DRAFT INTERNATIONAL STANDARD

ISO/DIS 3506-5

ISO/TC **2**

Secretariat: **DIN**

Voting begins on:
2019-10-10

Voting terminates on:
2020-01-02

Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners —

Part 5:
Special fasteners (also including fasteners from nickel alloys) for high temperature applications

Caractéristiques mécaniques des fixations en acier inoxydable résistant à la corrosion —

Partie 5: Fixations spécifiques (incluant les fixations à partir d'alliages de nickel) résistant à la chaleur et pour applications à températures élevées

ICS: 21.060.99

This document is circulated as received from the committee secretariat.

Reference number
ISO/DIS 3506-5:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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.

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 documents 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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 2, *Fasteners.*

A list of all parts in the ISO 3506 series can be found on the ISO website.

Introduction

The properties of stainless steel and nickel alloys fasteners for high temperature applications result from the chemical composition of the material, from the heat treatment process and from the manufacturing process of the fasteners. Static or dynamic properties at room temperature like tensile strength, hardness or fatigue resistance are not exhaustive to design fasteners for high temperature applications properly.

In fact, at high temperatures e.g. above 300 °C, additional phenomena occur, for instance:

— decrease in tensile properties and hardness,

— hot oxidation and scaling,

— stress relaxation,

— creep.

All these phenomena significantly affect durability and service life of fasteners. Therefore:

— a proper choice of material grade is essential to avoid heavy hot oxidation,

— qualification of fasteners through dedicated tests should be performed.

Different tests are currently available to assess the behaviour of machined and standardized samples (see for example ASTM E292 or ASTM E328).

In addition to such tests, this document includes guidelines for test methods on finished fasteners. These are useful to get results as representative as possible of the actual service conditions.

All grades included in this document are heat-treated. Heat treatment process is crucial to reach mechanical properties and suitable microstructure that are essential to stand phenomena described above and to get acceptable durability for the fasteners and the assembled joint.

---

1 It is intended to revise ISO 3506-3 and ISO 3506-4 in the future in order to include reference to this document.

Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners —

Part 5:
Special fasteners (also including fasteners from nickel alloys) for high temperature applications

1 Scope

This document specifies the mechanical and physical properties of bolts, screws, studs and nuts, with coarse pitch thread and fine pitch thread made of corrosion-resistant stainless steels and nickel alloys, intended for use at high temperatures up to 800 °C.

NOTE Fasteners specified in this document are also suitable when used at low temperatures, typically down to - 50 °C. For more information, see ISO 3506-6.

The term “fasteners” is used in this document when bolts, screws, studs and nuts are considered all together.

It specifies fastener properties in relation to three material categories: martensitic steels, precipitation hardening austenitic steels and nickel alloys.

ISO 3506-6 provides general rules and additional technical information on suitable stainless steels and nickel alloys as well as their properties.

This document applies to fasteners:

— with ISO metric thread in accordance with ISO 68-1,

— with diameter/pitch combinations in accordance with ISO 261 and ISO 262,

— with coarse pitch thread M3 to M39, and fine pitch thread M8×1 to M39×3,

— with thread tolerances in accordance with ISO 965-1 and ISO 965-2, and

— of any shape but with full loadability.

Stainless steels and Nickel alloys grades may be used for sizes outside the diameter limits of this document (i.e. for d < 3 mm or d > 39 mm), provided that all applicable chemical, mechanical and physical requirements are met.

Fasteners with reduced loadability (i.e. thin nuts and bolts, screws and studs with head or shank weaker than the threaded shank) are not dealt with in this document.

It does not specify requirements for functional properties such as:

— Torque/clamp force properties

— Shear strength

— Fatigue resistance, or

— Weldability

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 3506-1, *Fasteners — Mechanical properties of corrosion resistant stainless steel fasteners — Part 1: Bolts, screws and studs with specified grades and property classes*

ISO 3506-2, *Fasteners — Mechanical properties of corrosion resistant stainless steel fasteners —Coarse pitch thread and fine pitch thread— Part 2: Nuts with specified grades and property classes*

ISO 3506-6, *Fasteners — Mechanical properties of corrosion resistant stainless steel fasteners — Part 6: General rules for the selection of stainless steels and nickel alloys for fasteners*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 16228, *Fasteners — Types of inspection documents*

EN 10319-2, *Metallic materials — Tensile stress relaxation testing — Part 2: Procedure for bolted joint models*

3 Terms and definitions

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

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

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

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

Detailed explanations for stainless steel and nickel alloys grades and properties are specified in ISO 3506-6.

