BS EN 13802:2013

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Railway applications — Suspension components — Hydraulic dampers

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National foreword

This British Standard is the UK implementation of EN 13802:2013. It supersedes BS EN 13802:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RAE/3/-/4, Railway Applications - Suspension components.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 76215 4

ICS 45.040

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 December 2013.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13802

December 2013

ICS 45.040

Supersedes EN 13802:2004

English Version

Railway applications - Suspension components - Hydraulic dampers

Applications ferroviaires - Eléments de suspension - Amortisseurs hydrauliques

Bahnanwendungen - Federungselemente - Hydraulische Dämpfer

This European Standard was approved by CEN on 5 October 2013.

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN 13802:2013 E

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Foreword

This document (EN 13802:2013) 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of an identical text or by endorsement, at the latest by June 2014, and conflicting national standards shall be withdrawn at the latest by June 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 13802:2004.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

The main changes with respect to the previous edition are listed below.

- Clause 1 — The complete hydraulic dampers, with their end mountings, are now considered in the scope. This new consideration has been taken into account in the whole standard.
- Clause 2 — The normative references have been updated.
- 4.2.1.2 — A new item concerning the life cycle of the dampers has been added.
- 4.2.2.2 — The value of $T_{ao,min}$ to take by default has been decreased.
- 4.2.2.3 — The value of $T_{ae,min}$ to take by default has been decreased.
- 4.2.4 and 5.2.4 — The requirements concerning the behaviour against the vibrational exposures are now given as recommendations.
- 4.3.3 — A criterion about of the surface protection has been defined.
- 4.3.4 — A criterion about the noise generated by the damper has been defined.
- 4.3.9 — The supply of the value of the mass is now required.
- 4.4.1 — A criterion about the orientation of the damper has been defined.
- 4.4.6 and 5.4.6 — The definition of the dynamic characteristics of the dampers has been revised.
- 6.3 — Requirements about the serial tests have been added.
- Clause 7 — The position of the permanent marking of horizontally orientated dampers has been specified.
- B.2 — Methods of calculation of the damper length have been defined in this new sub-clause.

- B.3 Preferred interface dimensions of end mountings have been defined in this new sub-clause.

- Annex F Dynamic test velocities have been defined in this new annex.

NOTE The above list of changes includes the significant technical changes from EN 13802:2004 but is not an exhaustive list of all modifications from the previous version.

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, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard applies to hydraulic dampers and their end mountings used on rail vehicles. The dampers covered in this standard include:

- dampers that control the dynamic behaviour of a vehicle:
  - suspensions dampers, (e.g. primary vertical dampers, secondary vertical dampers and secondary lateral dampers);
  - yaw dampers;
  - roll dampers;
  - inter-vehicles dampers.
- dampers that control the dynamic behaviour of mechanical systems:
  - pantograph dampers;
  - motor dampers, etc.

All relevant terminology which is specific to the subject is defined in this European Standard.

2 Normative references

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

EN 13913, *Railway applications — Rubber suspension components — Elastomer-based mechanical parts*

EN 14363, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests*

EN ISO 2813, *Paints and varnishes — Determination of specular gloss of non-metallic paint films at 20°, 60° and 85° (ISO 2813)*

EN ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests (ISO 9227)*

3 Terms, definitions and symbols

For the purposes of this document, the following terms, definitions and symbols apply.

NOTE 1 In this document, the spatial characteristics of the damper are defined with reference to its axes (see Figure 1). Axial characteristics are defined along the X-axis. Extension of the damper is defined as positive and compression as negative. Transverse characteristics are defined in the Y-Z plane. Rotations are defined as positive in a clockwise direction.

NOTE 2 Decimal multiple and sub-multiple of units defined below can be used.

3.1 Terms and definitions

3.1.1
damper
hydraulic damper with end mountings

3.1.2
hydraulic damper
device with a fluid as the damping medium

3.1.3
damper characteristic
relationship (assuming that there is no force as a function of velocity phase shift) between damper force and damper velocity established at a damper displacement of large amplitude and low frequency to discount the dynamic influence of the damper structure and fluid stiffness

3.1.4
damper displacement
displacement or stroke, relative axial displacement of the damper ends

3.1.5
damper fluid
damping medium (usually oil)

3.1.6
damper specification
document used to define the performance requirements and capabilities of a damper (see Annex A)

3.1.7
dynamic damper characteristic
damper characteristic (see 3.1.3), but including the phase shift effect, and thus including influence of damper structure and fluid stiffness

3.1.8
end mounting
components fitted at both ends of the damper for its mounting on the vehicle, usually elastomer based component

Note 1 to entry: Mountings are not specified in detail in this document.

3.1.9
friction characteristic type damper
hydraulic damper that has a diagram force as a function of displacement which has a more or less rectangular shape (see Figure 7)

3.1.10
leakage
visible evidence of accumulation of fluid, which has originated from within the damper

3.1.11
priming
operation allowing the removal of temporary imperfection to the damper characteristic caused by entrapment of gas (usually air) in the damper pressure chamber

3.1.12
life time
total time or distance travelled in which a damper remains in service use until its final withdrawal

Note 1 to entry: The life time can consist of several service intervals.

3.1.13
service interval
minimum continuous time or distance travelled in which a damper remains in service use, with only periodic visual inspections and without any dismounting or repairing

3.1.14
symmetrical damper characteristic
damper characteristic (see 3.1.3) having the same compression and extension force as a function of velocity characteristic throughout the operating range (see Figure 8)

3.1.15
asymmetric damper characteristic
damper characteristic (see 3.1.3) not having the same compression and extension force as a function of velocity characteristic throughout the operating range (see Figure 9)

3.2 Symbols

A_c	[J]	Area of the force/displacement diagram that is the dissipated energy in a cycle
c_d	[N.s/m]	Dynamic damping rate, this includes the effect of phase shift
d_c	[m]	Compression margin, the part of damper compression travel never reached by the piston during operation in the given mechanical system NOTE 1 $d_c = L_{u,\min} - L_{\min}$
$d_{c,\text{Fnull}}$	[m]	Displacement corresponding to zero force value in compression (measured on the diagram force as a function of displacement and is negative by convention).
d_e	[m]	Extension margin, the part of damper extension travel never reached by the piston during operation in the given mechanical system NOTE 2 $d_e = L_{\max} - L_{u,\max}$
$d_{e,\text{Fnull}}$	[m]	Displacement corresponding to zero force value in extension (measured on the diagram force as a function of displacement and is positive by convention)
d_n	[m]	Nominal travel, the travel over which the damper meets the operational requirements established by the damper specification NOTE 3 The nominal travel is indicative of the operating travel of the damper in the given mechanical system.
d_w	[m]	Working stroke NOTE 4 $d_w = L_{u,\max} - L_{u,\min}$

d_0	[m]	Damper displacement amplitude at sinusoidal motion NOTE 5 $d(t) = d_0 \times \sin(\omega \times t)$
D_{max}	[m]	Diameter of an envelope cylinder in which the main body of the damper shall be contained (dust guard included) (see Figures 2 and 3)
D_{res}	[m]	Diameter of the additional damper reservoir envelope (see Figure 3)
f	[Hz]	Excitation frequency NOTE 6 $f = \omega$ / (2 x π) either $f = v_0$ / (2 x π x d_0)
F	[N]	Damper force, the axial force of the damper
$F_{c,vn}$	[N]	Nominal damper compression force (is negative by convention) NOTE 7 Force at nominal velocity.
$F_{c,v0}$	[N]	Damper compression force at maximum velocity of the test (measured at mid stroke on the diagram force as a function of displacement and is negative by convention)
$F_{cmax,vmax}$	[N]	Maximum damper compression force measured on the diagram force as a function of displacement at the maximum damper velocity v_{max} (is negative by convention)
$F_{cmax,v0}$	[N]	Damper maximum compression force with sinusoidal displacement (measured on the diagram force as a function of displacement and is negative by convention)
$F_{e,vn}$	[N]	Nominal damper extension force (is positive by convention) NOTE 8 Force at nominal velocity.
$F_{e,v0}$	[N]	Damper extension force at maximum velocity of the test (measured at mid stroke on the diagram force as a function of displacement and is positive by convention)
$F_{emax,vmax}$	[N]	Maximum damper extension force measured on the diagram force as a function of displacement at the maximum damper velocity v_{max} (is positive by convention)
$F_{emax,v0}$	[N]	Damper maximum extension force with sinusoidal displacement (measured on the diagram force as a function of displacement and is positive by convention).
F_0	[N]	Damper force amplitude at sinusoidal motion
H_{res}	[m]	Height of the additional damper reservoir to damper centreline (see Figure 3)
k_d	[N/m]	Dynamic damper stiffness

L [m] Damper length

The damper length definition will vary according to attachment details which are defined in the damper specification.

If not otherwise specified, the damper length is between the centres of the end mountings (see Figure 4).

L_{del} [m] Damper length at delivery

NOTE 9 The length of the damper to permit mounting it on a vehicle at rest on straight, horizontal track (except for particular cases, for example pantograph dampers).

L_{i} [m] Length of the damper installed

NOTE 10 Length when the damper is mounted on a vehicle at rest on straight, horizontal track.

$L_{\max}$ [m] Damper length when the damper is fully extended

$L_{\min}$ [m] Damper length when the damper is fully compressed

L_{n} [m] Nominal damper length $L_{\text{n}} = \frac{(L_{\max} + L_{\min})}{2}$

$L_{\text{u,max}}$ [m] Maximum utilization length of the damper

NOTE 11 The maximum length of the damper during operation.

$L_{\text{u,min}}$ [m] Minimum utilization length of the damper

NOTE 12 The minimum length of the damper during operation.

$T_{\text{ae,max}}$ [°C] Maximum ambient temperature (i.e. temperature of the air surrounding the damper) in extreme situations

$T_{\text{ae,min}}$ [°C] Minimum ambient temperature (i.e. temperature of the air surrounding the damper) in extreme situations

$T_{\text{ao,max}}$ [°C] Maximum ambient temperature for normal vehicle operation

$T_{\text{ao,min}}$ [°C] Minimum ambient temperature for normal vehicle operation

T_{n} [°C] Nominal test temperature of the damper (see 4.2.2.1)

$T_{\text{s,max}}$ [°C] Maximum transportation or storage temperature to be experienced by the damper

$T_{\text{s,min}}$ [°C] Minimum transportation or storage temperature to be experienced by the damper

v [m/s] Damper velocity, piston velocity that is the relative axial velocity of the damper

v_{max}	[m/s]	Maximum damper velocity

NOTE 13 Highest velocity to be encountered during operation by the damper for the application specified and considered in the design of the damper. The value of this velocity is part of the performance description of the damper.

v_n	[m/s]	Nominal damper velocity

NOTE 14 Upper velocity to be encountered during operation by the damper for the application specified. The value of this velocity is part of the performance description of the damper.

v_0	[m/s]	Damper velocity amplitude at sinusoidal motion

NOTE 15 $v(t) = d_0 \times \omega \times \cos(\omega \times t) = v_0 \times \cos(\omega \times t)$

Φ	[rad]	Force as a function of displacement phase shift at sinusoidal motion (see the definition for c_d and k_d)
ω	[rad/s]	Angular velocity of excitation

NOTE 16 $\omega = \frac{v_0}{d_0}$

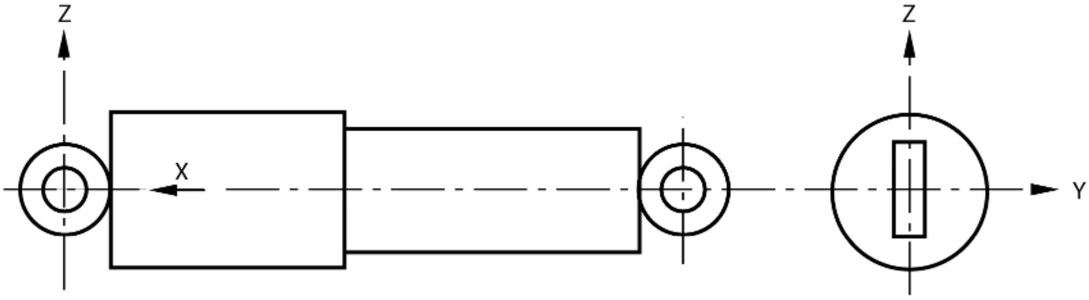


Figure 1 — Spatial definition

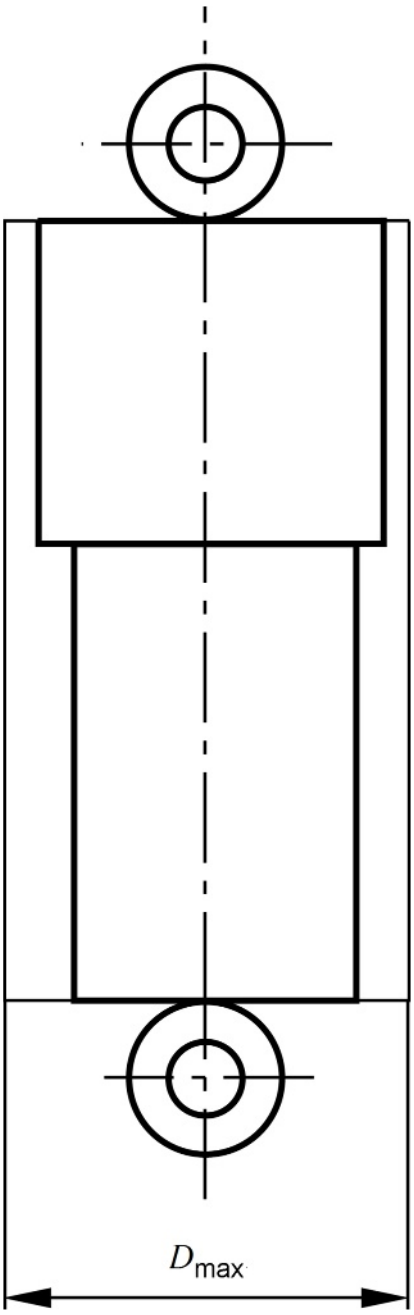


Figure 2 — Diameter D_{max} of the damper space envelope

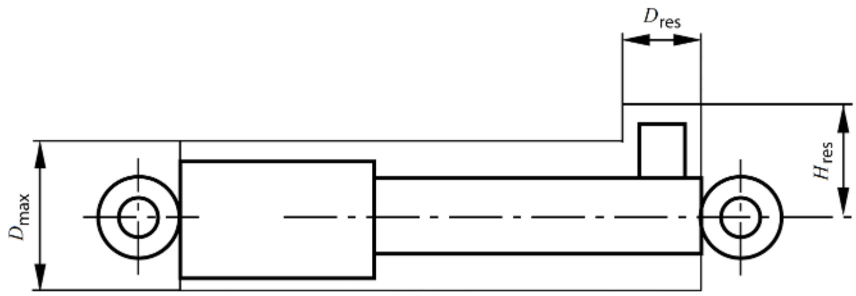


Figure 3 — Cross sectional dimensions of damper (D_{max} , D_{res} , H_{res})

