BRITISH STANDARD

BS EN
15049:2007

Railway applications — Suspension components — Torsion bar, steel

The European Standard EN 15049:2007 has the status of a British Standard

ICS 45.060.01

BSI
British Standards

National foreword

This British Standard is the UK implementation of EN 15049:2007.

The UK participation in its preparation was entrusted to Technical Committee RAE/3, Railway rolling stock material.

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Foreword

This document (EN 15049:2007) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This document shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2008 and conflicting national standards shall be withdrawn at the latest by February 2008.

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

Introduction

Work on this European Standard started at the beginning of 2002 with the aim of incorporating the existing documents, such as UIC leaflets (International Union of Railways) and the internal standards of the various railways as well as national standards into one standard.

1 Scope

This European Standard applies to torsion bars made of steel for anti-roll bar systems used on railway vehicles.

This European Standard includes straight and bended torsion bars, but does not detail the other components of the anti-roll bar systems such as levers, bearings, bushes etc.

This European Standard constitutes guidelines on the following topics:

— design;

— specification of technical requirements;

— production requirements;

— tests;

— supply conditions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 method*

EN 10089, *Hot-rolled steels for quenched and tempered springs — Technical delivery conditions*

EN 10204, *Metallic products — Types of inspection documents*

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

EN 10247, *Micrographic examination of the non-metallic inclusion content of steels using standard pictures*

EN 13925-2, *Non-destructive testing — X-ray diffraction from polycrystalline and amorphous materials — Part 2: Procedures*

EN ISO 643, *Steels — Micrographic determination of the apparent grain size (ISO 643:2003)*

EN ISO 1302, *Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation (ISO 1302:2002)*

EN ISO 2162-3:1996, *Technical product documentation — Springs — Part 3: Vocabulary (ISO 2162-3:1993)*

EN ISO 3887, *Steel — Determination of depth of decarburization (ISO 3887:2003)*

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

EN ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T) (ISO 6508-1:2005)*

EN ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles (ISO 9934-1:2001)*

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

EN ISO 18265, *Metallic materials — Conversion of hardness values (ISO 18265:2003)*

DIN 50602, *Metallographic examination — microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions*

NF A04-106, *Iron and steel. Methods of determination of content of non metallic inclusions in wrought steel. Part II: micrographic method using standards diagrams*

SS 111116, *Steel — Method for estimation of the content of non-metallic inclusions — Microscopic methods — Jernkontoret's inclusion chart II for the assessment of non-metallic inclusions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 2162-3:1996 and the following apply.

3.1
anti-roll bar system
suspension system having an influence on the rolling behaviour of the vehicle. Generally, it includes the torsion bar and any other components

3.2
anti-roll bar
spring bar which is mainly stressed by a torsional moment. It can either be produced as bended bar or a straight torsion bar with levers

3.3
straight torsion bar
straight spring bar which is mainly stressed by a torsional moment

NOTE The term "torsion bar made of steel" refers to the finished end product. For the purpose of simplification, the term "torsion bar" is used in the wording of this European Standard for anti-roll bars with torsion bars of round cross section and made of steel.

3.4
bended torsion bar
mainly U-shaped and manufactured out of round spring material

4 Symbols and abbreviations

The symbols and abbreviations used in this standard are listed in table 1. All parameters are expressed as SI basic units and units derived from SI basic units. Decimal multiples and submultiples of units defined in Table 1 can be used.

Table 1 — Symbols and definitions

Symbols	Units	Definitions
A	%	Elongation at rupture
d	m	Outer diameter of the middle part of the torsion bar
d_a	m	Outer diameter of the torsion bar in the area of bearing
d_f	m	Root diameter of the head profile
d_p	m	Diameter of shrink fit
e	m	Area to take test pieces
F	N	Applied load at the lever
l	m	Distance between load application and middle of torsion bar
L_f	m	Distance between the two load application points
L_a	m	Length between the centre of the two bearings
L_s	m	Length between the centre of the two levers
l_x	m	Crank depth in the middle part of the torsion bar
l_z	m	Distance between load application and centre of the bearing
M_t	Nm	Torsional moment
M_{tmax}	Nm	Max. torsional moment
ΔM_t	Nm	Difference of torsional moments
r	M	Bending radius of bended torsion bar

Table 1 (*concluded*)

Symbols	Units	Definitions
R_m	Pa	Material strength
$Rp0,2$	Pa	Yield strength
R_t	Nm/degree	Torsional spring rate
Z	%	Percentage reduction of area after fracture
δ	-	Depth of residual stress
σ_D	Pa	Residual stress
ϑ	degree	Angle of twist
ϑ_{max}	degree	Max. angle of twist
ϑ_A	degree	Angle of twist at the beginning of stress
$\Delta\vartheta$	degree	Difference of angles of twist
τ_{zul}	Pa	Permissible shear stress

5 Requirements

5.1 Introduction

The component shall be defined in a technical specification which consists of the following documents (see 5.2 and 5.3).

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

5.2 Documents to be provided by the customer

The customer shall provide a technical specification including:

An interface drawing (possibly, a general assembly drawing of the mechanical system or a sub-assembly drawing) defining at least:

— the space envelope;

— the functional dimensions and their tolerances;

— the application points of the forces;

— a technical specification detailing at least:

  — the conditions of utilisation (forces, movements, temperatures, assembly, environment, maintenance, storage etc.);

  — the requirements (characteristics of the product, tolerances and expected service life);

  — the approval procedure and type test requirements (e.g. characteristics to be checked and tests to be carried out, order of tests and checks).

The product requirements given in Table 2 shall be defined by the customer:

Table 2 — Elements to be defined in the technical specification and agreed by the parties

Characteristic to be defined	Reference
Space envelope	6.1
Spring rate	5.5
Maximum anti-roll angle or moment, for static (exceptional loads)	5.5
Maximum anti-roll angle or moment for dynamic (fatigue condition)	5.5
Service life requirement	6.2.2
Material	6.3.1
Toughness	8.4
Surface protection	6.4
Marking	Clause 10

5.3 Documents to be provided by the supplier

The supplier of the torsion bar shall provide a technical documentation defining its product, including at least a component drawing.

