EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13298

March 2003

English version

Railway applications - Suspension components - Helical suspension springs, steel

Applications ferroviaires - Eléments de suspension -
Ressorts de compression hélicoïdaux, en acier

Bahnanwendungen - Federungselemente - Schrauben-
Druckfedern aus Stahl

This European Standard was approved by CEN on 29 November 2002.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36   B-1050 Brussels

Ref. No. EN 13298:2003 E

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Foreword

This document (EN 13298:2003) has been prepared by Technical Committee CEN/TC 256 "Railway Applications" the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2003, and conflicting national standards shall be withdrawn at the latest by September 2003.

In this European Standard the annexes A to E are normative.

The preparation of this European Standard started in early 1992 with the aim to integrate the existing documents such as UIC 822 (International Union of Railways) and internal documents of various railway companies into a concise standard.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard is applicable to helical steel suspension springs used in the suspension of rail vehicles.

It deals specially with cylindrical compression springs made from round section steel bars of constant diameter and with constant inclination of coiling.

It deals also with helical springs with different shapes (e.g. conical and/or inclination of coiling not constant and/or steel bar with other cross sections, etc.).

This standard gives guidance for:

— design;

— specification of technical and quality requirements;

— the approval procedure and quality assurance of production methods;

— the examinations and tests to be carried out;

— the delivery conditions.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 473, *Non-destructive testing – Qualification and certification of NDT personnel – General principles.*

EN 10002-1, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature.*

EN 10045-1, *Metallic materials – Charpy impact test – Part 1: Test methods.*

EN 10083-1, *Quenched and tempered steels – Part 1: Technical delivery conditions of special steels.*

EN 10228-1, *Non-destructive testing of steel forgings – Part 1: Magnetic particle inspection.*

prEN 10089:1998, *Hot-rolled steels for quenched and tempered springs – Technical delivery conditions.*

EN ISO 2162-1:1996, *Technical product documentation – Springs – Part 1: Simplified representation (ISO 2162-1:1993).*

EN ISO 2162-2:1996, *Technical product documentation – Springs – Part 2: Presentation of data for cylindrical helical compression springs (ISO 2162-2:1996).*

EN ISO 2162-3, *Technical product documentation – Springs – Part: 3 Vocabulary (ISO 2162-3:1996).*

EN ISO 4288, *Geometrical Product Specification (GPS) – Surface texture: Profile method - Rules and procedures for the assessment of surface texture (ISO 4288:1996).*

EN ISO 10289, *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).*

EN ISO 14284, *Steel and iron – Sampling and preparation of samples for the determination of chemical composition (ISO 14284:1996).*

ISO 4967:1998, *Steel – Determination of content of non-metallic inclusions – Micrographic method using standard diagrams.*

ISO 9227, *Corrosion tests in artificial atmospheres – Salt spray tests.*

ISO/TR 10108, *Steel – Conversion of hardness values to tensile strength values.*

ISO 10209-1, *Technical product documentation – Vocabulary – Part 1: Terms relating to technical drawings: general and types of drawings (ISO 10209-1:1992).*

EURONORM 103, *Iron and steel - Macrographic determination of the ferritic or austenitic grain size of steels.*

EURONORM 104, *Determination of the decarburization depth of unalloyed and low-alloy structural steels.*

UIC 515-4, *Passenger rolling stock - Trailer bogies - Running gear - Bogie frame structure strength test*[1].

DIN 50 602:1985, *Metallographic examination; microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions.*[2]

NF A 04-106:1984, *Iron and steel – Methods of determination of content of non metallic inclusions in wrought steel – Part II: Micrographic method using standard diagrams.*[3]

SS 11 11 16: 1987, Steel – Method for assessment of the content of non-metallic inclusions – Microscopic method – Jernkontoret's inclusion chart II for the assessment of non-metallic inclusions.[4]

3 Terms, symbols, units and their abbreviations

3.1 Terms

For the purposes of this European Standard, the terms and definitions given in EN ISO 2162-3 and the following apply.

3.1.1
spring
term "helical suspension spring, steel" refers to the finished product. For simplification purposes, in the text of the present standard, the term "spring" is used for all types of helical compression springs, made from steel, independent of their category

3.1.2
transverse deflection (bowing)
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 centred position

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[1]	Can be obtained from: UIC Direction Générale, 16 rue Jean Rey, F-75015 Paris.

[2]	Can be purchased from: Beuth Verlag GmbH, Burggrafenstr. 6, 10772 D-Berlin.

[3]	Can be purchased from: Association française de normalisation (AFNOR), 11, av. Francis de Pressensé, F-93571 Aint-Denis La Plaine CEDEX.

[4]	Can be purchased from: SIS-Standardiseringen i Sverige, box 64 55, S-11 3 82 Stockholm.

3.1.3
clearance factor

clearance between the active coils with reference to the wire diameter on a cylindrical helical spring with constant inclination, made with circular wire and featuring closed and ground ends

3.1.4
decarburization

loss of carbon on the metal surface during the hot forming of the spring

3.1.5
space requirements

volume occupied by the spring under its various operational conditions

3.1.6
creep

loss of the spring length under a defined static or dynamic force in a defined time

3.1.7
contact line

line located between each end coil and the adjacent active coil of the cylindrical helical spring with constant inclination, made with circular wire and featuring closed and ground ends (form D according to ISO 2162-2), in the loaded condition

3.1.8
active coil

complete spiral turn of the wire with constant diameter, which remains without contact with adjacent coils within the entire working envelope of the spring

3.2   Symbols, units and their abbreviations

The majority of the symbols, used in this standard and described in Table 1, are in accordance with EN ISO 2162-2.

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Table 1 — Symbols and their definition

No	Symbol	Unit	Description
1	A	%	Elongation at rupture
2	A_R	%	Allowable deviation of axial stiffness
3	d	mm	Diameter of the steel bar
4	D	mm	Mean diameter of the winding (average coiling diameter)
5	D_e	mm	Outer spring diameter
6	D_i	mm	Inner spring diameter
7	e	mm	Clearance between the active coils
8	$F_j(F_1, F_2,..)$	N	Axial static force, applied on the spring, with:
	F_A	N	Minimum operational force
	F_B	N	Maximum operational force
	F_{cth}	N	Theoretical force, corresponding to the solid length of spring
	$F_{cj}(F_{C0}, F_{C1})$	N	Defined test loads for determination of bowing (transverse displacement)
	F_M	N	Force at minimum allowable length
	F_U	N	Lower test force for determination of stiffness K_S (or flexibility)
	F_V	N	Upper test force for determination of stiffness K_S (or flexibility)
9	g	m/s^2	Earth acceleration (gravity)
10	G	MPa	Shear modulus (default value is $G = 79\ 000$ MPa)
11	L_0	mm	Free length of spring
	$L_j(L_1, L_2, ..)$	mm	Length of the spring when subjected to an axial force F_j
	L_A	mm	Length of the spring when subjected to the axial force F_A
	L_B	mm	Length of the spring when subjected to the axial force F_B
	L_C	mm	Solid length of spring
	L_M	mm	Minimum allowable length of spring
	L_U	mm	Length of the spring when subjected to an axial force F_U
	L_V	mm	Length of the spring when subjected to an axial force F_V
12	n	-	Number of active coils
13	n_t	-	Total number of coils
14	Q_j	N	Transverse static force, applied to the spring to produce a translation of r_j (transverse displacement of the two supporting surfaces)
15	r_j	mm	Translation (transverse displacement of the two supporting surfaces
	r_E	mm	Maximum possible transverse displacement (to bump stops)

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Table 1 *(continued)*

16	$R_{p0,2}$	MPa	Yield limit at 0,2%
17	R_m	MPa	Ultimate strength (tensile strength)
18	K_s	N/mm	Axial stiffness
19	$1/K_s$	mm/N	Axial flexibility
20	K_t	N/mm	Transverse stiffness
21	$1/K_t$	mm/N	Transverse flexibility
22	s_h	mm	Axial displacement of the spring between two axial loads F_j
23	α	-	Coefficient of clearance between active c
24	Φ_c	N	Transverse bowing force of the spring at the defined axial force F_j
25	Θ_c	d°	Angle between two directions of bowing of a spring, submitted to two different axial loads.
26	σ_{max}	MPa	Residual compression stress
27	δ	mm	Depth under surface

3.3   Definition of the geometrical characteristics

In the this standard the characteristics of the spring are defined with reference to its axis.