3.1
stainless steel
steel with at least 10,5 % (mass fraction) of chromium (Cr) and maximum 1,2 % (mass fraction) of carbon (C)

3.2
martensitic stainless steel
stainless steel (3.1) with high amounts of chromium but very little nickel or other alloying elements , which can be hardened by heat treatment for increasing strength but with reduced ductility, and with highly magnetic properties

3.3
precipitation hardening steel
steel that can be hardened through precipitation in the metallic matrix of a constituent from a supersaturated solid solution

3.4
nickel alloy
alloy whose main constituent is nickel

3.5
soaking time
time that the entire part being heat-treated (throughout its cross-sections) remains at the specified set temperature

3.6
stainless steel and Nickel alloy bolt and screw with full loadability
bolt and screw with head stronger than the threaded and unthreaded shanks (with unthreaded shank diameter $d_s \approx d_2$ or $d_s > d_2$) or screw threaded to the head, and fulfilling the minimum ultimate tensile load

3.7
stainless steel and Nickel alloy stud with full loadability
stud with unthreaded shank diameter $d_s \approx d_2$ or $d_s > d_2$, and fulfilling the minimum ultimate tensile load

3.8
stainless steel and Nickel alloy nut with full loadability
regular nut or high nut fulfilling the requirements for proof load and minimum height above or equal to 0,80*D*, in accordance with ISO 3506-2

3.9
heat resistance
extent to which a fastener retains functional properties (e.g. resistance against oxidation, relaxation, creep) during exposure to a specified temperature for a specified duration and/or to temperature cycles

3.10
creep
time-dependent strain that occurs after the application of a force which is thereafter maintained constant

3.11
relaxation
time-dependent stress loss for a constant strain

4 Symbols

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

A	Total elongation after fracture, mm
A_T	Total elongation after fracture for full size fastener at high temperature, mm
$A_{s,nom}$	Nominal stress area in thread, mm^2
b	Thread length, mm
d, D	Nominal thread diameter, mm
d_1	Basic minor diameter of external thread, mm
d_2	Basic pitch diameter of external thread, mm
D_2	Basic pitch diameter of internal thread, mm
d_3	Minor diameter of external thread (for nominal stress area calculation), mm
$d_{h\ bolt}$	Hole diameter for adaptor in tensile testing device for externally threaded fasteners, mm
$d_{h\ nut}$	Hole diameter of nut grip in tensile testing device, mm
d_s	Diameter of unthreaded shank, mm

F_{mf}	Ultimate tensile load, N
$F_{mf,T}$	Ultimate tensile load at high temperature, N
$F_{n,T}$	Ultimate stripping load at high temperature for the nut, N
F_P	Proof load for nut, N
F_{pf}	Load at 0,2 % non-proportional elongation for full-size fastener, N
$F_{pf,T}$	Load at 0,2 % non-proportional elongation for full-size fastener at high temperature, N
h	Thickness of the nut grip in tensile testing device, mm
H	Height of the fundamental triangle of the thread, mm
l	Nominal length of fastener, mm
L_0	Total length of fastener before tensile test, mm
L_1	Total length of fastener after fracture, mm
L_2	Clamping length before tensile test, mm
l_t	Overall length of stud, mm
l_{th}	Free threaded length of fastener in testing device, mm
m	Height of the nut, mm
P	Pitch of the thread, mm
R_{mf}	Tensile strength for full size fastener, MPa
$R_{mf,T}$	Tensile strength for full size fastener at high temperature, MPa
$R_{n,T}$	Ultimate nut strength at stripping load at high temperature, MPa
R_{pf}	Stress at 0,2 % non-proportional elongation for full-size fastener, MPa
$R_{pf,T}$	Stress at 0,2 % non-proportional elongation for full-size fastener at high temperature, MPa
S_P	Stress under proof load for nuts, MPa

5 Designation system for fasteners made from stainless steels and nickel alloys

All stainless steels and nickel alloys specified in this document belong to three different categories:

— **martensitic stainless steels**: CH0, CH1, CH2, V, VH, VW,

— **precipitation hardening austenitic steels**: SD,

— **nickel alloys**: SB and 718.

The chemical composition and heat treatment of fasteners for these three material categories are specified in Clause 6.

The marking, labelling and designation with the fasteners symbols of Clause 6 shall be as specified in Clause 11.

6 Materials and manufacture

6.1 Chemical composition

Tables 1 to 3 specify the limits for chemical composition of the stainless steels and nickel alloys for fasteners. The chemical composition shall be assessed in accordance with the relevant International Standards.