This documentation shall detail any information required in the technical specification of the customer.

5.4 Design analysis

The principal characteristics of the torsion bar (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 etc.);

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

The customer and the supplier shall agree on the contents of the documentation and on the analysis method to be used.

5.5 Arrangement and design

The individual bar with circular cross section is the starting point in the design of torsion bars.

The introduction of the torsional moment into torsion bars is mostly effected by rockers which are connected to the torsion bar ends through positive or non-positive locking. By means of the rocker, a force acting vertically

with regard to the bar axis is transformed into a moment and the resulting torsion of the free torsion bar end into a displacement of the force introduction point.

The transformation of a vertical movement into a torsion bar attained by means of the rockers allows this combination to be used in an advantageous way as anti-roll device of rail vehicles.

The arrangement of the torsion bars as anti-roll device in the rail vehicle is effected in transverse direction, the bar axis being for the most part aligned parallel to the track plane.

A principle representation for the purpose of symbol illustration is shown in Figures 1 and 2.

The torsion bar (antiroll bar) and the stabilizer are working around zero position with alternating loads. They are not pre-tensioned during manufacturing.

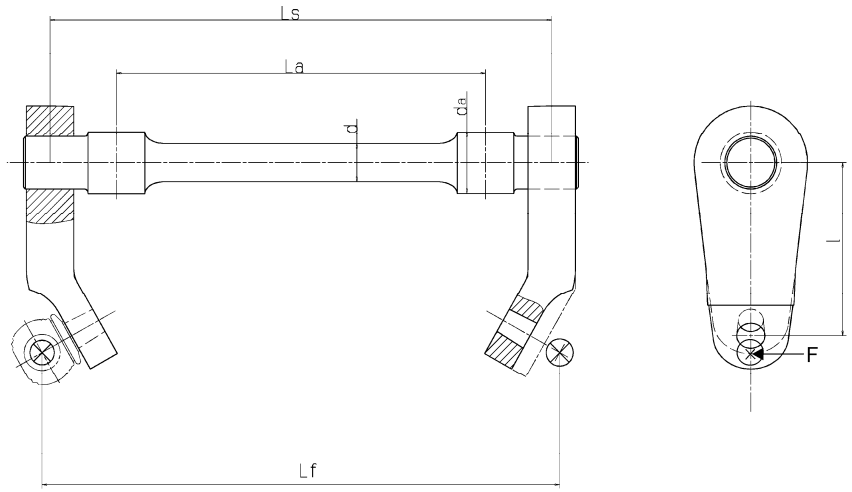


Figure 1 — Example for a straight torsion bar with mounted levers

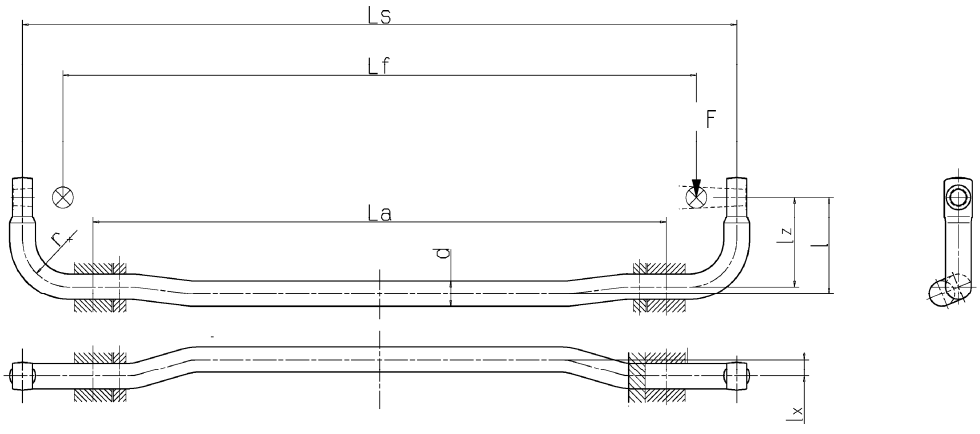


Figure 2 — Example for a bended torsion bar

5.6 Straight torsion bar ends and connections

5.6.1 General

The dimensioning and design of straight torsion bars require special attention regarding the areas of force introduction, as, in most cases, supplementary stresses which can strongly affect the service life of the spring elements work in this region.

As regards straight torsion bars, for the purpose of stress transmission, in most cases, ends are forged which ensure the connection to the levers by means of serrations or slip joints through interference fit.

5.6.2 Design of the straight torsion bar end

Figures 3 and 4 are showing execution types of straight torsion bar lever connections.

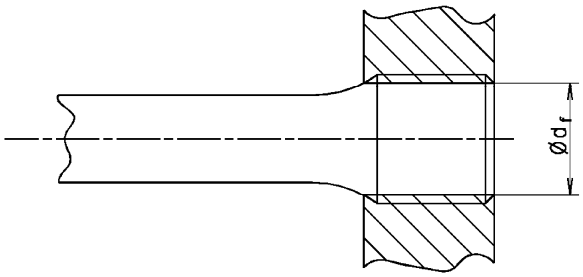
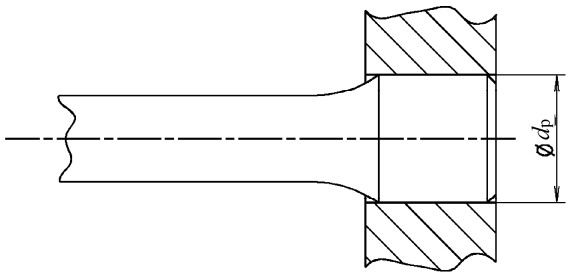


Figure 3 — Cylindrical or conical tooth system

NOTE Special care should be taken when using cylindrical toothings for torsion bar heads subjected to alternating stress because of clearance.



Key

d_p recommended shrink fit to be entered

Figure 4 — Frictional shrink fit

6 Product definition

6.1 Geometrical characteristics and space envelope

The shape and dimensions with their corresponding tolerances of the finished anti-roll bar shall be defined in the technical specification.

The geometrical and functional characteristics shall be defined on the component drawing of the torsion bar.