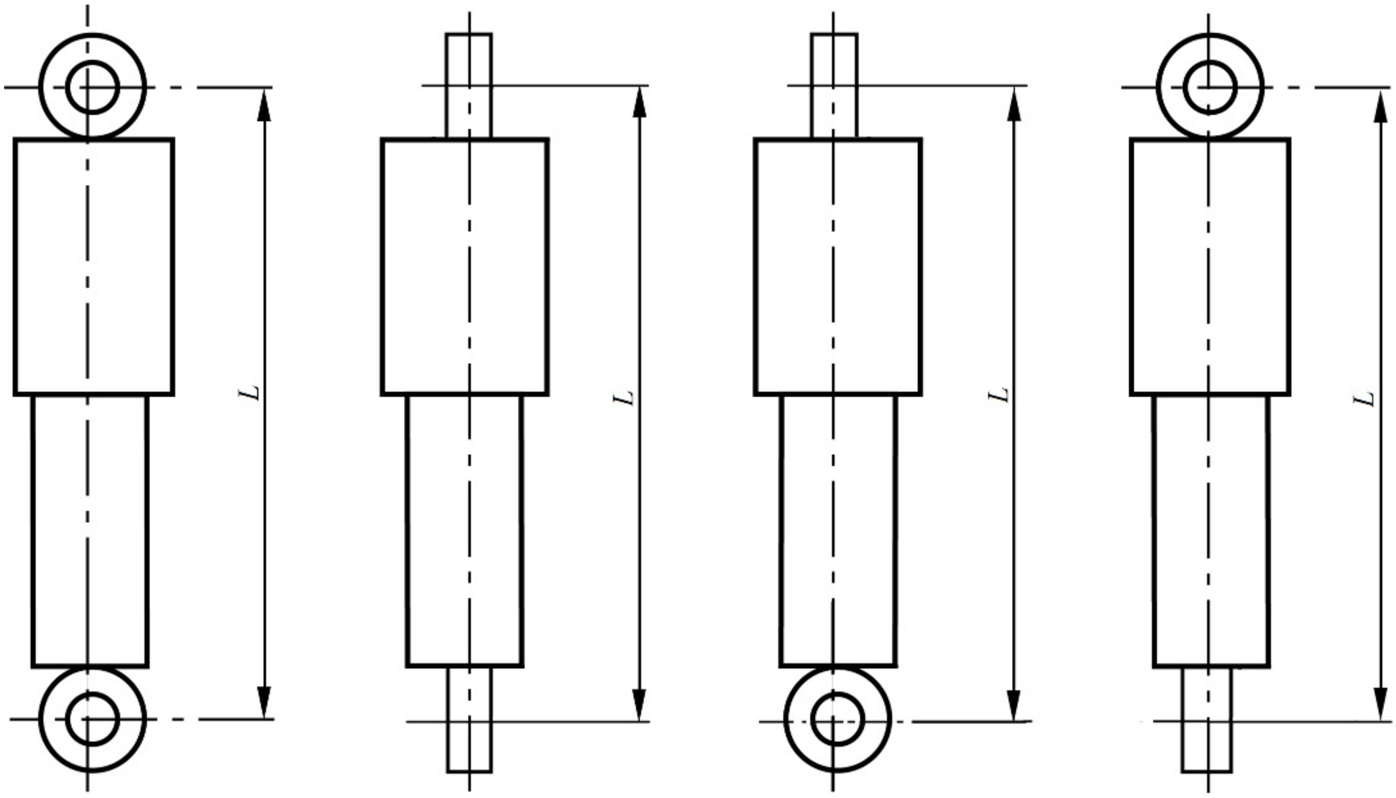


Figure 4 — Definition of damper length L

4 Method of specifying

4.1 Overview

4.1.1 General

Requirements shall be defined by means of a damper specification. An example of a pro-forma, which may be used for this purpose, is given in Annex A. This pro-forma allows the evaluation of the conformity of the damper in comparison to the requirements.

End mountings shall be defined in a technical specification according to the relevant European Standards. Rubber end mountings shall be defined according to EN 13913.

4.1.2 Operational environment

The damper specification shall give details on the operational environment listed below, to enable provision of a safe and effective product.

- Service conditions (see 4.2.1);
- Climatic conditions (see 4.2.2);
- Special environmental conditions (see 4.2.3);
- Mounting conditions (if required).

The defined movements of the damper in its mechanical system shall be performed without collisions and failures under all specified service conditions.

That means especially taking care of all relative movements of the fixation points of the damper considering the limits of the mechanical system (including manufacturing tolerances) for defining the lengths and angles of the damper.

When specifying the damper, it is recommended to take care of the possible mounting constraints of the damper in its mechanical system. For example, fitting of the connection parts (screw, nut), space required for the clamping tools, etc.

4.1.3 Technical requirements

The damper specification shall specify the characteristics for defining the damper according to its usage. These characteristics shall be selected from those specified in Table 1. The required variation criteria (tolerances) of the force as a function of velocity characteristic shall be identified and specified in accordance with 4.4.5. Unless otherwise defined, the characteristics of the damper are defined under the range of temperatures from 17 °C to 23 °C.

Table 1 — Items to be considered for inclusion in the damper specification

Item	Definition	Testing
Operational environment requirements	**4.2**	**5.2**
Service conditions	4.2.1	5.2.1
Service interval	4.2.1.1	
Life cycle	4.2.1.2	
Climatic conditions	4.2.2	5.2.2
Nominal test temperature	4.2.2.1	
Operating temperature range	4.2.2.2	5.2.2.1
Temperature extremes	4.2.2.3	5.2.2.2
Storage temperatures	4.2.2.4	5.2.2.3
Specific climatic conditions	4.2.2.5	5.2.2.4
Special environmental conditions	4.2.3	5.2.3
Vibrational exposure	4.2.4	5.2.4
Physical characteristics	**4.3**	**5.3**
Strength [a]	4.3.1	5.3.1
Fire resistance	4.3.2	5.3.2
Surface protection [a]	4.3.3	5.3.3
Noise	4.3.4	5.3.4
Whole life environmental impact	4.3.5	5.3.5
Leakage	4.3.6	5.3.6
Length and stroke [a]	4.3.7	5.3.7
Overall dimensions and interface [a]	4.3.8	5.3.8
Mass	4.3.9	5.3.9
Functional requirements	**4.4**	**5.4**
Orientation [a]	4.4.1	5.4.1
Nominal force and nominal velocity [a]	4.4.2	5.4.2
Maximum force and maximum velocity [a]	4.4.3	5.4.3
Force as a function of displacement characteristic	4.4.4	5.4.4
Force as a function of velocity characteristic [a]	4.4.5	5.4.5
Acceptance [a]	4.4.5.2	5.4.5.2
Dynamic characteristics	4.4.6	5.4.6
Dynamic damping characteristics		5.4.6.3
Dynamic stiffness characteristics		5.4.6.4
Priming	4.4.7	5.4.7
[a] These items are mandatory.		

4.2 Operational environment requirements

4.2.1 Service conditions

4.2.1.1 Service interval

The damper specification shall specify the service interval of the damper.

For a given service interval (time, distance), the damper specification shall specify:

- the maximum permissible variation of functional characteristics;
- the maximum permissible rate of damper failure.

When stating service intervals and capabilities the factors stated in 4.2.3 shall be taken into account in addition to the following:

- exposure to vibration;
- contamination;
- abrasive dusts; and
- the range of climatic conditions normally experienced on railway vehicle suspensions.

4.2.1.2 Life Cycle

The damper specification shall specify the life time and expected life cycle parameters of the damper.

The data for Life Cycle Calculations shall be identified.

4.2.1.3 Track conditions

If the track conditions are different to the track conditions identified in EN 14363 then the track quality shall be defined.

4.2.2 Climatic conditions

4.2.2.1 Nominal test temperature (T_n)

The nominal test temperature (T_n) is (20 ± 3) °C.

4.2.2.2 Operating temperature range ($T_{ao,min}$ to $T_{ao,max}$)

The range of ambient operating temperature shall be defined:

- $T_{ao,min}$
- $T_{ao,max}$

When exposed to the minimum and maximum operating temperatures, the damper shall conform to the characteristics specified for these temperatures. After exposure to the operating temperature range and return to the ambient temperature, the damper shall conform to the specified damper characteristics.

The damper specification should define whether the characteristics of the damper at extreme temperatures are for information only or a performance requirement. If not known, the following limits are taken into consideration:

— $T_{ao,min}$ = - 25 °C;

— $T_{ao,max}$ = + 40 °C.

In case of low temperature, especially when the ambient operating temperature is lower than - 25 °C, the resilience of the steel parts exposed to impacts and the behaviour of the rubber elements should be considered.

4.2.2.3 Temperature extremes ($T_{ae,min}$ to $T_{ae,max}$)

The temperature extremes shall be defined.

If the temperature extremes are not known, the following limits can be taken as typical values:

— $T_{ae,min}$ = - 40 °C

— $T_{ae,max}$ = + 70 °C

When exposed to the above range of temperatures, the damper is not required to conform to the specified characteristics, but it is required to function safely. The specific requirements to achieve safety (for example, the maximum force required to compress or extend a damper) shall be determined taking account of the specific application and any associated risk. After exposure to the extremes, however, the damper shall be required to recover and to conform to the specified characteristics.

4.2.2.4 Storage temperatures ($T_{s,min}$ to $T_{s,max}$)

The damper specification shall specify the minimum and maximum temperatures which dampers are required to withstand during transport or storage. Dampers which experience extremes of temperature, low or high, shall recover to the characteristics as defined in the damper specification upon reaching the operating temperature range.

4.2.2.5 Specific climatic conditions

The damper specification shall specify the specific climatic conditions in which the damper shall be required to operate. Typically these can include:

— snow and ice;

— high relative humidity;

— exposure to bright sunlight;

— exposure to ozone.

4.2.3 Special environmental conditions

The damper specification shall specify any special environmental conditions in which the damper shall be required to operate. Special environmental conditions can include:

— projection of ballast;

- projection of oil or petroleum products;
- projection of organic waste;
- saline spray;
- washing plant agents (dilute acids, alkalis, detergents).

4.2.4 Vibrational exposure

The damper specification should specify the vibration exposure conditions under which the damper shall be required to operate.

4.3 Physical characteristics

4.3.1 Strength

In the case where the damper is used for a supplementary function of mechanical stop or hoisting device, the following requirements shall be specified.

The tensile and/or the compressive load that the damper is required to withstand without sustaining any damage, or permanent change in characteristic, or reduction in service interval, shall be specified. The static loads shall be applied steadily along the *X*-axis of the damper as follows:

- fully compressed (compressive axial load);
- fully extended (tensile axial load).

The damper characteristic shall not have changed as a result of testing, nor shall the damper or any of its components have suffered any damage or permanent distortion which impairs the correct functioning of the damper.

NOTE Generally, the damper does not have such a role. This is provided by separate mechanical devices.

4.3.2 Fire resistance

When there is a requirement for fire resistance, the damper specification shall specify the requirements for test and acceptance for fire resistance performance of the damper.

4.3.3 Surface protection

The colour, the gloss number, the area to be protected and the mechanical characteristics of the protection system of the damper (adherence, shock resistance, elasticity, resistance against flying ballast, salt spray resistance) shall be specified in the damper specification.

No damage resulting from corrosion shall affect the functioning of the damper during the agreed lifetime.

4.3.4 Noise

When determined as necessary, the noise requirements shall be specified in the damper specification.

Noise generated by the complete damper in function shall not interfere with the general noise requirements.

4.3.5 Whole life environmental impact

When determined as being necessary, requirements relating to contamination during operation, such as fluid loss, and/or the disposal of components such as oil and the final disposal of the damper, shall be specified in the damper specification.

4.3.6 Leakage

The damper shall operate without excessive loss of fluid throughout its operating life in the operating temperature range.

NOTE Fluid loss is excessive when there is visible evidence of accumulation of fluid on the body of the damper.

4.3.7 Length and stroke

A minimum two of the following three variables shall be specified:

— $L_{\text{u,min}}$

— $L_{\text{u,max}}$

— d_{w}

The damper shall include an extension margin and a compression margin to ensure correct operation of the final product in order to cover the manufacturing tolerances of the parts of the mechanical system.

$$d_{\text{c}} = L_{\text{u,min}} - L_{\min} > 0$$

$$d_{\text{e}} = L_{\max} - L_{\text{u,max}} > 0$$

If necessary (especially for friction characteristic type dampers), the delivery length L_{del} shall be defined.

By default, $L_{\text{del}} = L_{\text{i}} - 5\text{ mm}$.

4.3.8 Overall dimensions and interface

The damper specification shall define the maximum overall dimensions required for the damper, determined from a defined volume-envelope. The overall dimensions shall be determined using simple volume elements (such as cylinders) in a set of reference co-ordinates linked to the damper when it is assumed fully compressed ($L_{\text{u,min}}$) or fully extended ($L_{\text{u,max}}$). See Figure 2 and Figure 3.

