TB

RAILWAY INDUSTRY STANDARD

OF THE PEOPLE'S REPUBLIC OF CHINA

ICS 45.060

S 40

TB/T 2211-2010

Partially replacing TB/T 1025-2000, replacing TB/T 2211-1991

Steel helical spring of suspension mechanism for rolling stock

机车车辆悬挂装置钢制螺旋弹簧

Issued on: December 02, 2010 **Implemented on: June 01, 2011**

Issued by: Ministry of Railways of People's Republic of China

Table of contents

Foreword

This standard was drafted in accordance with the rules given in GB/T 1.1-2009.

This standard partially replaces the suspension spring part of the TB/T 1025-2000 “Technical conditions for the supply of hot coil helical compression springs for rolling stock”, AND the part which is not replaced is the spring used for buffer and traction device.

As compared with TB/T 1025-2000 “Technical conditions for the supply of hot coil helical compression springs for rolling stock”, the main technical changes of this standard are as follows:

- ADD the spring material dedicated for railway AND some spring materials of European standards (SEE 6.3.3 and Table 5 of 6.4.1);

- ADD the information of spring transverse movement (SEE item 15 of Table 1), transverse stiffness (SEE 5.2.3.2), transverse free offset or bending (SEE 5.2.3.3), transverse stiffness test (SEE 7.3), and transverse fatigue test (SEE Appendix C); DETAIL the spring transverse characteristics, calculation, and test methods;

- MAKE reference to the determination of non-metallic inclusions in steel – Standard rating chart microscopy method in GB/T 10561-2005.

This standard replaces TB/T 2211-1991 “Fatigue test of cylindrical helical spring for rolling stock”. As compared with TB/T 2211-1991, the main technical changes are as follows:

- DELETE the Appendix C “Repeatability of shot peening pre-stressing effect” of EN 13298:2002 (SEE Appendix C of 2003 version);

- ADD the TB/T 1758 “Technical conditions for shot peening of rolling stock springs”, which is directly quoted in the standard (SEE 5.3.2.4);

- ADD the “Fatigue test” requirements (SEE 7.9);

- ADD the transverse fatigue test methods; ADJUST the spring vertical and transverse fatigue test specifications (SEE Appendix C);

- MAKE adjustment against the contents of the reference (SEE references).

This standard, through the re-drafting method, modifies and adopts EN 13298:2002 “Railway applications - Suspension components – Helical suspension springs, steel”.

Steel helical spring of suspension mechanism for rolling stock

1 Scope

This standard specifies the geometric characteristics, application requirements, technical specification, test methods, product quality, marking and packaging of the steel helical spring of suspension mechanism for the newly designed rolling stock (hereinafter referred to as spring).

This standard applies to:

- Steel helical spring of suspension mechanism for railway rolling stock;
- Equal pitch cylindrical compression springs made of circular cross-section equal-diameter steel bar;
- Other different shaped helical springs (such as conical helical springs, unequal pitch springs, or the springs made of steel bar having other shaped cross-sections).

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) are applicable to this Standard.

GB/T 224-2008 Determination of depth of decarburization of steels (ISO 3887:2003, MOD)

GB/T 228-2002 Metallic materials – Tensile testing at ambient temperature (ISO 6892:1998, EQV)

GB/T 229-2007 Metallic materials - Charpy pendulum impact test method (ISO 148.1:2006, MOD)

GB/T 1222-2007 Spring steels

GB/T 6394-2002 Metal – Methods for estimating the average grain size

GB/T 6461-2002 Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates – Rating of test specimens and manufactured articles subjected to corrosion tests (ISO 10289:1999, IDT)

GB/T 10125-1997 Corrosion tests in artificial atmospheres – Salt spray tests (eqv ISO 9227:1990)

GB/T 10561-2005 Steel - Determination of content of nonmetallic inclusions – Micrographic method using standard diagrams (ISO 4967:1998, IDT)

GB/T 10610-2009 Geometrical product specifications (GPS) - Surface texture: Profile method - Rules and procedures for the assessment of surface texture (ISO 4288:1996, IDT)

GB/T 20066-2006 Steel and iron – Sampling and preparation of samples for the determination of chemical composition (ISO 14284:1996, IDT)