Restrictions regarding the space requirement and enveloping space shall be specified in the technical specification.

6.2 Mechanical requirements

6.2.1 Loading and allowable stresses

The loading to which components are submitted and allowable stresses shall be defined in the technical specification. They shall be agreed between customer and supplier.

The torsion bar shall be able to withstand the mechanical stresses during its functioning in service, without any deterioration or permanent deformation.

6.2.2 Service life

The dynamic stress alterations in the operational phase determine the obtainable duration of service life. The service life of the torsion bar shall be defined in the technical specification. It shall be agreed between customer and supplier.

A static loading is:

— a loading constant in time.

A quasi-static loading is:

— a loading variable with time with negligibly small stress range (stroke stress) (e.g. stress range up to 0,1 $\times$ fatigue strength);

— a variable loading with greater stress range but only a number of cycles of up to 10^4.

A dynamic loading is:

— a loading variable with time with a number of loading cycles over 10^4 and stress range greater than 0,1 $\times$ fatigue strength at:

a) a range of constant stress;

b) a range of variable stress.

6.2.3 Investigation of the strain

The strain in the cross section of torsion bars is a combination of torsional and bending stress. The comparison-tension can be adequately determined analytically with existing calculation programs. A verification by means of a Finite Element Method (FEM) analysis can take place according to application-case.

6.2.4 Evaluation of the strain

The dimensions of straight and bended torsion bars are determined at given torsional stiffness and the agreed allowable stress in order to achieve the service life and the maximum roll angle during service.

Anti roll bars – consisting of straight torsion bars with levers or U-shaped bended bars – are mainly working alternated around zero stress position. The design condition is mainly unloaded or the unloaded line is the zero position.

Straight torsion bars and U-shaped bended bars for anti-roll bars are not preset.

a) allowable statical stresses

The allowable load strain depends on the torsion bar diameter, the surface quality and the tensile strength after tempering.

b) allowable dynamic strain

Anti roll bars are specifically project designed. If necessary, the life endurance shall be proved by a fatigue test.

NOTE For life time estimation, life cycle diagrams for alternate loaded parts could be taken from the existing literature or from experience of the supplier.

6.3 Physical requirements

6.3.1 Material grade

The characteristics of the material shall be appropriate to the requirements specified in the technical specification.

The alloy to be used for the manufacture of the torsion bar shall be defined.

It is recommended to use the alloys defined in EN 10089 (see also Annex A). It is permitted to use alloys different to those defined in EN 10089. In this case, the chemical and mechanical characteristics shall be completely defined.

The alloy of the torsion bar material shall be in accordance to Annex A for recommended material qualities.

6.3.2 Internal integrity

The material of the torsion bar shall not exhibit internal faults which would prove detrimental in use. Where it is necessary to establish that the internal integrity is acceptable, then tests as defined in 8.16 are to be carried out.

6.3.3 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.

6.3.4 Forged torsion bar ends

If not agreed otherwise, the torsion bar ends are forged.

When forging the torsion bar heads, attention shall be paid to the correct course of the fibres. The fibre course is checked in according to 8.9.

6.3.5 Decarburization

There are two types of decarburization:

— complete decarburization, where the upper layer has a pure ferrite microstructure;

— partial decarburization, where the surface of the torsion bar has a ferritic / pearlitic or ferritic / martensitic microstructure.

Complete decarburization is not permissible. Unless otherwise specified, the depth of partial decarburization shall be lower than 1 % of the outer diameter d of the torsion bar.

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

The decarburization test is defined in 8.7.

6.3.6 Surface condition

The surface quality of the torsion bar is kept under visual supervision before and after shot peening (without surface protection). The torsion bar shall not show any defects (seams, notches, tool marks, cracks etc.). The roughness of surfaces which have not been subjected to shot peening shall be defined.

The roughness of surfaces shall be defined according to EN ISO 1302.

Service life affecting surface defects are not permissible. The control of the surface condition shall be carried out according to 8.12.

Tool marks on bended torsion bars shall be limited.

6.3.7 Residual compressive stresses on the surface

Residual stresses produced by shot peening improve the fatigue behaviour of the torsion bar. Figure 6 shows a typical distribution of the residual stresses as a function of depth. The generation of residual stresses by means of shot peening is prescribed.

Parts of the torsion bar which are submitted to stresses during its functioning in service shall have residual compressive stresses on the surfaces (e.g. middle part of the torsion bar, tooth systems).

Unless otherwise specified, residual compressive stresses on the surfaces of the other parts of the torsion bar are permitted.

The technical specification shall define the parts of the torsion bar where residual compressive stresses on the surfaces are required.

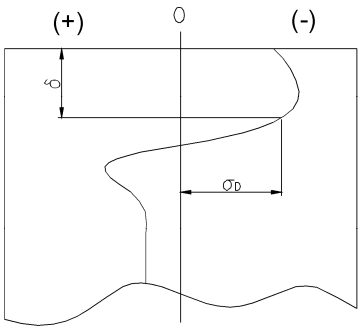
If not otherwise indicated in the technical specification, the following residual stress values are to be observed. The values given below are for straight bars only:

$\sigma_D \leq$ - 500 MPa at δ = 0,1 mm,

$\sigma_D \leq$ - 100 MPa at δ = 0,3 mm

inside the material.

The use of sharp-edged shot is not allowed.



Key

+ tension

- compression

Figure 5 — Example of the distribution of stresses produced by shot peening as a function of depth

6.3.8 Grain size

The index value of the austenitic grain size defined according to EN ISO 643 shall be 7 or higher.

6.4 Surface protection

6.4.1 Generalities

There are two kinds of protection:

A temporary protection: Designed surfaces shall be protected against corrosion as minimum until mounting of the torsion bar on the vehicle.

A permanent protection: Designed surfaces shall be protected against corrosion during a defined period of functioning in service.

6.4.2 Temporary protection

The system selected and its duration of efficiency shall be defined by the supplier in the definition documents of the torsion bar and submitted to agreement by the customer.