Maximum values are specified, unless otherwise indicated. The final choice of the chemical composition within the specified fastener symbol is at the discretion of the manufacturer, unless otherwise agreed between the purchaser and the manufacturer.

General rules and information are specified in ISO 3506-6 for the choice of an appropriate stainless steel or nickel alloy grade in relation to the application.

Table 1 — Chemical composition for martensitic stainless steel fasteners

Material category	Fastener symbol	ISO name for material [a]	Material reference [b]	Chemical composition mass fraction, %									
				C	Si	Mn	P	S	Cr	Mo	Ni	Fe	Other elements
Martensitic stainless steel	CH0	X20Cr13	4021-420-00-I	0,16 to 0,25	1,00	1,50	0,040	0,030 [c]	12,0 to 14,0	---	---	Balance	---
		X20Cr13	1.4021 *	0,16 to 0,25	1,00	1,50	0,040	0,030 [c]	12,0 to 14,0	---	---		---
	CH1	X30Cr1 3	4028-420-00-I	0,26 to 0,35	1,00	1,50	0,040	0,030 [c]	12,0 to 14,0	---	---		---
		X30Cr1 3	1.4028 *	0,26 to 0,35	1,00	1,50	0,040	0,030 [c]	12,0 to 14,0	---	---		---
	CH2	X17CrNi16-2	4057-431-00-X	0,12 to 0,22	1,00	1,50	0,040	0,030	15,0 to 17,0	---	1,50 to 2,50		---
		X17CrNi16-2	1.4057 *	0,12 to 0,22	1,00	1,50	0,040	0,030	15,0 to 17,0	---	1,50 to 2,50		---
	V or VH [d]	X22CrMoV12-1	1.4923 *	0,18 to 0,24	0,50	0,40 to 0,90	0,025	0,015	11,0 to 12,5	0,80 to 1,20	0,30 to 0,80		V 0,25 to 0,35
	VW	X19CrMoNbVN11-1	1.4913 *	0,17 to 0,23	0,50	0,40 to 0,90	0,025	0,015	10,0 to 11,5	0,50 to 0,80	0,20 to 0,60		V 0,10 to 0,30 Nb 0,25 to 0,55 B < 0,0015 Al < 0,020 N 0,05 to 0,10

[a] In accordance with ISO/TS 4949.

[b] Material references are given for information: * means a composition included in EN 10088-3, ** means a composition included in UNS,[20] *** means a composition included in EN 10269, and no star mean a composition included in ISO 15510.

[c] Particular ranges of sulfur mass fraction can provide improvement of particular properties. For machinability, a controlled sulfur mass fraction of 0,015 to 0,030 % is recommended.

[d] Symbol V for lower yield stress $R_{pf} \geq 600$ MPa, or symbol VH for lower yield stress $R_{pf} \geq 700$ MPa, in accordance with Table 2.

Table 2 — Chemical composition for precipitation hardening austenitic stainless steel fasteners

Material category	Fastener symbol	ISO name for material [a]	Material reference [b]	Chemical composition mass fraction, %									
				C	Si	Mn	P	S	Cr	Mo	Ni	Fe	Other elements
Precipitation hardening austenitic stainless steel	SD[d]	X6NiCrTiMoVB25-15-2	4980-662-86-X	0,08 [c]	1,00	2,00	0,040	0,030	13,5 to 16,0	1,00 to 1,50	24,0 to 27,0	Balance	Ti 1,90 to 2,35 Al 0,35 V 0,10 to 0,50 B 0,001 to 0,010
		X6NiCrTiMoVB25-15-2	1.4980 *	0,03 to 0,08	1,00	1,00 to 2,00	0,025	0,015	13,5 to 16,0	1,00 to 1,50	24,0 to 27,0		Ti 1,90 to 2,30 Al 0,35 V 0,10 to 0,50
		X6NiCrTiMoVB25-15-2	Alloy 660 S66286 *	0,08 [e]	1,00	2,00	0,040	0,030	13,5 to 16,0	1,00 to 1,50	24,0 to 27,0		Ti 1,90 to 2,35 Al 0,35 V 0,10 to 0,50 B 0,001 to 0,010

[a] In accordance with ISO/TS 4949.

[b] Material references are given for information: * means a composition included in EN 10088-3, ** means a composition included in UNS,[20] *** means a composition included in EN 10269, and no star mean a composition included in ISO 15510.

[c] A minimum carbon content may be required for specific applications.

[d] Secondary melting of the raw material is recommended due to the beneficial effect on the functional properties of the finished fasteners. The melting process is left to the choice of the fastener manufacturer, unless otherwise agreed.