TB/T 1335-1996 Specification for strength design and test appraisement for railway rolling stock

TB/T 1758 Technical specification for shot peening of springs for locomotive

ISO 2162.2:1996 Technical product documentation – Springs – Part 2: Presentation of data for cylindrical helical compression springs

ISO 2162.3 Technical product documentation – Springs – Part 3: Vocabulary

ISO/TR 10108:1989 Steel – Conversion of hardness values to tensile strength values

EN 10083.1 Quenched and tempered steels – Part 1: Technical delivery conditions of special steels

EN 10089:2003 Hot rolled steels for quenched and tempered springs – Technical delivery conditions

3 Terms and definitions, symbols, units, descriptions and geometric characteristics

3.1 Terms and definitions

The terms and definitions as defined in ISO 2162.3 AND the following terms and definitions apply to this document.

3.1.1

Transverse deflection (bowing)

It refers to the natural transverse movement of the axis of the spring under an axial force, while the top and the bottom surface of the spring remain parallel and the spring is free to move laterally. The transverse force Φ_C is the force required to move the spring back to the initial centered position.

3.1.2

Clearance factor

5.2.2 Geometric conditions

5.2.2.1 Space requirements

Two types of space requirements can be defined:

- The space required by the spring to withstand only the axial force F_j;

- The space required by the spring when its two supporting surfaces are subject to transverse displacement r_E (the supporting surface is kept parallel).

When defining the space in the technical specification, it shall consider the space required by the springs (inner, middle, and outer rings) for different purposes. It shall specify any requirements and restrictions relating to the working space of the spring.

5.2.2.2 Reference length

The reference length is the length L_A corresponding to the load condition “ready to run” F_A (that is, the static load of the spring). Unless otherwise specified in the technical specifications, on this length a tolerance is applied to ensure a defined height of the total suspension system. The tolerance of the nominal size L_A is ± 1%.

5.2.3 Mechanical conditions

5.2.3.1 Axial stiffness

The axial stiffness is defined in the z-axis direction as following:

- Either by the value K_s, which is the gradient of the force-displacement line (deformation) as shown in Figure 2 and Figure 3:

$$K_s = \frac{F_v - F_u}{L_u - L_v} \quad (1)$$

- OR by the force-displacement line (deformation) as shown in Figure 4.

Note: It is allowed to use the axial flexibility to substitute the axial stiffness, AND the flexibility is the reciprocal of stiffness ($1/K_s$).

Under single load (F_A) conditions, it is allowed for the stiffness to be defined as shown in Figure 2.

In defining the spring stiffness beyond the range of the applied force (from F_U to F_V in Figure 3), it shall consider the non-linearity factor of the stiffness OR increase the allowable tolerance.

In the case of using the force-displacement diagram containing a deviation range for definition, it shall consider the hardening effect caused by the end the loading procedure and acceptance criteria shall be specified in the technical specification.

5.3 Basic requirements

5.3.1 Summary

5.3.1.1 Coiling direction

Normally, the coiling direction shall be right-handed. If there are more than one springs are used together, the direction of coiling changes from right to left direction from outside to inside the direction shall be specified.

5.3.1.2 Form and type of end coil

The definition of the different forms of spring end coil is in ISO 2162.2:1996.

In accordance with the general rules, the suspension spring is:

- Cylindrical;
- Have the same pitch;
- Made of round bar;
- End closed and ground.

The form and type of the end coil shall be specified in the technical specification. If not specified, it shall be in accordance with the requirements of Appendix A.

5.3.2 Surface quality

5.3.2.1 Surface quality of bar material

Steel bar shall be processed unless otherwise agreed by both parties.

If other values are not specified in the technical specification, then before the coiling operation, the maximum roughness MRR of the steel bar surface shall not exceed 2.5 μm.

5.3.2.2 Surface quality of springs

Spring surface shall not have any defects (delamination, peeling, grooving, processing knife marks, cracks, hairline, etc.).

Note: These defects will damage the performance and life of the spring.

It shall follow the requirements of clause 7.6.1 to perform magnetic flaw detection.

5.3.2.3 Decarbonization

When the internal depth δ of the material is 0.5 mm, the pre-stressing force (compressive stress) is about 100 MPa.