The overall dimensions of the damper shall remain within the specified volume envelope.

It is recommended to use typical dimensions given in Annex B.

4.3.9 Mass

The mass of the specified damper shall be given.

A maximum mass limit may be specified in the damper specification.

4.4 Functional requirements

4.4.1 Orientation

The damping function shall be guaranteed for all specified positions, which will occur during operation and under all service conditions.

The range of the damper angular position during operation shall be specified. This range shall include variations arising from factors such as:

- the dynamic movements of the mechanical system to which the damper belongs;
- a change in loading of the vehicle;
- inflated or deflated air-springs;
- manufacturing tolerances.

The mean position shall be identified together with the maximum and minimum working values.

4.4.2 Nominal force ($F_{\text{c,vn}}$, $F_{\text{e,vn}}$) and nominal velocity (v_{n})

The nominal compression force ($F_{\text{c,vn}}$), nominal extension force ($F_{\text{e,vn}}$) and nominal velocity (v_{n}) shall be specified.

Annex C gives several examples of nominal velocities for typical applications.

4.4.3 Maximum force ($F_{\text{cmax,vmax}}$, $F_{\text{emax,vmax}}$) and maximum velocity ($v_{\max}$)

The compression force at maximum velocity ($F_{\text{cmax,vmax}}$), extension force at maximum velocity ($F_{\text{emax,vmax}}$) and maximum velocity ($v_{\max}$) shall be specified.

4.4.4 Force as a function of displacement characteristic

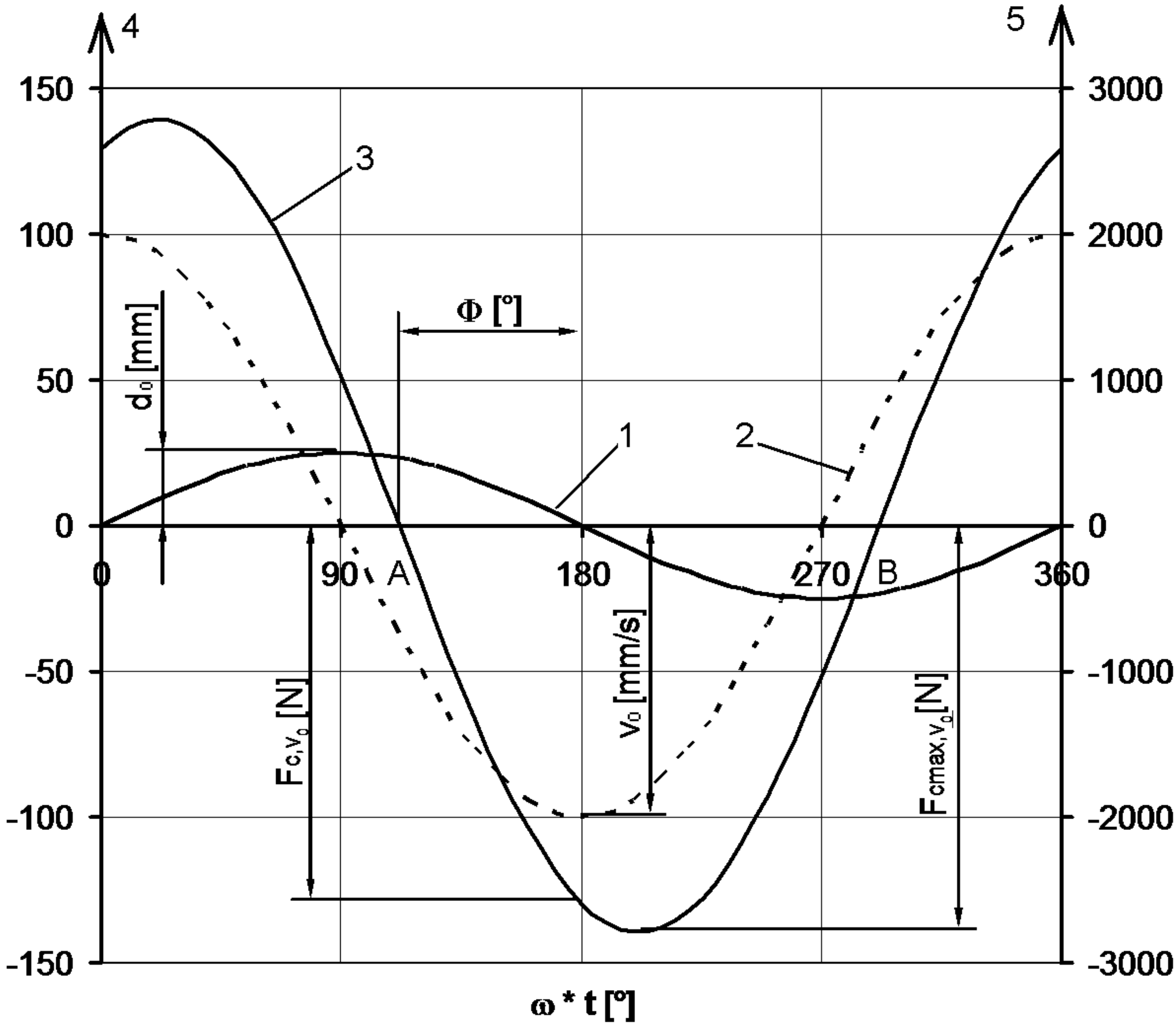
A force as a function of displacement characteristic may be included in the damper specification.

The force as a function of displacement characteristic is the variation in damper force $F(t)$ as a function of damper displacement $d(t)$ (see Figure 5). It shall be established for a given damper displacement and length. If these are not specified, a default damper displacement of d_0 = 25 mm shall be used and the default length shall be L_i .

The evaluation of the force as a function of displacement diagram allows the diagnosis of the functioning of the damper.

Consequently, the record of this diagram shall be made at a scale to ensure correct analysis. When the damper is excited by a sinusoidal input, the shape of the theoretical force as a function of displacement diagram is the one shown:

- in Figure 6 for a symmetrical linear characteristic damper;
- in Figure 7 for a symmetrical friction characteristic type damper.



Key

1 displacement $d(t)$ [mm]

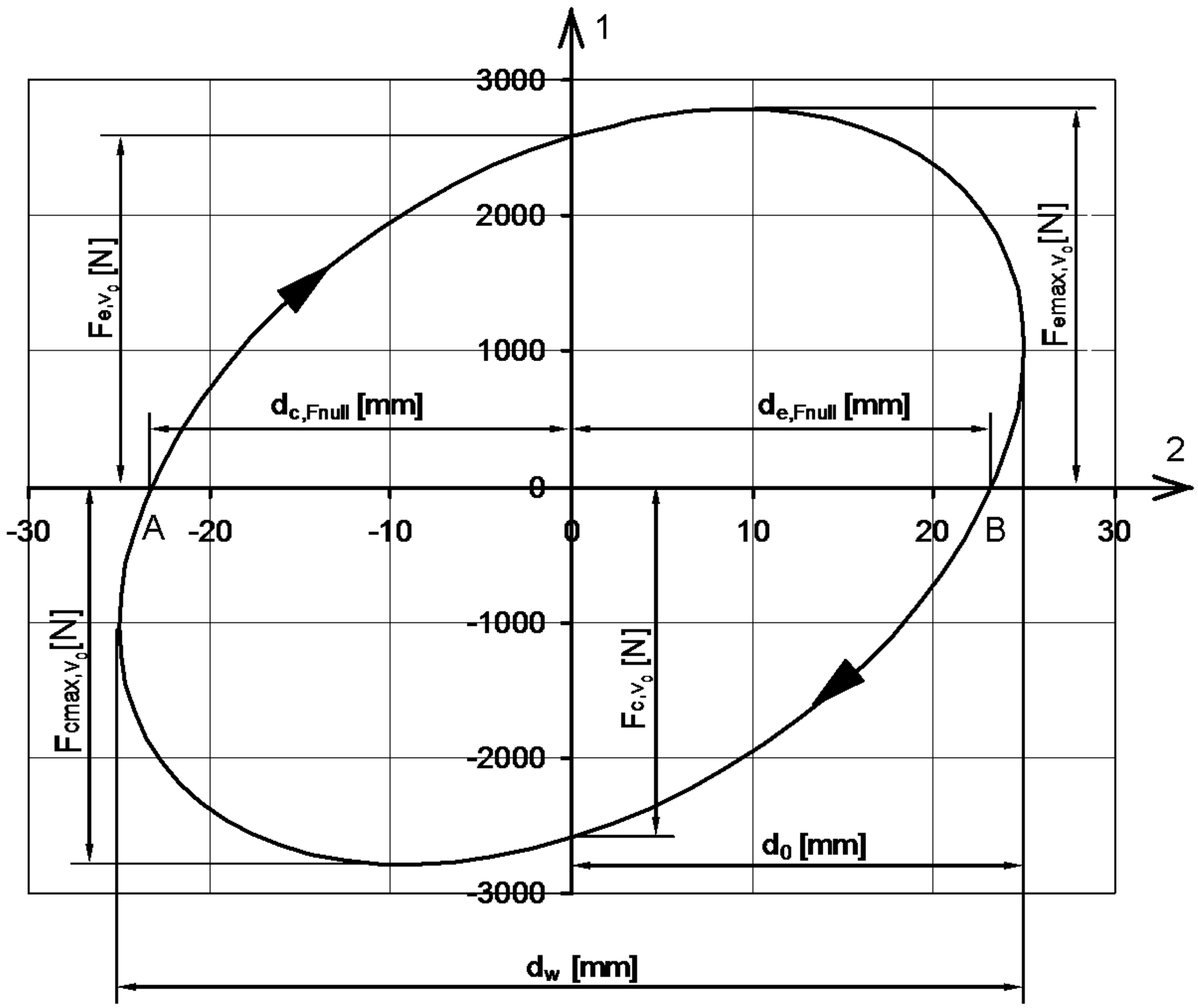
2 velocity $v(t)$ [mm/s]

3 damper force $F(t)$ [N]

4 displacement d [mm] or velocity v [mm/s]

5 damper force F [N]

Figure 5 — Example of a diagram of travel, velocity and force for a symmetrical linear characteristics damper

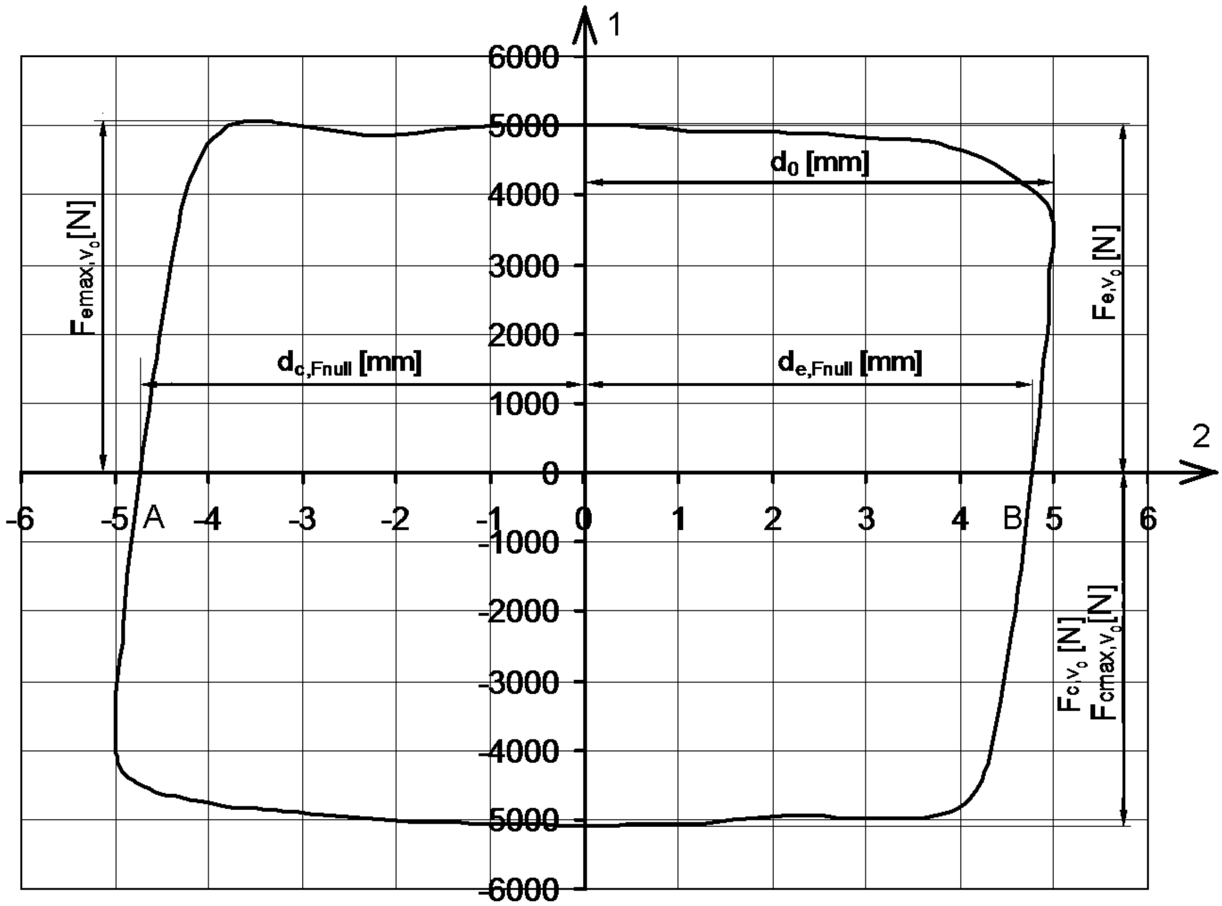


Key

1 damper force F [N]

2 displacement d [mm]

Figure 6 — Example of force as a function of displacement diagram for a symmetrical linear characteristics damper at v_0



Key

1 damper force F [N]

2 displacement d [mm]

Figure 7 — Example of force as a function of displacement diagram for a symmetrical friction characteristic type damper at v_0

The values of the forces $F_{e,v0}$ and $F_{c,v0}$ shall be taken at mid-travel on the diagram. In the case of a real diagram, maximum force values $F_{emax,v0}$ and $F_{cmax,v0}$ can differ significantly from the same forces evaluated at maximum velocity $F_{e,v0}$ and $F_{c,v0}$ (see Figure 6 and Figure 7).