The axial characteristics are defined along the Z-axis, the transverse characteristics are defined in the X-Y-plane (see Figure 1).

material cross section:	circular
direction of coiling:	right hand
end-form:	closed, ground (form D acording to EN ISO 2162-2:1993)
type of spring:	cylindrical compression spring with constant inclination of coiling (no. 4-1 according to EN ISO 2162-1:1993)
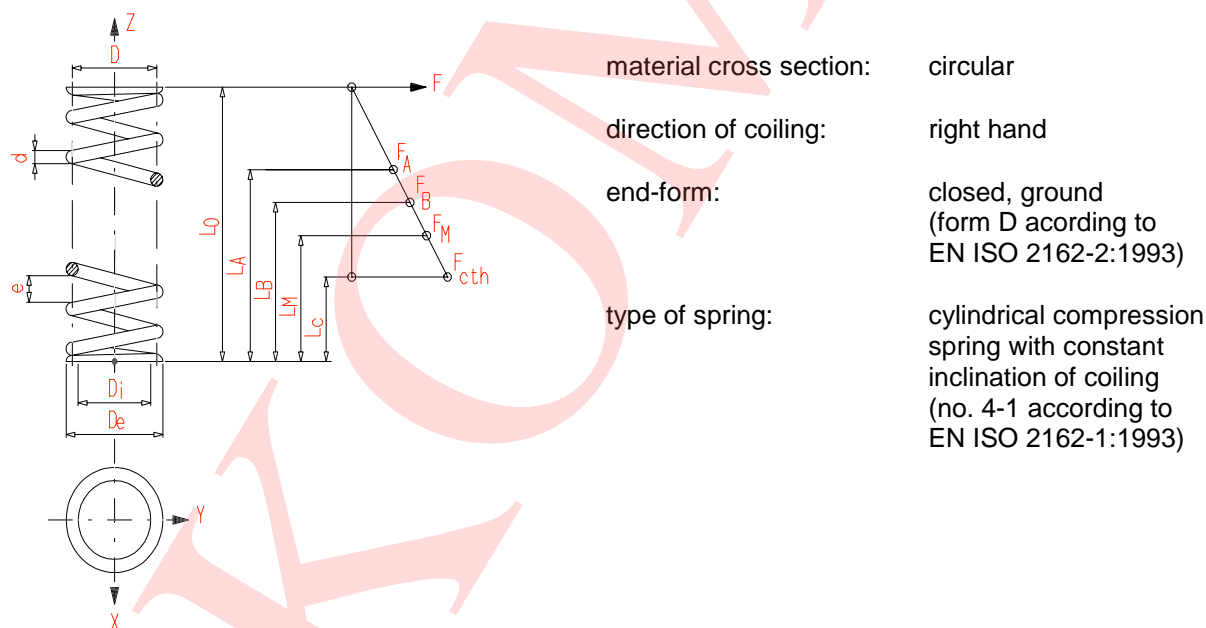
Figure 1 — Example of the presentation of a spring with its axial characteristics

4 Classification of the product

Helical springs covered by this standard are divided into two categories (see Table 2). The category of the spring has to be defined in the technical specification. The classification is the responsibility of the mechanical system designer.

Table 2 — Classification of the springs

Category A	Category B
Axial and transversal stiffness and/or bowing defined	Only axial stiffness defined

5 Requirements

5.1 Service conditions

The service conditions shall be defined by the customer to enable the suspension designer and the spring manufacturer to provide an effective and safe product (service conditions, climatic conditions, environmental conditions, etc.).

5.2 Functional requirements

5.2.1 General

The following product requirements shall be defined by the suspension designer (see Table 3).

Table 3 — Elements to be defined in the technical specification by the suspension designer (totally or in parts)

Defined in	Testing	Elements to be defined	Remarks
5.2.2.1	7.5.3	Space requirements	-
6.2.2	7.5.1	Outside diameter	-
6.2.2	7.5.1	Inside diameter	-
6.2.5	7.2.1	Minimum spring length (to bump stop)	-
5.2.2.2	7.5.2	Reference length	-
5.2.3.1	7.2.2	Force applied (F_A and F_B)	-
5.2.3.1	7.2.2	Axial stiffness (and tolerance)	-
5.2.3.2	7.3	Transverse stiffness	Category
5.2.3.3	7.4	Free transverse deflection or bowing	A springs
5.2.3.4	to be defined	Endurance	only
5.3.1.1	---	Direction of coiling	Right hand
5.3.1.2	7.5.4	Form and type of end coils	Form D EN ISO 2162-2
5.3.2.1	7.6.1	Surface finish	-
5.3.2.2	7.6.1	Surface defects	-
5.3.2.3	7.6.4	Decarburization	-
5.3.2.4	7.6.2	Prestressing of the surface	-
5.3.3	7.6.4	Grain size	-
5.3.4	7.2.3	Creep	-

5.2.2 Geometrical conditions

5.2.2.1 Space requirements

The space (interior and exterior) is the volume occupied by the spring during all working conditions of the mechanical system of which the spring is part.

Two types of space requirement can be defined:

— space required by the spring as a function of the applied axial force F_j;

— space required by the spring as a function of the transverse displacement r_E of the two bases (bases to remain parallel).

The space required by the spring (inside and outside) for different functioning configurations shall be considered in the space defined in the technical specification.

Any requirement or limitation concerning the working space of the spring shall be defined.

5.2.2.2 Reference length

The reference length is the length L_A at load condition "ready to run" F_A (i.e. tare load), unless otherwise stated in the technical specification. On this length a tolerance is applied to ensure a defined height of the total suspension system.

In default a tolerance of 1 % of the nominal value of L_A is applied.

5.2.3 Mechanical conditions

5.2.3.1 Axial stiffness

The axial stiffness is defined in the Z-axis

— either by the value K_S (gradient of the force-deflection line) (see Figures 2 and 3);

$$K_s = \frac{F_v - F_u}{L_u - L_v}$$

— or by a force-deflection diagram (see Figure 4).

NOTE   It is permitted to define the axial flexibility instead of stiffness, where flexibility is the inverse of the stiffness $(1/K_S)$.

For single load case conditions (e.g. F_A) the stiffness can be defined as shown in Figure 2.

The definition of a stiffness value over a force range (e.g. F_U to F_V) (see Figure 3) shall take into account any non-linearity of the stiffness value or increase in the permitted tolerance.

The definition of a force-deflection diagram with envelope-curves shall also take into account the stiffening effect by the end coil geometry. On springs with other than constant inclination of windings a distinct increase of stiffness may be realised.

Tolerances for the stiffness shall be defined. Unless a different tolerance is indicated in the technical specification, the static axial stiffness shall be within ± 5 %. It is known that the tolerance for the springs as defined in 3.3 is relatively high with a small number of coils (less than 5 coils). A recognised method to determine the tolerance as a function of the number of coils is by the formula as shown below:

$$A_R = \pm 0,05 \cdot \frac{5}{n} \cdot 100 \quad \text{in \%}$$

The requirements shall be specified. The different definitions of the axial stiffness are depicted in Figures 2 to 4.
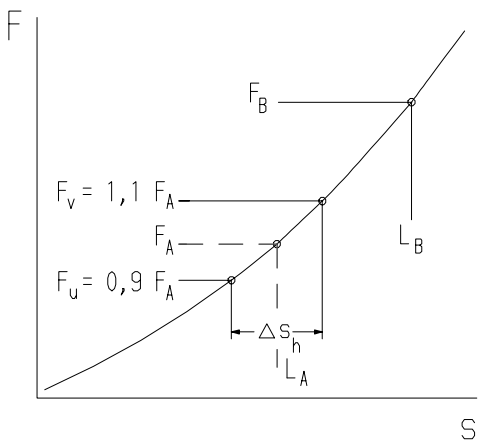
Figure 2 — Axial stiffness at force F_A
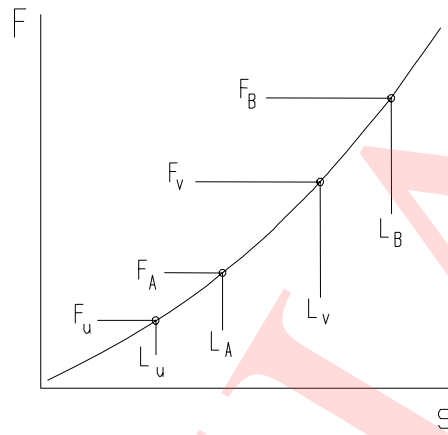
Figure 3 — Axial stiffness between F_U and F_V
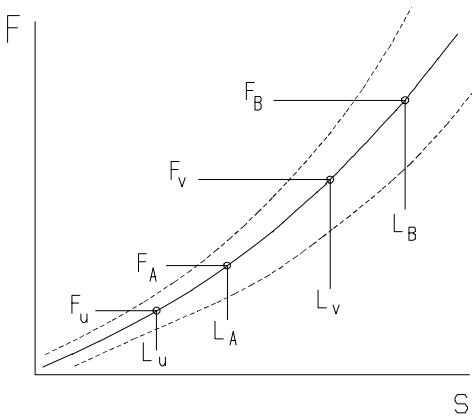
Figure 4 — Force-deflection diagram

In case of a stiffness defined by a force displacement curve, the envelope-curves (tolerances) are derived from the definition (nominal) curve, for a given force, by a displacement variation equal to the chosen tolerance.

In the technical specification, the envelope curves shall be defined between F_U and F_V forces, where $F_U < F_A < F_V \leq F_B$.

5.2.3.2 Transverse stiffness

This item shall be specified only if a defined behaviour in the transverse direction is essential for the operation of the suspension system.

The transverse stiffness is defined in the X-Y-plane by the value

$$K_t = \frac{Q_j}{r_j} \quad \text{at the axial force } F_j \text{ (for } Q_j \text{ and } r_j, \text{ see Table 1)}$$

This characteristic shall be measured in a plane which is parallel to the support bases (force surface) of the spring. It is defined by the relation between a force variation and the corresponding displacement variation for a given static axial force F_j, applied to the spring.