5.3.3 Grain size

As for the grain size of the steel, the austenite grain size as obtained by the test in accordance with the provisions of GB/T 6394-2002 shall be more than or equal to grade 6.

5.3.4 Creep

The creep after applying the force F_B for 96 h shall not exceed 1% of L_B, unless otherwise specified in the technical specification. After the creep of the spring, the spring length is reduced, AND it shall verify the residual deformation amount Σe of the spring in accordance with the method of A.6.2 in Appendix A, which shall comply with the technical specification.

6 Product technical specification

6.1 Technical characteristics of products

Technical specification can be made entirely by the purchaser (e.g., including spring design calculations) or jointly by the purchaser (determining the performance and the appropriate volume) and the manufacturer (making recommendations). The technical requirements may include the following documents:

- The general drawing or assembly drawing of the suspension;
- Parts drawing;
- Technical data sheet.

The main characteristics of the spring (form, size, material, stiffness, etc.) are determined by the relevant design analysis. The design analysis shall, as a part of the technical specification, at least specify the following:

- Calculation method;
- Load and displacement used for the analysis.

The following result is obtained:

- Comparison of the calculated characteristics with the required characteristics (static stiffness or flexibility, clearances between active coils, etc.);
- Comparison of allowable stress and calculated stress of selected materials.

6.4.3 Toughness

If the technical specification does not specify the toughness of the spring material, the toughness value (KU) shall be greater than or equal to 10J (at 20°).

Note: The toughness of the spring material is obtained by the corresponding impact test.

6.5 Surface protection

It shall take the anti-corrosion measures which comply with the technical specification for the spring, AND the anti-corrosion measures and the final coating color shall be specified in the technical specification.

The specific content shall include:

- The way of surface treatment;

- The designation of coating material:

- The number and thickness of coating;

- Color.

The salt spry test and the mechanical properties (adhesion, impact resistance, elasticity, color fastness, etc.) of the spring protective layer shall be specified in the technical specification.

If in the technical specification, it requires performing the salt spray test BUT does not specify the specific values of the salt spray test duration, it shall perform the test in accordance with the requirements of GB/T 10125-1997, AND the test duration shall be as the following:

- Category A spring: 400 h;

- Category D spring: 300 h.

Note: The aging characteristics of the protection system are obtained by the salt spray test.

7 Test method

7.1 Summary

7.1.1 General test conditions

Unless otherwise specified in the technical specification, the test shall be carried out at a temperature of 20 °C ± 10 °C.

7.1.2 Test device

$$r_A = |r_{A1}| = |r_{A2}|$$

$$r_B = |r_{B1}| = |r_{B2}|$$

7.4 Horizontal free offset or bowing

The transverse free offset test is carried out on the device as specified in 7.3. Both parties shall agree on the contents of the test, marking and record details.

The test method is as follows:

- Determination of bowing direction (transverse free deformation direction). The bowing direction is the direction along which the lower support plate moves when the spring is under the action of only the static axial force F_{ej} (SEE Figure 8).

- Determination of bowing force Φ_c (transverse free deformation force). Φ_c refers to the force required to return the lower support plate to the initial center position when the spring is only subjected to the static axial force F_{ej}.

Note: If the lower support plate in Figure 8 can only move in one direction, then every time after the measurement, the spring shall be rotated an angle (desirable 45°) before the next measurement, AND the direction of the maximum movement is the direction of the spring transverse free deformation. It may measure the spring transverse free deformation force accordingly.

7.5 Geometric characteristic test

7.5.1 Diameter

Unless otherwise specified in the technical specification, the diameter D_e and D_i is measured in the free state of the spring.

7.5.2 Reference length

The reference length L_A is measured in accordance with the requirements of 5.2.2.2 and 7.2.1.

7.5.3 Space requirements

In accordance with the operating conditions of the spring, the inspection of the spring containment space can be carried out by the following methods a) or method b) or simultaneously using both the method a) and b).

a) Under the action of only the axial force, during measurement:

- The spring upper and lower support plate shall be kept parallel, coaxial, AND shall not rotate;

- The axial force used shall be kept within the tolerance of ± 1%.

Unless otherwise specified in the technical specification, the test shall be performed using the bar materials which are taken from the same materials as the spring.

