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Fasteners — Calculation methods for bolt/nut assemblies — Nut design

Fixations — Méthodes de calcul pour les assemblages vis/écrou — Conception des écrous

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 2, *Fasteners*, Subcommittee SC 12, *Fasteners with metric internal thread*.

This first edition of ISO 16224 cancels and replaces the first edition (ISO/TR 16224:2012), which has been technically revised.

The main changes are as follows:

— the type of ISO document has been changed from Technical Report to International Standard;

— the title has been changed to “Fasteners — Calculation methods for bolt/nut assemblies — Nut design”;

— explanations for the loadability of bolt/nut assembly including the influencing factors have been moved to Annex A;

— some editorial corrections have been made on the Formulae (1), (6), (7) and (11);

— the deviations assumed for D_2 and D_1 have been amended (see Table 1);

— Figure 2 was amended to include the nuts with chamfers on both sides;

— the symbol θ was introduced to consider countersunk (chamfer) angles other than 90° (e.g. 110° to 120° for thin nuts);

— for the conversion from the nut material strength R_{mn} to Vickers hardness and vice versa in the range of 130 HV to 303 HV, a regression Formula was introduced, which gives similar values to the original Alexander’s calculation[15];

— the values of minimum hardness, HV_{min}, and corresponding stress under proof load S_p were recalculated and amended considering the above changes (see Tables 2 and 3);

— all the technical backgrounds for the specifications in ISO 898-2:2022 have been explained for traceability of the specified values of minimum hardness and the proof loads (see Annex B);

— calculations for nuts with sizes M1,6 ≤ D < M5 and 39 mm < D ≤ 100 mm (not included in ISO 898-2) were added in order to standardize the new nut heights corresponding to style 1 and style 2 as specified in ISO 898-2 (see Annex C).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Fasteners — Calculation methods for bolt/nut assemblies — Nut design

1 Scope

This document specifies calculation methods for nuts designed to be mated with bolts, screws and studs in accordance with ISO 898-1, for use in bolted joints under tensile loading and for tightening with tension and torsion taking into account the three possible failure modes: bolt breaking, bolt thread stripping and nut thread stripping (see Clause 5).

The terms “bolt” and “nut” are used as the general terms in this document for externally threaded fasteners (i.e. bolts, screws and studs) and internally threaded fasteners (i.e. tapped holes), respectively.

This document is primarily applicable to steel hexagon nuts:

— with ISO metric thread (coarse pitch and fine pitch, see ISO 68-1);

— with diameter/pitch combinations according to ISO 261 and ISO 262;

— with thread tolerances according to ISO 965-1 and ISO 965-2;

— with nominal thread diameters 5 mm ≤ D ≤ 39 mm, and additionally with D < 5 mm and D > 39 mm (see Annex C);

— with a hexagon shape and width across flats $s \geq 1{,}4D$.

The calculation methods are also applicable to non-standard nuts or internally threaded parts with ISO metric threads. However, dimensional factors affecting the rigidity of nuts such as the width across flats, outer diameter of cylindrical nuts or other features (e.g. shape of flange) as well as thread tolerances can affect the loadability of the individual bolt/nut assemblies, see Annex A for influencing factors.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 898-2, *Fasteners — Mechanical properties of fasteners made of carbon steel and alloy steel — Part 2: Nuts with specified property classes*

ISO 16047, *Fasteners — Torque/clamp force testing*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Symbols

For the purposes of this document, the following symbols apply:

A_s stress area of the bolt taking into account the thread tolerance, in mm^2

$A_{s,nom}$ nominal stress area of the bolt specified in ISO 898-1, in mm^2

A_{Sb} shear area of the bolt thread, in mm^2

A_{Sn} shear area of the nut thread, in mm^2

C_1 nut dilation factor

C_2 thread bending factor for bolts

C_3 thread bending factor for nuts

d nominal thread diameter of the bolt, in mm

d_1 minor diameter of the bolt thread on basic profile, in mm

d_2 pitch diameter of the bolt thread, in mm

d_3 minor (root) diameter of the bolt thread on design profile, in mm

d_a countersunk diameter of the nut, in mm

d_A equivalent diameter of the stress area A_s, in mm

D nominal thread diameter of the nut, in mm

D_1 minor diameter of the nut, in mm

D_2 pitch diameter of the nut, in mm

D_m mean diameter of bell mouthed section of formed nut in the effective nut height or the length of thread engagement m_{eff}, in mm

F tensile load, (general), in N

F_{Bb} bolt breaking load, in N

F_m ultimate tensile load, in N

F_p proof load, in N

F_S stripping load of bolt/ nut assembly, in N

F_{Sb} bolt thread stripping load, in N

F_{Sn} nut thread stripping load, in N

F_u ultimate clamp force according to ISO 16047, in N

F_y yield clamp force according to ISO 16047, in N

h_c height of chamfer per nut face, in mm

H height of the fundamental triangle of the thread according to ISO 68-1, in mm

HV Vickers hardness, in HV

m height of a nut, in mm

m_c critical nut height giving same probabilities of stripping and breaking failure modes, in mm

m_{eff} effective nut height, in mm

$m_{eff,c}$ critical effective nut height giving same probabilities of stripping and breaking failure modes, in mm

m_{mc} critical nut height giving same probabilities of stripping and breaking failure modes taking into account the deviations in a manufacturing lot, in mm

P thread pitch, in mm

r root radius of the bolt, in mm

R_{eL} lower yield stress according to ISO 898-1, in MPa

R_m tensile strength of the bolt material according to ISO 898-1, in MPa

R_{mn} tensile strength of the nut material, in MPa

$R_{p0,2}$ stress at 0,2 % non-proportional elongation according to ISO 898-1, in MPa

R_s strength ratio denoted by $(R_{mn} \cdot A_{sn})/(R_m \cdot A_{sb})$

s width across flats of the nut, in mm

S_p stress under proof load, in MPa

x shear strength/tensile strength ratio

μ_{th} coefficient of friction between threads

θ countersunk angle of the nut, in degrees

τ_{Bb} shear strength of the bolt material, in MPa

τ_{Bn} shear strength of the nut material, in MPa

5 Calculation of the fracture loads in bolt/nut assemblies

5.1 General

When static tensile overload is applied to bolt/nut assemblies, three possible failure modes (i.e. bolt breaking, bolt thread stripping and nut thread stripping) characterized by three different fracture loads can occur:

— bolt breaking load, F_{Bb};

— bolt thread stripping load, F_{Sb};

— nut thread stripping load, F_{Sn}.

Of these failure modes, bolt breaking after elongation is intended by the design principle because it indicates the full loadability (performance) of the bolt/nut assembly. Furthermore, a thread stripping partially induced in the tightening process is difficult to detect; therefore, it increases the risk of fracture due to the reduction of the clamp force and/or the loadability in service.

NOTE This document does not address bolt/nut assemblies with bolts with reduced loadability due to the head or shank design.

The three possible fracture loads depend principally on the nut height, the hardness or the material tensile strength and the material shear strength of the nut, the hardness or the material tensile strength and