6.4.3 Permanent protection

The customer shall define in the technical specification its requirements such as:

— the decoration characteristics (colour, reflecting brightness etc.);

— the mechanical characteristics (resistance to impact, gravelling, abrasion, deformation by folding etc.);

— the ageing characteristics (resistance to salt spray etc.).

The system of protection against corrosion shall be defined on the component drawing of the torsion bar.

6.5 Characteristic moment of torsion / angular displacement

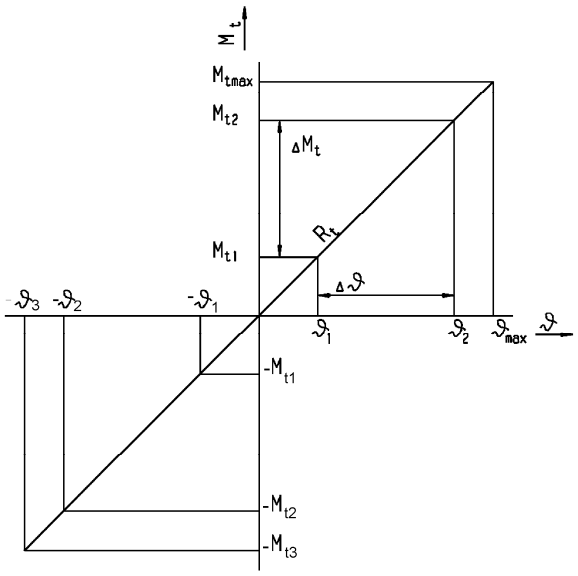
The technical specification shall define at least:

— the application points of forces necessary to apply a moment of torsion;

— the values to be obtained (criteria);

— the method of definition.

Unless otherwise specified, the characteristic moment of torsion / angular displacement is defined by the ratio of change of moment of torsion to the corresponding change of angular displacement (see Figure 1). Figure 6 is a theoretical representation of a torsion bar diagram with the used equation symbols.



$\Delta M_t = M_{t2} - M_{t1}$

$\Delta \vartheta = \vartheta_2 - \vartheta_1$

$$R_t = \frac{\Delta M_t}{\Delta \vartheta}$$

Figure 6 — Torsion bar diagram

NOTE $-M_{t1}$ to $-M_{t3}$ and $-\vartheta_1$ to $-\vartheta_3$ are values for the counter loading direction.

The characteristic moment of torsion / angular displacement is determined by using the following equation:

$R_t = (M_{t2} - M_{t1}) / (\vartheta_2 - \vartheta_1)$

with: $M_{t1} < M_{t2}$ and $\vartheta_1 < \vartheta_2$

NOTE Values of M_{t1} and ϑ_1 can be negatives when the characteristic is defined on an alternative movement (crossing by 0).

The technical specification shall define:

— the data values: (M_{t1} and M_{t2}) or (ϑ_1 and ϑ_2);

— the values to be obtained: (ϑ_2 - ϑ_1) or (M_{t2} - M_{t1});

— the tolerances.

6.6 Mass

The mass of the torsion bar shall be defined on its component drawing.

7 Mechanical properties for manufacturing

7.1 Hardness

The surface hardness in HRC, which is measured after heat treatment and before shot peening, shall be between 48 HRC and 52 HRC for straight torsion bars and between 45 HRC and 50 HRC for bended torsion bars. Definition of hardness with other units shall be agreed. The values for tensile strength shall be converted according to EN ISO 18265.

7.2 Tensile strength

By special agreement a tensile strength test shall be carried out for determination of the yield stress $R_{p0,2}$, the tensile strength R_m and the elongation at rupture A.

The tensile strength characteristics of the material of the finished torsion bar shall be defined in the technical specification.

Unless otherwise specified, the tensile strength of the finished torsion bar shall be as follows:

Straight torsion bars with ground surface after heat treatment, made of material according to EN 10089 shall reach a tensile strength R_m = 1 600 MPa to 1 800 MPa. The allowable torsional static shear stress for a bar diameter of 40 mm shall be τ_{zul} = 765 MPa.

Bended torsion bars may not be surface ground after heat treatment. To reduce the notch sensitivity the materials shall be tempered up to R_m = 1 450 MPa to 1 650 MPa according to EN 10089. The allowable torsional static shear stress for a bar diameter of 40 mm shall be τ_{zul} = 700 MPa.

In both cases the elongation at rupture shall be greater than 6 %.

7.3 Toughness

The notch impact characteristic of the material of the finished torsion bar shall be defined in the technical specification. Unless otherwise specified, the mean value of the notch impact strength (KU) shall be greater than or equal to 10 J (at a temperature of 20 °C). Each individual result of the tests defined in 8.4 shall be at least 75 % of the mean value.

8 Tests and test procedures

8.1 General requirements

If not otherwise specified, the test pieces for tests and measurements will be the finished anti-roll bar.

If not otherwise specified, the tests will be carried out at room temperature according to relevant standards.

8.2 Measuring equipment

The torsion bar properties defined in Clauses 5, 6 and 7 shall be measured using the usual equipment which will be adapted for the size of the anti-roll bar and the accuracy requirements.

8.3 Tensile strength

Unless otherwise required, the tensile test piece for the determination of the mechanical data can be taken from the heat treated but not shot peened torsion bar.

The test with the test piece shall be carried out according to EN 10002-1.

The test piece for measuring the tensile strength shall be taken in accordance with EN 10002-1 at the locations defined in Annex E. The test piece shall be produced in accordance with EN 10002-1.

8.4 Toughness

Unless otherwise required, the three notch impact strength test pieces for the determination of the toughness can be taken from the heat treated but not shot peened torsion bar.

The test pieces shall be carried out according to EN 10045-1.

The impact test shall be carried out in accordance with EN 10045-1.

Three test pieces shall be taken at the location defined in Annex E.

8.5 Hardness

The torsion bar itself is used as test pieces before shot peening.

The hardness test shall be carried out at the locations agreed between customer and supplier.

The measure of the hardness HRC shall be carried out according to the requirements of EN ISO 6508-1.

8.6 Material

The chemical composition is to be documented in the inspection certificate of the supplier according to 3.1-certificate of EN 10204.

The verification of the characteristics of the material shall be carried out according to the requirements of EN 10089.