However, maximum forces values $F_{emax,vmax}$ and $F_{cmax,vmax}$ represent maximum forces applied by the damper, while forces evaluated at maximum velocity $F_{e,v0}$ and $F_{c,v0}$ shall be used as an index of the damping performance.

The force as a function of displacement diagram shall be regular and shall not have any irregularity indicative of malfunctioning of the damper (for example vibrational phenomena, jumping, loss of force, sudden change in the shape of the diagram).

The customer and the supplier may agree the detail of an acceptable diagram if some irregularities appear on the diagram.

The values of forces $F_{emax,v0}$ and $F_{cmax,v0}$ which shall be taken into account to establish the force as a function of velocity characteristic (see 4.4.5) are those produced by the damper at the instantaneous test velocity v defined. In most cases these values are located near to the zero displacement point.

The variation in characteristic at $T_{ao,min}$ and $T_{ao,max}$ for all specified velocities shall be defined.

The variation of the characteristic with frequency should be defined, especially for a friction characteristic type damper.

The characteristic should be agreed between the customer and the supplier.

4.4.5 Force as a function of velocity characteristic

4.4.5.1 General

The force as a function of velocity characteristic and appropriate test velocities shall be defined. The force as a function of velocity characteristic is the variation in damper force F as a function of damper velocity v. It shall be established for a given damper displacement and length. If these are not known, a default damper displacement of $d_0 = 25$ mm shall be used and the length assumed to be the nominal length (L_n).

There are two different forces as a function of velocity characteristics, one for each direction of travel:

a) an extension characteristic;

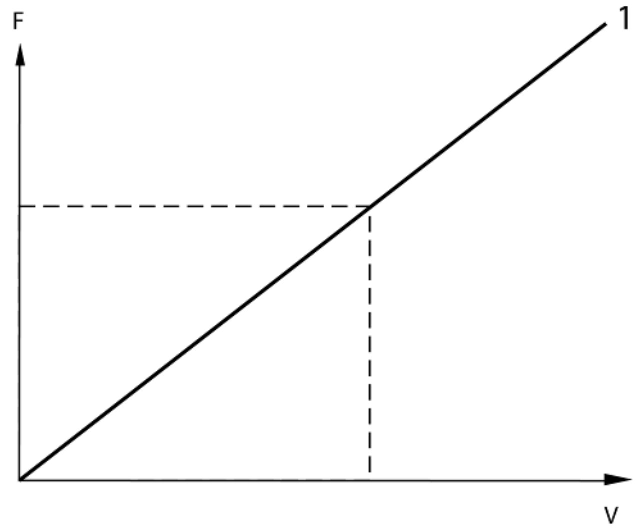
b) a compression characteristic.

These may be:

— The same (for symmetrical dampers) and, in practice, a tolerance will apply. The damper specification shall define how close the symmetry shall be achieved by the control of the tolerances to be applied (see Figure 8);

or

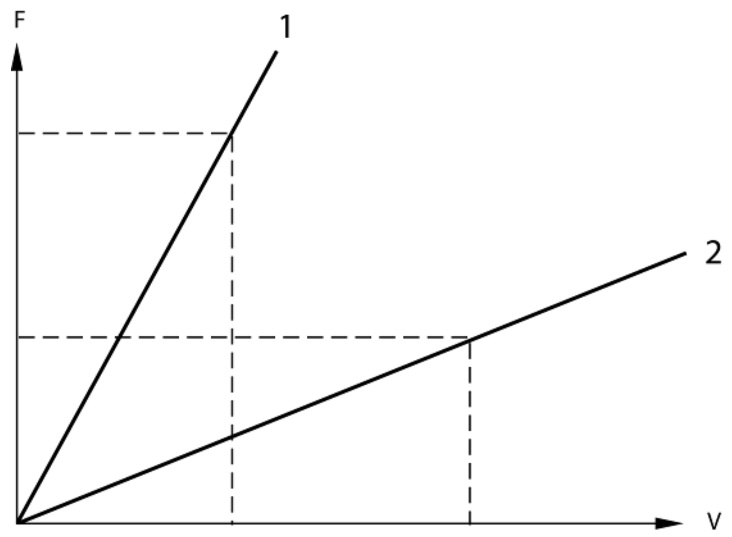
— Different (for asymmetrical dampers), in which case the absolute values of $F_{e,vn}$ and $F_{c,vn}$ differ (see Figure 9).



Key

1 characteristic for extension and compression

Figure 8 — Variation of force as a function of velocity for a symmetrical damper



Key

1 characteristic for extension (or compression)

2 characteristic for compression (or extension)

Figure 9 — Variation of force as a function of velocity for an asymmetrical damper

4.4.5.2 Acceptance

The force as a function of velocity characteristics for damper extension and compression shall be within the tolerances specified.

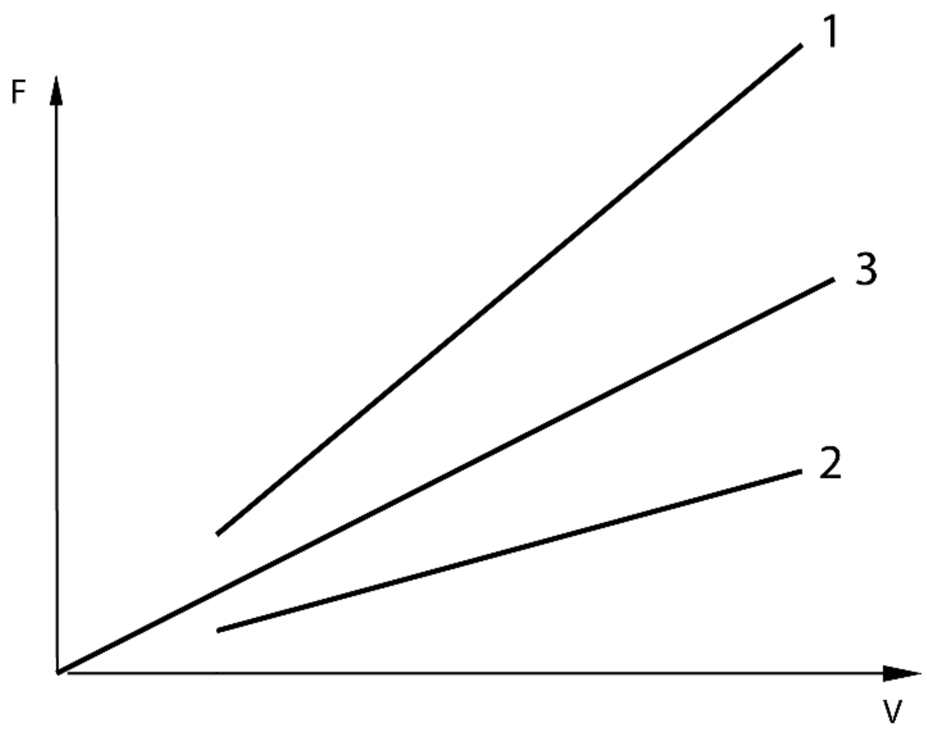
The tolerances shall be defined:

a) by max./min. envelope curves established for different ranges of velocities (see Figure 10);

or

b) by max./min. force values established for specified velocities (see Figure 11).

NOTE Typical tolerance on force value at nominal velocity is ± 15 % for a new damper.



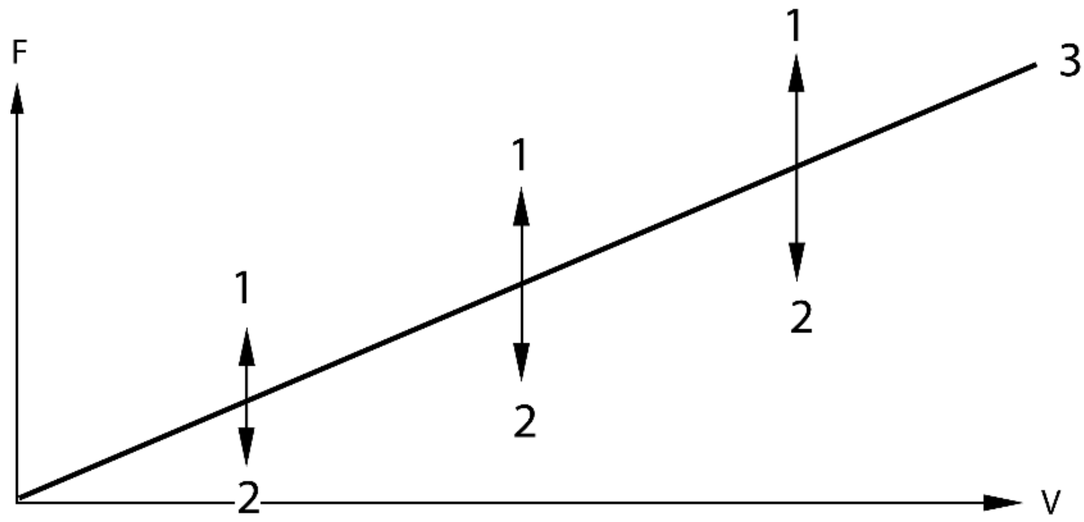
Key

1 maximum tolerance

2 minimum tolerance

3 nominal characteristic

Figure 10 — Typical force as a function of velocity envelope



Key

1 maximum tolerance at the given velocities

2 mnimum tolerance at the given velocities

3 nominal characteristic

Figure 11 — Typical max/min force limits

Annex D gives examples of typical envelope curves for the following two cases:

— linear damper characteristic;

— friction characteristic type damper.

4.4.6 Dynamic characteristics

The test and analysis methods to be used to evaluate the dynamic characteristics of the damper shall be stated in the damper specification.

For friction characteristic type dampers, it is suggested to perform dynamic tests with sinusoidal displacement. Suggested velocities and amplitudes are reported in Annex F.

The damper specification shall state whether damper tests shall be performed using a damper with or without its end mountings.

Nominal inclination angle in service shall be applied to the damper under test.

If the Maxwell's model is used then the test results shall be processed to derive the values k_{d} and c_{d}, according to the definitions provided in 3.2. Maxwell's model is generally used for reproducing the actual experimental behaviour of a real damper and it is composed of a dashpot c_{d} in series with a spring k_{d} (see Figure 12). The advantage of this model is that stiffness and damping parameters are independent from frequency, and hence the model may be easily used for numerical simulations of rail vehicle dynamics in the time domain.

Another model can be agreed between the customer and the supplier. In this case, other parameters have to be defined.

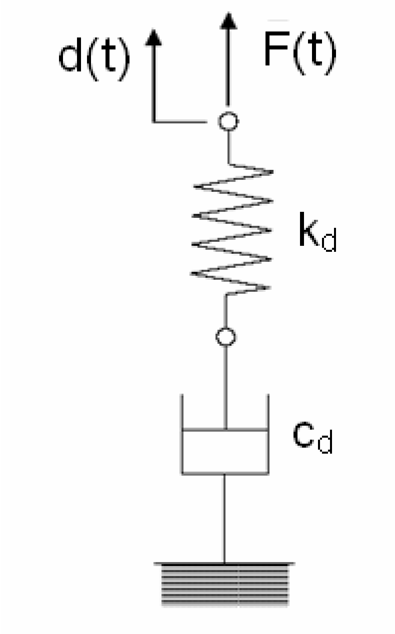


Figure 12 — Maxwell's reference model

The measured force and displacement data shall be post-processed so as to obtain the following parameters:

— dynamic damper stiffness k_{d};

— dynamic damping rate c_{d}.

The two parameters above can be defined as a function of the amplitude of the deformation applied to the damper. For example, a value of equivalent stiffness and equivalent damping rate is obtained for each amplitude considered in the tests (see Annex F).

The damper force of a symmetrical linear damper under a sinusoidal displacement is defined as:

$$F(t) = \frac{d_0 \times \omega \times k_{\mathrm{d}}}{\sqrt{\omega^2 + (k_{\mathrm{d}}/c_{\mathrm{d}})^2}} \sin\left(\omega \times t + \arctan\frac{k_{\mathrm{d}}}{\omega \times c_{\mathrm{d}}}\right)$$

with damper maximum extension force:

$$F_{\mathrm{emax,v0}} = \frac{d_0 \times \omega \times k_{\mathrm{d}}}{\sqrt{\omega^2 + (k_{\mathrm{d}}/c_{\mathrm{d}})^2}}$$

and force-displacement phase shift:

$$\Phi = \arctan\frac{k_{\mathrm{d}}}{\omega \times c_{\mathrm{d}}}$$

The phase shift Φ can be determined out of the test results using the best-fit approximation of the force and deformation time histories, $F(t)$ and $d(t)$.

The parameters k_{d} and c_{d} can be calculated by conversion of the formulae above:

$$k_{\mathrm{d}} = \frac{\left(F_{\mathrm{emax,v0}} + F_{\mathrm{cmax,v0}}\right)/2}{d_0}\sqrt{1+\tan^2 \Phi}$$

$$c_{\mathrm{d}} = \frac{k_{\mathrm{d}}}{\omega \times \tan \Phi} = \frac{\left(F_{\mathrm{emax,v0}} + F_{\mathrm{cmax,v0}}\right)/2}{d_0 \times \omega \times \sin \Phi}$$

If the force as a function of displacement phase shift Φ is greater than 80° (for example, at low frequencies when $\omega \times c_{\mathrm{d}} << k_{\mathrm{d}}$), the influence of the error of measurement of Φ can be significant. In this case, it could be useful to determine for each velocity v_0 the parameters c_{d} and k_{d} in two steps as follows:

a) at low frequency (with large amplitude): $c_{\mathrm{d}} \approx \dfrac{\left(F_{\mathrm{emax,v0}} + F_{\mathrm{cmax,v0}}\right)/2}{d_0 \times \omega}$;

b) at high frequency (with small amplitude): $k_{\mathrm{d}} \approx \omega \times c_{\mathrm{d}} \times \tan \Phi$.