7.7 Mechanical performance requirements

7.7.1 Hardness

Spring hardness (surface and interior) is tested by Rockwell hardness method. It can also be replaced by Brinell or Vickers hardness method. AND the hardness values obtained by different methods shall be converted in accordance with ISO/TR 10108-1989. The surface hardness test shall be carried out on the spring.

Unless otherwise specified in the technical specification, the sample shall be taken from the bar used to make the spring AND have the same heat treatment process as the spring.

7.7.2 Tensile strength

The test of the yield strength of the material shall be carried out in accordance with the provisions of GB/T 228-2002, AND the sample produced shall be in accordance with the provisions of EN 10083.1.

Unless otherwise specified in the technical specification, the sample shall be taken from the bar used to make the spring AND have the same heat treatment process as the spring.

7.7.3 Impact toughness

Unless otherwise specified in the technical specification.

- Impact toughness test shall be in accordance with the provisions of GB/T 229-2007, AND the preparation of sample shall comply with the provisions of EN 10083.1;

- The sample shall be taken from the bar used to make the spring AND have the same heat treatment process as the spring.

7.8 Surface protection

Depending on the form and size of the spring test, the sample shall be either the spring itself OR the standard sample.

In the salt spray test, the corrosion resistance test shall be in accordance with the requirements of GB/T 10125-1997. AND the evaluation criteria shall be in accordance with the provisions of GB/T 6461-2002.

7.9 Fatigue test

The fatigue test of the spring shall be in accordance with the provisions of Appendix C.

8 Product quality

8.1 Product certification procedures and samples

The manufacturer shall carry out product certification in the following cases:

a) Springs made from new manufacturing plants;

b) New spring produced by a qualified plant (the spring has at least one characteristic that is different from the spring that has been certified);

c) Produced by the qualified plant, but spring production conditions have changed (in accordance with new technical specification);

d) Produced by the qualified plant, but the process has changed, including changes in the bar material process.

All sample springs required for certification shall come from the same production lot (same raw material and same manufacturing process). AND the sample shall be representative of the actual manufacturing process of the spring.

The sample shall be not less than the number of springs required for a locomotive or vehicle AND it shall be specified in the technical specification.

The spring certification procedure consists of two phases:

Phase 1: CHECK whether the technical specification is consistent with the requirements of 6.1;

Phase 2: CHECK whether the technical specification is consistent with all the features specified in Chapter 5 and Chapter 6.

In the phase 2 of the certification procedure, in addition to the spring provided by the new manufacturer, the inspection item of the spring from the qualified manufacturer may be simplified in accordance with the valid quality assurance system of this manufacturer. For example, the material data and corrosion resistance system characteristics, etc., which are currently used by the manufacturer.

In any case, the simplified certification procedure shall be negotiated between the user and the manufacturer.

If the following conditions are met, the product qualification certificate is granted:

The data of inner and outer diameters shall be measured directly from the spring.

A.3 End coil of spring

A.3.1 End coil form

The spring end coil form as specified in this Appendix shall comply with the requirements of type D of ISO 2162.2:1996.

A.3.2 End of end coil

Requirements for the end of the end coil:

a) Numerical requirements

Unless otherwise specified in the technical specification, after the both end coils are ground, the thickness shall be from 3 mm to 1/4 of the nominal size of the bar material cross section.

b) Operation

The spring end thickness shall be measured directly from the spring.

A.4 Contact line

A.4.1 Features

The length of the contact line between the last coil and the adjacent active coil changes with the magnitude of the axial force applied.

A.4.2 Value requirements

In accordance with the requirements of 5.2.3.1, when the spring is subjected to static load F_V, the contact line length of the upper and lower end coils of the spring is 0.33 times the pitch diameter D, AND it shall be at least 20 mm.

A.4.3 Operation

The contact line length value shall be measured directly from the spring.

The test requirements are as follows:

a) Test conditions:

During the test, the spring end coil shall be kept parallel and coaxial.

b) Test method:

The spring shall be subjected to an axial compression load, comprising the following procedures:

- INCREASE the axial load from 0 to F_V;

- MAKE the load F_V remain within the range of ±1%;

- MEASURE the length of the contact line.

Note: This measurement can be made at the same time as axial stiffness measurement (SEE 5.2.3.1).