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 raw bar. The conditions of sampling shall be in accordance with EN ISO 14284.

8.7 Depth of decarburization

Unless otherwise specified in the technical specification, the depth of decarburization is to be tested according to EN ISO 3887.

8.8 Grain size

The location of sampling shall be defined in the technical specification of the torsion bar.

The examination shall be carried out in accordance with EN ISO 643.

8.9 Forged torsion bar ends

Unless otherwise specified, a checking of the fibre course in the forged heads of straight torsion bars shall be carried out.

For checking the fibre course the head shall be cut longitudinally. The checking shall be carried out by using a solvent and a macroscopic examination.

8.10 Residual compressive stresses on the surface

If required, the method for measuring residual compressive stresses shall be completely defined and agreed between customer and supplier.

Unless otherwise specified, the verification of the reproducibility of the process of shot peening shall be carried out according to the ALMEN method defined in Annex C.

The measure of residual compressive stresses on the surface can be carried out by X-ray diffraction according to the requirements of EN 13925-2.

The shot peening intensity shall be 40 Almen A (0,4 mm archheight) up to 60 Almen A (0,6 mm archheight).

The surface treated by shot peening shall give coverage of equal or more then 95 %. For complicated shaped torsion bars areas not affected by high stresses a lower coverage can be agreed. It is assumed that this value has been obtained once the shot can be seen to cover the total surface area when viewed under 10-fold magnification.

8.11 Surface defects

The surface quality of the torsion bar is kept under visual supervision before and after shot peening (without surface protection). The verification shall be carried out all over the torsion bar, except the surfaces at tips, before application of the protection coating against corrosion.

The examination of the surface condition shall be performed by means of electromagnetic crack detection according to EN 10228-1 for the forged torsion bars or EN ISO 9934-1 for the non-forged torsion bars. The specific test conditions for the check of torsion bars are defined in Annex B.

The staff shall be qualified and certified according to EN 473.

8.12 Surface condition

The surface roughness of areas of the torsion bar not subjected to shot peening shall be checked according to EN ISO 4288.

8.13 Dimensional check

The checking of the dimensions is carried out by using all suitable equipment for this purpose and in particular by means of the gauges and fixations designed by the supplier and approved by the customer.

8.14 Characteristic moment of torsion / angular displacement

Measurements shall be carried out by applying:

Either a moment of torsion. In that case, the corresponding angular displacement shall be recorded.

Or an angular displacement. In that case, the corresponding moment of torsion shall be recorded.

At least two cycles shall be carried out successively from unloaded position to $M_{t\max}$ (or from unloaded position to $\vartheta_{\max}$), at a constant velocity of displacement, without interruption. The last cycle shall be recorded.

The characteristic shall be determined on the last cycle.

The technical specification shall define the following parameters:

— the extreme data values of the cycle moment of torsion / angular displacement unloaded position and $M_{t\max}$ (or unloaded position and $\vartheta_{\max}$);

— the velocity of application of the moment of torsion (or of the displacement).

8.15 Mass

The mass shall be measured using test instruments adapted to the precision level required.

8.16 Internal integrity

Unless otherwise specified in the technical specification the verification of the internal integrity is performed by an ultrasonic test of the bar used for the manufacturing of the torsion bar.

The test method shall be agreed between the customer and the supplier.

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 torsion bars;

— any attenuation of the ground echo greater than 50 %.

8.17 Surface protection

The test methods for checking the specified characteristics shall be completely defined in the technical specification of the torsion bar.

8.18 Loading and allowable stresses

The extreme moment of torsion or angular displacement, specified in the technical, shall be applied on the torsion bar during 1 min minimum.

A visual check shall be made during the test.

A verification of the alignment of the ends of the torsion bar shall be made after the test.

9 Quality assurance and final approval

9.1 Quality assurance system and staff qualification

The plant of the supplier shall be qualified to produce the torsion bars of the required quality level. The quality control system of the supplier shall be in place. 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 torsion bars are satisfied.

9.2 Product qualification procedures and samples

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

A certification of the torsion bar is necessary in the following cases:

Case 1 torsion bar of a new supplier;

Case 2 new torsion bar of a known supplier (torsion bar featuring at least one difference to a torsion bar already qualified);

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

Case 4 changes in the manufacturing procedures of a qualified torsion bar with a known supplier, including changes in manufacture of the steel bars.

All torsion bars which are a part of the necessary sample for the qualification tests shall be from 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 torsion bars 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 Clause 6.

Phase 2: Verification of the conformity to all characteristics in Clause 8 and defined in the technical specification.

Phase 2 of the qualification procedure of the torsion bars, with the exception of those supplied by a new supplier (case 1), can be simplified in accordance with the quality assurance system in force with the supplier. 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 definition documents of the torsion bar provided by the supplier are approved by the customer (phase 1);

— the characteristics of the torsion bar are in accordance with the requirements of this standard 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 torsion bar can be cancelled:

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

— after systematic service failures of the torsion bars.

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

9.3 Control and monitoring of production quality

9.3.1 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 European Standard.

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

If certain characteristics defined in Clauses 6 and 8 require per unit checking on each torsion bar delivered, these checks and tests shall be agreed between the parties.

9.3.2 Quality assurance plan

The quality assurance plan in accordance with a certified quality system for the products shall make reference to the quality manual of the supplier and shall address the specific elements for the torsion bar.

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 supplier 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.

9.3.3 Control by sampling lots

One lot is composed of torsion bars 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 3.

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 4.

9.4 Requirements for control and monitoring of production quality

9.4.1 General

All requirements relating to final approval or acceptance testing by the customer or an organisation independent of both parties are part of the contract and shall be specified.

Tables 3 and 4 give a guideline for the tests.