In case of a non-linear force – velocity characteristic the parameter k_{d} can also be taken out of the force – displacement diagram. It is the gradient in point A and B of Figure 7.

4.4.7 Priming

The damper specification shall define the requirements with regard to loss of priming during service, transport or storage.

Dampers shall not lose priming during service or after storage or transport when maintained within the extreme temperature range ($T_{\mathrm{ae,min}}$ to $T_{\mathrm{ae,max}}$).

If the damper loses priming, information on how to treat the damper to reach a primed condition shall be given in the damper specification.

The damper shall then remain in an operational (primed) condition following this treatment for the duration of its service interval.

5 Test methods

5.1 General requirements

5.1.1 Test compliance

All the test requirements shall be achieved to obtain test compliance.

The list of type tests and serial tests shall be defined. An example is given in Annex E.

5.1.2 Testing machine

The testing machine shall be able to measure forces in extension and compression along the damper axis direction.

The testing equipment shall have a sufficiently high stiffness value in order to avoid a significant effect on the test results.

The test velocity shall have the following characteristic:

$$v(t) = v_0 \times \cos(\omega \times t)$$

where

$v(t)$	is velocity (m/s);
v_0	is peak velocity (m/s);
ω	is the pulsation (rad/s);
t	is time (s).

The testing equipment shall have accuracy in accordance with the required measurements. The uncertainty shall be given with the results of the measurements.

Unless otherwise specified, the maximum admissible uncertainties in measurements are the following:

Forces:	± 250 N;
Displacements:	± 10 % with a maximum of ± 1 mm;
Frequency:	± 0,01 Hz;
Velocity:	± 0,05 x v_0.

5.1.3 Test temperature

Unless otherwise specified, the test temperature of the damper shall be the nominal test temperature T_n.

At the serial tests, any deviations from that range should be properly compensated in the testing procedure.

Testing shall include the influence of ambient temperature range during service.

5.1.4 Test sample

If not otherwise specified, the serial and type tests shall be performed without end mountings.

For the friction characteristic type damper, it is recommended to perform the type tests with and without end mountings.

5.2 Operational environment requirements

5.2.1 Service conditions

The method of evaluation of the damper shall be specified in the damper specification.

It shall be evaluated by one of the following:

a) an endurance test on a test rig;

b) an endurance test in service;

c) a combination of a) and b).

When method a) or method c), is used, the damper specification shall specify the orientation of the damper during evaluation this would typically be in the position as for service operation.

5.2.2 Climatic conditions

5.2.2.1 Operating temperature range ($T_{ao,min}$ to $T_{ao,max}$)

Two test procedures shall be carried out in accordance with Table 2. The procedure shall be executed at the minimum test temperature $T_{ao,min}$ and at the maximum test temperature $T_{ao,max}$.

Table 2 — Verification of damper characteristic over the operating temperature range

Initial preparation	The damper shall be in a primed condition
Principal equipment	Dynamic testing machine as defined in 5.1.2.
Testing position	The actual installed position of the damper on the vehicle (an angle to the horizontal) shall be specified. The testing position shall be defined.
Testing length	The testing length shall be defined. The default length is the installation length L_i
Testing motion	Sinusoidal motion $d(t)$ (see NOTE 5 in 3.2).
Test damper displacement	The displacement shall be specified. The default displacement is ± 25 mm.
Test velocity	At the nominal velocity v_n
Initial test	The test defined in 5.4.2, shall be carried out at the nominal temperature T_n
Pre-test conditioning	The damper shall be exposed to the test temperature ($T_{ao,min}$ or $T_{ao,max}$) for at least 24 h. The damper shall be in its service assembly position for this period unless otherwise defined. No priming operation shall be carried out after this phase of pre-conditioning.
Chronology of the further tests	1. Carry out at least two complete consecutive cycles immediately after exposure at $T_{ao,min}$ and $T_{ao,max}$. Record the result of the second cycle in each case. 2. Carry out 20 continuous cycles. This shall be completed as quickly as possible after exposure to the test temperature. 3. Return the test piece to the nominal temperature T_n for at least 24 h. The damper shall remain in its service assembly position. 4. Carry out at least four complete continuous cycles. Record the result of the fourth.
Analysis	Test sequences 1 and 4 are designed to verify damper performance within the specified requirements of 4.2.2.2.

5.2.2.2 Temperature extremes ($T_{ae,min}$ to $T_{ae,max}$)

Two test procedures shall be carried out in accordance with Table 3. The procedure in Table 3 shall be executed at test temperature $T_{ae,min}$ (the minimum temperature) and at test temperature $T_{ae,max}$ (the maximum temperature).

Table 3 — Verification of damper characteristics over the temperature extremes

Initial preparation	The damper shall be in a primed condition.
Principal equipment	Dynamic testing machine as defined in 5.1.2.
Testing position	The actual installed position of the damper on the vehicle (an angle to the horizontal) shall be specified. The testing position shall be defined.
Testing length	The testing length shall be defined. The default length is the installation length L_i
Testing motion	Sinusoidal motion $d(t)$ (see NOTE 5 in 3.2).
Test damper displacement	The displacement shall be specified. The default displacement is ± 25 mm.
Test velocity	At the nominal velocity v_n
Initial test	The test defined in 5.4.2, shall be carried out at the nominal temperature T_n
Pre-test conditioning	The damper shall be exposed to the test temperature ($T_{ae,min}$ or $T_{ae,max}$) for at least 24 h. The damper shall be in its service assembly position for this period unless otherwise defined. No priming procedure shall be carried out before the test.
Chronology of the further tests	1. Carry out at least two complete consecutive cycles immediately after exposure at $T_{ae,min}$ and $T_{ae,max}$. Record the result of the second cycle in each case. 2. Carry out 20 continuous cycles. This shall be completed as quickly as possible after exposure to the test temperature. 3. Return the test piece to the nominal temperature T_n for at least 24 h. The damper shall remain in its service assembly position. 4. Carry out at least four complete continuous cycles. Record the result of the fourth.
Analysis	Test sequences 1 and 3 are designed to verify damper performance within the specified requirements of 4.2.2.3.

5.2.2.3 Storage temperatures ($T_{s,min}$ to $T_{s,max}$)

Two test procedures shall be carried out in accordance with Table 4. The procedure shall be executed at the minimum test temperature $T_{s,min}$ and at the maximum test temperature $T_{s,max}$.

Table 4 — Verification of damper characteristics after exposure to storage temperatures

Initial preparation	The damper shall be in a primed condition.
Principal equipment	Dynamic testing machine as defined in 5.1.2.
Testing position	The actual installed position of the damper on the vehicle (an angle to the horizontal) shall be specified. The testing position shall be defined.
Testing length	The testing length shall be defined. The default length is the installation length L_i
Testing motion	Sinusoidal motion $d(t)$ (see NOTE 5 in 3.2).
Test damper displacement	The displacement shall be specified. The default displacement is ± 25 mm.
Test velocity	At the nominal velocity v_n
Initial test	The test defined in 5.4.2, shall be carried out at the nominal temperature T_n
Pre-test conditioning	The damper shall be exposed to the test temperature ($T_{s,min}$ or $T_{s,max}$) for at least 24 h. Priming procedure may be carried out before the test.
Chronology of the further tests	1. Return the test piece to the nominal temperature T_n for at least 24 h. 2. Carry out at least four complete continuous cycles. Record the result of the fourth.
Analysis	Test sequence 2: is designed to verify damper performance within the specified requirements of 4.2.2.4.

5.2.2.4 Specific climatic conditions

Special tests for specific requirements shall be defined in the damper specification.

5.2.3 Special environmental conditions

If required, special environmental conditions test method shall be defined in the damper specification.

5.2.4 Vibrational exposure

If required, resistance to vibration test method shall be defined in the damper specification.

5.3 Physical characteristics

5.3.1 Strength

The strength of a damper shall be tested in accordance with the following method:

— Carry out axial compression and extension force tests on the damper.

— The damper shall then be subjected to the forces defined in the damper specification (static compression and/or extension forces) for at least 15 s, according to the requirements of 4.3.1.

— The damper shall then be tested again in accordance with 5.4.4 to verify the damper characteristic and ensure that it has not suffered damage (e.g. no fluid leaks, etc.).

5.3.2 Fire resistance

Special tests for specific requirements shall be defined in the damper specification.

5.3.3 Surface protection

The surface protection including gloss number shall conform to EN ISO 2813 and other relevant characteristics (e.g. colour) of the damper. The test results shall be recorded and compared with the specified criteria. Unless otherwise defined, a salt spray test according to EN ISO 9227 shall be carried out. Where parameters are not specified, the time that shall be used is 480 h, for all dampers.

5.3.4 Noise

Special tests for specific requirements shall be defined in the damper specification.

5.3.5 Whole life environmental impact

Special tests for specific requirements shall be defined in the damper specification.

5.3.6 Leakage

The following procedure shall be executed as a minimum.

Table 5 — Leakage test

Principal Equipment	Dynamic testing machine as defined in 5.1.2.
Testing position	The actual installed position of the damper on the vehicle (an angle to the horizontal) shall be specified. The testing position shall be defined.
Testing length	See test damper displacement.
Testing motion	Sinusoidal motion $d(t)$ (see NOTE 5 in 3.2).
Test damper displacement	— minimum test length: $L_{\text{u,min}} + 5\ \text{mm}$ — stroke: 75 % of the working stroke, d_w with a maximum of 100 mm — (for information: maximum test length: $L_{\text{u,min}} + 5\ \text{mm} + 0{,}75 \times d_{\text{w}}$)
Test velocity	Unless otherwise specified, at the nominal velocity v_{n}
Pre-test conditioning	No priming procedure shall be carried out before the test unless specified.
Number of cycles before inspection	20 complete cycles.
Inspection	Remove the covers and examine for fluid leakage according to 4.3.6.

5.3.7 Length and stroke

Confirmation that $L_{\min} < L_{\text{u,min}}$ and $L_{\max} > L_{\text{u,max}}$ shall be established by reference to the specified values of $L_{\min}$ and $L_{\max}$.

5.3.8 Overall dimensions and interface

The extreme overall length, when extended to $L_{\text{u,max}}$, together with the maximum external cross section of the damper shall be recorded and compared with the values specified. For the case where an additional reservoir (dome) is present, the maximum dimension shall also be recorded and compared with the specified dimensions.

5.3.9 Mass

The mass of the damper shall be measured and compared with the maximum value, if specified.

5.4 Functional requirements

5.4.1 Orientation

The testing position of the damper shall be defined in the damper specification.

5.4.2 Nominal force ($F_{c,vn}$, $F_{e,vn}$) and nominal velocity (v_n)

The nominal force at nominal velocity shall be determined using the method defined in 5.4.5.

5.4.3 Maximum force ($F_{cmax,vmax}$, $F_{emax,vmax}$) and maximum velocity (v_{max})

The maximum extension and compression forces developed when the damper is subjected to the maximum velocity (v_{max}) shall be recorded and compared with the specified value.

5.4.4 Force as a function of displacement characteristic

In order to verify compliance with 4.4.4, the procedure specified in Table 6 shall be performed for each specified displacement.

These tests shall not be performed at velocities exceeding the maximum velocity defined.

For sinusoidal motion, the peak force should theoretically be at mid-travel assuming infinite damper stiffness.

Table 6 — Force as a function of displacement characteristic test

Principal equipment	Dynamic testing machine as defined in 5.1.2.
Testing position	Nominal inclination angle in service shall be applied to the damper under test (an angle to the horizontal shall be specified). The testing position shall be defined.
Testing length	The default length is the installation length L_i. If L_i is not specified, L_n is used.
Testing motion	Sinusoidal motion $d(t)$ (see NOTE 5 in 3.2).
Test damper displacement	Test shall be carried out at specified displacement. (see 4.4.4).
Test velocity	Test shall be carried out at each velocity specified. Typical nominal velocities are given in Annex C. If the application requires, additional velocities can be specified (see examples of values in Annex F). The test is normally carried out with the test velocities changing in the ascending order.
Pre-test conditioning	No priming procedure has to be carried out before the test unless specified.
Measure	At each velocity, four complete cycles shall be carried out. The fourth cycle is recorded and used in order to evaluate: — the maximum extension force ($F_{\text{emax,v0}}$) — the maximum compression force ($F_{\text{cmax,v0}}$) Additional values such as the compression force at maximum velocity $F_{c,v0}$, the extension force at maximum velocity $F_{e,v0}$ and the area of the force displacement diagram A_c may be provided if agreed between the customer and the supplier.
Diagram	The scales (force axis and displacement axis) shall be sufficiently large to have a realistic view of the behaviour of the damper. The maximum extension and compression values shall be written on the diagram.
Analysis	The diagram shape shall be in compliance with 4.4.4 without irregularities or discontinuities.

5.4.5 Force as a function of velocity characteristic

5.4.5.1 General

The force as a function of velocity v_0 characteristic is extracted from the results of the force as a function of displacement test (see 5.4.4).

Test results shall be shown in force as a function of displacement diagrams and (in case of several velocities) in a force as a function of velocity characteristic (showing the maximum forces) in order to verify if:

- maximum forces are within tolerance;
- measured values correlate with the specification.

In order to verify compliance with 4.4.5, each pair of forces as a function of velocity points of the procedure described in 5.4.4 shall be recorded on a graph. Then, the force as a function of velocity characteristic shall be drawn with all the recorded points. Two curves (one for extension and one for compression) shall be drawn for each specified displacement.

5.4.5.2 Acceptance

Each point of the extension and the compression curves shall be within the tolerances specified in 4.4.4.