NOTE The transverse stiffness is not an independent value but it is cross related to the axial stiffness and other spring characteristics and shall be defined with this in mind.

The technical specification shall define the nominal value of the transverse static stiffness K_t (with its tolerance) together with relative axial force F_j to be taken into account.

In addition to that, the direction in which is defined the transverse stiffness of the spring shall be specified.

Unless a different tolerance is indicated in the technical specification, the transverse static stiffness shall lie within a tolerance of ± 15 % versus the specified value.

It is possible to define the transverse static flexibility instead of the transverse static stiffness, whereby flexibility is the inversion of stiffness ($1/K_t$).

5.2.3.3 Free transverse deflection or bowing

This item shall be specified only if a defined behaviour of the free transverse deflection is essential for the operation of the suspension system.

The value and direction of free deflection depend on the axial force applied and exhibit similar scatter to the transverse stiffness value.

The **direction of bowing** is defined by the AB straight line (see Figure 5) which is the projection to the straight line between the two loading surface centres of the spring.

The direction of bowing of a spring submitted to a static axial force F_{CO} shall be marked on the spring by a permanently visible system. The F_{C0} value shall be defined in the technical specification. The position of marking towards the spring centre shall indicate the direction of bowing.

Any limitation of the **bowing force** Φ_C, when the spring undergoes an axial Force F_{C0} shall be stipulated in the technical specification. Due to the requirements in connection with the installation of the spring on the vehicle (to which it belongs) it can be necessary to specify the Φ_C force figure on the spring. If the case arises, this requirement shall be stipulated in the technical specification under the specific marking conditions (see clause 9).

The maximum permissible angle θ_C between bowing directions of a spring which undergoes an axial force F_{C0} on the one hand, and an axial force F_{C1} on the other hand (see example, Figure 5) shall be defined in the technical specification, together with the values of F_{C0} and F_{C1}.
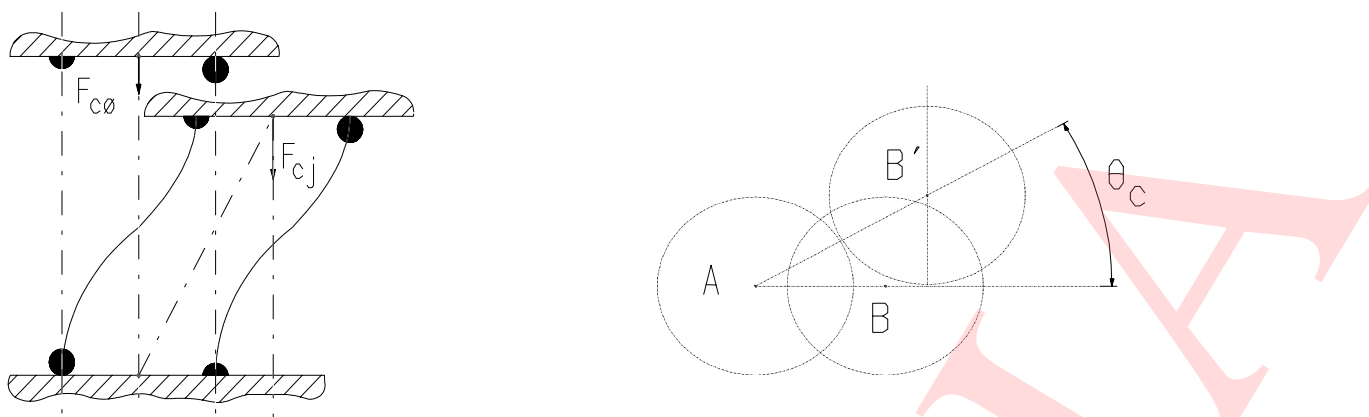
AB   is the straight line defining the bowing direction of a spring submitted to an axial force F_{C0}.

AB'   is the straight line defining the bowing direction of a spring submitted to an axial to an axial force F_{C1}.

θ_C is the angle between the two direction of bowing defined as above.

NOTE   — The F_{CO} value is usually equal to F_A (see definition in 3.2);
              — The F_{C1} value is usually equal to a static axial force F_j corresponding to a functioning mode of the vehicle to which it belongs, (see definitions in 3.2).

Figure 5 — Bowing of a spring (example)

While the spring is submitted to a static axial force F_{C0}, the value of the bowing force Φ_C shall lie within the limits indicated in the technical specification. Unless a different value is indicated in the technical specification, the angle θ_C between the bowing directions of a spring submitted to an axial force F_{C0} on one hand and to an axial force F_{C1} on the other hand shall be $\leq 30°$.

5.2.3.4   Endurance

The springs shall resist the static and dynamic requirements to which they are subjected in service. The life of the spring is limited either by rupture or by creep.

It depends specifically on:

— the stress level and the stress range applied;

— physical characteristics of the spring (internal and external integrity);

— material and mechanical characteristics;

— corrosion resistance.

Freedom from rupture by varying cyclic loads will be achieved by keeping the stress level and the stress range within allowable limits (see 6.1).

The endurance of a spring can be defined by a fatigue test, which consists of quasistatic and dynamic loads, simulating the ones encountered in service. If a fatigue test is required, the test loading program and the acceptance criteria shall be completely defined in the technical specification.

5.3 Essential requirements

5.3.1 General

5.3.1.1 Direction of coiling

Normally, the direction of coiling shall be to the right. If several springs are nested 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 compression springs is given in EN ISO 2162-1. The different types of end coils of springs are defined in EN ISO 2162-2.

As a general rule, suspension springs are:

— cylindrical;

— with constant winding inclination;

— formed from cylindrical bar;

— featuring closed and ground ends (form D according to EN ISO 2162-2).

The form and type of end coils shall be defined in the technical specification. In default of other requirements, the provisions of annex A shall apply.

5.3.2 Surface quality

5.3.2.1 Surface quality of the bar

The bars shall be machined, unless otherwise agreed between the parties.
If no other value is indicated in the technical specification, the maximum R_a value of the surface of the bar before coiling shall not exceed 2,5 µm.

5.3.2.2 Surface quality of the springs

The surface of the springs shall not present any defects (lamination, grooves, machining marks, cracks, crevices, etc.) which may be detrimental to spring performance or life.
Any defect shall be identified during the electromagnetic crack detection test according to 7.6.1.

5.3.2.3 Decarburization

There are two types of decarburization:

— total decarburization, in which case the superficial layer has a purely ferritic structure;

— partial decarburization, in which case the superficial spring layer has a ferritic-perlitic or a ferritic-martensitic structure.

Total spring decarburization is not acceptable. Unless otherwise agreed a depth of partial decarburization is permitted for the spring:

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— 1% of the wire diameter d for circular bar springs;

— 1% of the smallest full wire cross section (active coil) for a non-circular bar spring.

In any case the partial decarburization depth shall not exceed 0,5 mm.

5.3.2.4 Prestressing of the surface

The spring surface shall be prestressed. Shot peening increases the fatigue performance of the spring. A typical stress distribution as a function of the depth is shown in Figure 6.

NOTE   Shot peening is a recommended method of prestressing.
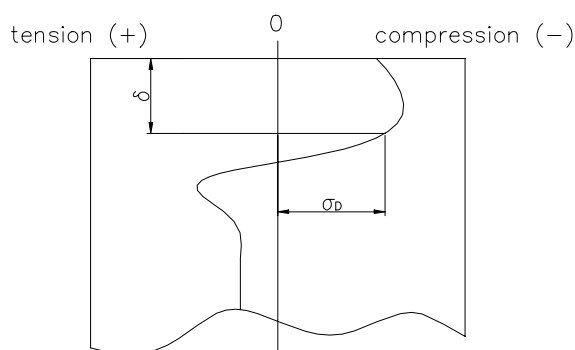
The following prestress figures apply unless otherwise stated in the technical specification:

approximately 500 MPa approx. 0,2 mm;

approximately 100 MPa approx. 0,5 mm

within the material

Figure 6 — Example of the stress distribution created by shot peening, as a function of depth

5.3.3 Grain size

The steel, when tested in accordance with one of the methods described in EURONORM 103 shall be an austenitic grain size of 6 or finer.

5.3.4 Creep

The value of creep under the force F_B shall not exceed 1% of the length L_B after 96 h, unless otherwise stated in the technical specification. The clearance between the coils shall remain within the limits as defined in A.6.

6 Product specification

6.1 Technical specification

The technical specification shall be prepared in total by the customer or jointly by the customer and the supplier. The technical specification should comprise for example the following documents:

— general assembly drawing of the suspension or sub-assembly drawing;

— component drawing;

— technical data sheet.

The definition of the type of drawing is given in ISO 10209-1.

The principal characteristics of the spring (form, dimension, material, stiffness, etc.) shall be determined by the relevant design analysis.

In order to satisfy this requirement, a design analysis, which shall be part of the technical specification, shall define at least:

— calculation method;

— loads and displacements utilised for the analysis;

— the following results:

  — comparison of the calculated functional characteristics with the required characteristics (static stiffness or flexibility, clearance between active coils, etc.);

  — comparison of the calculated stresses with the allowable stresses of the selected material.