Table 3 — Checks and tests to be carried out

Characteristic to be verified	Clause	Condition	Final test
Geometrical and dimensional characteristics	6.1		✶
Fatigue test	6.2.4	●	
Material grade chemical compositions	6.3.1	●#	(1)
Decarburisation	6.3.5		✶
Internal integrity	6.3.2	●	
Inclusion cleanliness	6.3.3	●#	
Forged torsion bar ends	6.3.4	●	
Grain size	6.3.8	●#	
Surface hardness	7.1		✶
Tensile strength	7.2	●#	
Toughness	7.3	●#	
Residual compressive stresses on the surface	6.3.7		✶
Surface protection	6.4	●	
Surface conditions	6.3.6		✶
Marking	10		✶

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

● to be agreed

(1) copy of steel manufacturer's inspection certificate according to 3.1-certificate of EN 10204

by special agreement between customer and supplier, these tests can be performed on a test piece taken from a torsion bar or a sample of same material cast processed in the same heat treatment batch

Table 4 — Test pieces for statistical tests, number of tests

Type of tests and trials	No. of parts to be tested in batches with following quantities					
	lower than 10	10 to 25	26 to 50	51 to 90	91 to 150	larger than 150
General geometric requirements	2	3	4	4	5	5
Critical geometric requirements	100 % check					
Fatigue test	Type test if required					
Decarburisation	1	1	1	1	1	1
Internal integrity	1 check per cast					
Inclusion cleanliness	1 check per cast					
Forged torsion bar ends	Type test if required					
Grain size	1 check per cast					
Surface hardness	1	1	1	1	1	1
Tensile strength	1 check per cast					
Toughness	1 check per cast					
Measuring of residual compressive stresses on the surface	Type test if required					
Estimating of residual compressive stresses on the surface	1 ALMEN check per batch					
Surface protection	2	3	4	4	5	5
Corrosion resistance	Type test if required					
Surface conditions	100 % check					
Marking	2	3	4	4	5	5

9.4.2 Non-compliance

If there is any non-compliance, the following rules shall apply:

In the case of individual tests:

— rejection of the torsion bar.

In the case of tests according to the quality assurance plan or batch:

— rejection of the relevant batch.

In such a case a special control plan and acceptance criteria shall be agreed upon by the customer and supplier (individual testing, measures for improvement etc.)

Depending on the type and significance of the rejection, product suitability should be questioned.

New tests or trials, with or without improvements, may only be carried out at the request of the supplier if the customer gives his approval.

9.4.3 Documentation

If required, 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.

9.5 Handling instructions

After shot peening any straightening work is forbidden.

The torsion bar shall be covered during welding work on the vehicle so that the surface is not damaged by weld spatter. Welding torches, welding electrodes and welding tongs shall not touch the torsion bar.

10 Marking of torsion bars

Each torsion bar shall be permanently marked with a system that remains legible during the service life (identification bandage, stamping on bar face surface 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;

— additional indications if required by the customer.

Locations and method of marking shall be defined on the component drawing of the torsion bar.

11 Packaging

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

The following data at least shall be indicated on the packaging:

— identification of the supplier;

— contract number or purchase order number;

— quantity of articles in the package;

— designation of the articles.

Annex A
(normative)

Material for hot formed and quenched and tempered torsion bars

A.1 General

EN 10089 describes the mechanical and chemical properties of alloyed steels which can be used for the manufacture of hot formed torsion bars.

A.2 Material for torsion bars, steel

The material for torsion bars as defined in this European Standard shall be selected according to EN 10089.

Table A.1 has been taken from Annex D of EN 10089:2002 and describes the mechanical and chemical properties of alloyed steels. These properties shall be used for the manufacture of hot formed torsion bars.

Table A.1 — Guidance values for the maximum mechanical properties of quenched and tempered test pieces

Designation		Quench hardening temperature °C	Quench hardening medium	Tempering temperature °C	$R_{p0,2}$ MPa	R_m MPa	A %	Z %	Impact energy at 20 °C *KU* J
Name	Number	± 10 °C		±10 °C	min.		min.	min.	min.
38Si7	1.5023	880	Water	450	1 150	1 300 to 1 600	8	35	18
46Si7	1.5024	880	Water	450	1 250	1 400 to 1 700	7	30	15
56Si7	1.5026	860	Oil	450	1 300	1 450 to 1 750	6	25	13
55Cr3	1.7176	840	Oil	400	1 250	1 400 to 1 700	3	20	5
60Cr3	1.7177	840	Oil	400	1 300	1 450 to 1 750	3	20	5
54SiCr6	1.7102	860	Oil	450	1 300	1 450 to 1 750	6	25	8
56SiCr7	1.7106	860	Oil	450	1 350	1 500 to 1 800	6	25	8
61SiCr7	1.7108	860	Oil	450	1 400	1 550 to 1 850	5,5	20	8
51CrV4	1.8159	850	Oil	450	1 200	1 350 to 1 650	6	30	8
45SiCrV6-2	1.8151	880	Oil	400	1 550	1 600 to 1 900	7	40	13
54SiCrV6	1.8152	860	Oil	400	1 600	1 650 to 1 950	5	35	8
60SiCrV7	1.8153	860	Oil	400	1 650	1 700 to 2 000	5	30	5
46SiCrMo6	1.8062	880	Oil	450	1 400	1 550 to 1 850	6	35	10
50SiCrMo6	1.8063	890	Oil	450	1 420	1 650 to 1 950	6	30	5
52SiCrNi5	1.7117	860	Oil	450	1 300	1 450 to 1 750	6	35	10
52CrMoV4	1.7701	860	Oil	450	1 300	1 450 to 1 750	6	35	10
60CrMo3-1	1.7239	860	Oil	450	1 300	1 450 to 1 750	6	30	8
60CrMo3-2	1.7240	860	Oil	450	1 300	1 450 to 1 750	6	30	8
60CrMo3-3	1.7241	860	Oil	450	1 300	1 450 to 1 750	6	30	8

NOTE Sampling and sample preparation should be the same as given in EN 10083-1.

Annex B
(normative)

Inspection of torsion bars made of round bars by the magnetic crack detection method

B.1 Object

This annex defines the specific conditions which shall be applied for checking the surface quality of torsion bars made of round bars.

B.2 Tests

For the detection of defects parallel to the axis of the bar (longitudinal defects) and defects being more or less perpendicular with regard to the bar axis (transverse defects), two methods are to be applied for induction:

— longitudinal defects: induction by means of current flowing in the direction of the longitudinal axis of the torsion bar;

— transverse defects: induction by means of current flowing through an auxiliary conductor being placed in the axis of a solenoid formed by the torsion bar.