5.4.6 Dynamic characteristics

5.4.6.1 General

For the definition of the dynamic characteristic of the friction characteristic type damper, the fourth cycle shall be used to evaluate dynamic stiffness k_d and damping c_d, according to the methodology reported in 4.4.6 and in Table 6 (force as a function of velocity diagram). Dynamic stiffness k_d and damping c_d shall be reported on a graph, as a function of the frequency.

It is left to an agreement between the customer and the supplier to extend this methodology to other dampers. The test and analysis methods to be used to evaluate the dynamic characteristics of the damper are defined in the damper specification. If not otherwise agreed, these should be based upon the Maxwell model (see 4.4.6).

5.4.6.2 Dynamic damping characteristics

For dampers of small operating damper displacement, where the dynamic damping characteristic forms part of the damper performance description, all measured values of the dynamic damping rate at the test temperature and within the stated frequency and amplitude range shall be equal to or exceed the minimum dynamic damping rate stated.

5.4.6.3 Dynamic stiffness characteristics

For dampers where minimum dynamic stiffness values form part of the damper performance description, all values measured at the test temperature and within the stated frequency and amplitude range shall lie within a percentage tolerance band applied above the minimum dynamic stiffness characteristic. Dampers shall comply with the values and percentage tolerance stated.

5.4.7 Priming

The self priming of the damper shall be demonstrated.

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

6 Production control

6.1 General

Supply of hydraulic dampers shall be subject to a formal quality control process.

NOTE A process conforming to EN ISO 9001 would meet this requirement. Other means of quality assessment, such as IRIS, would be subject to an agreement between the customer and the supplier.

6.2 Product verification

If required by the quality control process there shall be formal verification of production samples, an example process is given in Annex G.

6.3 Results of the tests

In cases of non-conformity with the requirements of Clause 4, the following measures shall apply:

a) in case of a per unit check (100 %):

  1) rejection of the damper;

b) in case of test according to a quality assurance plan:

  1) rejection of the corresponding batch.

For case “b”, a special control plan and acceptance criteria should be agreed between the customer and the supplier (e.g. unit control, corrective action). Depending on the nature and level of defect, the approval of the product may be withdrawn.

7 Marking

Each damper shall be permanently marked with a system that remains legible during the service interval (e.g. identification band, stamping on damper end). The identification system shall be defined.

The following data shall be included:

— identification of the manufacturer;

— code of the manufacturer’s plant, if there is more than one;

— date of manufacture (at least month and year);

— article reference of the manufacturer;

— nominal force and nominal velocity;

— additional information, if required (for example : serial number).

If the damper requires a particular orientation in the mechanical system in which it is mounted, a marking of the orientation shall be indicated on it and shall be defined in the damper specification.

If a rotational position about the X axis is needed for horizontal oriented dampers, a permanent and unique marking to be defined in the damper specification document is required on the lower side of the installed position of the damper, except when there is an additional reservoir (dome) that is already on top of the damper.

8 Packaging

The dampers shall be packed, either individually or per delivery batch, in such a way that they cannot be damaged during transport.

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

- identification of the supplier;
- contract number or purchase order number;
- quantity of articles in the package;
- description of the articles.

9 Maintainability

A damper can be maintainable, adjustable or neither.

If maintainability is required, the maintenance manual should be provided by the supplier. The maintenance manual should indicate dismounting, mounting, adjustment, list of spare parts including criteria for replacement, tools, etc.

Annex A
(informative)

Damper specification

The damper specification pro-forma in Table A.1 may be used to record the customer aspirations (requirements) and the potential supplier's suggestions (damper capability) against the customer's aspirations:

Table A.1 — Damper specification

Customer details		**Supplier details**
Name of the company: Contact:		Name of the company: Contact
Reference:		Reference:
Vehicle:		Detail of Damper:
Application: (e.g. Primary / Secondary / Transversal / Vertical / Yaw / Pantograph / motor)		Part Reference:
Damper specification:		Drawing Number:
Date **:**		Date:
Issue :		Issue:
	Damper requirement (To fill in by the supplier)	Damper capability (To fill in by the customer)
Operational environment requirements		
Service conditions		
Service interval (distance, time):		
Maximum failure rate:		
Climatic conditions		
Operating temperatures		
Minimum, $T_{\text{ao,min}}$:		
Maximum, $T_{\text{ao,max}}$:		
Acceptable variation of characteristics within ambient temperatures range:		
Extreme temperatures		
Minimum, $T_{\text{ae,min}}$:		

Maximum, $T_{ae,max}$:		
Storage temperatures		
Minimum, $T_{s,min}$:		
Maximum, $T_{s,max}$:		
Specific climatic conditions		
Specific climatic conditions: (e.g. snow and ice, high relative humidity, exposure to bright sunlight, exposure to ozone)		
Other conditions		
— Projection of ballast: — Projection of oil or petroleum products: — Projection of organic waste: — Saline spray: — Washing plant agents (dilute acids, alkalis, detergents):		
Vibrational exposure		
— Location in vehicle (e.g. Between bogie and body): — Resonant sources:		
Physical characteristics		
Strength: — Compressive axial load — Tensile axial load		
Fire resistance:		
Surface Protection: — Colour and gloss		
Noise:		
Whole Life Environmental Impact:		
Leakage:		
Length and Stroke , two of: — $L_{u,min}$ — $L_{u,max}$ — d_w		
Delivery length:		

Overall Dimensions and Interface. Related drawing N°: — D_{max} : — D_{res} : — H_{res} : — End side dust guard: — End side tank:		
Mass (without end mountings) — Maximum/minimum: — Tolerance:		
Functional Requirements		
Orientation: — angle to horizontal as a result of load and/or suspension state change		
Nominal force ($F_{c,vn}$, $F_{e,vn}$): and Nominal Velocity (v_n):		
Maximum force ($F_{cmax,vmax}$, $F_{emax,vmax}$): and Maximum Velocity (v_{max}):		
Force as a function of velocity characteristic — Symmetrical / asymmetrical: — Test velocity, damper displacement and length: — Target values – tolerances: Either % tolerance on force - extension - compression or Max/min force values at discrete velocities		
Force as a function of Displacement Characteristic — Test damper displacement and length: — Target values – tolerances:		

Dynamic characteristics — Amplitude range: — Frequency range: — Damper stiffness k_d: — Minimum dynamic stiffness: — % tolerance on dynamic stiffness: — Dynamic damping rate c_d: — Minimum dynamic damping rate: — % tolerance on dynamic damping rate: — Reference frequency for values: — Reference amplitude for values:		
Priming: — Conditions under which priming shall be carried out		
Testing		
Testing position (usually installation position): Testing length (usually installation length): Test displacement:		

Annex B
(informative)

Damper dimensions

B.1 Range of damper overall dimensions

Table B.1 presents a range of dimensions of dampers, defined in Figure B.1, that are generally used.

Table B.1 — Damper dimensions

Size	D_{max} [mm]	D_{res} [mm]	H_{res} [mm]
1	70	45	60
2	85	75	90
3	105	90	90
4	115	105	90
5	125	115	90
6	125	135	190
The size of the damper should be in accordance with the forces that the damper is expected to experience.			

An additional tank (reservoir dome), the dimensions of which are defined by D_{res} and H_{res}, is optional.

Adopting one of these suggested sizes, when incorporating a damper in a mechanical system design, will minimise the dimensional variety of dampers.

The diameters D1 and D2 shall be defined (see Figure B.3 and Figure B.4).

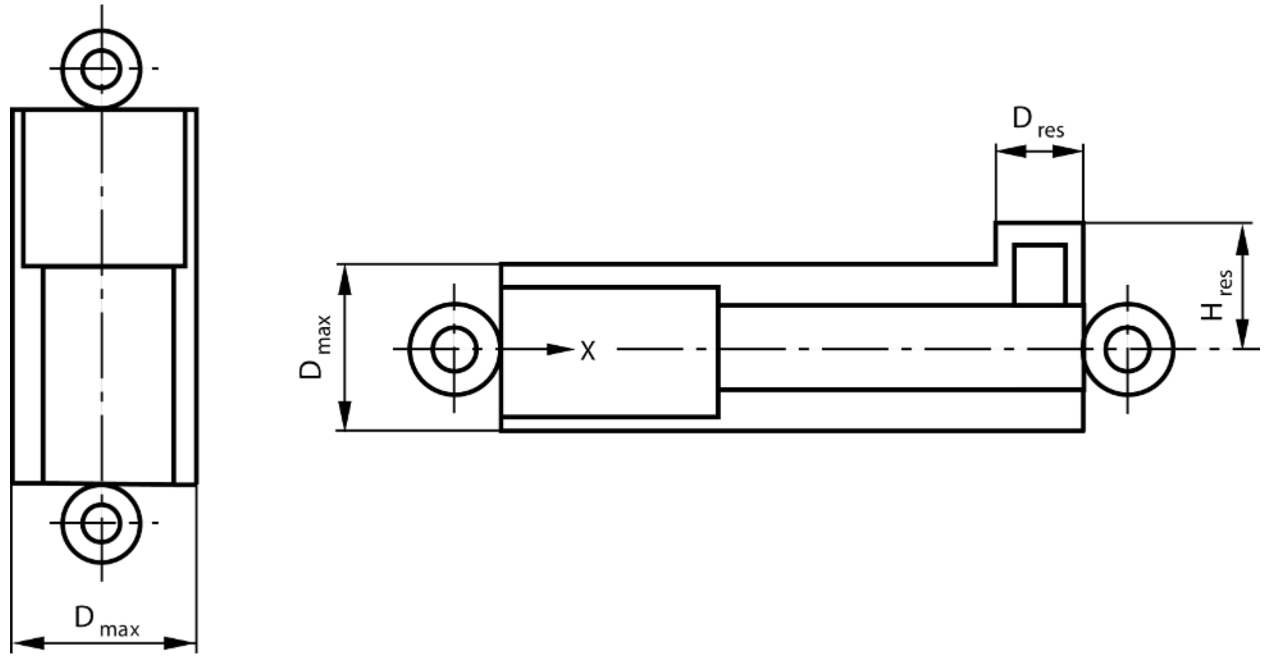


Figure B.1 — Definition of standard volume envelope

B.2 Calculating the damper length

The relevant damper lengths $L_{\min}$ and $L_{\max}$ are defined according to the following formulae (see Figure B.2):

$$L_{\min} = L_{d} + L_{x} + L_{y} + d_{w} + d_{e} + d_{c} = L_{u,\min} - d_{c} \text{ [mm]}$$

$$L_{\max} = L_{d} + L_{x} + L_{y} + 2 \times (d_{w} + d_{e} + d_{c}) = L_{u,\max} + d_{e} \text{ [mm]}$$

where

L_{d}: damper dead length is the sum of all damper length affecting components (see Figure B.2 and Table B.2);

L_{x}: length from bottom of reservoir tube to centre of end mounting;

L_{y}: length upper side of from dust cap to centre of end mounting.

For lengths L_{x} and L_{y} of trunnion or cylindrical bushes see Figure B.3, of stem end bushes see Figure B.4.

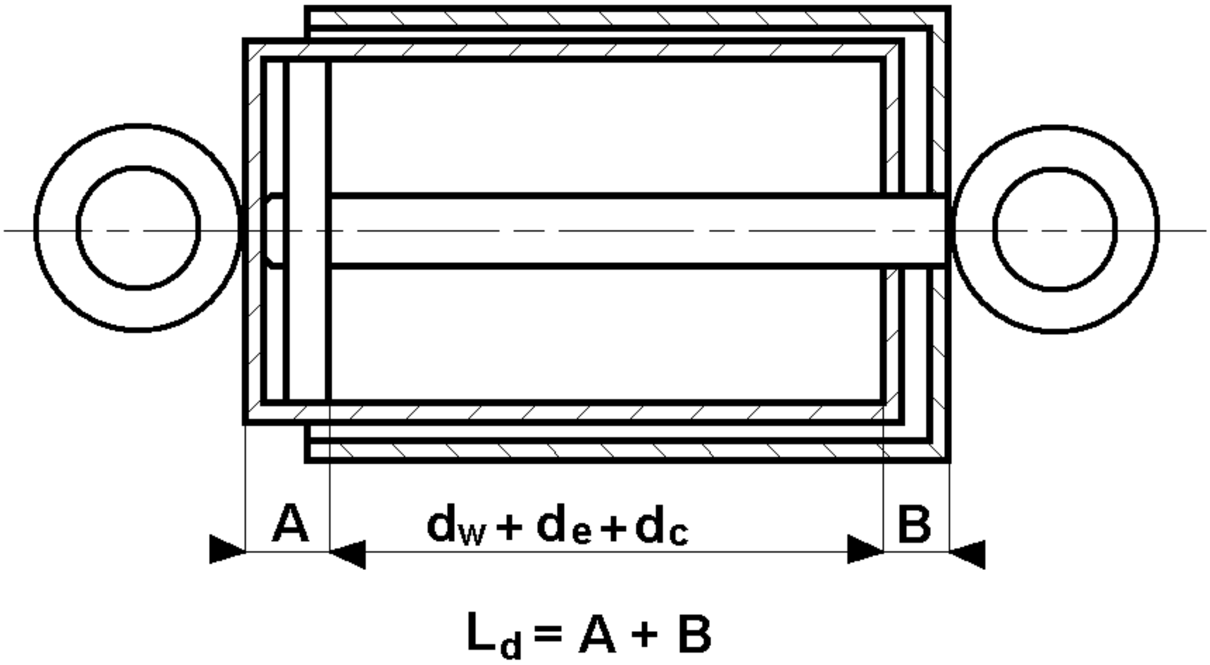


Figure B.2 — Definition of damper dead length (damper fully compressed)