The customer and the supplier have to agree on the contents of the documentation and on the analysis method to be utilised.

The technical data are summarised in Table 4.

Table 4 — Elements to be defined in the technical specification by the customer or the supplier (totally or in parts)

Defined in	Testing	Elements to be defined
6.2.1	---	Cross-section of the material
6.2.2	7.5.1	Diameter D_i and D_e
6.2.3	---	Number of coils
6.2.4	----	Unloaded (free) length
6.2.5	----	Solid length
6.2.6	----	Distance between coils
6.2.7	Annex A	Perpendicularity
6.3.2	7.6.5	Internal integrity
6.3.3	7.6.6	Chemical composition
6.3.4	Annex D	Inclusion cleanliness
6.4.1	7.7.1	Hardness
6.4.2	7.7.2	Tensile strength
6.4.3	7.7.3	Resilience
6.5	7.8	Surface protection
9	----	Marking

6.2 Design characteristics

6.2.1 Cross section of the material

Usually the cross section of the material is round. The dimension and its tolerance shall be defined in the technical specification.

6.2.2 Diameter

The mean diameter D shall be specified.

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The inner diameter D_i and/or the outer diameter D_e shall be specified depending on the kind of installation. If no tolerance is specified reference shall be made to annex A.

6.2.3 Number of coils

The number of active coils n and the number of total coils shall be specified.

6.2.4 Unloaded (free) length

If the free length L_0 is different from the reference length, the free length is only specified as indicative. In this case no tolerance is applicable.

6.2.5 Solid length

The solid length L_C may be specified as indicative. The minimum length L_M shall always be larger than L_C. No tolerance shall apply to L_C.

6.2.6 Distance between coils

In order to achieve acceptable behaviour of the spring it is necessary to define the minimum distance between the active coils e_{min}, while the spring is subjected to a force F_j.
Depending on design practice, F_j may be the maximal force F_B.

The minimum distance may be defined as

— the coefficient of aeration α, see A.6, method 1;

— the remaining deflection Σe between the length of the spring subjected to the force F_j and the solid length, see A.6, method 2.

In any case the distance shall be proved by design calculation.

F_j and coefficient α or Σe shall be specified.

6.2.7 Perpendicularity of the spring axis versus the support base

If there are special requirements, the acceptable deviation shall be specified, otherwise the provisions of annex A shall apply.

6.3 Material

6.3.1 General

The alloy to be used for the manufacture of the spring shall be defined in the technical specification.

It is recommended to use the alloys defined in prEN 10089 (see also annex B of this standard.) It is permitted to use alloys different to those defined in prEN 10089. In this case, the chemical and mechanical characteristics shall be completely defined in the technical specification.

6.3.2 Internal integrity

The material of the springs shall not exhibit internal faults which would prove detrimental in use. In case where it is necessary to establish that the internal integrity is acceptable, then tests as defined in 7.6.5 are to be carried out.

As a result of the test, the material shall not show:

⎯ any anomaly greater than the one of the reference defect. The reference defect is a hole with a flat bottom and 1,2 mm diameter, drilled into the middle of the reference bar of the same dimension and quality as destined for the fabrication of the springs*;*

⎯ any attenuation of the ground echo greater than 50 %*.*

6.3.3 Chemical composition

According to the requirements of prEN 10089 (see also annex B of this standard).

6.3.4 Inclusion cleanliness

The contents of the non-metallic inclusions, verified by one of the test methods as defined in annex D shall be within the limits given in annex D, unless otherwise defined in the technical specification.

6.4 Mechanical characteristics of the spring

6.4.1 Hardness

The hardness values on the surface and in the core of the section are defined in the technical specification in consideration of:

⎯ conditions of the utilisation of the spring;

⎯ alloy to be used;

⎯ diameter of the material.

Unless otherwise defined in the technical specification, the values for the surface hardness shall be between 45 HRC and 51 HRC. The hardness value and the tensile strength are compared by means of ISO/TR 10108.

The hardness value in the core shall not differ by more than 3 points HRC compared with the surface value.

6.4.2 Tensile strength

The tensile strength of the spring is the value obtained from the relative tests as defined in 7.7.2.

If the technical specification does not define any different figures, the minimum tensile strength shall be as follows:

$R_{p0,2}$ $\geq$ 1 150 Mpa;

R_m $\geq$ 1 400 Mpa;

$A\%$ $\geq$ 6.

6.4.3 Ductility

The ductility of the material of the spring is the one obtained by the relative impact test. In case the technical specification does not define any different figures, the value of the impact strength (KU) shall be greater or equal to 10 Joules (at a temperature of 20 °C).

6.5   Surface protection

The spring shall be protected against corrosion by a system which fulfils the technical specification requirements. The chosen protection system, as well as the final colour of the coating, shall be stipulated in the technical specification.

The protection system shall be specified by:

— the type of surface preparations, if any;

— designation of the materials;

— number and thickness of the coats;

— colour code.

The mechanical characteristics of the protection system of the spring (adherence, shock resistance, elasticity, resistance against flying ballast, etc.), as defined in the technical specification, shall be adhered to.

The ageing characteristics of the protection system are those given by the salt spray test. Without particular figures in the technical specification the following times in the salt spray test, performed according to ISO 9227, shall be met:

— 300 h for springs category B;

— 400 h for springs category A.

7   Test methods

7.1   General

7.1.1   General test conditions

Unless otherwise stated the tests shall be carried out at a temperature of (20 ± 10) °C.

7.1.2   Instrumentation

The spring characteristics, defined in clauses 5 and 6 of this standard, shall be measured with usual devices, adapted to the size of the spring and to the accuracy requirements.

For the tests defined under 7.2, 7.3, 7.4 and 7.5.3, the spring shall be fitted in a testing fixture, reproducing its fitting into the mechanical system for which it is envisaged (diameter and height of the centering devices in particular).

7.1.3   Definition of the test piece

Unless specified otherwise the test piece to be used for carrying out tests and measurements shall be the finished spring.

7.2   Axial force-deflection testing

7.2.1   General

The testing machine used shall be class 0,5 as defined in EN 10002-1.

During the measurement of the length L_j the corresponding static axial force F_j shall be maintained constant within a limit deviation of ± 1 % with reference to the nominal value.

Before measurement, the spring shall be compressed to solid length, or if this is not allowable, to the specified minimum achievable length.

The supports shall be flat, parallel, non turnable and kept coaxial during the test.

7.2.2 Axial stiffness test

The test method depends on the way in which the requirement is specified:

a) Stiffness values
   The stiffness value is obtained from the load difference and the length difference by increasing the load from F_U to F_V and recording the respective length L_U and L_V.

$$K_s = \frac{F_v - F_u}{L_u - L_v}$$

b) By load deflection and envelope curve
   The stiffness line is obtained by increasing the load from F_U to F_V and recording the corresponding length. The cycle is recorded in adequate small increments or by electronic devices.

7.2.3 Creep test

The spring shall be subjected to an axial force F_B, which is maintained within a limit deviation of ± 1%. In order to determine creep, the test has to be extended until the stabilisation of the variation of the length. The test is considered to be finished, when the reduction in length in a time period of 24 h is less than one tenth of the length reduction during the first 24 h of the test.

The length L_B shall be measured at the beginning of the test and the variation as a function of time is registered. The value of creep is the difference in the length between the beginning and the end of the test.
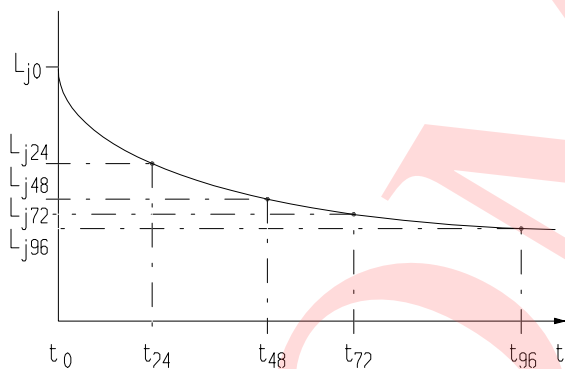
The length of the spring, subject to a constant static axial force F_j is generally stabilised after 96 h.

Figure 7 — Example of a typical creep curve

7.3 Transverse stiffness test

The performance of any test and the apparatus for the performance of the test is part of the specification.

To best simulate the installation of the spring in the suspension system the following parameters are recommended:

— the support plates are kept parallel and non turnable in rotation to the spring axis;

— the supports are equipped with centres of specified diameter and height;

— one of the supports is allowed to float free in the X-Y-plane (normally the lower support).

