just before entering the tempering furnace should be 80 °C – 120 °C. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.
- 7.5.4 Furnace used for tempering shall be electric, oil or LPG fired indirect heating type equipped with independent pyrometer for each zone to control temperature within ± 10 °C. The tempering should be done in temperature range of 400 °C - 500 °C. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.
- 7.5.5 Since the heat treatment is carried out with the aim to achieve a homogenous fine grain structure, the tempered martensitic distribution across the complete cross-section of the active coil should be as under for various steel materials.

The tempered martensitic distribution across the complete cross-section of the active coil should be uniformly distributed and hardness difference from core to surface

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should not be more than 20 BHN. The hardness shall be as per ISO 683-14 or EN 10089 (latest). The values for the surface hardness shall be between 419 - 486 BHN**.

** Conversion of hardness from HRC to BHN is taken from conversion table.

7.5.6 Springs should be water cooled after tempering to approximately 100 °C. Temperature controlling system equipped with sensors shall be installed compulsorily in spring manufacturing units for 100% effective controlling of process temperature for bars and springs.

7.6 Scragging:

7.6.1 Each and every spring shall be hot scragged three times in quick succession. Scragging load/height should be as laid down in the drawing. In case there is no indication in the drawing, the springs shall be scragged home. The scragging load in such cases should not exceed 1.5 times the theoretical axial load, corresponding to home length. The hot scragging temperature should be more than 90 °C.

7.6.2 Long duration scragging is to be introduced as a process check at regular intervals and necessary documents of the test results are to be maintained. For long duration scragging, the spring shall be compressed three times, holding it at the home load for two minutes in the first two strokes and for 48 hours at the last stroke.

7.6.3 The scragged spring should not show further permanent set on subsequent loading.

7.6.4 Permanent set shall not exceed 2 mm of free height of primary spring, which is measured before scragging. Similarly, permanent set shall not exceed 3.5 mm of free height of secondary spring, which is measured before scragging.

7.7 End Grinding:

7.7.1 Both the end surfaces of the spring should be ground to ensure square seating of the spring. The ends should not have any sharp edge/burrs. The actual ground end surface shall be atleast 75% of the mean coil circumference of the spring. The end faces of the spring should not have blue marks due to end grinding as the same leads to temper brittleness.

7.7.2 The springs shall be grounded on automated grinding machines with effective cooling system. It is important that cooling during the grinding process is carried out flawlessly. Tip cutting should never be done as it will reduce the number of coils.

7.7.3 The grinding angles at the ends of the springs shall be $270^{\circ} + 15^{\circ} - 0^{\circ}$. For grinding angles measurement, calibrated gauges should be available with the spring manufacturers.

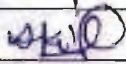
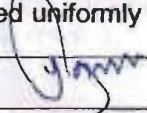

7.8 CRACK DETECTION:

100% of the springs shall be tested for crack detection in accordance with EN 10228-1/ASTM E 709 (latest) for both longitudinal and transverse cracks. Alternatively, magnetic particle testing of the springs for crack detection may be carried out in accordance with DIN EN ISO 9934-1, DIN EN ISO 9934-2, DIN EN ISO 9934-3, DIN EN ISO 3059 & DIN EN ISO 9712.

7.9 SURFACE TREATMENT AND PROTECTION:

7.9.1 Shot Peening:

All the springs shall be shot peened in a continuous type shot peening machine, preferably with self-sieving arrangement in accordance with EN 13298 Annex C to improve fatigue life of the spring. During shot peening, it should be ensured that the springs are shot peened uniformly over the entire area of the springs. The intensity

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and coverage should be checked with the help of almen strip in accordance with EN 13298 Annex C. Almen Intensity should be checked minimum two times per shift of production. The minimum coverage (When checked visually) should be 90% and intensity when checked with Almen strip Type - A in accordance with EN 13298 Annex C should be between 0.4 mm and 0.6 mm.

- 7.9.1.1 The characteristics of the Almen test samples shall comply the Table C.1 of Annex C of EN 13298 (latest).
- 7.9.1.2 The number of samples to be mounted on the "sample carrying spring" depends on the free length (L_0) of the spring and shall be as follows:

| Free length (L_0) of the Spring | Nos. of Almen test samples & Locations |
|-------------------------------------|---|
| $L_0 \geq 500$ mm | 6 samples to be mounted, 3 on the inside of the spring, the 3 remaining samples on the outside of the spring, the samples shall be located at the two ends and in the middle section of the spring. |
| $500 > L_0 \geq 300$ | 4 samples to be mounted, 2 on the inside of the spring, the 2 remaining samples on the outside of the spring, the samples shall be located at the two ends of the spring. |
| $L_0 < 300$ mm | 2 samples to be mounted, 1 on the inside of the spring, the other one sample on the outside of the spring, the samples shall be located in the middle section of the spring. |

- 7.9.1.3 To ensure effective shot peening on more critical inside of the spring, the mounting locations of 4 samples (2 on bottom inside & outside and remaining 2 on top inside & outside of the spring) should be at approx. 1.1 turns from end of first in-active coil.
- 7.9.1.4 Ensure use of rounded jet grains for effective shot peening. Rounded jet grains of size 0.45 -1.0 mm as per IS:4606 shall be used.

7.9.2 Phosphatizing:

All the springs shall be phosphated by using zinc phosphate within 30 minutes. after shot peening. The thickness coat shall be more than 5 μ m of fine crystalline nature and it can be evaluated as per method given in IS: 3618 (latest). The class of phosphate coating shall be Class C, as per IS: 3618 (latest).