The used testing devices shall be prepared in such a way that the above-mentioned directions of magnetisation will be obtained, the magnetic field strength for both directions reaching at least 3,2 kA/m. The level of induction is defined by the intensity of the magnetising current.

The indication of defects is effected by means of liquid containing fluorescent magnetisable particles. The liquid shall not affect the surface of the test pieces. The visual test is carried out under ultra-violet lighting whose intensity attains at least 15 W/m² at a distance of 0,3 m from the light source. The intensity of the ambient light shall be less or equal 40 lx.

The inspection of the sensitivity of the system is to be undertaken at the testing station itself. Testing shall include the measurement of the field strength as well as the use of calibration parts showing actual defects of known type, position, size and distribution. If such parts are not available, calibrated test pieces having been produced at this particular purpose and showing equivalent defects may be used.

NOTE Defects showing another direction as those mentioned above can be detected using the same method but by means of a higher magnetic field strength. In this case the systematic distinction between longitudinal and transverse defects is not possible.

B.3 Safety measures

When fixing the electrodes at the torsion bar ends, special care shall be taken that the current passing through the torsion bar does not produce any sparking.

After current flow, a significant residual magnetism may remain, in particular at the torsion bar ends. The torsion bar shall consequently be demagnetised after magnetic inspection, e.g. by applying alternating current on the bar, the intensity of the current constantly being reduced from its maximum value to zero. After demagnetisation, the residual magnetism shall not exceed 0,4 kA/m at any point of the torsion bar surface.

Annex C
(normative)

Checking shot peening efficiency by ALMEN method

C.1 Field of application

The ALMEN method described below is applied when the order or its appended documents require shot peening of the torsion bars without specifying the methods of checking its efficiency.

C.2 Checking the procedure

If a steel strip held in a holder is shot peened on one of its surfaces only, this strip will be curved when removed from the holder, the convex surface being the shot peened side. The magnitude of the deflection depends on the effective intensity of the shot.

The test piece defined in this way is exposed to the same shot peening cycle as the torsion bars observing the following parameters:

— speed of movement of the torsion bar in the shot peening machine;

— velocity of the shot;

— nature and dimensions of the shot.

C.3 Equipment and installations

C.3.1 ALMEN A2 test piece

(Applicable for arc heights of less than 0,609 mm.)

Characteristics:

Steel: Cold rolled with the following chemical composition:

0,65 < C ≤ 0,73	0,40 ≤ Mn ≤ 0,70
0,15 < Si ≤ 0,35	
P ≤ 0,035	S ≤ 0,035

Hardness: 44 HRC to 50 HRC

Length: (76,2 ± 0,4) mm

Width: $19\ ^{+0,05}_{-1,0}$ mm

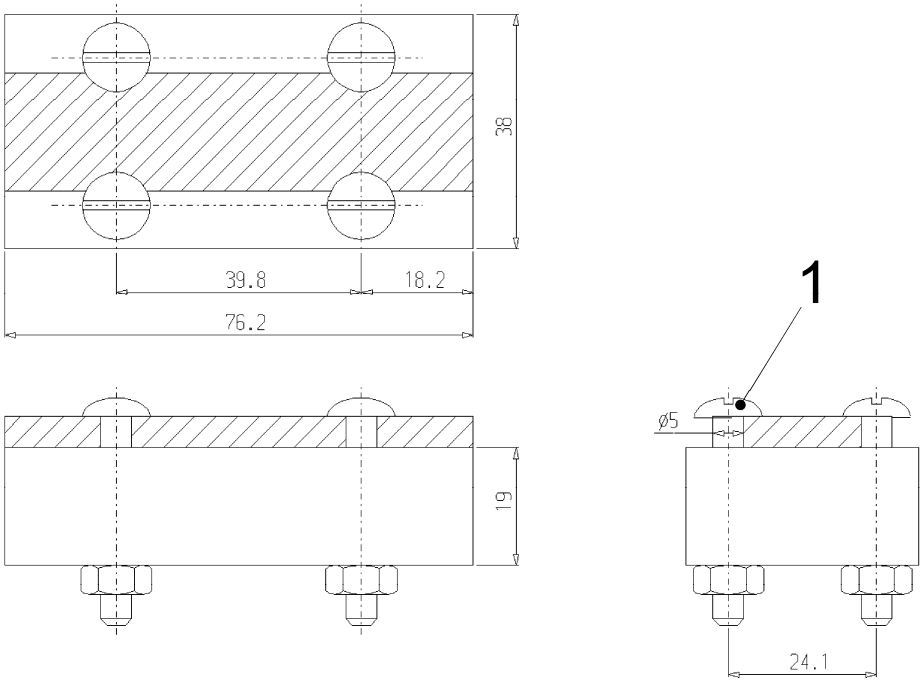
Thickness: $1,3\ ^{+0,02}_{-0,03}$ mm

Flatness: Surface between 2 parallel planes 0,04 mm apart.

C.3.2 Test piece holder

The standardised test piece holder is shown in the Figure C.1.