A.5 Geometric tolerances

A.5.1 Definitions

The two end coils of the spring specified in this Appendix shall be parallel to each other AND perpendicular to the spring axis.

The technical specification shall specify the deviation of the maximum allowable perpendicularity of the end coil relative to the spring axis.

If the spring does not indicate the perpendicularity deviation, its perpendicularity deviation at free state may be valued as follows:

- Spring free length $L_o \leq 150$ mm, the deviation $p \leq 2\% L_o$;

- Spring free length $L_o > 150$ mm, the deviation $p \leq 1.5\% L_o$.

A.5.2 Numerical requirements

The perpendicularity deviation of the spring end coil shall be less than or equal to the maximum value as specified in the technical specification.

A.5.3 Operation

The perpendicularity value shall be measured from the spring.

Measurement methods:

The perpendicularity deviation of the end coil is measured by the straight ruler in accordance with the following requirements.

PLACE the spring onto a plane and against a vertical bar on this plane. Then, ROTATE the spring until finding the location where the maximum offset is located (SEE Figure A.1).

The test shall be carried out on both end faces of the spring.

Appendix B

(Normative)

Magnetic flaw detection of helical spring surface defects made by circular steel bar

B.1 Summary

This Appendix specifies the application conditions for using the magnetic flaw detection methods to check the surface completeness of the helical spring which is coiled by steel bar materials.

B.2 Method

Two magnetization methods are required to detect the defects (longitudinal defects) parallel to the axial direction of the bars AND the defects (transverse defects) perpendicular to the axial direction.

- Longitudinal defect: current magnetization along the longitudinal axis of the spring;

- Horizontal defects: current magnetization through the auxiliary conductor, AND the auxiliary conductor is placed on the helical axis of the spring.

The inspection device used shall be capable of generating cyclic magnetization in the direction indicated earlier, AND the magnetic field strength is at least 3 kA/m in each magnetization direction. The magnetic induction level is identified by the intensity of the magnetizing current.

Defects can be detected by a magnetic solution containing fluorescent powder, AND the solution shall not adversely affect the inspection part. The inspection shall be carried out under the UV light with a radiation illuminance greater than or equal to 15 W/m^2 AND measured at a distance of 0.3 mm. The ambient light illuminance shall be less than or equal to 10 Lx (lux).

System sensitivity tests shall be carried out in the field, including the measurement of field strength and the use of the reference coil body of known types, location, size and distribution of the actual defects. If it cannot satisfy these conditions, it may use the reference coil with artificial defects.

Note: Defects in different directions can be detected in the same way, BUT greater magnetic field strength shall be used. In this case, longitudinal defects and transverse defects shall not have a regular difference.

Appendix C

(Normative)

Fatigue test of steel helical spring for suspension

C.1 Test requirements

For the springs (category B springs) that only bear axial loads, only axial fatigue tests are carried out.

For springs (category A springs) that are subject to both axial and transverse loads simultaneously, fatigue tests are carried out in both axial and transverse directions.

The fatigue testing machine shall be loaded with a sinusoidal (or approximately sinusoidal) force or displacement, AND the accuracy shall be above level 1.5.

Fatigue testing machine shall have automatic counting function, which can automatically shut-down after reaching to the set number. AND it shall have the automatic shutdown function in case of spring fracture, in order to ensure safety.

In the suspension system, the upper and lower ends of the series two high-diameter helical spring are sometimes fitted with a rubber pad. In the case of vertical fatigue tests, it is allowed to assemble the spring and the rubber pad (same as the actual conditions of the rolling stock) before performing the fatigue test. AND it may also perform the test without installing the rubber pad. However, during the transverse fatigue test, it shall assemble the spring and the rubber pad (same as the actual conditions of the rolling stock) to perform the test, because the presence of rubber pad has a significant effect onto the spring stress.

C.2 Vertical fatigue test

During the test, FIX the test spring on the dedicated support AND it shall be the same as the actual installation conditions on the locomotive vehicle (in particular the type, diameter and height of the positioning device). During the test, the upper and lower supports remain parallel and coaxial.

The test load is: $F_j \pm kF_j$

Where:

F_j - The axial static load of spring;

k – The dynamic load factor, unless otherwise specified by in the technical specification, k = 0.25 for locomotive and bus AND k = 0.4 for truck.