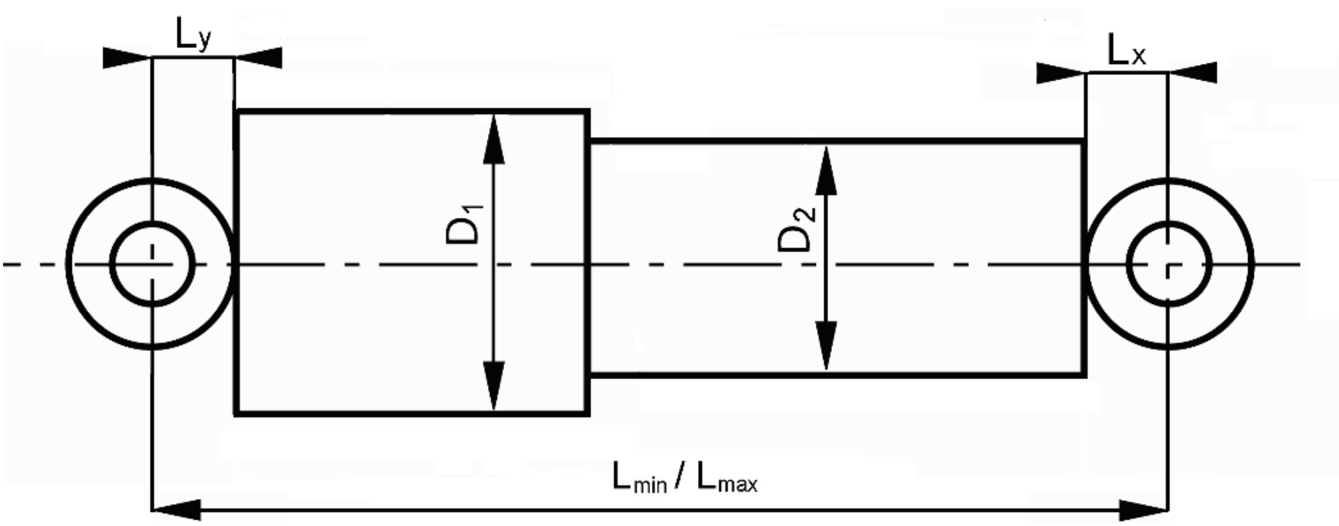


Figure B.3 — Definition of damper with trunnion or cylindrical bush length

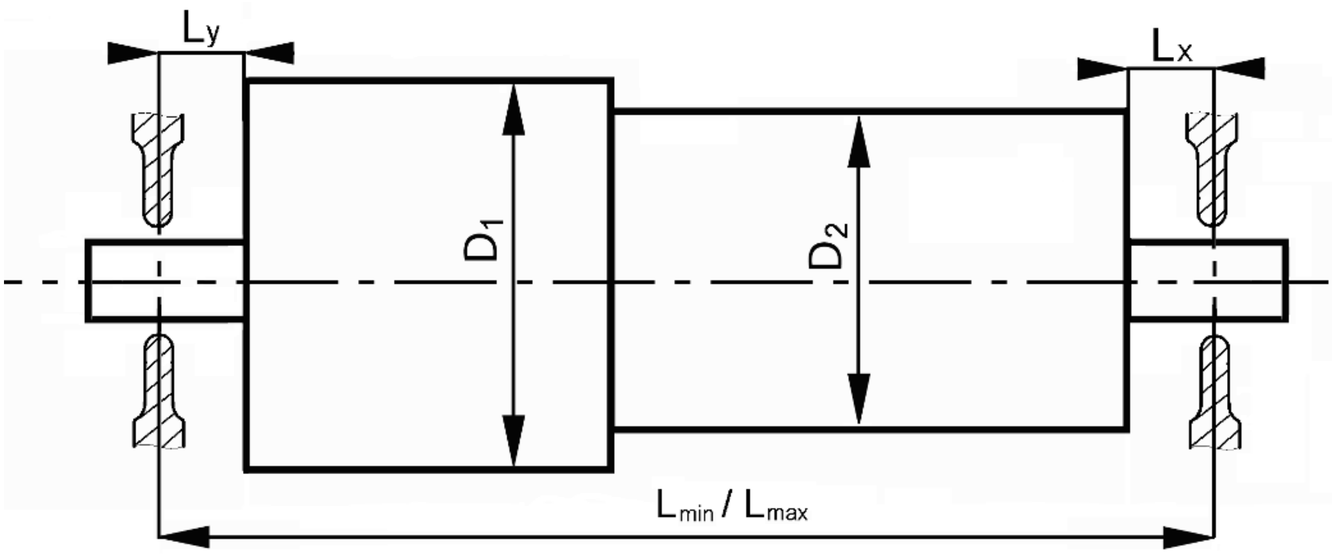


Figure B.4 — Definition of damper length with stem or bush

Table B.2 — Preferred ranges of dead length L_d

	Dead length L_d			
	Minimum [mm]		Maximum [mm]	
Maintainable version				
Primary vertical damper	97,5	104,5[a]	132	
Secondary vertical damper	97,5	104,5[a]	137	
Secondary lateral damper	97,5		137	
Yaw damper	142		160	
Maintenance-free version				
Primary vertical damper	96,5	105,5[a]	106	108[a]
Secondary vertical damper	96,5	105,5[a]	106	108[a]
Secondary lateral damper	96,5		106	

[a] This value is valid only for a damper with stem end bushes.

B.3 Preferred end mounting dimensions

In Table B.3 preferred values of trunnion and cylindrical bushings are listed for calculating the damper lengths (see B.2). The diameter $\varnothing B$ and the distances L_x , L_y can be seen in Figure B.5.

Table B.3 — Preferred values of trunnion and cylindrical bushes

Damper ring outer diameter	Axle distance to damper body
$\varnothing B$ [mm]	L_x , L_y [mm]
60	30
70	35
80	40
90	45
110	55

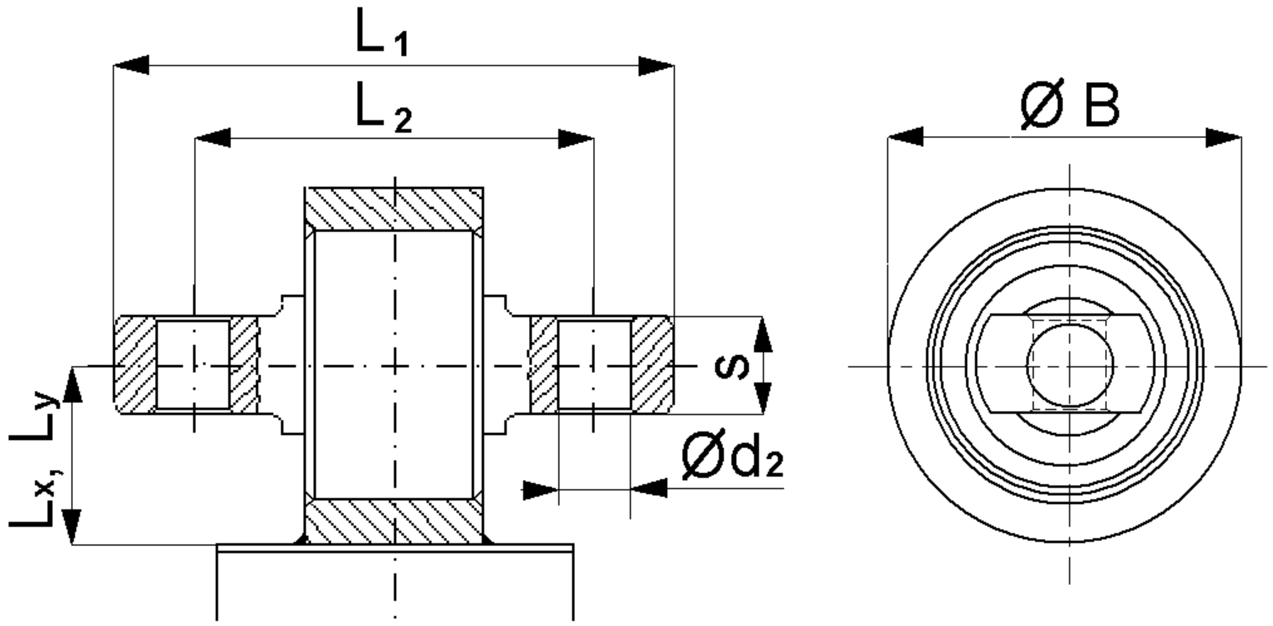


Figure B.5 — Dimensions of trunnion bush

Preferred interface dimensions for all types of end mountings:

— Form A with trunnion bush (see Table B.4 and Figure B.5);

— Form B with cylindrical bush (see Table B.5 and Figure B.6);

— Form C with stem end bush (see Table B.6 and Figure B.7).

Table B.4 — Preferred interface dimensions of trunnion bushes (Form A)

Size	L_1 ± 1 [mm]	L_2 ± 0.2 [mm]	s ± 0.2 [mm]	$\varnothing d_2$ +0.3/-0.2 [mm]
1	135	108	16	14
2	135	96	16	17
3	175	140	20	17
4	180	130	28	22

Table B.5 — Preferred interface dimensions of cylindrical bushes (Form B)

Size	L_1 [mm]	$\varnothing d_1$ ± 0.2 [mm]	$\varnothing d_2$ ± 0.2 [mm]
1	55	24	30
2	66	28	40

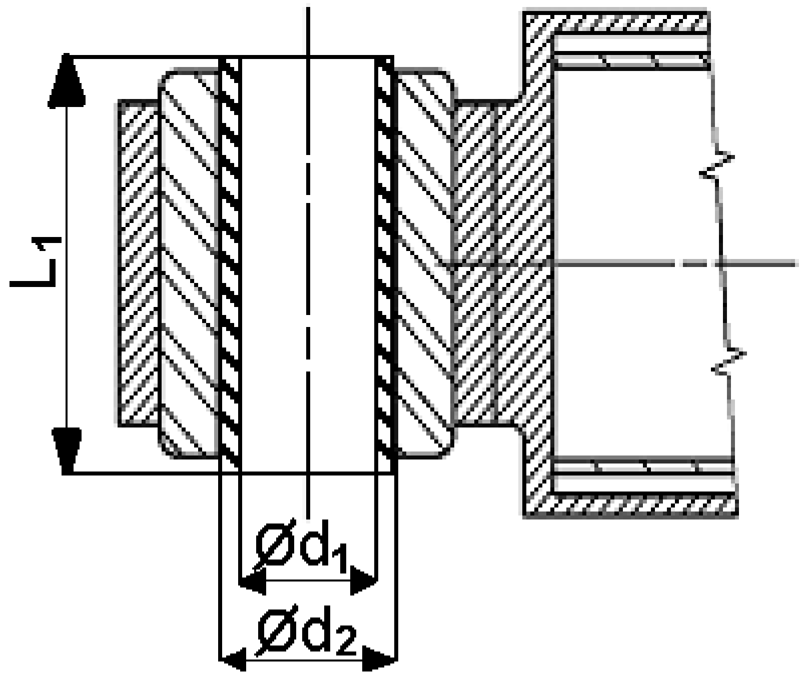


Figure B.6 — Dimensions of cylindrical bush

Table B.6 — Preferred interface dimensions of stem end bushes (Form C)

Size	$\varnothing d_1 \pm 0.5$ [mm]	$\varnothing d_h \pm 0.5$ [mm]	$s \pm 0.5$ [mm]	Radius of rubber [mm]	Chamfer of plate	$L_x \pm 0.5$ [mm]
1	30	31	10	≤ 1.5	> 1.5 mm × 45°	27.5
2	35.5	37	10	≤ 2	> 2 mm × 45°	29.5
NOTE Diameter d_h of bore hole in the adapting steel plate.						

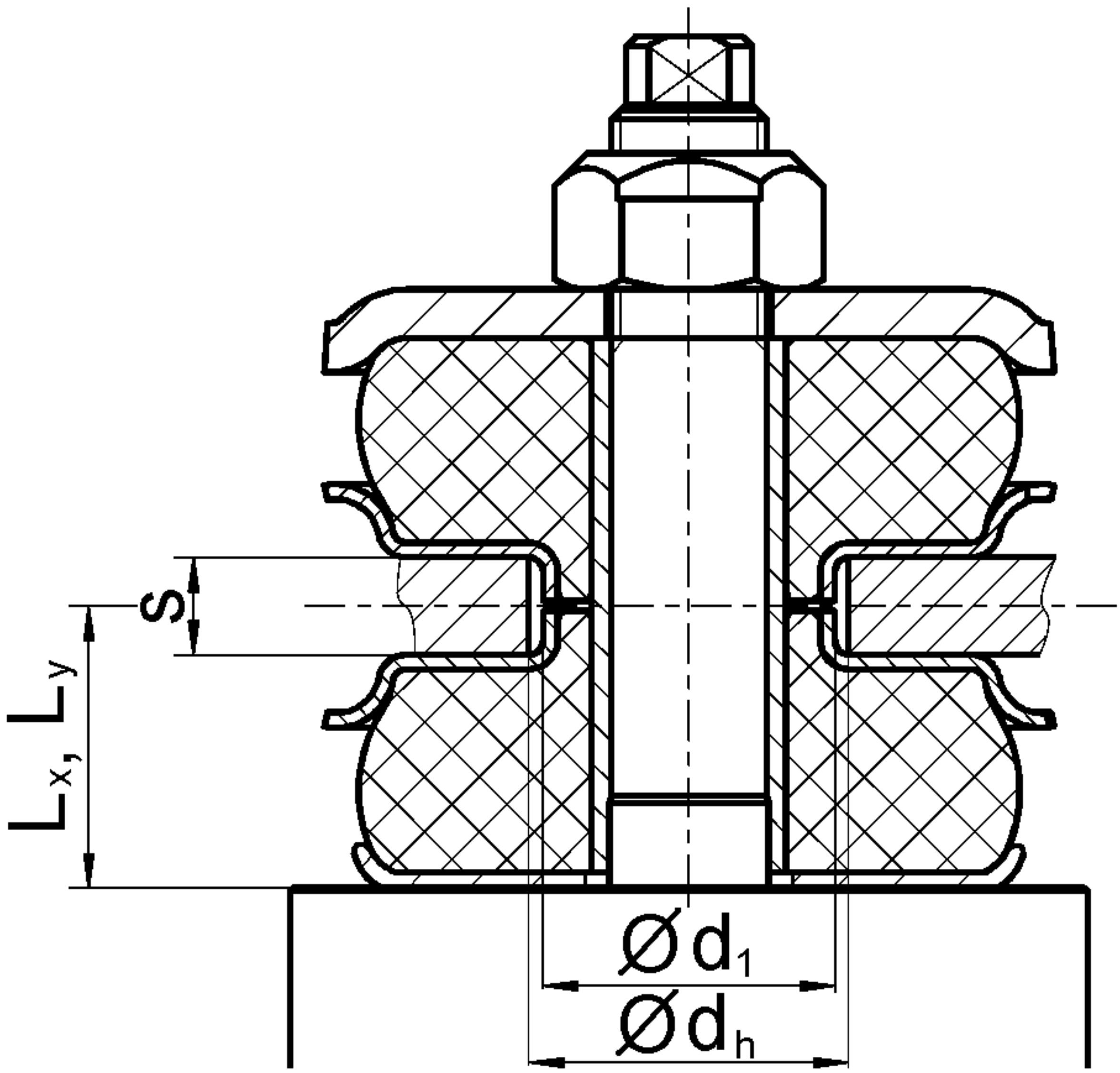


Figure B.7 — Dimensions of stem end bush

Annex C
(informative)

