INTERNATIONAL STANDARD

ISO 3408-4

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Ball screws —

Part 4: **Static axial rigidity**

Vis à billes —

Partie 4: Rigidité axiale statique

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 3408-4 was prepared by Technical Committee ISO/TC 39, *Machine tools*.

ISO 3408 consists of the following parts, under the general title *Ball screws*:

— *Part 1: Vocabulary and designation*

— *Part 2: Nominal diameters and nominal leads — Metric series*

— *Part 3: Acceptance conditions and acceptance tests*

— *Part 4: Static axial rigidity*

— *Part 5: Static and dynamic axial load ratings and operational life*

Ball screws —

Part 4:
Static axial rigidity

1 Scope

This part of ISO 3408 sets forth terms and mathematical relations relevant to the determination of the static axial rigidity of the ball screw.

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.

ISO 3408-1:2006, *Ball screws — Part 1: Vocabulary and designation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3408-1 apply.

4 Symbols and subscripts

4.1 Symbols

Symbol	Description	Unit
α	Contact angle	degrees, °
ρ	Reciprocal curvature radius	mm^{-1}
τ	Ratio of the semi-major to the semi-minor axes of the contact ellipse	—
φ	Lead angle	degrees, °
Δl	Elastic deflection	µm
c_E	Material constant	—
c_k	Geometry factor	$N^{-2/3}$ µm
d_{bo}	Diameter of the deep hole bore	mm
d_c	Diameter of load application on the ball screw shaft	mm
D_c	Diameter of load application on the ball nut	mm
D_{pw}	Ball pitch circle diameter	mm
D_w	Ball diameter	mm
D_1	Outer diameter of ball nut	mm

Symbol	Description	Unit
E	Modulus of elasticity	N/mm^2
f_{ar}	Correction factor for accuracy classes (rigidity)	—
f_{al}	Correction factor for load application	—
f_{rs}, f_{rn}	Conformity (ratio of ball/balltrack radius to ball diameter) of ball screw shaft and ball nut	—
F	Axial force, load	N
i	Number of loaded turns	—
k	Rigidity characteristic	N/μm$^{3/2}$
l	Length	mm
l_s	Unsupported length of ball screw shaft	mm
m	Poisson's constant (e.g. for steel m = 10/3)	—
n	Rotational speed	min^{-1}
P_h	Lead	mm
q	Time percentage	%
R	Rigidity	N/μm
s_a	Backlash (axial play)	μm
Y	Auxiliary value according to Hertz for the description of the elliptic integrals of the first and second kinds	N$^{-2/3}$·μm$^{4/3}$
z_1	Number of effectively loaded balls per turn	—
z_2	Number of unloaded balls in the recirculation system, only for systems where balls will be recirculated after one turn	—

4.2 Subscripts

Symbol	Description
ar	refers to accuracy
b	refers to ball
bs	refers to ball screw
c	refers to nut body/ball screw shaft
e	refers to external load or the resulting deformation respectively
lim	refers to limit load (at this value the contact between balls and balltracks of ball screw shaft and ball nut is eliminated)
m	refers to equivalent
N	refers to normal load which acts upon balls and balltracks of the ball screw shaft and ball nut in the direction of the contact angle
n	refers to ball nut
pr	refers to preload
s	refers to ball screw shaft
b/t	refers to ball/balltrack area
nu	refers to ball screw within the loaded ball nut area
1	refers to ball nut 1
2	refers to ball nut 2

5 Determination of static axial rigidity, R

5.1 General

The static axial rigidity of a ball screw exerts a major influence on its positioning accuracy. It is a function of the design of the ball screw, its support and bearing arrangement. For the purpose of the calculation given below support and bearing arrangement have been disregarded.

The static axial rigidity of ball screws is not linear. For the purpose of the study of rigidity, a ball screw can be conceived as a combination of several linear and non-linear spring elements. For this reason the rigidity value indicated is correct only for one load application.

The deflection to be determined is caused by

— axial deflections of the screw shaft and the ball nut body,

— radial deflections of the screw shaft and the ball nut body,

— deflections of the balls and the thread land.

The calculation of the deflections attributable to the ball contact is based on the theory related to Hertz stress. The following preconditions should be met as closely as possible:

— the material of the contacting partners shall be homogenous and isotropic,

— in addition, Hooke's law applies, i.e., no plastic deformation, and

— in the contact area only normal stress shall be acting, i.e., a level pressure surface is generated.

Moreover, the applied simplified theory of Hertz specifies identical elasticity modulus and transversal contraction parameter for the material of ball screw shaft, ball nuts and balls.

When calculating axial rigidity it is important to differentiate between ball nuts that have backlash and those that have none, i.e. preloaded ball nuts.

It is possible to generate preload by different methods:

a) **Single ball nut with continuous thread**. Preloading by oversize balls, resulting in four-point-ball-contact.

See Figure 1.

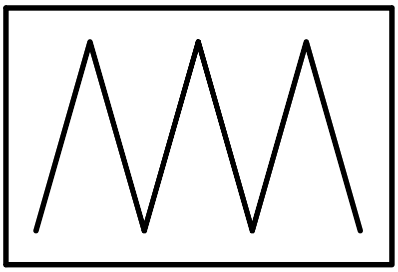

Figure 1