A possible test apparatus is shown in Figure 8:
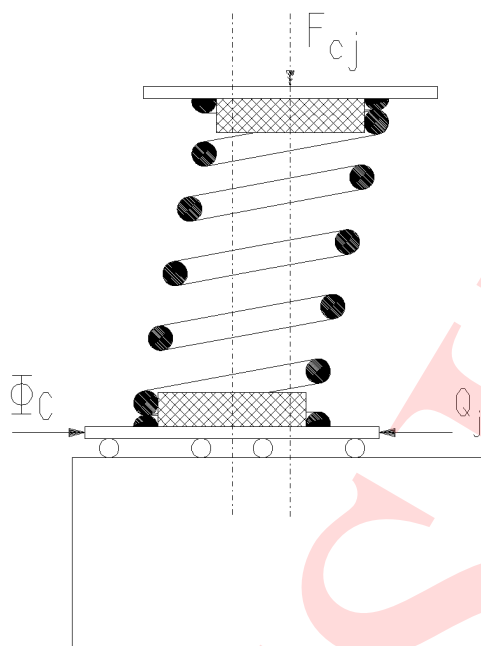
Figure 8 — Schematic view of test set-up

During the test, the spring support plates shall be kept parallel and the axial force F_j, applied to the spring, shall be maintained constant within ± 1 %.

Test method:

— Application of a static axial force F_j to the spring;

— Offset of the spring support plates in the direction of bowing (see 5.2.3.3);

— from 0 to r_{A1}, with measurement of the corresponding transverse force Q_{A1};

— from r_{A1} to r_{B1}, with measurement of the corresponding transverse force Q_{B1};

— Return to equilibrium (balance position).

— Offset of the spring support plates in the direction which is opposite to the bowing direction (see 5.2.3.3);

— from 0 to r_{A2}, with measurement of the corresponding transverse force Q_{A2};

— from r_{A2} to r_{B2}, with measurement of the corresponding transverse force Q_{B2};

— Return to equilibrium (balance position).

The transverse static stiffness is calculated by the following formula:

$$K_t = \tfrac{1}{2} \left| \frac{Q_{B1} - Q_{A1}}{r_{B1} - r_{A1}} + \frac{Q_{B2} - Q_{A2}}{r_{B2} - r_{A2}} \right|$$

The r_A and r_B values shall be defined in the technical specification:

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

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

7.4 Test of free transverse deflection

The test of the free transverse deflection is tested in the apparatus as defined in 7.3. The application of the test together with details of marking and documentation shall be agreed between the parties.

Test method:

— Determination of the bowing direction (direction of free transverse deflection). The direction of bowing is the direction in which the mobile measuring platform (see Figure 8) moves, when the spring is subjected to a static axial force F_{Cj};

— Determination of the bowing force (force of free transverse deflection). The value of the Φ_C force is the value which is necessary to bring the mobile measuring platform back to its initial centred position, while the spring is subjected to a static axial force F_{Cj}.

7.5 Test of geometrical characteristics

7.5.1 Diameter

The dimensions of D_e and D_i are measured with the spring at free length L_0, unless otherwise specified.

7.5.2 Reference length

The measurement of the reference length L_A shall be in accordance with 5.2.2.2 and 7.2.1.

7.5.3 Space requirements

Depending on the operational conditions of the spring, the spring space envelope can be checked either by one or by both test methods A or B:

A) Checking of the spring space envelope, as a function of the axial force:
During the measurement

— the spring support plates shall be maintained parallel, coaxial and non turnable;

— the axial force applied shall be maintained constant at ± 1 %.

The space required by the spring is checked while the spring is successively submitted to a static axial force F_A and a static axial force F_B.

The F_A and F_B values shall be defined in the technical specification, according to the prescriptions of 5.1. The specific test conditions (e.g. external ring or internal spigot) shall be agreed.

B) Checking of the space envelope of a spring, submitted to an offset to the support plates:
During the measurement

— the spring support plates shall be maintained parallel, coaxial and non turnable;

— the axial and transverse forces applied shall be maintained constant at ± 1%.

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The space required by the spring is checked while the spring is simultaneously submitted to a static axial force F_j and an offset of the support plate r_E.

The F_j and r_E values shall be defined in the technical specification, according to the requirements of 5.1. The specific test conditions (e.g. external ring or internal spigot) shall be agreed.

7.5.4 Form and type of end coil

The check of the form and type of end coil is defined in A.3, for cylindrical helical springs with constant pitch and with closed and ground ends.

The method of checking the form of end coils for special springs shall be defined in the technical specification.

7.6 Test of general and essential requirements

7.6.1 Surface quality

7.6.1.1 General

The surface quality of the spring shall be visually verified before and after shot peening (without surface protection) (see 5.3.2.2).

7.6.1.2 Surface quality of the bar

The surface quality of the bar shall be checked in accordance with EN ISO 4288.

7.6.1.3 Surface quality of the spring

The examination of the surface condition is performed by means of electromagnetic crack detection according to EN 10228-1. The specific test conditions for the check of helical springs, formed from wires or bars with circular cross section, are defined in annex E.

7.6.2 Superficial compression stress

The method for measuring residual stresses shall be approved and, if possible, shall make reference to the corresponding European standard.

One of the methods which can be used is the method of measurement by diffraction of the X-rays on the spring. The ALMEN test as described in annex C is recommended to verify the effectiveness of the shot peening. Any other test method for the effectiveness of shot peening than the ALMEN test shall be agreed between customer and supplier.

7.6.3 Decarburization

The decarburization shall be determined according to EURONORM 104 on a cross section of the material, taken from a spring.

7.6.4 Grain size

The grain size shall be determined by a metallographic test according to EURONORM 103 on a cross section of the material, taken from a spring.

7.6.5 Internal integrity

Unless otherwise specified in the technical specification, the verification of the contents of internal faults is performed by ultrasonic tests of the bar. This verification is not necessary for steel bars with a diameter of 20 mm or smaller, independent of the category of spring.

The ultrasonic test shall be effected as a transverse check with a head of 10 mm diameter and a frequency of 5 MHz. The check shall be performed on the entire volume of the bar.

If required, a proof of internal integrity can be agreed.

7.6.6   Chemical composition

Unless otherwise specified in the technical specification, the chemical composition shall be determined by means of a chemical analysis of a cross section of material, taken from the bar. The conditions of sampling shall be in accordance with ISO 14284.

7.6.7   Inclusion cleanliness

The inclusion cleanliness shall be determined by one of the test methods as described in annex D. The acceptance criteria are defined in annex D in conjunction with the test method proofed by suppliers certificate.

Unless otherwise specified in the technical specification, the test piece is taken from the bar of the same cast as the spring material.

7.7   Mechanical requirements

7.7.1   Hardness

The hardness test on the spring (surface and internal) is performed by the ROCKWELL method in accordance with the applicable International Standards. BRINELL or VICKERS are permitted alternative methods, the hardness values as per different methods shall be compared by means of ISO/TR 10108. The test of the hardness on the surface is to be performed on the spring.

Unless otherwise specified in the technical specification, the test pieces shall be taken from the bar, utilised for the manufacture of the spring and heat treated according to the identical process as the spring.

7.7.2   Tensile strength

The test for the yield limit of the material shall be performed according to EN 10002-1 on test pieces in accordance with EN 10083-1.

Unless otherwise specified in the technical specification, the test pieces shall be taken from the bar, utilised for the manufacture of the spring and heat treated according to the identical process as the spring.

7.7.3   Resilience

Unless otherwise specified in the technical specification:

⎯ the resilience test shall be performed according to EN 10045-1 on test pieces, taken from the bar in accordance with EN 10083-1;

⎯ the test piece shall be taken from the bar, utilised for the manufacture of the spring and heat treated according to the identical process as the spring.

7.8   Surface protection

Depending from the type of test and the size of the spring, the test piece shall be the spring or a normalised test piece.

The evaluation criteria shall be in accordance with EN ISO 10289. The verification of the resistance in the salt spray test shall be according to ISO 9227.

8 Quality of the product

8.1 General

The plant of the spring manufacturer shall be qualified to produce the helical suspension springs of the required quality level. The quality control system of the supplier shall be organised. A summary of relevant standards is contained in the Bibliography.

The assessment of the supplier's quality system may be performed directly by the customer or by an organisation independent of both contracting parties.

The staff trained in non-destructive testing shall be qualified in accordance with EN 473.

The representative of the customer shall be permitted to carry out all the verifications necessary to ensure that all the conditions specified by the order for the manufacture of the material and of the springs are satisfied.

8.2 Product qualification procedures and samples

Before being used on a rail vehicle a spring shall be qualified accordingly.

A certification of the spring is necessary in the following cases:

Case 1   spring of a new manufacturer;

Case 2   new spring of a known manufacturer (spring featuring at least one difference to a spring already qualified);

Case 3   qualified spring to be produced by a known manufacturer, when there are new more severe operational conditions (new technical specifications);

Case 4   changes in the manufacturing procedures of a qualified spring with a known manufacturer, including changes in manufacture of the steel bars.

All springs which are part of the necessary sample for the qualification tests shall be out of the same manufacturing lot (same basic material and same manufacturing procedure).

The sample shall be representative of the actual manufacturing process.

The sample shall comprise, as a minimum, the number of springs necessary for one vehicle and shall be defined in the technical specification.

The qualification procedure shall consist of two phases:

Phase 1:   Verification of the conformity to the technical specification and requirements of 6.1;

Phase 2:   Verification of the conformity to all characteristics in clauses 5 and 6 of this standard and defined in the technical specification.

Phase 2 of the qualification procedure of the springs, with the exception of those supplied by a new manufacturer (case 1) can be simplified in accordance with the quality assurance system in force with the manufacturer. The verification of known characteristics such as the material data or the behaviour of the corrosion protection system already in use with the supplier, can be optional.