Dimensions in millimetres



Key

1 4 round headed bolts

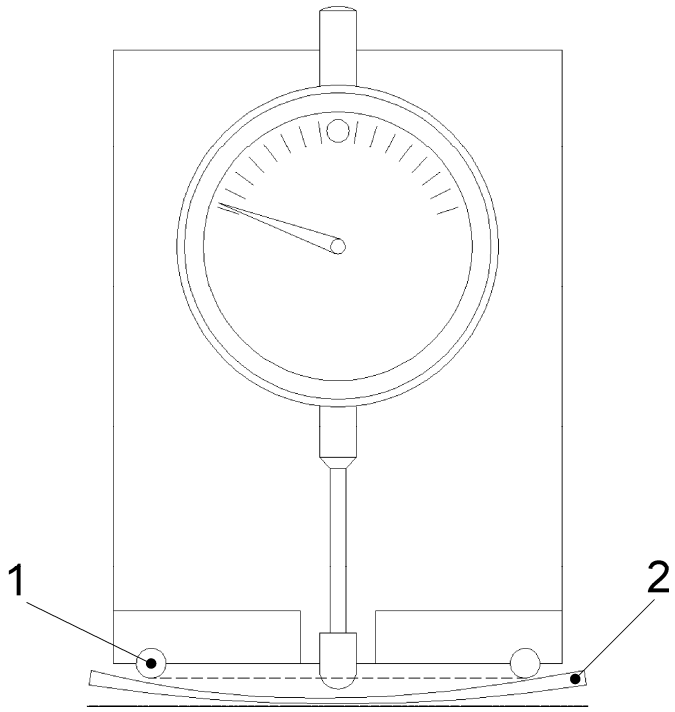
Figure C.1 — ALMEN test arrangements

Steel hardness of the steel strip holder: 62 HRC to 65 HRC

The test piece holder is fixed to a suitable assembly so that the test piece is exposed to shot peening under the same conditions as the torsion bars. The quantity of piece holder and the position of the holder should be agreed by customer and manufacturer.

C.3.3 ALMEN measuring device

The indicator is used to determine the curvature of the test piece. It consists of a dial gauge (graduated in 1/100 mm) mounted on a plate with hardened steel balls forming the corners of a rectangle (see Figure C.2) and situated in the same plane to ± 0,05 mm. The dial gauge sensor is in the centre of the rectangle.



Key

1 hardened steel balls

2 ALMEN test strip

Figure C.2 — ALMEN measuring sytem

The movement of the sensor makes a measurement which depends on the transverse and longitudinal curvature of the test piece.

The measurement of deflection is made on the smooth concave side to eliminate any variation due to roughness of the shot peened surface.

Annex D
(normative)

Examination for inclusions

D.1 Object

It is recognized that EN 10247:2007 has been published. However, the required testing facilities existing in various CEN member countries have not yet been adapted to the requirements of EN 10247 by customers, suppliers as well as by independent test laboratories. In order to ensure the application of the present document which is already widely accepted and applied throughout Europe it is still considered necessary to apply the three national standards listed below. An early revision of the present EN is foreseen in order to accommodate the requirements of EN 10247 as soon as its content has been fully implemented:

— DIN 50602;

— NF A 04-106;

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

— SS 111116.

D.2 Test methods

D.2.1 Test method according to DIN 50602

If it is agreed to use the method according to DIN 50602 the requirements of Table D.1 shall be respected, if not otherwise agreed.

Table D.1 — Degree of cleanliness under the microscope according to DIN 50602 (procedure K), valid for non metallic oxide inclusions

Steel bars Diameter *d* mm	Cumulated coefficient K (oxides) for each melt
140 < *d* ≤ 200	K4 ≤ 50
100 < *d* ≤ 140	K4 ≤ 45
70 < *d* ≤ 100	K4 ≤ 40
35 < *d* ≤ 70	K4 ≤ 35
17 < *d* ≤ 35	K3 ≤ 40
8 < *d* ≤ 17	K3 ≤ 30
d ≤ 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 D.2, 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 111116

If it is agreed to the method according to SS 111116 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 SS 111116 (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)

Taking of test pieces - Areas of the location of test pieces

In the present clause the locations of test pieces are defined which are required for checking the mechanical characteristics of a straight part of the torsion bars.

All test pieces of torsion bars shall be from the same production batch.

Area "*e*" to take test pieces.

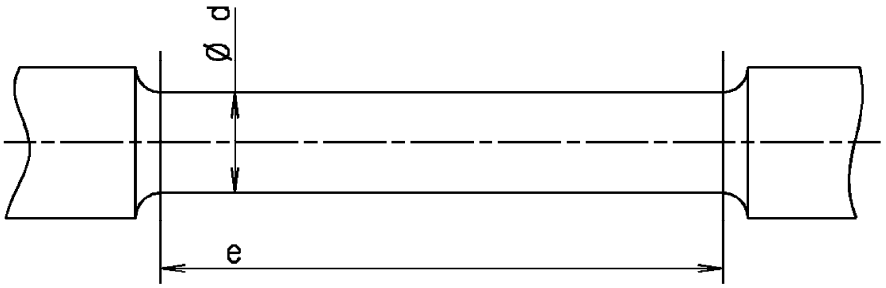


Figure E.1 — Area "e" with constant diameter of the torsion bar to take test pieces

The test pieces for the tensile strength test shall be taken from area "*e*" (Figure E.1) as shown in Figure E.2. The longitudinal axis of the test pieces shall be parallel to the axis of the torsion bar.

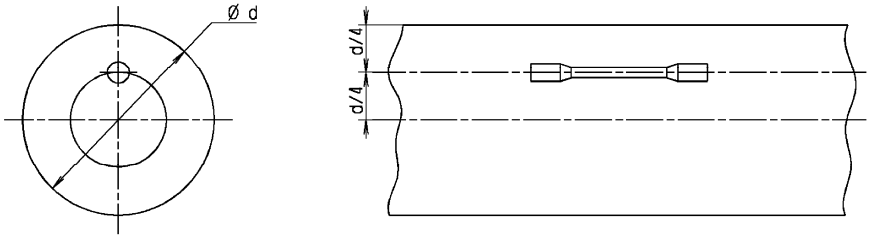


Figure E.2 — Location of the test pieces for the tensile strength test

The test pieces for the notch impact test shall be taken from area "*e*" (Figure E.1) as shown in Figure E.3. If the bar has a diameter of less than 50 mm the test pieces are taken out of a line of half the diameter.

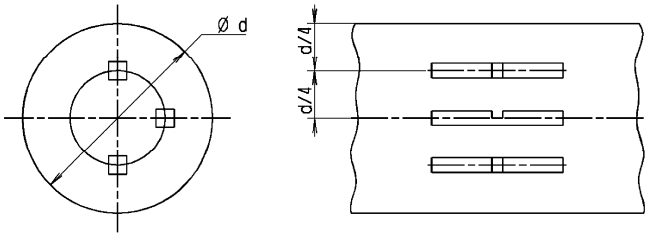


Figure E.3 — Location of the test pieces for the notch impact test

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