Table 3 — Chemical composition for nickel alloy fasteners

Material category	Fastener symbol	ISO name for material [a]	Material reference [b]	Chemical composition mass fraction, %									
				C	Si	Mn	P	S	Cr	Mo	Ni	Fe	Other elements
Nickel alloy	SB [d]	NiCr20TiAl	Alloy 80A N07080 **	0,10 [c]	1,00	1,00	0,045	0,015	18,0 to 21,0	---	Balance	3,0	Ti 1,8 to 2,7 Al 1,0 to 1,8 Fe < 3,0 Co < 2,0 Cu < 0,2 B < 0,008
		NiCr20TiAl	2.4952 ***	0,10 [c]	1,00	1,00	0,045	0,015	18,0 to 21,0	---	Balance	3,0	Ti 1,8 to 2,7 Al 1,0 to 1,8 Fe < 3,0 Co < 2,0 Cu < 0,2 B < 0,008
	718 [d]	NiCr19NbMo	Alloy 718 N07718 **	0,08 [c]	0,35	0,35	0,015	0,015	17,0 to 21,0	2,80 to 3,30	50,0 to 55,0	Bal-	Nb 4,75 to 5,50 Ti 0,75 to 1,15 Al 0,2 to 0,8 Co < 1,0 Cu < 0,3 B < 0,006
		NiCr19NbMo	2.4668 ***	0,08 [c]	0,35	0,35	0,015	0,015	17,0 to 21,0	2,80 to 3,30	50,0 to 55,0		Nb 4,75 to 5,50 Ti 0,65 to 1,15 Al 0,2 to 0,8 Co < 1,0 Cu < 0,3

[a] In accordance with ISO/TS 4949.

[b] Material references are given for information: * means a composition included in EN 10088-3, ** means a composition included in UNS,[20] *** means a composition included in EN 10269, and no star mean a composition included in ISO 15510.

[c] A minimum carbon content may be required for specific applications.

[d] Secondary melting of the raw material is recommended due to the beneficial effect on the functional properties of the finished fasteners. The melting process is left to the choice of the fastener manufacturer, unless otherwise agreed.

6.2 Heat treatment for fasteners

Fasteners in accordance with this document shall be heat treated in order to meet the physical and mechanical properties specified in Clause 7.

Heat treatment requirements are specified in Table 4. The minimum tempering temperature for martensitic stainless steel grades shall be selected in accordance with Table 4, by taking into account the mechanical and physical properties required in Table 7 as well as the temperature at which the fasteners are intended to be used.

The process steps shall be as follows:

— for SD, SB and 718, solution annealing (AT) shall be carried out; in addition, it is strongly recommended that AT is performed after the manufacture of the fasteners. In case of externally threaded fasteners with tensile strength R_m above or equal to 1100 MPa, AT could be performed on the raw material (before manufacturing the fasteners) subject to prior agreement between the purchaser and the manufacturer at the time of the order.

— for cold and hot forged fasteners, heat treatment shall be performed after the manufacture of the fasteners.

— for fasteners machined from bars, heat treatment can be carried out on the raw material or after the manufacture of the fasteners.

For externally threaded fasteners, thread rolling can be carried out before or after heat treatment, or between solution annealing (AT) and precipitation hardening (P) steps.

Table 4 — Heat treatment for fasteners

Fastener symbol	Heat treatment condition	Temperature range for quenching/solution annealing °C (and soaking time)	Temperature for tempering/ precipitation hardening °C (and soaking time)
CH0	+ QT	950 to 1050	≥ 450 [a]
CH1	+ QT	950 to 1050	≥ 450 [a]
CH2	+ QT	950 to 1050	≥ 450 [a]
V	+ QT	1020 to 1070	≥ 680
VH	+ QT	1020 to 1070	≥ 660
VW	+ QT	1100 to 1130	≥ 670
SD	+ AT + P	970 to 990 (≥ 1h)	710 to 730 (≥ 16h)
		890 to 910 (≥ 1h)	
SB	+ AT + P	1050 to 1080	1st step: 840 to 860 (≥ 24h) 2nd step: 690 to 710 (≥ 16h)
718	+ AT + P	940 to 1010	1st step: 710 to 730 (≥ 8h) 2nd step: 610 to 630 (≥ 18h)

QT Quenched and Tempered

AT Solution annealed (Annealing Treatment)

P Precipitation hardened

[a] Tempering temperature between 500 °C and 600 °C should be avoided (loss of toughness and increased risk of intergranular corrosion): see information in Annex A.

Soaking times which are not specified in Table 4 are left to the choice of the manufacturer.