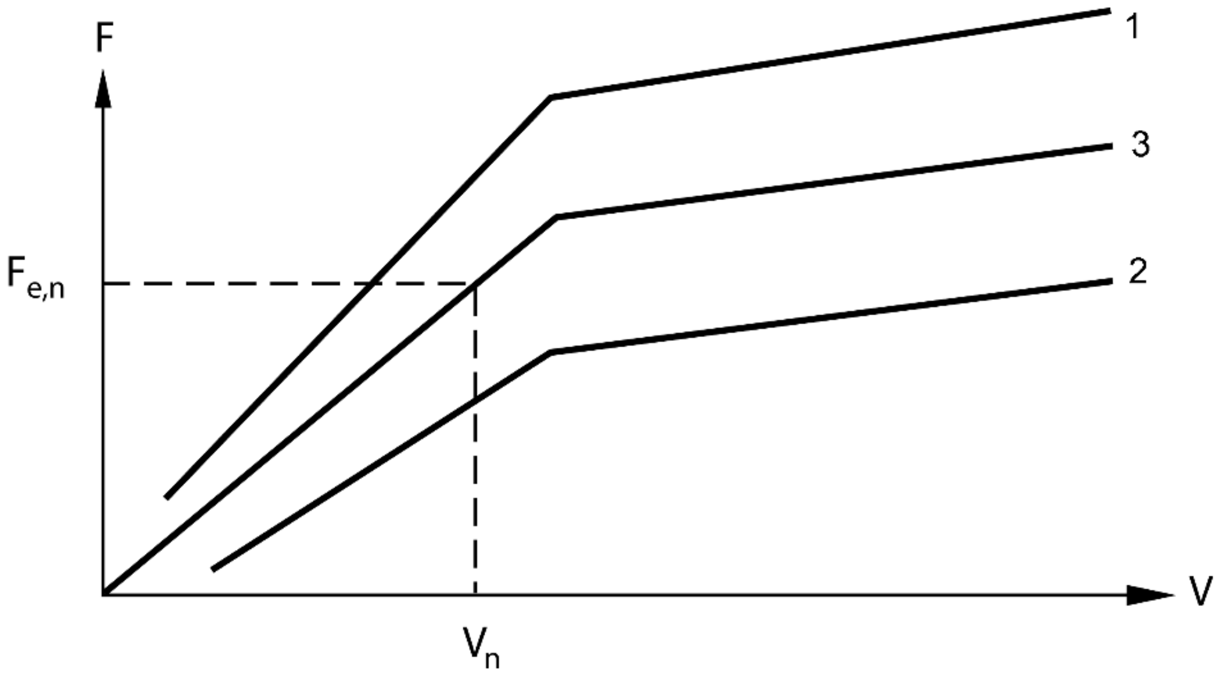
Nominal velocities

This annex gives a non-exhaustive list of nominal velocities, which are usually adopted according to a damper's main applications:

- Primary suspension damper (in vertical direction): 0,3 m/s;
- Secondary suspension damper (in vertical direction): 0,15 m/s;
- Secondary suspension damper (in transverse direction): 0,1 m/s;
- Yaw damper between vehicle body and bogie:
  - 0,002 6 m/s;
  - 0,05 m/s;
  - 0,1 m/s.
- Damper between adjacent vehicle bodies:
  - longitudinal installation 0,001 m/s;
  - transverse installation 0,1 m/s;
  - vertical installation 0,1 m/s;
- Damper for the pantographs:
  - 0,03 m/s;
  - 0,06 m/s.

Annex D
(informative)

Examples of force as a function of velocity characteristic



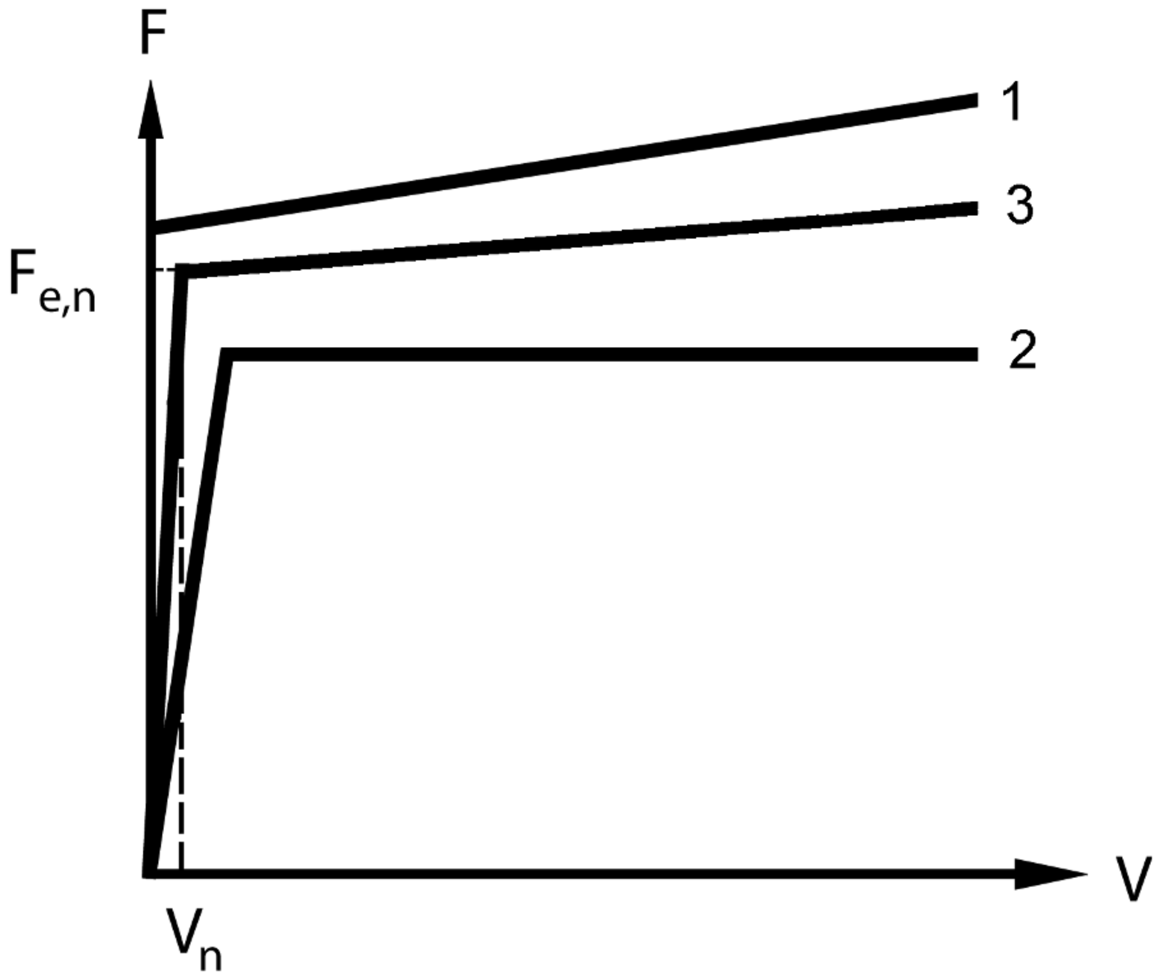
Key

1 maximum tolerance

2 minimum tolerance

3 nominal characteristic

Figure D.1 — Linear characteristic under nominal value



Key

1 maximum tolerance
2 minimum tolerance
3 nominal characteristic

Figure D.2 — Friction characteristic type

Annex E
(informative)

Checks and tests to be performed according to damper category

Table E.1 shows a pro-forma that can be used by the customer in defining required tests for verification of specific characteristics.

Table E.1 — Form for requests for type test and serial test

Test	Sub-clause	Type test	Serial test
Service conditions	5.2.1		Non applicable
Strength	5.3.1		Non applicable
Leakage	5.3.6		Non applicable
Operating Temperature Range	5.2.2.1		Non applicable
Temperature Extremes	5.2.2.2		Non applicable
Storage temperatures	5.2.2.3		Non applicable
Specific Climatic Conditions	5.2.2.4		Non applicable
Orientation	5.4.1		
Fire Resistance	5.3.2		Non applicable
Surface Protection	5.3.3		
Length and Stroke	5.3.7		
Overall Dimensions and interface	5.3.8		
Mass	5.3.9		
Nominal Velocity and Nominal Force	5.4.2		
Maximum Velocity and Maximum Force	5.4.3		
Force as a function of Displacement Characteristic	5.4.4		
Force as a function of Velocity Characteristic	5.4.5		
Dynamic Characteristics	5.4.6		
Noise	5.3.4		
Priming	5.4.7		Non applicable

Annex F
(informative)

Dynamic test velocities

A sinusoidal displacement shall be applied. Testing velocity, displacement and frequency are related, as reported in excitation frequency f (see 3.2). The value proposed in Table F.1 will be recommended for dynamic test.

For dampers with small displacement amplitude in service, it is recommended that the customer specifies additional parameters for tests with small stroke (for example: A_c).

Table F.1 — Typical displacement and velocity value for dynamic test

Displacement amplitude d_0 [mm]		**1**	**2,5**	**5**	**12,5**	**25**
		Frequency [Hz]				
Velocity [m/s]	**0,002 6**	0,41	0,17	0,08	0,03	0,02
	0,010	1,59	0,64	0,32	0,13	0,06
	0,020	3,18	1,27	0,64	0,25	0,13
	0,030	4,77	1,91	0,95	0,38	0,19
	0,050	7,96	3,18	1,59	0,64	0,32
	0,100	15,92	6,37	3,18	1,27	0,64
	0,150	-	9,55	4,77	1,91	0,95
	0,300	-	-	9,55	3,82	1,91
	0,500	-	-	-	6,37	3,18

Annex G
(informative)

Conformity assessment procedures, samples, validity and monitoring

G.1 Conformity assessment procedure of the product

If required by the customer, a First Article Inspection (FAI) shall be planned. The details of the FAI shall be defined by the customer.

The damper manufacturing processes shall be performed only by suppliers approved by the customer.

This subclause specifies the requirements and procedures to be applied for the product qualification. The requirements shall be applied in the following cases:

— Case 1: damper of a new supplier;

— Case 2: new damper of a known supplier (damper featuring at least one difference to an already approved damper);

— Case 3: already approved damper to be produced by a known supplier, but when the operational conditions of the damper are changed (new damper specification);

— Case 4: changes in the manufacturing procedures of an already approved damper with a known supplier, including the manufacturing plant.

All dampers which are part of the chosen sample for the verification tests should be from the same manufacturing batch (same basic material and same manufacturing procedure).

The sample shall be representative of the serial production, and not a prototype.

The customer shall specify the number of dampers to be subjected to the tests detailed in Clause 5. The order of the tests shall be specified if required.

The conformity assessment procedure involves verification of the conformity assessment of the product to the stated requirements.

All the characteristics specified shall be verified on the product submitted for verification.

Any simplified conformity assessment process shall be subject to a separate agreement between the customer and the supplier.

The verifications shall be performed in accordance with the specified prescriptions.

The test facilities used to perform the verification tests shall be agreed between the customer and the supplier.

The laboratory or organization in charge to carry out the verification tests shall be agreed between the customer and the supplier.

G.2 Validity of the product approval

After conformity assessment of the product, any modification in design, technology, composition, changes in manufacturing process or modifications in the manufacturing plant, shall be reported to the customer for approval before implementation.

The customer may, in such cases, ask for reassessment of the conformity assessment of the product.

Conformity assessment may also be reassessed after:

— interruption of the manufacturing process for more than two years;

— failures in service that indicate inadequate damper quality.

G.3 Control and monitoring of production quality

For the purposes of this subclause, the terms and definitions given in EN ISO 9000 apply.

The supplier shall propose the methods for checking the manufacturing quality of his products within a quality plan submitted for the approval of the customer.

The customer may require verification of specific characteristics. Table E.1 may be used as a basis for defining the required tests.

The conformity of some requirements can be proved and documented by a certificate (e.g. according. to EN 10204, certificate 3.1).

If not otherwise agreed between the customer and the supplier there is a unitary testing at nominal velocities.

G.4 Traceability

An identification and traceability system for the product should be established.

NOTE A process conforming to EN ISO 9001 would meet this requirement. Other means of quality assessment, such as IRIS, would be subject to an agreement between the customer and the supplier.

Bibliography

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[3] EN 10204, *Metallic products — Types of inspection documents*

[4] EN ISO 9000, *Quality management systems — Fundamentals and vocabulary (ISO 9000)*

[5] EN ISO 9001, *Quality management systems — Requirements (ISO 9001)*

[6] IRIS, *International Railway Industry Standard*

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