A simplified qualification procedure shall be, in any case, subject to a separate agreement between customer and supplier.

The qualification of the product is granted if the following conditions are fulfilled:

— the technical specification is approved by the customer (phase 1);

— the characteristics of the spring are in accordance with the requirements of this norm and those defined in the technical specification (phase 2).

After the qualification of the product, any modifications in design, changes in manufacturing procedures or modification in the manufacturing plant, shall be communicated to the customer before implementation.

The customer can cancel the qualification of the product. The qualification of the spring can be cancelled:

— after an interruption of fabrication of more than one year;

— after systematic service failures of the springs.

The customer shall announce to the manufacturer the application and details of the intended qualification procedure.

8.3 Control and monitoring of production quality

8.3.1 General

The control of the product shall take the form of:

a) a quality assurance plan for in-process inspection and testing; or

b) a control by sampling lots in accordance with the requirements of this standard.

The manufacturer shall propose the methods for the control and monitoring of production quality in his offer.

If certain characteristics defined in clauses 5 and 6 require per unit checking on each spring delivered, these checks and tests have to be agreed between the parties.

8.3.2 Quality assurance plan

The quality assurance plan shall be in accordance with an approved quality system for the products, shall make reference to the quality manual of the manufacturer and shall address the specific elements for the spring.

NOTE   Guidance on approved quality systems is given in the EN ISO 9000 series.

This plan shall take into account the manufacturing procedures and shall offer the same confidence level with respect to the characteristics of the product as does the verification by lots. Customer and manufacturer shall agree whether the quality assurance plan is to be presented and approved.

If any non-conformity is detected by the customer on the products delivered, the application of the quality assurance plan can be suspended. In this case the checking and the tests as defined by "Control by sampling lots" shall apply.

8.3.3 Control by sampling lots

One lot is composed of springs according to the same technical specification, manufactured according to the same procedures and made from the same material (same cast).

The checks shall be performed in accordance with the definition in Table 5.

Where no sampling plan is defined in the technical specification, the statistical control of certain characteristics shall be done according to the checking frequencies indicated in Table 6.

8.4   Final acceptance requirements

8.4.1   General

Any requirements concerning a final acceptance inspection or reception tests by the customer or by an organisation independent of the contracting parties are part of the contract and shall be made known.

A guideline for the checks is given in Tables 5 and 6.

Table 5 — Checks and tests to be effected according to spring category

Characteristic to be verified	Reference	To be agreed	Final test	
			category A	category B
Reference length	7.5.2		✳	✳
Axial stiffness	7.2.2		✳	✳
Transverse stiffness	7.3	•	✳	
Bowing (direction, force, angle)	7.4	•	✳	
Material cross section			✳	✳
Spring diameter	7.5.1		✳	✳
Space requirements	7.5.3		✳	✳
Form and type of end coil	7.5.4		✳	✳
Contact line length	A.4	•	✳	
Non-perpendicularity	A.5		✳	✳
Surface finish	7.6.1		✳	✳
Surface protection	7.8	•	✳	✳

Table 5 *(continued)*

Internal integrity	7.6.5	●	(2)	(2)
Inclusion cleanliness	7.6.7	●#	✶	
Chemical composition	7.6.6	●#	(1)	(2)
Decarburization	7.6.3	●#	(1)	
Grain size	7.6.4	●#	(1)	
Hardness surface	7.7.1		✶	✶
Hardness core	7.7.1	●#	✶	
Tensile strength	7.7.2	●#	✶	
Resilience	7.7.3	●#	✶	
Superficial compression stress	7.6.2	●#	✶	✶
Marking	9		✶	✶

✶   control on basis of quality assurance plan or final control by lots

●   to be agreed

(1) 1 check per cast

(2) copy of steel manufacturer's inspection certificate

by special agreement between customer and supplier, these tests can be performed on the spring or on samples taken from a bar, processed at the same time as that for the spring.

Table 6 — Sampling for statistical checks, checking numbers

Number of springs per lot	10 to 50	51 to 150	151 to 300	301 to 500	501 to 800	801 to 1 300	1301 to 2 000	2001 to 3 000
Number of springs to be checked	5	8	12	17	23	30	38	47

8.4.2   Documentation

The traceability of the documentation shall be in accordance with an appropriate quality control system (see Bibliography). The supplier shall keep at the disposal of the customer or its representative all the documentation to permit verification of the process. This documentation shall include heat treatment furnace procedures and furnace charts and shot peening efficiency data.

The extent of documentation to be provided shall be specified by the order.

8.5   Non conformity

In case of non conformity the following rules shall apply:

in case of a per unit check:

—   rejection of the spring,

in case of a test according to quality assurance plan or per lot:

— rejection of the corresponding lot.

In this case a special control plan and acceptance criteria shall be defined between the customer and the supplier (unit control, corrective action, etc.).

9 Marking

Each spring shall be permanently marked with a system that remains legible during the service life (identification bandage, stamping on spring end, etc.). The identification system shall be approved by the customer.

The following indications shall be included:

— identification of manufacturer;

— code of the individual manufacturing plant, if the manufacturer has more than one plant;

— date of manufacture (month and year);

— any traceability code, if required;

— bowing for category A springs only (angle, force, direction);

— additional indications if required by the customer.

10 Packaging

The springs shall be packed, either individually or per delivery lot in order that they cannot deteriorate during transportation.

On the packaging the following indications shall be present as a minimum:

— identification of the supplier;

— contract number or purchase order number;

— quantity of articles in the package;

— designation of the articles.

Annex A
(normative)

Helical cylindrical compression springs with constant inclination, formed from cylindrical steel bars and featuring formed and ground ends

A.1 Object

This annex specifies the geometrical and dimensional characteristics such as the distance between the coils of the suspension springs, featuring the following elements:

— cylindrical springs;

— constant inclination;

— formed from cylindrical steel bars;

— formed and ground ends.

A.2 Inner and outer diameters

a) Definition

The definition of the inner D_i and the outer diameter D_e of cylindrical springs is given in the ISO 2162-2.

According to the installation conditions of the springs in the suspension system the technical specification shall define the value D_i together with its tolerance and/or the value of D_e together with its tolerance.

The default tolerances of D_i and D_e are defined in Table A.1.

Table A.1 — Tolerances of D_i and D_e

Diameter	Tolerance
D_i	1,5 % of D_i
D_e	1,5 % of D_e

b) Values to obtain

The inner diameter D_i and the outer diameter D_e shall be in accordance with the technical specification.

c) Control

The sample shall be the spring.

A.3 Ends of the spring

A.3.1 Type of spring ends

The ends of the springs as defined in this annex is the type D according to EN ISO 2162-2.

A.3.2 Extremities of the end coils

a)   Values to obtain

Unless otherwise stipulated in the technical specification, the extremity of each end coil shall feature, after the grinding of the spring ends, a thickness between 3 mm and one quarter of the nominal cross section of the bar.

c)   Control

The sample shall be the spring.

A.4 Contact line

a)   Characteristic

The length of the contact line between the end coil and the adjacent active coil varies as a function of the applied axial force.

b)   Values to be obtained

The length of the contact line (on both spring ends) shall be at least 0,33 of the mean diameter D while the spring is subjected to an axial static load F_v as defined in 5.2.3.1 (axial stiffness).

c)   Control

The sample shall be the spring.

— Test conditions:
   During the test the spring ends shall remain parallel and coaxial.

— Test method:
   The spring shall be submitted to an axial compression load, including the following operations:

   — applications of an axial load increasing from 0 to F_V;

   — maintaining a load F_V at ± 1 %;

   — measurement of the length of the contact line.

NOTE   This measurement can be taken during the measurement of the axial stiffness as defined in 5.2.3.1.

A.5 Geometrical tolerances

a)   Characteristic

The ends of the springs as defined in this annex shall be perpendicular to the spring axis and shall be parallel.

The technical specification shall define the limit deviation of the perpenducularity of the ends with reference to the spring axis.

The default values of the deviation of the perpendicularity with reference to the uncompressed spring is defined as follows:

— for springs with a free length of $L_0 \leq 150$ mm p $\leq 2\%$ of L_0 ;

— for springs with a free length of $L_0 > 150$ mm p $\leq 1{,}5\%$ of L_0 ;

b) Values to obtain

The deviation of the perpendicularity of the spring ends shall be smaller or equal to the maximum value as defined in the technical specification.

c) Control

The sample is the spring.

Test method:
The deviation from the perpendicularity of the spring is performed by means of a fixed square set as defined below.

The spring is placed on a flat surface and placed against a vertical pole on this surface.
It then is rotated until the position with the maximum deviation is found (see Figure A.1).