7.9.3 Final Painting:

7.9.3.1 After phosphate treatment, all the springs shall be painted as per RDSO Specification No. M&C/PCN/132/2021 (latest) for Painting of Helical Coil Springs of LHB Coaches and Similar Applications (Single Pack).

7.9.3.2 Any other proven painting scheme, may also be permitted with approval by RDSO, depending on case to case basis subject to complying at least the following tests requirements:

| S. No. | Tests | Requirements |
|--------|---|---|
| 1. | Resistance to Salt Spray Test (1000 hours) according to EN ISO 9227 | No rusting, cracking, flaking, blistering & corrosion |
| | i. Evaluation of Degree of Rusting according to EN ISO 4628-3 | Ri1 or better |
| | ii. Evaluation of Degree of Cracking according to EN ISO 4628-4 | 1(S3) or better |
| | iii. Evaluation of Degree of Flaking according to DIN EN ISO4628-5 | 0(S0) or better |
| | iv. Evaluation of Degree of Blistering according to EN ISO 4628-2 | 2(S2) or better |
| | v. Evaluation of Detachment and | < 3 mm, no delamination |

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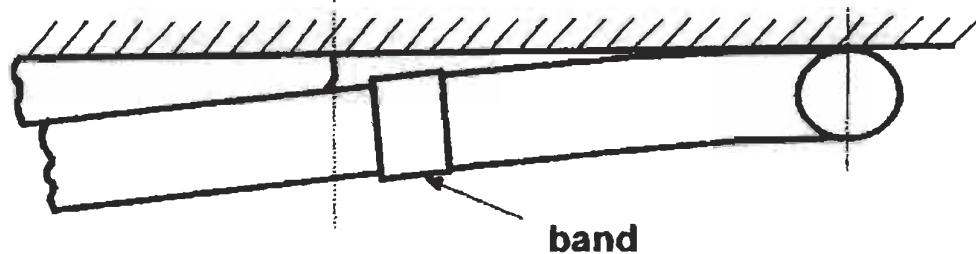
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| | corrosion around the scratch according to EN ISO 4628-8 | |
| 2. | Evaluation of Adhesion according to EN ISO 2409 | Cross-cut Rating (GT): ≤ GT0-1 |

7.9.3.3 The Type and Acceptance Test Reports of brand and make of paint, which are applied on springs shall be kept ready during Inspections. As quality control measure, type tests of brand and make of paint which is used for applications on springs, shall be conducted once in a year from NABL certified Lab and report of the same shall be kept ready during Inspections.

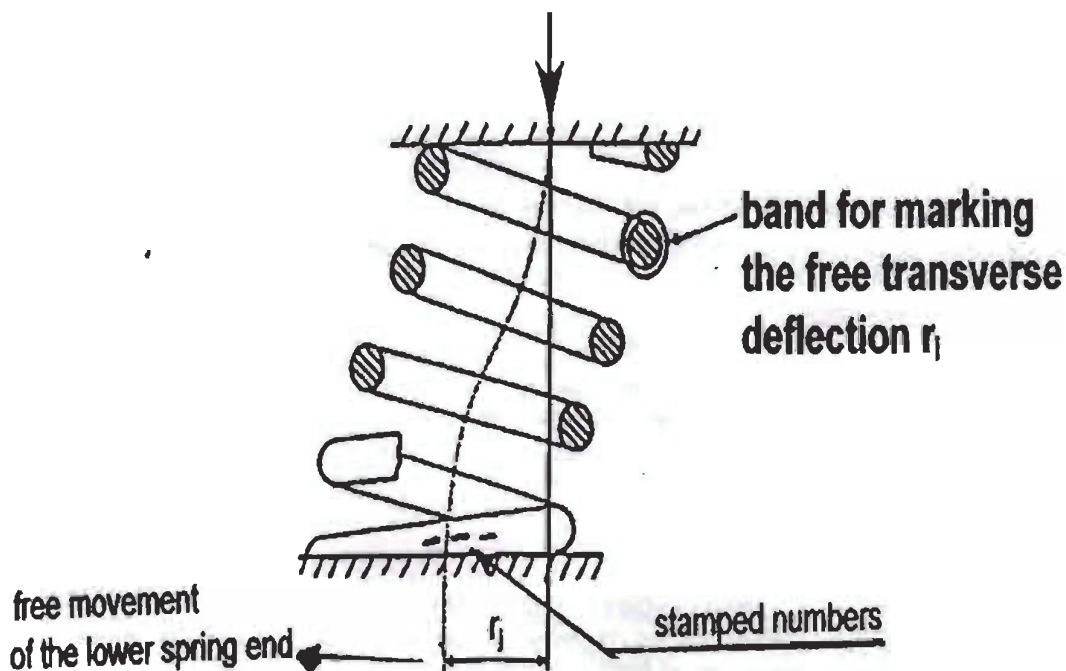
7.9.4 Special Spring Marking (Besides Stamping):

7.9.4.1 In addition to the stamping at end coil of the spring (Para 7.3), each spring is to be marked with a band of bronze, copper or brass. The band is secured with a cyanogen acrylate adhesive (e.g. Loctite Js 496), or with a compression joint. The following are to be stamped on the band:

- Spring length under test load corresponding to tare condition in mm
- Value "r_i" of the free transverse deflection in (mm) under test load corresponding to tare condition (only for category 'B' Springs).



Further, the direction of free transverse deflection "r_i" of every flexi-coil spring (category 'B') is to be marked with a band of aluminum adhesive tape (e.g. Tesaflex 171). The band is to be attached to the painted spring as in the sketch below:



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