6.3 Finish

Unless otherwise specified, fasteners in accordance with this document shall be supplied clean.

Fasteners are often used in bolted joints where the preload is applied by torque tightening. Therefore, lubrication of stainless steel and nickel alloys fasteners is recommended in order to avoid galling during tightening.

NOTE 1 Several parameters can increase the risk of galling for stainless steel and nickel alloys fasteners in bolted assemblies during tightening such as thread damage, high preload, high tightening speed.

NOTE 2 For the time being, requirements concerning surface discontinuities and torque/clamp force properties are not specified in International Standards for stainless steel and nickel alloys fasteners.

A controlled torque/clamp force relationship can be obtained for stainless steel and nickel alloys fasteners by means of an adequate finish, either just with a lubricant or with a coating, top coat and/or sealer including lubricant. In this case, the designation and/or labelling should include the letters “Lu” immediately after the fastener symbol, e.g. SD Lu. In conjunction, appropriate measures and means of tightening should be selected in order to achieve the required preload.

When specific requirements are necessary, it shall be agreed between the supplier and the purchaser at the time of the order.

6.4 Design of bolt/nut assemblies

Two styles of nuts are specified in ISO 3506-2 in accordance with their minimum heights:

— for standard hexagon nuts (without flange and without prevailing torque feature) the styles are specified in accordance with the nut minimum height, m_{min}:

  — style 1 for regular nut with $0{,}80\ D \le m_{min} < 0{,}89\ D$,

  — style 2 for high nut with $m_{min} \ge 0{,}89\ D$;

— For other nuts (nuts with flange, nuts per drawing, ...) the styles are specified in accordance with the minimum design thread height, $m_{th\ design}$:

  — style 1 for regular nut with $0{,}73\ D \le m_{th\ design} < 0{,}83\ D$,

  — style 2 for high nut with $m_{th\ design} \ge 0{,}83\ D$.

More information of basic design principles for nuts and loadability of bolted assemblies are given in ISO 3506-2.

With regard to material properties, bolts, screws and studs shall be mated with nuts in accordance with the combinations specified above the thick stepped line in Table 5.

Table 5 — Combination of bolts, screws and studs with nuts

Bolts, screws and studs	Nuts						
	CH0	CH1	CH2	V, VH and VW	SD	SB	718
CH0							
CH1				Possible mating nuts			
CH2							
V, VH and VW							
SD							
SB							
718							

Nuts should be mated with bolts, screws, studs (and washers) with the same fastener symbol (e.g. CH0 bolts with CH0 nut). However, matching fasteners of different materials is possible and providing that:

— an experienced fastener metallurgist shall be consulted, and

— the component with the lowest corrosion resistance is always taken into account, and

— the risk of galling is also considered.

NOTE When using stainless steel and nickel alloy fasteners in bolted joints with clamped parts made of dissimilar materials, it is advised to consider the use of isolation components in order to avoid galvanic corrosion.

6.5 Resistance to high temperature environment

High temperature materials for fasteners specified in this document are designed primarily for use at temperatures where creep strength as a rule is the dimensioning factor and where high-temperature oxidation occurs (it should be noted that SD, SB and 718 also provide a good resistance to wet corrosion).

6.6 Service temperatures for fasteners

Mechanical properties specified in Clause 7 for fasteners are tested at an ambient temperature range of 10°C to 35 °C. Mechanical properties of the fasteners decrease when used at high temperatures. The maximum service temperature in relation to the fastener material is specified in Table 6, however depending on the service conditions the applicable temperature may be lower.

Table 6 — Maximum service temperature for fasteners

Fastener symbol	Maximum service temperature
CH0	400 °C
CH1	400 °C
CH2	450 °C
V	600 °C
VH	600 °C
VW	600 °C
SD	700 °C
SB	800 °C
718	700 °C

When fastener properties have to be assessed for a specific application, it is advisable to perform tensile test at high temperature and/or stress rupture test and/or relaxation test on the finished fasteners at the expected service temperature. Test methods are specified in 9.5 to 9.8.

The tests should be performed under conditions that are as near as possible to the ones of the final assembly in the considered application (clamped parts, clamp force, service temperature, etc.). The contracting parties shall agree on all test conditions before of the order.

7 Mechanical and physical properties

7.1 Mechanical properties of bolts, screws and studs

When tested by the methods specified in Clause 9, the bolts, screws, studs and nuts of the specified fastener symbol shall meet, at ambient temperature, all the applicable requirements specified in Tables 7 to 11, regardless of which tests are performed during manufacture or final inspection.