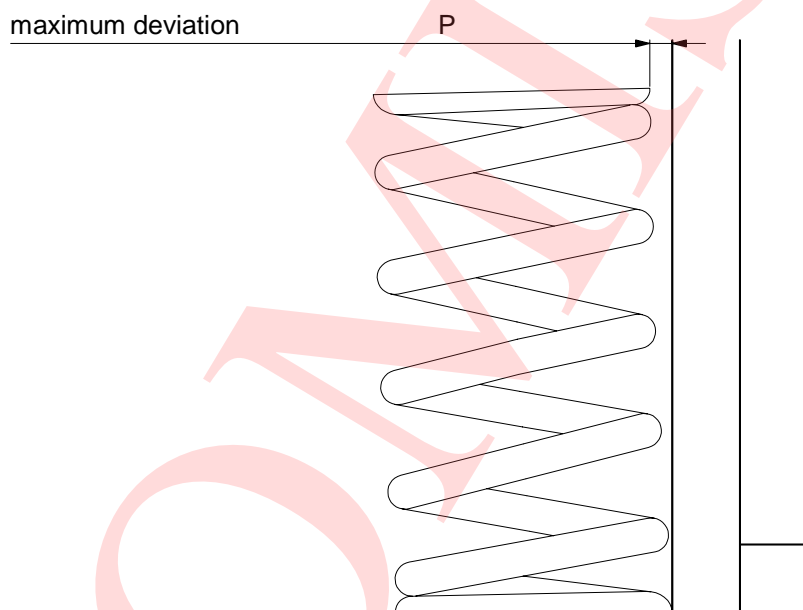The measurement shall be taken with the spring placed on the two ends.

Figure A.1 — Measurement of the perpendicularity

A.6 Distance between the coils

A.6.1 Method 1

a)   Definition

Method 1 can be used to determine the clearance between active coils of cylindrical helical springs with constant inclination, made from circular material and featuring ground and formed ends.

The distance between the active coils is defined by the coefficient of clearance which represents the distance between the coils in regard to the bar diameter.

The coefficient of clearance shall be determined by the following equations:

$$\alpha = \frac{L_j - (n+1)d}{n \times d} \tag{A.1}$$

with

$$n = \frac{G \times d^4}{K_s \times (D_i + D_e)^3} \tag{A.2}$$

The definition of the terms used in the equations can be found in 3.2.

The technical specification shall define minimum value of the coefficient of clearance while the spring is subject to a defined static load F_j.

For springs which are installed in vehicles, where the axial load is proportional to the loading condition, it is recommended to respect the values as defined in Table A.2:

Table A.1 — Coefficients of clearance

Axial load	Category	α_{min}
F_j	A	0,4
F_j	B	0,3

Unless otherwise specified, the force $F_j = F_B$

Definition: the load F_B is derived from:

   $m_{VOM} \cdot g$ for locomotives;

   $(m_{VOM} + 1,2 \times C2) \cdot g$ for passenger coaches;

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$(m_{VOM} + 1{,}2 \times C3) \cdot g$ for freight wagons.

where

C2 is the load mass as defined in UIC 515-4;

C3 is the maximum load mass which can be carried by vehicle;

VOM is the vehicle in running order.

b) Values to obtain

The coefficient of clearance shall be in accordance with the values given in the technical specification.

c) Test method

The sample is the spring.

Test method
The verification of the coefficient of clearance is performed by first measuring L_j, d, D_i, D_e and K_S of the spring and by applying the equations (A.1) and (A.2).

The length L_j of the spring when subjected to the static axial load F_j shall be measured according to the methods as defined in 7.2.1.

The static axial stiffness K_S shall be determined according to the method as defined in 7.2.2.

A.6.2 Method 2

a) Characteristic

Method 2 is based on the determination of the remaining deflection Σe between the coils over the entire spring length, when the spring is subjected to the load F_j and the solid length.

The remaining deflection is:

$$\Sigma e = L_M - L_c \tag{A.3}$$

with

$$L_c \leq d \times (n_t - 0{,}3) \tag{A.4}$$

NOTE d includes the allowable tolerance of the wire thickness as well as the thickness of the surface protection.

The minimum Σe shall be defined in the technical specification.

For category B springs as well as category A springs with the criteria $r_j / D = 0{,}05$ and $L_M/D \geq 2$ the following remaining deflection is recommended

$$\Sigma e \geq 0{,}02 \times D_e \times n \qquad \text{(A.5)}$$

For the remaining category A springs the following recommendation is valid:

$$\Sigma e \geq 0{,}04 \times D_e \times n \qquad \text{(A.6)}$$

The remaining deflection depends from the value of the lateral displacement and the slenderness of the spring.

b)   Values to be obtained

The remaining deflection shall be in accordance with the values indicated in the technical specification.

c)   Test method

The verification is performed by compressing the spring to length L_M and then L_C as indicated in 7.2.1. Then the difference in length is calculated. This test shall be done with the spring before application of the surface protection. If the spring can not be tested to the solid length due to design reasons, a calculation of the remaining deflection is sufficient.

Annex B
(normative)

Materials for hot formed and treated helical suspension springs

B.1 General

The mechanical and chemical properties of alloyed steels which can be used for the manufacture of hot-formed helical suspension springs are described in prEN 10089.

Annex D (informative) of prEN 10089:1998 shall be taken as normative reference for the purposes of this standard.

B.2 Material for helical suspension springs, steel

The material for helical suspension springs as defined in this standard is to be selected according to prEN 10089.

Annex C
(normative)

Repeatability of prestressing by means of shot peening

C.1 Object

The control of the parameters of the shot peening procedure is essential to guarantee the reproducibility and uniformity of the shot peening between the individual springs and between the manufacturing lots.

The properties of the shot, its size, its form, its hardness and its impact speed and angle shall be tightly controlled in order to achieve a uniform result.

In order to master the shot peening process two parameters, amongst others, shall be verified:

— intensity of the blast;

— covering of the beaten surface.

C.2 Check of the intensity

C.2.1 Generalities

The quantification of the impact energy of the shot is essential for the control of the shot peening operation.

The ALMEN method is considered to be one of the effective possibilities to assure the intensity and the reproducibility of the shot peening procedure.

The designation of an ALMEN intensity shall include:

— ALMEN bow height;

— type of test sample.

C.2.2 ALMEN method

a) Definition of the test sample

Three types of test samples can be used (N, A, C). The test samples are differentiated by their thickness:

— Type N: 0,8 mm;

— Type A: 1,3 mm;

— Type C: 2,4 mm.

The characteristics of the samples are given in Table C.1. The limitation of the utilisation of the samples is as follows:

— Type N: up to a bow height of 0,45 mm;

— Type A: bow height from 0,1 mm to 0,6 mm;

— Type C: bow height of more than 0,15 mm.

An ALMEN test sample shall not be re-utilised after shot peening.

NOTE   The ALMEN test sample type A should be utilised if possible, the other types can be utilised if the bow height of the type A sample is out of limits.

Table C.1 — Characteristics of the test sample

Characteristics	Value
Steel	Cold rolled with the following chemical composition $0,65 \leq$ C $\leq 0,73$ $0,40 \leq$ Mn $\leq 0,70$ $0,15 \leq$ Si $\leq 0,35$ P $\leq 0,035$ S $\leq 0,035$
Hardness	44 HRC to 50 HRC
Length	$(76,2 \pm 0,4)$ mm
Width	$(19 {}^{+0,05}_{-0,10})$ mm
Thickness	$(1,30 {}^{+0,02}_{-0,03})$ mm
Flatness	surface between 2 parallel planes 0,04 mm apart

b)   Test methods

With this method a ALMEN test sample is fixed to a metallic base as defined in Figure C.1. Then the test sample is exposed to the same shot peening procedure as the spring.

The ALMEN test sample supports shall be mounted

— either on a spring with the same dimensions as the springs to be checked;

— or, if a spring with the same dimensions is not available, to a spring with similar geometrical dimensions.

The number of samples to be mounted on the "sample carrying spring" depends on the free length L_O of the spring.

— $L_O \geq 500$ 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.

— $500 > L_O \geq 300$ mm   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.

— $L_O < 300$ 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.

Dimensions in millimetres
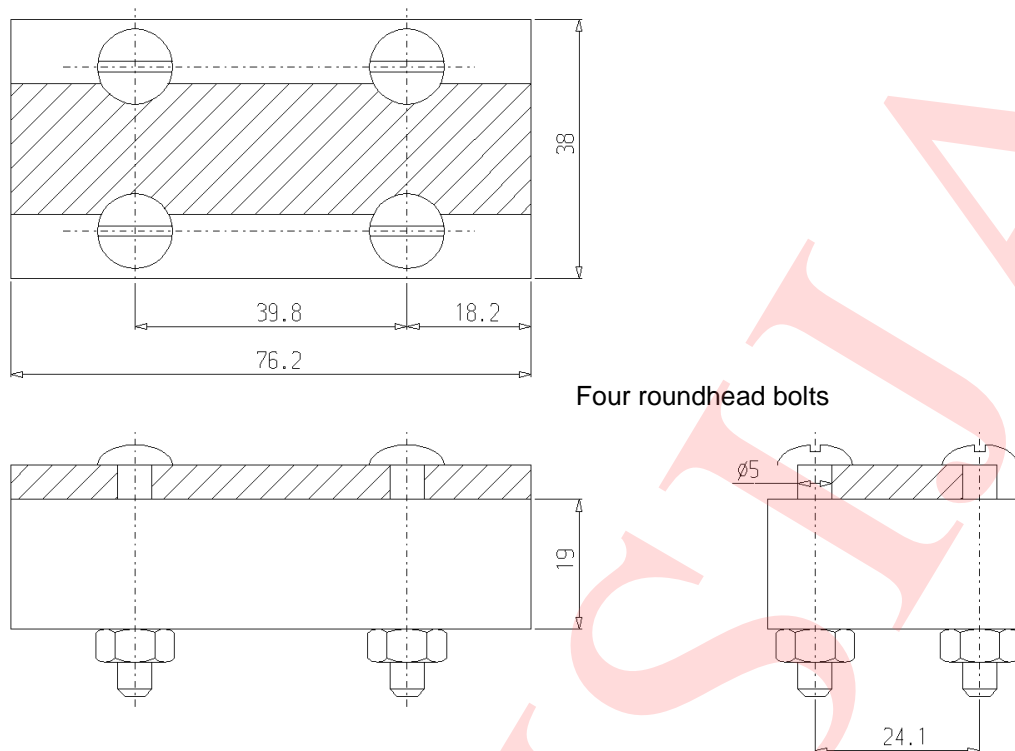

Figure C.1 — ALMEN test fixture

Hardness of the steel support: between 62 HRC and 65 HRC

c)   Values to be obtained

After removal of the sample from the support the residual stress and the plastic deformation of the surface as a result of the shot peening produces a bowing of the sample in the direction of the shot peened surface.

The ALMEN bow (height of the bow measured with the ALMEN system as defined in Figure C.2) shall be between 0,4 mm and 0,6 mm on the test sample type A, provided that no different values are defined in the technical specification.

A specific correlation shall be performed for the ALMEN bows of the test samples type C and N.

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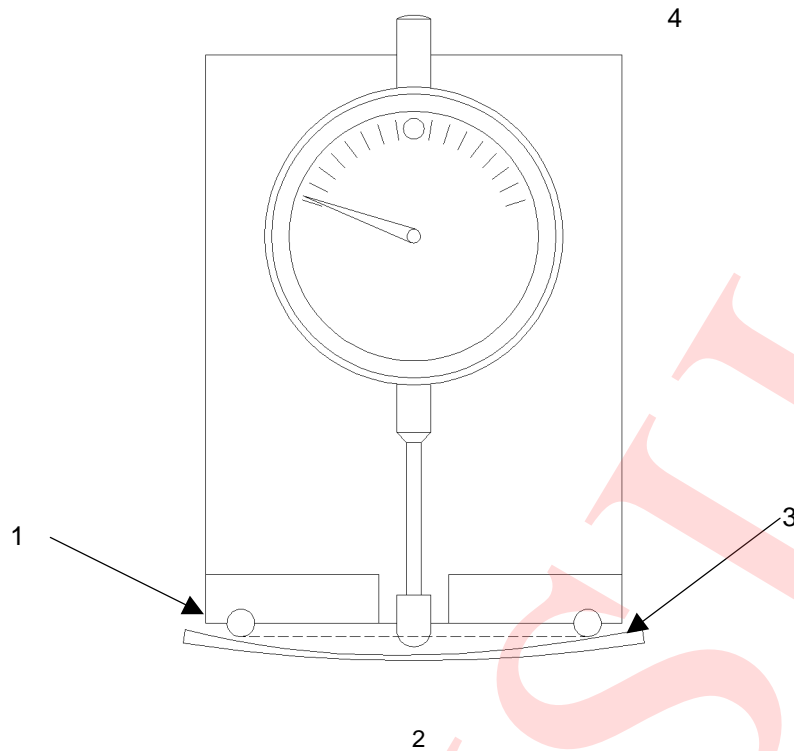
Key
1   Hardened steel balls
2   ALMEN bow
3   Test sample
4   Micrometer

Figure C.1 — ALMEN measuring system

The ALMEN measuring system is designed to measure the bow height of the test sample. It is a micrometer (scale 1/100 mm) mounted on a support with four hardened steel balls which are forming the corners of a rectangle and which are firmly fixed in a plane.

C.3 Check of the covering

a)   Definition

The covering is achieved if the surface of the spring is completely and uniformly shot peened (100 % covering).

b)   Test method

The check of the surface covering is performed visually with help of a magnifying glass with an magnification factor of 10 or by an other method as accepted by the customer.

Annex D
(normative)

Examination for inclusions

D.1 Object

At the time of publication of this European Standard no European Standards exist for the microscopic verification of non metallic inclusions in special steels. Various procedures are standardised in national standards. Up to the publication of an EN the customer and the supplier will have to agree on the application of one of the following national standards.

DIN 50 602:1985, *Metallographic examination; microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions.*

NF A 04-106:1984, *Iron and steel – Methods of determination of content of non metallic inclusions in wrought steel – Part II: Micrographic method using standard diagrams.*

NOTE   The standard NF A 04-106 is similar to ISO 4967:1998.

SS 11 11 16:1987, *Steel – Method for assessment of the content of non-metallic inclusions – Microscopic method – Jernkontoret's inclusion chart II for the assessment of non-metallic inclusions.*

D.2 Test methods

D.2.1 Test method according to DIN 50 602

If it is agreed to use the method according to DIN 50602 the requirements of Table D.1 shall be respected.

Table D.1 — Degree of cleanliness under the microscope according to DIN 50 602 (procedure K), valid for non metallic oxide inclusions

Steel bars Diameter d mm	Cumulated coefficient K (oxides) for each cast
$140 < d \leq 200$	K4 ≤ 50
$100 < d \leq 140$	K4 ≤ 45
$70 < d \leq 100$	K4 ≤ 40
$35 < d \leq 70$	K4 ≤ 35
$17 < d \leq 35$	K3 ≤ 40
$8 < d \leq 17$	K3 ≤ 30
$d \leq 8$	K2 ≤ 35

D.2.2 Test method according to NF A 04-106

If it is agreed to use the method according to NF A 04-106 for the examination, the requirements of Table D.2 shall be respected.

The assessment is effected with reference to Table 1, method B.

For material with a cross section of more than 30 mm, the isolated inclusions of type D are acceptable, if their diameter is lower than 50 µm.

Table D.2 — Acceptable number of fields (small series and wide series) of each type

Type of inclusions Index	A	B	C	D
1	10	20	10	30
2	1	5	1	5
3	0	1	0	0

D.2.3 Test method according to SS 11 11 16

If it is agreed to the method according to SS 11 11 16 for the verification of the inclusions, the requirements of Table D.3 shall be followed.

Table D.3 — Degree of cleanliness by microscopic examination according to norm SS 11 11 16 (maximum values)

Type of inclusion	Series	Width of inclusion
Type B	fine	≤ 4
	middle	≤ 3
	wide	≤ 2
Type C	fine	≤ 4
	middle	≤ 3
	wide	≤ 2
Type D	fine	≤ 4
	middle	≤ 2
	wide	≤ 1

Annex E
(normative)

Magnetic detection of surface imperfections of helical springs formed from cylindrical steel bars

E.1 Object

This annex specifies the specific conditions to be applied when checking the surface integrity of helical springs, formed from cylindrical steel bars by means of magnetoscopic methods.

E.2 Methods

Two methods of exciting are necessary in order to detect the defects parallel to the axis of the bar (longitudinal defects) and the defects which are more or less perpendicular to the axis of the bar (transverse defects).

— longitudinal defects: exciting by passage of the current in the direction of the longitudinal axis of the spring;

— transverse defects: excitement by passage of pass the current in an auxiliary conductor, which is placed in the axis of the solenoid, formed by the spring.

The inspection equipment employed shall be capable of achieving magnetisation of the ring as specified above with a magnetic field strength of minimum 3 kA/m for each direction of magnetisation. The induction level is identified by the intensity of the magnetising current.

Defects are detected using a magnetic solution containing fluorescent particles, such liquid shall have no harmful effects on the parts being examined. The inspection is carried out under UV-light of at least 15 W/m^2 light intensity, measured at a distance of 0,3 m. The surrounding light intensity shall be ≤ 10 lx.

A verification of the system sensitivity shall be carried out on site. This shall include measuring the field strength as well as the use of reference rings with real defects of known type, location, size and distribution. Where these are not available, fabricated reference rings with artificial defects may be used.

NOTE   The detection of defects with a different orientation than the ones mentioned above can be performed by the same method but with a higher magnetic intensity. In this case the systematic differentiation between longitudinal and transverse defects is not possible.

E.3 Special precautions

In order to avoid the creation of any electrical arcs by the current passing in the spring, special care has to be taken in the application of the electrodes at the spring ends.

After the passing of the current a considerable residual induction can remain especially in the spring ends. The magnetic check therefore shall be followed by the demagnetisation, which could be performed by passing an alternating current through the spring wire. The current shall be steadily reduced from its maximum to zero. After this operation the residual magnetism on any point of the spring surface shall not exceed 0,3 kA/m.

Bibliography

EN ISO 9000:2000, *Quality management systems – Fundamentals and vocabulary (ISO 9000:2000).*

EN ISO 9001:2000, *Quality management systems - Requirements (ISO 9001:2000).*

UIC leaflets

UIC 822:1985, *Technical specification for the supply of helical compression springs, hot or cold coiled, for tractive and trailing stock.+*

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